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ANALYSIS OF INERT GAS SYSTEMS OF MODERN CHEMICAL TANKERS

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The content, advantages and disadvantages of inert gas systems on modern chemical tankers were analyzed. The first stage addresses the requirements of the SOLAS International Convention for the Safety of Life at Sea to ensure the efficient filling of chemical tankers with inert gases, equipment and controls necessary to ensure the safety of handling operations. In the second stage explained description of the structures of systems for production and storage of inert gas (nitrogen) on a ship. The experience of operating inert gas (nitrogen) systems on a chemical tanker is presented. The ways of improving design of a liquid nitrogen tank have been determined, which allows reducing operational losses. Based on the performed analysis, it is possible to develop a model of a liquid nitrogen tank, which will allow to calculate and optimize the evaporation process under different operating modes.

Keywords: chemical tankers, inert gas systems, storage of liquid nitrogen

INTRODUCTION

Onboard a chemical tanker inert gas systems can be used for:

- preventing fire and explosion by keeping the atmosphere in the tank under LEL;
- prevention of chemical reaction;
- maintaining cargo quality.

The flammable gases which commonly found in a chemical media cannot be released to the atmosphere. The atmosphere that cannot maintain combustion is considered to be inert. Inert gas is used to displace air in the tank to create non-combustible space.

The fire hazard caused by the cargo fixed in the cargo tank depends on the ignitability of the product and the oxygen in the atmosphere. By filling the tank with an inert gas such as nitrogen, the oxygen content can be reduced to a level where the atmosphere will no longer maintain combustion.

Minimum oxygen concentration (MOC) is defined as the minimum oxygen concentration below which combustion is not possible, regardless of the concentration of flammable vapor present for most hydrocarbons, the MOC varies from 10.5% to 12.0%. It depends on the temperature, pressure and type of inert gas. SOLAS [1] require that the atmosphere must be maintained in an atmosphere at a maximum oxygen content of 8%, although some chemicals may have a lower oxygen content that should be maintained.

The inert atmosphere will again become flammable when air enters. It is therefore important that the tank remains completely closed. The natural breathing of the tank through the ventilation system introduces air into the atmosphere of the tank during the voyage. It is therefore important that the oxygen level is checked regularly and, if necessary, replenished with inert gas.

SOLAS indicates that the maximum amount of oxygen that allows the tank to be effectively inerted is 8%. The rules also describe the equipment and controls necessary to ensure the safety of the operation. Not all chemical tankers are equipped with inertial potential, but more and more are being supplied with inert systems, usually nitrogen.

From January 1, 2016, vessels using inert gas comply with the new SOLAS 16.3.3 rules, which should only use nitrogen to inert their tanks [1].

SOLAS rules require reliable and safe operation of inert gas systems, regardless of the source of inert gas and the method of its storage [1].

The main criteria for the reliability of inert gas systems, in addition to safety, are the purity of the inert gas and the reduction of emissions during storage.

EXPOSITION

The sources of inert gas available to tankers from the chemical industry are:

- -savings of stagnant nitrogen;
- -saving nitrogen;
- -nitrogen generators from adsorption adsorbents;
- -nitrogen generators using membrane separation;
- -nitrogen supplied from shore;
- -heated inert gas generators.

There are also systems that allow you to get nitrogen when you burn, usually gas oil. The resulting inert gas is cheap and efficient. However, the inert gas produced has many impurities. It must be cooled and cleaned with water to remove soot and sulfuric acid before being fed to cargo tanks. Some cargoes react with carbon dioxide. Other loads have a high sensitivity to moisture or may cause discoloration. As a treatment, the process ineffectively removes all contaminants or prevents moisture transfer, oil inert systems are not commonly used on chemical media.

High-pressure nitrogen gas can be stored in steel cylinders. Total size - 50 liters, pressure up to 200 bar. It can be used to compensate for the normal transport losses of IG and maintain the necessary pressure.

A typical installation on a ship consists of a number of such cylinders connected in parallel (Fig. 1). Compressed nitrogen can be obtained in several varieties of purity.

Nitrogen can be stored onboard in liquid form at a cryogenic temperature of 196° C. It is stored in insulated tanks made of cold-resistant material, usually stainless steel. The cryogenic tank has an inner and outer housing, the space between them is filled with insulation and maintained vacuum (Fig. 2) This allows nitrogen to be stored for a long time without noticeable damage.

Liquid nitrogen storage tanks installed on chemical carriers are refueled at the port from shore resources.

