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THE PROBLEM OF CARRYING INSUFFICIENTLY OPTIMAL GASSING-UP OPERATION AFTER TANKS INERTING WITH REFERENCE TO ETHYLENE CARRIERS

PROBLEM NIEOPTIMALNEGO PRZEPROWADZANIA OPERACJI ZAGAZOWANIA ZBIORNIKÓW ŁADUNKOWYCH PO INERTOWANIU NA ETYLENOWCACH

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Abstract: The paper describes a very crucial problem of carrying insufficiently optimal gassing-up process on ethylene carriers before cooling the cargo during its transport by the sea. At the beginning cascade system of the cargo reliquefaction plant has been described along with its parameters of work. The impact of nitrogen presence on ethylene cascade cycle's technical work and cooling capacity has been preceded by the detailed depiction of cargo handling operations – tank inspection, inerting and gassing-up. All operations have been circumscribed in terms of oversized amount of ethylene cargo loss, which, in turn, allows to draw a conclusion that gassing-up operation is performed in insufficiently optimal way.

Keywords: gassing-up, inerting, cascade cycle.

Streszczenie: Artykuł opisuje problem nieefektywnego przeprowadzenia operacji *gassing-up* na etylenowcach przed chłodzeniem ładunku podczas transportu. W pierwszej kolejności scharakteryzowano dwustopniowy obieg kaskadowy schładzania etylenu z wyszczególnieniem parametrów pracy kaskady. Opisano wpływ obecności azotu na pracę obiegu. Ze względu na to, że poruszony problem dotyczy początkowych operacji procesu chłodzenia ładunku, omówiono tu pierwsze trzy zabiegi, inspekcję zbiorników, inertowanie oraz *gassing-up*. Wszystkie operacje scharakteryzowano w odniesieniu do strat znacznych ilości ładunku etylenu, co w konsekwencji pozwala wysunąć wniosek, że *gassing-up* jest przeprowadzany w niewystarczająco efektywny sposób.

Słowa kluczowe: *gassing-up*, inertowanie, obieg kaskadowy.

1. INTRODUCTION

Gas carriers are very multi-faceted kind of ships that confirm the most hi-tech developments of ocean and material engineering, ship technology, electronics and informatics [*Transportation of Condensed Gases by Sea* 2002]. They make possible transport of liquefied natural gas and liquefied petroleum gas all over the world. Nonetheless, one of the most serious problems of sea travels constitutes transport of ethylene. To be precise, too much cargo is lost during gassing-up operation ahead of ethylene cooling.

2. CASCADE SYSTEM – DESCRIPTION OF WORK PARAMETERS

Transport of ethylene by the sea is connected with its cooling in cargo tanks to approximately minus 103°C. Due to the use of cascade cycles, maintenance of the pressure in these tanks closed to atmospheric becomes possible. During the sea transport cargo temperature is reduced maximally in extreme conditions, like sea water temperature of plus 30°C or higher, about 0,6 K every 24 hours, according to typical projects of ethylene carriers [Włodarski 1993; Nanowski 2014].

In case of ethylene, the pressure of cargo tanks is 0-4 bar g, the two stage compressing also leads to the high temperature at the compressor's discharge. In order to reduce temperature in case of this kind of cargo cascade cycle it is used together with two stage compression with inter-cooling. The diagram below describes the cascade cycle for the cargo of ethylene (Fig. 1). Parameters of the process are shown on Mollier diagram (Fig. 2) [Cool Pack 1.50].

