Study on rescue of liquid hazardous chemicals ship

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Abstract: Once the leakage and accident occur in the maritime transportation of hazardous liquid chemicals, the consequences are very serious. In order to improve the rescue capability of dealing with the accidents of hazardous chemicals at sea, a set of key technical schemes for the rescue of liquid hazardous chemicals ships is proposed and successfully applied in the emergency rescue project of liquid hazardous chemicals ships, which verifies the feasibility of this rescue scheme and provides reference and ideas for the rescue of liquid hazardous chemicals ships at sea.

Key words: liquid hazardous chemicals; ships; salvage at sea.
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1 Preface

With the rapid development of global economic integration, the shipping industry is playing an increasingly important role. According to the data of the international shipping association, the shipping industry accounts for 90% of the world trade flow. Among them, the transportation of liquid bulk hazardous chemicals at sea is an important part of the marine industry. There are many kinds of liquid hazardous chemicals, some of which are corrosive, flammable and volatile. Once leaked or shipwrecked, it will cause serious casualties and environmental pollution.

At present, the domestic and international research on the leakage accidents of liquid hazardous chemicals ships mainly focuses on the prevention and its harmfulness, and there is no in-depth research on the key technologies and practical operation fields of marine rescue and recovery. This paper puts forward a set of technical schemes for the rescue of liquid hazardous chemical ships, which is proved to be feasible and effective by practical engineering, and provides reference and ideas for the rescue of liquid hazardous chemical ships at sea.

2 Characteristics of maritime rescue

There are many kinds of hazardous chemicals, and it is usually difficult to deal with them in an emergency. At present, more than 40000 chemicals have been recorded, of which more than 3000 are listed in the《List of hazardous chemicals》[1]. Hazardous chemicals have explosive, flammable, toxic, corrosive, radioactive and other characteristics, and many kinds of substances have unstable physical and chemical properties [2], which makes it difficult to deal with emergency rescue.

Generally, the unloading volume and risk of liquid hazardous chemicals ship rescue project are very large, and the preparation time and operation time are very tight. And the social impact is also very large, which brings great pressure to the operation and coordination departments. At the same time, dealing with the leakage and accident at sea often encounter severe weather, such as strong winds, waves and dense fog, which greatly tests the adaptability of the rescue team [3].

3 key technologies for salvage of liquid hazardous chemicals ship

3.1 Safety protection

The leaked liquid hazardous chemicals pose a great threat to the life safety of rescuers, and it is very

easy to cause personal injury during the disposal process. Therefore, rescuers should do a good job in safety protection during the whole emergency rescue process.

3.1.1 Personal protection and anti-static

In the process of salvage of hazardous liquid chemicals at sea, personal protective equipment for rescuers is essential, and it is a prerequisite for successful rescue mission. According to the types and characteristics of hazardous chemicals, it is necessary to equip the corresponding personal protective equipment to ensure the life safety of frontline rescuers.

For flammable and explosive liquid hazardous chemicals, anti-static work shall be done at the same time. Rescuers shall wear anti-static clothing and be equipped with anti-static equipment on board. Before boarding, human static electricity shall be released. Chemical protective clothing, positive pressure air respirator, protective mask, etc. shall be worn to enter the closed cabin.

3.1.2 Nitrogen filling to prevent deflagration and explosion

Due to the leakage of hazardous chemicals, the ship has a large contact area with the outside world, and the air circulation is fast. The concentration of combustible gas is easily in the explosion range, and the oxygen concentration is not much different from the atmospheric concentration. In case of open fire, it is very easy to cause an explosion and deflagration accident.

The chemical property of nitrogen is stable. The cabin where the accident ship leaked and the cargo hold of the receiving ship were inerted with nitrogen, and the air and combustible gas in the cabin were replaced to ensure the operation safety.. The nitrogen production capacity of the nitrogen generator should be no less than three times of the total unloading flow, for example, the recovery pump flow in cargo no.1 hold is 200 m^3 /h, the recovery pump flow in cargo no.2 hold is 200 m^3 /h, and the total unloading flow per hour is 400 m^3/h, so the capacity of the nitrogen generator should be no less than 1200m^3/h.

Figure 3-1 protective clothing

Figure 3-2 electrostatic discharger

3.2 Scientific detection

Rescuers use gas detectors to sample and measure the gas in the leaked cabin, including the combustible gas concentration and oxygen content of the cabin. For gases with heavy specific gravity, the suction port of the instrument should be placed at the bottom of the cabin as far as possible during measurement; for unknown gases and non-volatile liquid hazardous chemicals, sampling should be done well.