When nitrogen is required in the gas state for use in cargo tanks, the liquid is converted back into gas using an evaporator that receives the necessary heat to evaporate from the surrounding air.

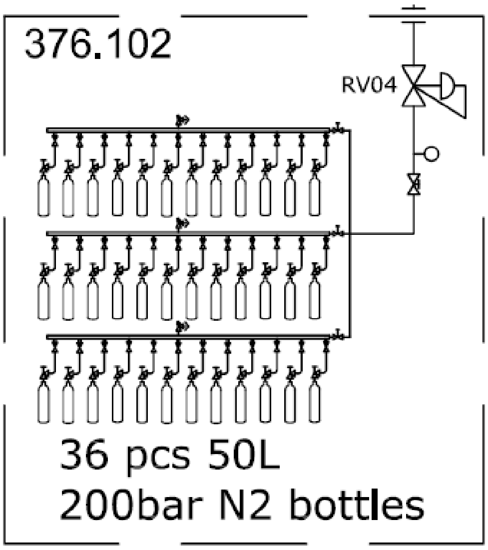

Fig. 1. *General view of high pressure nitrogen cylinders*

The LIN tank is made in the form of a double tank with an external and internal stainless steel tank (304L) and the gap is vacuum-insulated. When the LIN is stored in the tank, the volume of liquid will slowly increase due to heat transfer through the insulation layer. The density of the liquid decreases slowly over time with increasing temperature, and the volume of the liquid increases accordingly. During filling, the tank can be filled up to a maximum of 95% (Fig. 2).

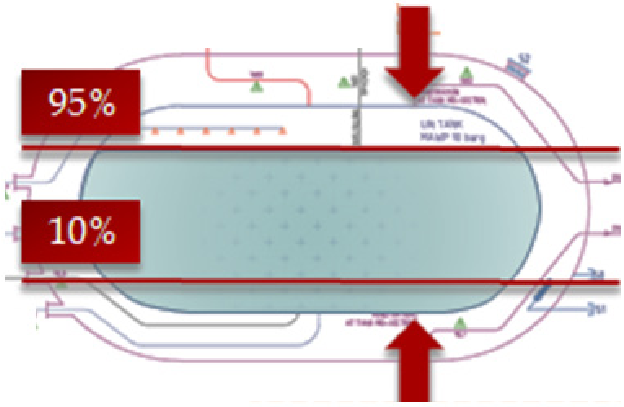

Fig. 2. *Schematic representation of the maximum filling level of the liquid nitrogen tank*

The gas extraction process is controlled by the pressure in the tank. The evaporation system is designed to evaporate liquid nitrogen according to customer needs. The LIN tank and evaporator system supplies gas and heated gas to the distribution pipelines. The LIN tank is designed for a maximum operating pressure of 10 bar (preset safety valve pressure). There is a slight drop in pressure through the evaporation system and the pipeline. Therefore, the tank pressure should always exceed 7 bar in order to provide sufficient gas supply pressure to the distribution pipelines.

Liquid nitrogen is taken from the bottom of the tank through a liquid removal valve, and then the liquid enters the evaporator system. Here, the product is heated while the phase transition from liquid to gas takes place. The circulating glycol loop heats the LIN in the evaporator. Circulating glycol is supplied at 165 ° C. All steam generators are heated with circulating glycol that is mixed with water. It controls temperature and freezing.

The liquid nitrogen tank consists of double tanks with stainless steel outer and inner tanks (304L) and the gap isolated by a vacuum layer. This design allows the liquid product to be stored for an extended period without significant heating from the environment. There are three main processes in the tank. These processes need to be controlled and controlled by the operator through a monitoring system. The operating staff must understand all these processes in order to understand the behavior of the system over time.

The process of heat loss. The LIN is slowly heated through the insulating layer. Over time, the liquid temperature rises and the saturation temperature rises. The density of the product will decrease. In the process of heat leakage, some liquid gas moves from the liquid phase to the gas phase in the upper part of the tank due to the increase in temperature. This increases the pressure in the tank.

The temperature of the stored product may vary through the column between the top and bottom of the tank, with the coldest product with the highest density below. This is called stratification. If the tank is nearly empty, the vapor phase will heat up faster than usual when there is a significant amount of liquid. The effect is that the gas phase heats up and expands faster. Therefore, the tank pressure rises rapidly at low reservoir levels (Fig. 3).

