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Study on Safety Design for Port Dangerous Goods Ro-Ro Terminal Engineering

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Abstract. According to the current situation of domestic transportation, this paper identifies and analyzes the characteristics and causes of accidents in ro-ro operation of dangerous goods in port. Combined with the quantitative risk assessment of accident consequences, this paper emphatically analyzes mutual safety influence with the surrounding environment. Based on that, safety design for dangerous goods ro-ro terminal engineering is demanded. The research results may serve as a reference for improving the inherent safety of dangerous goods ro-ro terminal engineering.

Keywords: Port Dangerous Goods; Safety Design; Ro-Ro Terminal Engineering.

1. Domestic status of ro-ro operation of port dangerous goods

The ro-ro transportation of dangerous goods in port is mainly distributed in coastal islands, between land and islands and inland waters. The ro-ro operation of dangerous goods in port has the following characteristics [1]:

(1) There are many kinds of goods in operation, but small amount of work per operation.

(2) There are fewer specialized ro-ro terminals, while general cargo terminals are more likely to take into account the ro-ro transportation of dangerous goods.

(3) Due to the limitation of regional location and surrounding environmental conditions, some of the suspended water islands cannot carry out the ro-ro operation of dangerous goods, which brings inconvenience to the production and life of islanders.

In view of the above characteristics, starting from the domestic status quo, this paper identifies and analyzes the risk factors existing in the ro-ro operation of port dangerous goods and the mutual safety influence with the surrounding environment, and puts forward the safety design requirements for the ro-ro operation of dangerous goods in port, so as to provide useful reference for solving the ro-ro transport of dangerous goods in port.

2. Identification and analysis of risk factors in ro-ro operation of dangerous goods in port

2.1 Risk identification and analysis of type of operation goods

The operation of dangerous goods in ro-ro port are generally dangerous goods with packaging. According to the classification and name of dangerous goods, the type of operation goods from class 1 to class 9 may be involved. According to the physical and chemical properties of different types of goods, the risks include fire risk, explosion risk, toxicity, cohesion, stability, volatility, diffusion, corrosion, radioactivity, taboo reaction, electrostatic characteristics and so on.

2.2 Risk factors and analysis during operation

In the process of operation, the main risk factors are leakage, fire, explosion, burn, low temperature, poisoning, asphyxia, drowning and other risk factors according to the different types of operation goods [2].

2.2.1 Risk of leakage accident

2.2.1.1 Human factors.

Due to the physiological and psychological factors of drivers of dangerous goods transport vehicles and dock operators, illegal operation, improper cooperation and other reasons, cause the vehicles collide and overturn when entering, exiting, reversing and turning in the ro-ro ship. If the packaging of the operation goods is damaged, it may lead to leakage accidents.

2.2.1 Factors of matter.

(1) The defects of the vehicle itself. The bad condition of the vehicle such as engine failure, steering wheel failure, brake failure, tire explosion and other reasons cause vehicle collision, rollover.

(2) Defective packaging of operation goods. The packages included in the International Maritime Dangerous Goods Code are: movable tank cabinets, medium bulk containers (rigid and flexible), containers, road tankers, pressure vessels (multi-cell gas containers, aerosol containers, small containers for gas), radioactive material packaging. Due to the packaging damage or packaging defects of operation goods, such as tank car tank wall thickness is not up to standard, tank car valve corrosion and other reasons, resulting in the leakage of operating goods.

2.2.2 Environmental factors.

(1) Due to poor access and narrow space in vehicle safety inspection area and dock driving area.

(2) In case of snow, rain and fog, the ramp and cabin pavement are slippery and the sight is not good.

Danger of fire and explosion accidents

2.2.2.1 Lax fire source control.

Ignition sources come from many aspects, and are usually summarized as: on-site smoking, motor vehicle smoke with fire, electric spark and arc, lightning strike and stray current, high temperature hot surface, metal collision, all kinds of man-made damage, natural disasters, spontaneous combustion and fire operations, electrostatic discharge, etc.Some operation goods, such as class 2.1 flammable gas and class 3 flammable liquid, which encounter ignition source, taboo objects, static electricity without timely emergency handling may lead to fire and even explosion accidents after the leakage accident.