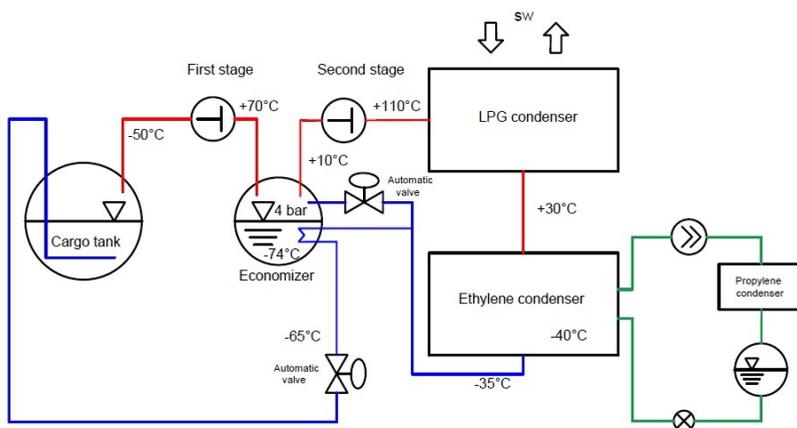


Fig. 1. The cascade cycle of ethylene cargo

Rys. 1. Obieg kaskadowy ładunku etylenu

Ethylene vapor of minus 50°C reaches the suction side of reciprocating compressors, where it is compressed to approximately plus 70°C (process 1–2). Having the pressure of 4 bar, vapor is directed to the intermediate intercooler – economizer that cools it before it enters the second compression stage (process 2–3) and sub-cools the condensate that flows back to the tanks. Then ethylene vapor of approximately plus 10°C is compressed the second stage to the temperature of around plus 110°C (process 3–4). Afterwards, it hits LPG condenser that is cooled by the seawater. Unfortunately, due to the fact that ethylene condenses only at the temperature of minus 35°C, LPG condenser is unable to liquify the ethylene vapor by the pressure of 17 bar g. So, ethylene vapor reaches plus 35°C (process 4–5). The temperature of minus 35°C is achieved in ethylene condenser (process 5–6), which is cooled by the cascade cycle. The cascade cycle utilizes propylene to condense cargo vapor. Further, after condensing, flowing via cargo economizer, the condensate is directed to an automatic valve decreasing the pressure to that one in the tank (process 7–8). An automatic valve also separates high pressure side from low pressure side in the cargo tank, in which the pressure does not exceed 4 bar g. Thereafter cooled condensate flows back to the cargo tank.

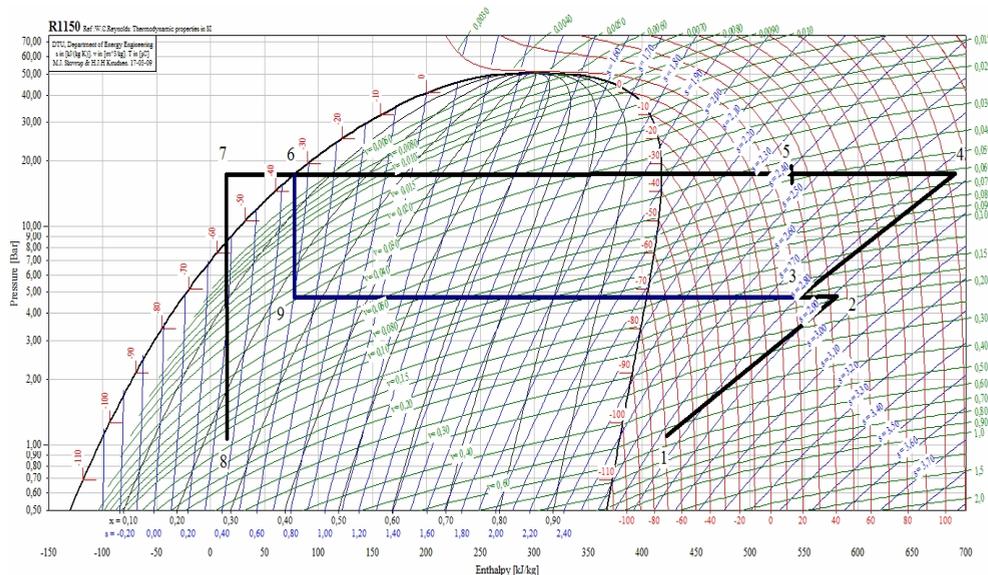


Fig. 2. Molier diagram of reliquefaction cycle
Rys. 2. Diagram Moliera ponownego schłodzenia etylenu

3. CARGO HANDLING OPERATIONS

The flow chart shows the general sequence of cargo handling operations, assuming a gas carrier comes directly from a shipbuilder or drydock (Fig. 3).

This paper describes the first three operations that have significant importance for the issue under discussion.

3.1. Tank inspection

Before any cargo operations are carried out, it is essential that interior of cargo tanks is visually inspected. The state of material, potential presence of corrosion, cleanliness must be checked, and that all fittings are properly secured. In addition, any free water must be removed. Once this inspection has been completed, cargo tanks should be securely closed and inerting operation may start [McGuire and White 2000].

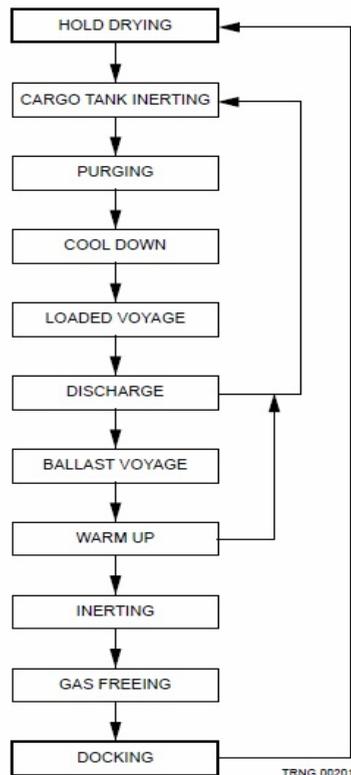


Fig. 3. Sequence of cargo handling operations [Ship owner's documentation 2015]