Inert the leaked cabin of the accident ship with nitrogen, so that the combustible gas concentration in the cabin can be controlled below the lower explosion limit and the oxygen content can be kept below 10%. Both conditions can be met at the same time, which can effectively avoid the explosion and deflagration, and is the key to ensure the safety of operation.

Figure 3-3 portable multi gas detector

3.3 Leakage plugging

Shut off the source of the valve, that is, when the pipeline conveying hazardous chemicals leaks, the leakage point is behind the valve, and the method of closing the valve of the pipeline conveying materials can be adopted. Plugging is an important method to deal with the leakage of liquid hazardous chemicals. It is mainly used for the outward discharge or leakage of cargo hold bulkhead, pipelines or devices containing hazardous chemicals due to the damage of sealing. Rescuers determine different sealing methods and materials according to the leakage location and physical and chemical properties of hazardous chemicals. Generally, mechanical plugging method and magnetic pressure plugging method are commonly used.

Figure 3-4 schematic diagram of plugging strip

3.4 Transfer recycling

Different lightering methods correspond to different lightering processes. The first choice is to use the accident ship's own unloading pump for lightering, and the second choice is to use the receiving ship's unloading pump. The pipelines between the two ships need to be well connected. If the above two transfer methods cannot be met, the external unloading pump shall be used to transfer and recover the liquid hazardous chemicals in the cargo hold of the accident ship. The external unloading pump shall meet the requirements of explosion-proof, anti-static and appropriate lift or suction. The following table is a comparison of several transfer modes.

Table 3-1 comparison of unloading methods

Unloading method	safety	feasibility	Operability	Unloading speed
Use accident ship unloading pump	good	good	good	good
Use the receiving vessel suction pump	good	good	fine	fine
Use external pump (put out of the cabin)	medium	fine	medium	poor
Use external pump (put into the tank)	poor	medium	poor	fine

4 Engineering application

In June, 2020, when the "Guang Hui 616" was sailing through the Shidao anchorage, hazardous chemicals leaked, and some of the leaked substances entered the pump compartment. "Guang Hui 616" loaded nearly 5000 tons of flammable and volatile liquid hazardous chemicals. After the leakage, the crew abandoned the ship, all ship equipment were closed, and anchored at the Shidao anchorage. The occurrence of the accident poses a great threat to the local shipping, fishery and aquaculture, environmental safety, human life and property safety. If it is not properly handled in time, the consequences will be unimaginable.

4.1 Operation idea

According to the preliminary investigation report, the ship data and loading conditions provided by the ship owner, and in combination with our relevant research on the leakage, transfer and recovery of dangerous chemicals, the unloading ideas of "Guang Hui 616" are as follows:

Preliminary preparation: the cargo hold of the receiving ship is inerted, "Guang Hui 616" berths, "Guang Hui 616" cabins are inerted, and the two ships dock together, connect pipelines, unload, sweep cabins, and complete operations.

4.2 Cabin inerting

The "Guang Hui 616" main pipeline has gas phase pipes leading to each cargo tank and slop oil tank. For cargo tank inerting, only connect the nitrogen gas pipe with the air return header pipe, and then adjust the gas phase pipe valve leading to each cargo tank to realize inerting of the corresponding compartment, as shown in the following figure:

Fig. 4-1 connect nitrogen to "Guang Hui 616" main pipeline

4.3 Gas detection

During the process of filling the cargo hold with nitrogen, the pressure in the cargo hold shall be kept positive. The Engineer shall use a gas detector to detect each compartment and keep the oxygen content in the engine room and cargo hold below 10%. For the measurement and statistics of combustible gas concentration and oxygen content in the cabin during the unloading of "Guang Hui 616", select the representative engine room, the left and right of cabin 4 to draw the gas measurement curve as follows:

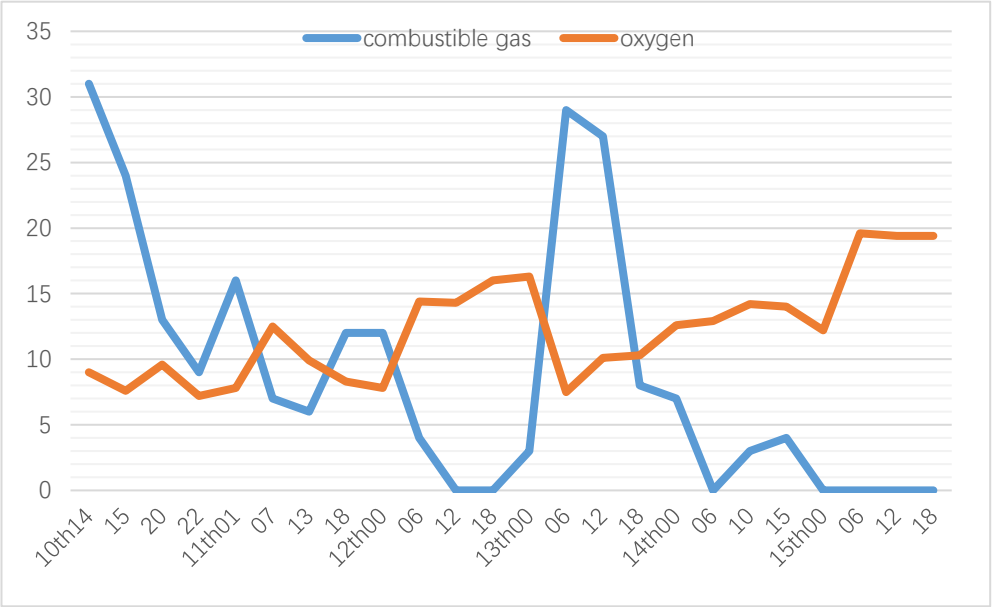

Figure 4-2 gas detection diagram of engine room

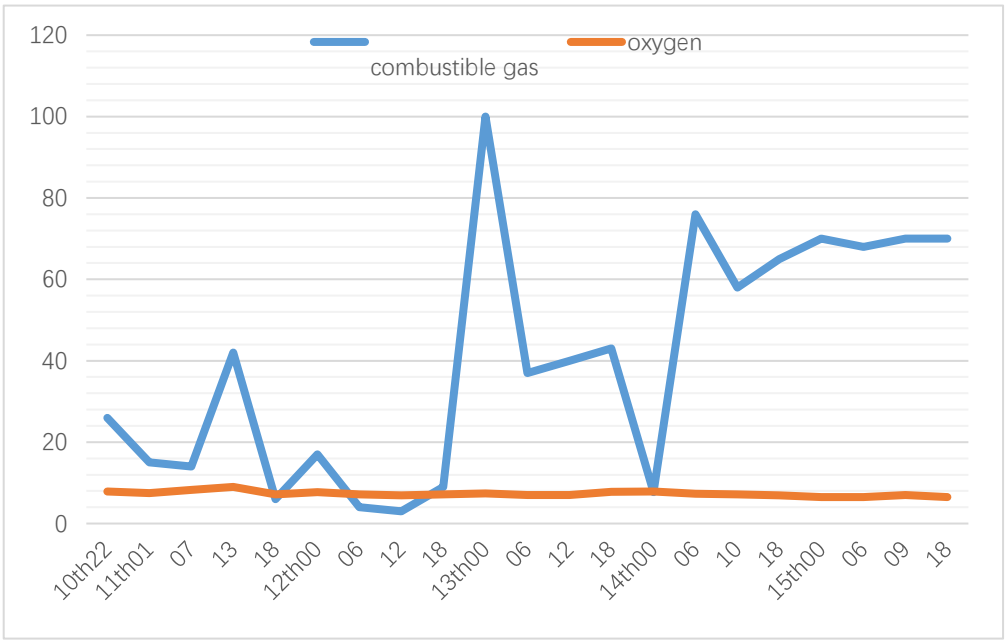

Figure 4-3 gas detection diagram of cabin no.4 left

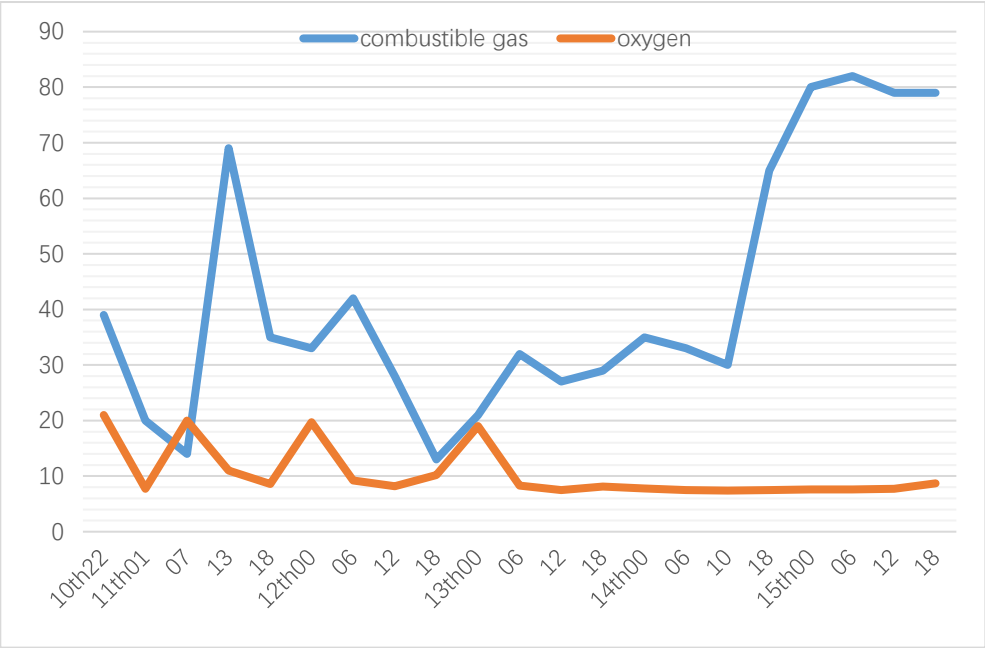

Figure 4-4 gas detection diagram of cabin no.4 right

According to the analysis of Figure 4-2 above, the concentration of combustible gas in the engine room is basically controlled within 35% of the lower explosive limit, especially in the late stage of operation, the concentration of combustible gas is reduced to 0%. This is because there is only a small amount of liquid cargo leakage in the engine room and nitrogen has been added all the time. Nitrogen has replaced the volatile combustible gas. It can be seen from the figure that the oxygen content is basically controllable, with fluctuations but little fluctuations. In the early stage of operation, the engine room is first filled with nitrogen, and the amount of nitrogen is sufficient, so the oxygen content in the cabin is well replaced in the early stage, and the oxygen content is less than 10%. In the late stage of operation, the oxygen content in the cabin is increased because the nitrogen is diverted to the cargo hold and pump room of the accident ship, etc.

According to the analysis of Figure 4-3 and Figure 4-4 above, the concentration of combustible gas on the left / right side of hatch No. 4 was basically controlled within 40% of the lower explosive limit in the early stage of operation, but the concentration of combustible gas increased continuously in the late stage of operation, and finally nearly reached the lower explosive limit. This is because the liquid level in hatch No. 4 was high and the gas space was small at the beginning, and nitrogen was well displaced. However, with the continuous unloading of liquid cargo. The liquid cargo in the cabin volatilizes