2.2.2.2 Defective packaging of operation goods.

Due to packaging defects and damage, some operation goods may cause fire and explosion accidents.For example, active metals such as sodium, potassium and calcium should be stored in kerosene liquid seal. If the active metals are directly exposed to air due to packaging damage, fire and explosion accidents may occur.

2.2.2.3 Defects of dangerous goods transport vehicles.

Explosion accidents are caused by strong impact due to poor vehicle conditions, such as engine failure, steering wheel failure, brake device failure, wheel blowout and so on. The fuel tank and air tank of transport vehicles are damaged or not tightly closed, and the fuel leakage are easy to cause fire accidents..

2.2.2.4 Mixed storage and loading of goods with conflicting properties.

Among the dangerous goods transported, there are articles with conflicting properties. If they are contacted in the process of loading and unloading, they may react with each other and cause fire and explosion accidents, such as the mixed storage of acids and alkalis, the mixture of explosives and detonators.

2.2.2.5 Improper emergency handling.

When the initial fire occurs at the wharf, if the means of fighting the fire are not appropriate, it will cause the spread of fire and lead to large-scale fire accidents. In this regard, it is required that the on-site operators must go through the port dangerous goods operation training and emergency response training, and understand the dangerous characteristics of all kinds of dangerous goods and the corresponding response means, so as to avoid being at a loss in the face of sudden fire accidents and missing the best time to fight.

2.2.3 Danger of personal injury accident.

Wharf apron operation, getting on and off the ship are all near water operations. Accidents such as drowning, vehicle injury and object strike may occur if operators encounter poor environment, protection defects or untie and fasten the ropein in violation of regulations.

In case of combustion and leakage (such as benzene and chlorine) of some operation goods, suffocating, toxic and harmful gases can be released, resulting in poisoning and suffocation accidents.

2.3 Influence and analysis of surrounding environment safety

2.3.1 Safety impact of ro-ro terminals on surrounding environment.

Ro-ro terminals that operate dangerous goods usually have a wide variety of goods, if the more dangerous goods are included, in case of fire, explosion, leakage and other accidents, it may cause injury to personnel and facilities in surrounding sensitive places(such as crowded places, places for production, loading, unloading and storage of inflammables and explosives), it can also cause secondary accidents.

2.3.2 The impact of the surrounding environment on the safety of the ro-ro terminals.

If there are places for production, loading and unloading, and storage of inflammable and explosive products around the ro-ro terminals, in case of leakage, fire and explosion accidents at the place, the operation safety of ro-ro terminals may be affected and may lead to secondary accidents.

3. Analysis of accident consequences

Take the explosion accident of class 1 explosives as an example, the simulated accident scenario is that a domestic port plans to transport class 1 explosives, and a dangerous goods explosion occurs [3].

(1) The location of the accident. All dangerous goods in the wharf are rolled on and off special ferry ships by professional transport vehicles, and the goods are not loaded, unloaded and stored in the wharf. After the ship has docked at the wharf, during the boarding of dangerous goods vehicles, the ship is vulnerable to unstable turbulence of wind, wave and current, accidents are easily caused by improper operation of transport vehicle drivers and other reasons. Therefore, the place where the transport vehicle gets on and off the ship is selected as the simulated accident point in this section.

(2) Selection of goods. According to the type of cargo transportation and operation plan, the cargo shall be transported in 20-foot containers, each vehicle shall not carry more than 5 tons of TNT equivalent, and measures shall be taken to ensure that the safe distance between vehicles meets the distance of detonation.In this paper, 5 tons of TNT equivalent is chosen as the calculation value of explosion accident influence range.