Rys. 3. Kolejność wykonywania operacji ładunkowych [Dokumentacja właściciela statku 2015]

3.2. Inerting

Before a flammable cargo is loaded, an inert atmosphere must be established inside the cargo tanks and piping systems [Ship owner's documentation 2015]. Therefore, content of oxygen must be reduced from 21% to required minimum according to the sort of carried cargo and occasion. IMO regulations stipulate that oxygen concentration must be very low before loading oxygen reactive cargoes [Polski Rejestr Statków 2001]. Such low oxygen levels can be achieved by nitrogen inerting provided not only from the shore, but the PSA (pressure swing adsorption) plant is also used for this purpose [McGuire and White 2000]. The type of the ship being under discussion in this paper abuses just PSA plant which allows nitrogen 'production' on the ship. Generation of an inert gas is presented in Figure 4.

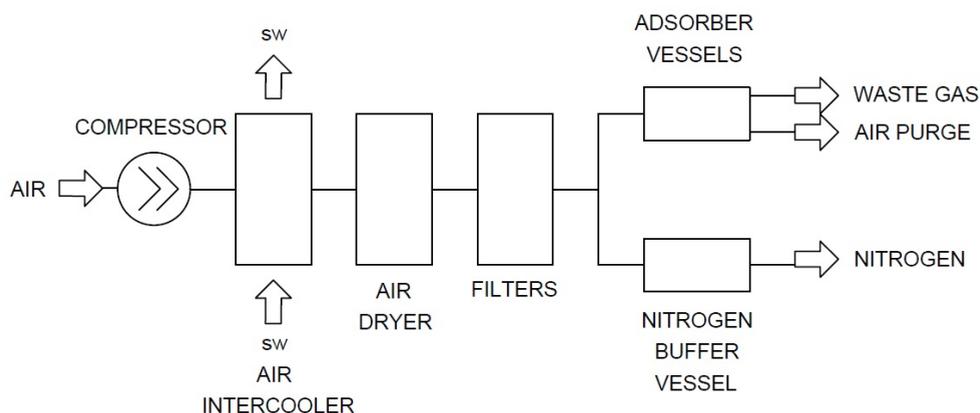


Fig. 4. Generation of an inert gas

Rys. 4. System generacji gazu obojętnego

The plant consists of isolating its components from the air by compressing the air, and further, passing it through membrane modules which divide the air into two parts, nitrogen and oxygen mixed with other gases. Received this way nitrogen is introduced into the cargo tanks. It is crucial to remember that inerting process should be held at as little amount nitrogen consumption as possible.

3.3. Gassing-up

Neither nitrogen nor carbon dioxide, the main constituents of inert gas, can be condensed by a ship's reliquefaction plant. This is due to the fact that at cargo temperatures, each is above its critical temperature and is incondensable. Therefore, removal of inert gas from the cargo tanks is highly necessary. This is achieved by the operation of gassing-up, using vapor from the cargo to be loaded at ambient temperature and removing it so that the reliquefaction plant can operate efficiently

[McGuire and White 2000]. Incondensibles prevent heat transfer in the condensers by blanketing the heat exchange surface. This seriously decreases the cooling capacity. The cargo vapor for purging can be delivered directly from shore via the crossover. It is more common to take cargo liquid from shore and generate the vapor using the ship's vaporizers. To save time at the terminal, the liquid cargo may be filled to the deck tank to purge at sea.

There are two purge lines fitted in each cargo tank, the top and bottom purge line (also used as liquid filling line). The outlet nozzles of the upper lines are directly upwards and those on the lower line are arranged downwards to ensure efficient purging.

To reduce consumption of purge gas, a basic rule should be retained, i.e. it should be passed into the tank through the lower purge line if the cargo has a higher density than the atmosphere in the tank. It is also important to refer to the correct temperatures when comparing densities. Conversely, if the purge gas is lighter than the tank vapor phase then it should be passed in via the top purge line [Ship owner's documentation 2015].