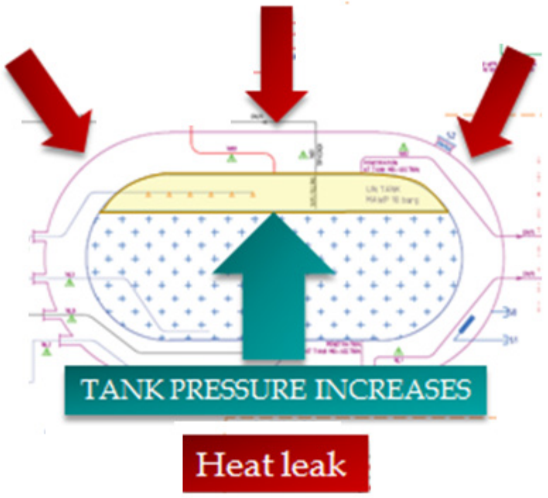

Fig. 3. *The process of losing the heat of a liquid nitrogen tank due to the effect of ambient temperature*

Nitrogen generators operate on the principle of adsorption (Fig. 4). Adsorption is a process in which a substance, typically gas, accumulates on the surface of a solid to which it forms a very thin film. Variable-pressure adsorption devices operate on the principle that the major air components (nitrogen and oxygen) are adsorbed as carbon molecular sieves pass through the material. The amount of each adsorbed gas is time dependent.

If the system is configured, the sieve adsorbs most of the oxygen in the air, allowing nitrogen to pass through and collect. Then oxygen can desorb (returns to the gas) and thereby restore the sieve.

To ensure a continuous nitrogen flow, units are equipped with two or more interconnected tanks that contain molecular sieve material. Air is compressed using an oil compressor and passes through one set of tanks, which is absorbed, while the other set of tanks is de-adsorbed.

So, during the production cycle, the plant will produce oxygen-rich waste that must be exhausted in a safe area. A number of intrinsic screen materials are sensitive to water, and compressed air must be passed through a dehumidifier to remove most of the humidity, before going through the tanks. The gas obtained by the adsorption process at variable pressure may have an oxygen content in the range from 0.1% to 5% by volume, depending on the flow rate.

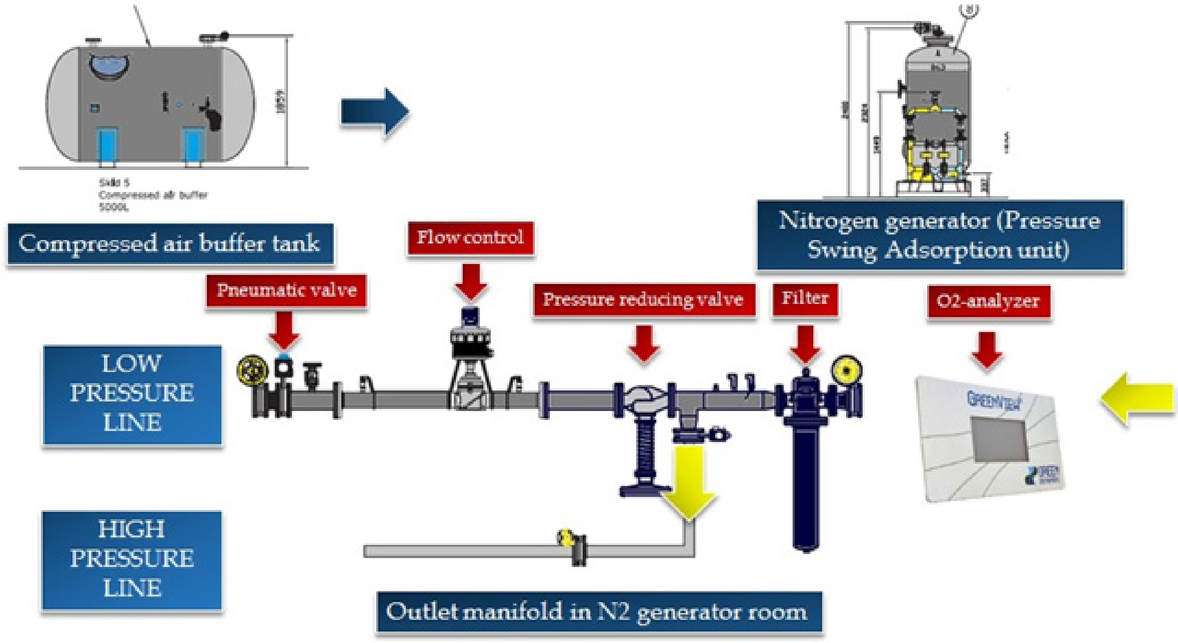

Fig. 4. *The principle of operation of the nitrogen generator system*

Membrane blocks are based on the fact that various gases penetrate in different steps through the walls of a thin hollow membrane. Gases, permeated by various indicators, are classified as: “slow”, “medium” or “fast” gases. The “slow” gases are methane, nitrogen, and carbon monoxide, the “middle” gases are argon and oxygen, and the “fast” gases are water vapor, hydrogen, and carbon dioxide. The fact that the two main components of air, nitrogen and oxygen have different degrees of penetration means that they can be separated. When water vapor quickly penetrates, this means that the nitrogen produced is also very dry.