Refer to Determination Method of External Safety Distance for Hazardouschemicals Production Units and Storage Installations (GB/T 37243-2019) calculation of external safety protection distance, and calculate the external safety protection distance according to Formula (1) according to article 5.4.1 of the code: according to the most serious accident scenario and the value of air shock wave overpressure safety valve given in Table 1:

$$\Delta p = 14\frac{Q}{R^3} + 4.3\frac{Q^{2/3}}{R^2} + 1.1\frac{Q^{1/3}}{R} \quad (1)$$

where:

Δp-- Overpressure of air shock wave, unit: 105 Pascal (Pa);

Q -- TNT equivalent of an explosion ,unit: kilograms (kg);

R -- Distance between the explosion point and the protected target, unit: meters (m).

If all the above goods explode under extreme accident conditions, the calculation results are shown in Table 1 according to Equation (1) and in combination with Table G.3 of GB/T 37243-2019 Determination Method of External Safety Distance for Hazardouschemicals Production Units and Storage Installations.

Table 1. Calculation results of overpressure value and safety impact distance after impact analysis reduction

pressure (kPa)	Influence (approximate value)	Safe distance after the reduction (m)	note
2.07	"Safe distance" (below this value, the probability of no serious damage is 0.95);Ejection limit; Some damage to the roof;10 percent of window glass is broken and should not be in the scope of influence.	1003	The distance between the company's office building and the berth operation point is about 1100m, and the distance between the surrounding passenger terminals and the berth operation point is about 1360m, which all meet the safety distance requirements after reduction. There are no other highly sensitive protection targets, important protection targets or general protection targets in the above scope
2	Highly sensitive protection targets, important protection targets and class1 of general protection targets should not appear in the scope of influence	1006	

4. Safety design requirements

4.1 External distance requirements.

For ro-ro terminals engaged in dangerous goods operations, the external safety protection distance shall comply with [4]:

(1) The net distance between the ro-ro ship and the surrounding passenger ship shall not be less than 300m;

(2) The net distance between the ro-ro ship and other cargo vessels shall not be less than 150m;

(3) The distance between the wharf apron engaged in ro-ro operation for class A and B dangerous goods and the place where sparks are emitted or the part of open fire shall not be less than 40m;

(4) The distance between other onshore facilities unrelated to ro-ro operation and the wharf apron engaged in ro-ro dangerous goods operation shall not be less than 40m;

(5) If there are sensitive facilities around the ro-ro terminals (such as crowded places, places where inflammables and explosives are produced, stored, loaded and unloaded), it is recommended to determine the safety distance according to the impact range of accident consequences.

4.2 Requirements for Layout

4.2.1 Setting of the turn-around area.

A fixed u-turn operation area shall be set up for the wharfs engaged in dangerous goods ro-ro operation, and convex mirrors, warning lights and warning signs shall be set up in the u-turn operation area according to the situation.

4.2.2 Road setting.

(1) Fire lanes should be set up around the parking lot to be ferry.

(2) The net width of the loading and unloading channel should be no less than 5.0m during operation, and the headroom height can meet the normal passage of vehicles.

(3) Protective railings, wheel guards and warning red lights should be set on both sides of the vehicle passage.

(4) The vehicle passage shall be marked with warning signs, including but not limited to maximum safety load signs, vehicle height limit and speed limit driving signs.

4.2.3 Emergency disposal site.

(1) It is recommended to set up an emergency disposal site in the wharf area engaged in the ro-ro operation of dangerous goods. The site shall be located in an area that is convenient for vehicle access and slightly lower than the surrounding ground.

(2) The site for emergency disposal of toxic liquid shall be located on the windward side of the annual minimum frequency direction of the wharf operation area.

(3) Corrosion prevention requirements should be considered in the emergency disposal site of corrosive liquids.

4.3 Fire and explosion prevention

(1) Explosion-proof intercom should be used if fire and explosion danger places exist in the wharf engaged in the ro-ro operation of dangerous goods, and the electrical devices used should comply with the provisions of the current national standard GB 50058 Code for Design of Electrical Installations in Explosive Atmospheres and GB 50052 Code for Design of Power Supply and Distribution System.

(2) When working with inflammable and explosive dangerous goods, on-site workers should be equipped with portable combustible gas detectors;When handling toxic and dangerous goods, portable toxic gas detectors should be equipped [5].