into gas, which slowly occupies most of the space in the cabin, so the concentration of combustible gas rises rapidly. It can be seen from the figure that the oxygen content is basically controlled below 10%, which fluctuates but not much. During the operation, the cargo hold is always filled with nitrogen to maintain the positive pressure in the hold, and no air enters, so the oxygen content is well controlled.

It can be seen that for the cabin with a small amount of liquid cargo leakage and extensive gas exchange with the outside world, the combustible gas concentration in the cabin shall be controlled below the lower explosion limit and the oxygen content shall be controlled below 10% during construction. For the compartments with a large amount of liquid cargo in cargo tanks and pump tanks and less gas exchange with the outside world, during the unloading process after opening the hatch cover, the oxygen content in the compartment shall be controlled below 10%, which is a feasible method to ensure the safety of operation.

4.4 Transfer and transportation

It is understood that the unloading system of "Guang Hui 616" has two sets of pipelines, one pipeline

in 1/3/5 cabin and one pipeline in 2/4 cabin. By adjusting the connecting valve, the liquid cargo flows to the designated cabin, and the liquid cargo at the bottom of each cabin is collected into one cabin to unload the cargo.

First, the same liquid cargo in the right side of No. 1 and No. 3 holds and the left side of No. 2 hold shall be unloaded clean by controlling the heel of the accident ship through ballast water. Then discharge the remaining liquid cargo into No. 4 left cabin (the discharge outlet is placed at the cabin bottom to prevent the liquid cargo from splashing and generating static electricity), and finally use the unloading pump in No. 4 left cabin to unload the remaining cargo.