In practice, inerting is carried at ambient temperature, between 0°C and plus 40°C for about 30 hours. This process generates atmosphere in the tank. The way of ethylene is following, ethylene condensate at approximately minus 94°C from deck tank is directed to ethylene vaporizer consisting of two heat exchangers. In the upper heat exchanger ethylene is vaporized in the tubes with condensing propylene on the shell side, in the lower heat exchanger the refrigerant is vaporized against seawater (tube side). Ethylene vapor outlet temperature is about minus 50°C. Too high temperature of ethylene would make steel cracks at the bottom of the tank. Ethylene vapor is introduced into the cargo tanks in series, bottom to the top, means that first bilobe tank is filled in the vapor and then, after achieving in the tank the pressure of 0,3 bar g the valve to another tank is opened and vapor is directed to it to replicate this part of the operation. After gassing-up of the fourth tank nitrogen (and ethylene) is vented to the atmosphere. Described process is shown in Figure 5 [Ship owner's data 2000; Ship owner's documentation 2015].

Interposing ethylene vapor, in tanks an attempt of gas cushion receive is made to separate both gases from each other, so that the ethylene could push the nitrogen out of the tank, utilizing as little quantity ethylene cargo as possible. As a matter of the fact, unlike to other hydrocarbons, due to similar densities of both gases creating a gas cushion is very difficult to achieve and even if it is formed, after a very precise filling up the first tank, opening a valve to another tank leads to perturbations of the surface of nitrogen and ethylene.

Consequence of these disorders is mixing the vapors in tanks what makes impossible venting only nitrogen. As long as a portable multi gas monitor does not show clear nitrogen, together with this gas ethylene is also lead out of the fourth tank. In this process, in case of four bilobe tanks of 2500 m³ each, from 70 tonns of ethylene taken from shore to the deck tank, about 10 tonns is 'lost' during gassing-up operation.

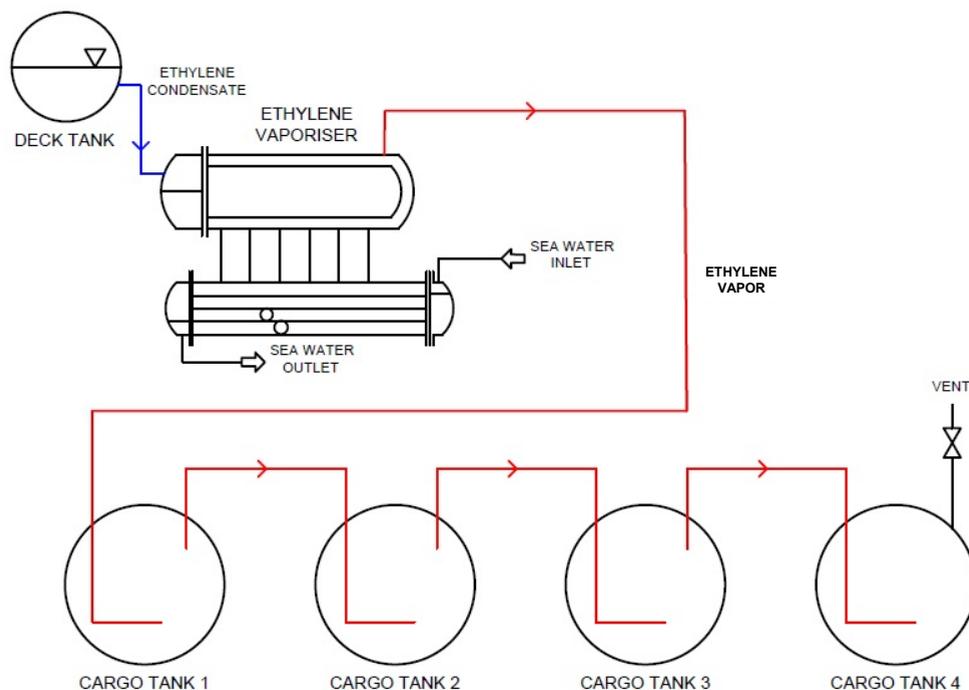


Fig. 5. Gassing-up, liquid cargo from deck tank, bottom to top

Rys. 5. Zagazowanie zbiorników ładunkowych, ciekły ładunek ze zbiornika na pokładzie

If the whole procedure is carried out alongside in port, received after gassing-up mixture of ethylene and nitrogen is returned from tanks to shore. However, if local rules do permit venting from the ship's vent mast, care must be taken to make certain that flammable or toxic vapor is not drawn into safe spaces [Ship owner's documentation 2015].

4. CONCLUSION

In conclusion, gassing-up is highly necessary so that the cargo of ethylene could be cooled down and properly prepared to the voyage. Precariousness of the thermodynamic process in the tank, to be precise, unfamiliarity with the thermodynamic conditions of mixing ethylene and nitrogen vapors during gassing-up process constitutes the reason for losing about 15% of cargo every time other hydrocarbon is replaced by ethylene cargo. These conditions should be comprehensively analysed to find a solution which makes possible decreasing quantity of vented ethylene vapor.

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