4.4 Lightning and ESD protection

(1) The hydraulic lifting mechanism should have reliable lightning protection grounding.

(2) The lightning protection device of the wharf engaged in the ro-ro operation of dangerous goods should comply with the relevant provisions of the current national standard GB 50057 Code for Design Protection of Structures Against Lightning, GB 50065 Code for Design of Acelectrical Installations Earthing and JT 556 Technical Requirements of Lightningproof and Earthing in The Port.

(3) The lightning protection of electrical and information systems should comply with the relevant provisions of the current national standard GB 50343 Technical Code for Protection of Building Etronic Information System Against Lightning.

(4) Terminals engaged in the ro-ro operation of inflammable and explosive dangerous goods shall effectively eliminate human static electricity through human static electricity elimination devices.

4.5 Shore connection facilities

(1) The gross weight of vehicles transporting dangerous goods shall not exceed the rated load of shore connection facilities, and the wharf using hydraulic lifting mechanism as shore connection facilities shall meet the requirements of wind resistance.

(2) Anti-freezing and anti-skid measures should be taken on the surface of the shore connection facilities.

(3) The hydraulic lifting mechanism should be equipped with a reliable safety locking device.

(4) The speed of vehicles passing through the shore connection facilities should be controlled below 5km/h.

(5) The length of the connecting passage between shore connection facilities, ship gangway and ship deck shall not be less than 1m.

4.6 Environmental protection and leakage prevention requirements

(1) Wharves engaged in dangerous goods ro-ro operation shall be equipped with anti-pollution emergency equipment and facilities in accordance with JT/T 451 Requirements on Emergency Response Equipments/Facilities for Oil Spill in Terminals in Ports.

(2) Suggestions for setting plugging equipment are as follows:

1) The wheel guard sill should be set with wedge hole blocker;

2) Fire sandbox should be installed on the shore side of shore connection facilities;

3) The wharf should be equipped with fire sandbags;

4) Wet rags should be set at the roadside of cryogenic frozen liquid road.

4.7 Fire Protection Requirements.

The amount of fire water, fire facilities, fire extinguishing system and fire alarm system shall be in accordance with the current national standards GB 50140 Code for Design of Extinguisher Distribution in Buildings, GB 50116 Code for Design of Automatic Fire Alarm System, GB 50347 Code of Design for Powder Extinguishing Systems, JTS 165 Design Code of General Layout for Sea Ports and GB 50974 Technical Code for Fire Protection Water Supply and Hydrant Systems and other relevant provisions [6].

4.8 Power supply and lighting requirements

(1) A reliable supply of electricity shall be provided to wharfs engaged in ro-ro operations of dangerous goods. The power system shall be implemented in accordance with the current national standards GB 50052 Code for Design of Elecric Power Supply Systems, GB 50053 Code for Design of 20kV and Below Substation and GB 50054 Code for Design of Low Voltage Electrical Installations and other relevant provisions.

(2) Explosion-proof type should be adopted for distribution box and lighting system facilities of wharf engaged in ro-ro operation of inflammable and explosive dangerous goods.

(3) The wharf engaged in ro-ro operation of dangerous goods shall be illuminated by diffuse light and the illumination value shall not be less than 50lx at night, and the illumination value on the ground of roads and parking lots to be transported at night shall not be less than 20lx.

4.9 Control system

Video surveillance system shall be set up in the wharfs engaged in ro-ro operation of dangerous goods, and the monitoring scope shall cover all the driving areas of dangerous goods vehicles.

5. Conclusion

(1) Combined with practical work experience, this paper puts forward various safety requirements for the design of dangerous goods ro-ro terminal.

(2) In this paper, the external protective distance from JTS 165 Design Code of General Layout for Sea Ports, according to the interpretation of provisions, it is mainly aimed at the external protection distance of oil and gas chemical wharf. It is suggested that the competent department of port industry formulate professional specifications according to the particularity of the dangerous goods ro-ro terminal, specify the external protection distance, and solve the problem of difficult inter island transportation of dangerous goods in some areas due to too high requirements of codes and standards.

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