The protection provided by the inert gas system depends on the proper operation and maintenance of the entire system. It is especially important to ensure the correct functioning of the return barriers, which do not allow vapors or liquids from cargo tanks to get into cars or other rooms through an inert gas distribution system.

When SOLAS requires tanks containing cargo to be inertible before unloading, inert gas must be introduced into the tank through a distribution system that allows the release of vapor into the atmosphere. This operation should continue until the oxygen content does not exceed 8% by volume.

It should be noted that the vapors released during this inertia process can be both combustible and dangerously toxic.

Theoretically, if the entire existing atmosphere in a cargo tank is replaced by an equal inertial volume, then the oxygen level in the tank’s atmosphere will be the same as the inert gas inlet. In practice, however, a lot of mixing takes place during the exchange, so that the volume of inert gases is equal to several volumes of the tank must be introduced there before the desired result can be achieved.

There are several methods of supplying inert gas to tanks and pipelines (thinning method, cascading method, moving method).

The rarefaction method occurs when the inert inlet gas is mixed with the atmosphere of the primary tank to form a homogeneous mixture throughout the tank, so that while the process continues, the concentration of initial gases gradually decreases. It is important that the inert gas inlet must have a sufficient penetration rate to the bottom of the tank, and therefore the limit must be placed on the number of tanks that can be filled at the same time.

The inerting cascade method is used to save time and inertia simultaneously with one or more tanks. The principle of inertia using a cascade is to control an inert gas through a series of reservoirs. When there is a nitrogen plant with sufficient pressure, several cargo tanks can be built in series. Nitrogen is introduced along the line to the first tank and exits through cargo lines to the next. Inert gas leaves the second tank from the line to the third and so on.

The method of movement depends on the fact that the inert gas is slightly heavier than the existing air in the tank, when the inert gas enters the tank, the existing air is displaced. When using this method, it is important that the inert gas has a very low inlet velocity, in order to provide a stable horizontal interface, it develops between the incoming and outgoing gases, although in practice this inevitably is a rarefaction due to turbulence caused by the inert gas flow. Typically, this method allows you to fill several tanks that must be loaded or cleaned at the same time.

Regardless of which method is used, it is important that oxygen or gas measurements are constantly monitored to verify the effectiveness of operations.

During unloading, an inert gas is introduced into the tank to provide an inert atmosphere. It is important that the introduction of inert gas exceeds the discharge rate of the cargo pump.

Positive inert gas pressure should be maintained in the space of the inertial cargo tank for the entire transition time to prevent possible air ingress. If the pressure drops below the set level (low pressure signal), measures must be taken to re-inject the tank with inert gas. Pressure loss is usually associated with lower air and sea temperatures.

If positive pressure is difficult to maintain, this indicates a leak from the tank system. Checks should be made for faulty valves and incorrectly fixed hatches. Other tank connections should also be checked and adjusted if necessary.

CONCLUSION

Considering modern systems of inert gases, the following advantages can be distinguished:

- inert gas in the cargo tank makes the atmosphere non-explosive;
- this allows you to wash the tank under high pressure, reduces the cleaning time of the tank;
- improves cleaning efficiency and reduces unloading time;
- it helps in the safe vaporization of gases in tanks;
- it forms an easily accessible fire extinguishing agent for other rooms;
- reduces cargo loss through evaporation;
- compliant with law and reduces premiums.

The disadvantages are:

- additional installation costs;
- additional maintenance requires labor;
- low visibility inside the tanks;
- low oxygen is not allowed in tanks;
- the oxygen content must be controlled.

Also during operation, the main disadvantage of the liquid nitrogen system was identified. In the presence of liquid nitrogen in the tank under the influence of ambient temperature. Liquid nitrogen evaporated in excess, which forced the use of high-quality nitrogen more. On the one hand, this gave a positive effect when high-quality nitrogen was used during cargo operations without additional start-up of the heating system for converting liquid nitrogen into a gaseous state. But during a long transition between ports, this effect forced to dump excess nitrogen gas in the open atmosphere.

REFERENCE

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