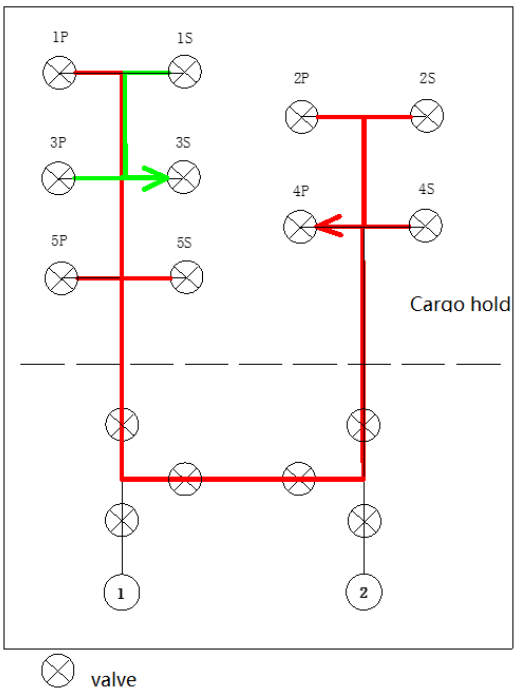

Figure 4-5 unloading pipeline system

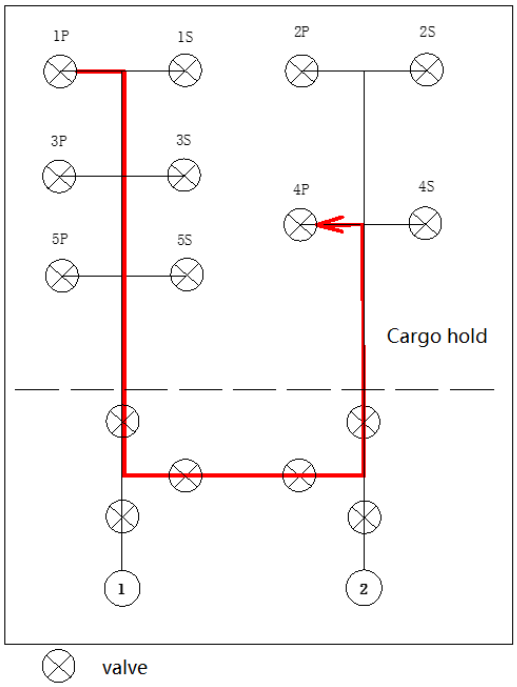

Figure 4-6 schematic diagram of liquid cargo flow

Always observe the gas pressure in the cargo hold. The best condition is to keep the positive pressure close to zero.

The best condition is to keep the unloading speed equal to the nitrogen replenishment speed. Negative pressure means that the outside air enters the cargo hold. Positive pressure means that the cargo hold is filling nitrogen too quickly, and the onboard breathing valve will discharge the gas in the hold. The discharge of combustible gas to the deck is not conducive to the operation of on-site personnel, and it is easy to explode and fire in case of open fire.

The hatch for opening the pump shall be wrapped and bound with a wet quilt. When measuring the gas, check whether the hatch quilt is sunken and whether there is air inlet sound, and use a gas measuring instrument to check whether there is gas leakage.

4.5 Stability control of accident ship

During unloading, there are free liquid surfaces in many tanks due to the unloading of liquid cargo, and the free liquid has a great impact on the stability of the ship. The original plan was to maintain the stability of the accident ship during the unloading process by adjusting the compartment connecting valve. In actual operation, the unloading speed and the adjustment speed were not synchronized, and the accident ship was inclined to the left by about 4 ° . After that, adjust the unloading speed and the unloading cabin to reduce the ship's heeling as much as possible. At the same time, keep the stability of the accident ship by pumping

ballast water from the accident ship. The effect is good.

5 Conclusion

The consequences of liquid hazardous chemicals ship accidents are serious and difficult to control. The leakage accident will not only cause casualties and property losses, but also have a serious impact on the marine environment and atmospheric environment [4]. In view of this problem, the key technologies for rescuing liquid hazardous chemicals ships are put forward and successfully applied in practical projects to verify the feasibility of the scheme. It provides reference and ideas for the salvage of hazardous liquid chemicals at sea.

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