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Optimization of Reliquefaction System on Gas Carrier to Maintain The Condition and Temperature of Cargo Tank

Abstract:

Transport of liquefied hydrocarbon gases and their derivatives (methane, ethane, propane, butane, ethylene, propylene and other liquefied gases) is done using gas carrier tankers. Large gas carriers are equipped with re-liquefaction system to handle cargo during the process of loading, voyaging, and unloading. A reliquefaction system is installed on gas carriers to handle the Boil off-gas (BOG) problem. Operation constraints Reliquefaction system operating the reliquefaction system include the compound characteristics, liquefaction unit operating conditions, and system performance. These issues also hinder the BOG liquefaction process. This research sought to investigate the whole operation process of the system. This case study was conducted by observing the objects directly on the MT. Chinagas Legend vessel whose main cargoes are LPG. In case studies, research is carried out by studying the phenomenon of case problems that occur directly on the object. The identified problems and its resolutions could add valueable information to science. The research results revealed that MT. Chinagas Legend had a reliquefaction system with 2-stage or 3-stage options. The former type was used for butane (C4H10) cargoes and the latter was used for propane (C3H8) cargoes. The common problem in the process of reliquefaction systems was the presence of contaminants carried with seawater and clogging the filters. A leak in the intake or discharge valve slowed down the reliquefaction process and rendered it ineffective. The problems can be overcome through periodic routine inspections on components that are directly in contact with sea water, such as sea water filters.

Keywords: cargo compressor, refrigerator, liquified petroleum gas, reliquefaction system, tank conditioning

INTRODUCTION

Liquified Petroleum Gas (LPG) is categorized as aprimary need for the society. LPG plays useful roles in industial sector, such as machinery cooler, fuel for cutting machines, fuel for spraying machine, and various other applications. In Indonesia, LPG is mainly used in households as fuel for various kitchen appliances, such as gas stoves. Such dominant use of LPG is the effect of government policy which enforces reduced use of kerosene (Yulianti & Astari, 2020). Another useful application of LPG is for car fuel. The LPG is part of hydrocarbon comodity.

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The liquid hydrocarbon and the derivatives (methane, ethane, propane, butane, ethylene, propylene and others) are widely used in chemical engineering as energy sources. The majority of the transportation and distribution chain is carried out by sea using gas carrier tankers (Miliajev et al., 2007). Natural Gas (NG) and Liquified Natural Gas (LNG) are also comodities transported by gas tanker.

This kind of vessel gas carrier has 3 categories. Small fully pressurized gas carriers have less than 5000 m^3 in capacity. Gas product cargoes are transported at atmospheric temperature in cylindrical or spherical steel vessels designed to with stand pressures of up to 20 bar (Mohitpour & Jenkins, 2016). This type of vessel is not equipped with reliquefaction system. Medium fully refrigerated (Midsize) is a gas tanker vessel with a fully-refrigerated system built for transporting liquid gas on low temperature and athmospheric pressure.The tanker vessels have prismatic-shaped cargo compartements made of 3.5% nickel steel, enabling the loading cargoes on temperature up to-48°C. Very Large Gas Carrier (VLGC) vessels have a loading capacity more than 70.000 m^3 (Winarto et al., 2017). This kind of vessels are equipped with reliquefaction system for handling cargoes during loading, voyaging, or unloading. Safety and loss due to loss of cargo can be mitigated with the installation of such systems.

The reliquefaction system on a gas carrier isaninstallation to deal with the Boil off Gas (BOG) problem. An economic analysis is performed to that system to examine its efficiency. The analysisis done by comparing the use of single nitrogen, ethylene, propylene, and joule thomson. The efficiency of the single nitrogen system, at 98.12 %, is the highest (Makapuan & Muharam, 2021).The Reverse Brayton refrigeration cycle works with nitrogen as the working fluid for reliquefaction of BOG on LNG carriers. The system works with vent gased being recycled and completely liquefied with the boiling gas (Kochunni & Chowdhury, 2020). The process is done without reducing the pressure on the turbine or losing the reliquefied methanol.

The common issues faced on operating reliquefaction system include the compound characteristics in the tank, the operating conditions of the liquefaction installation, and the system performance(Morozyuk et al., 2022). The a fore mentioned problems can hinder the liquefaction process of BOG as well. In overall, these problems reduce system performance, sub sequently reducing efficiency. This research sought to examine the operating process, monitoring the system as a whole. The identified problems and its solutions will provide valuable information for science in operating the Reliquefaction system on gas carriers. This research sought to investigate the whole operation process of reliquefaction system operating the reliquefaction system include the compound characteristics, liquefaction unit operating conditions, and system performance..

METHODS

This case study was conducted by observing the objects directly on the MT. Chinagas Legend vessel whose main cargoes are LPG. In case studies, research is carried out by studying the phenomenon of case problems that occur directly on the object (Elstub & Pomatto, 2022). This particular vessel is registered with IMO Number 9847944 and MMSI number 4777538700. The vessel has weight 55368 DWT with Length Over All (LOA) 230 meters. The overview of its tanks and their respective capacities are presented in Figure 1.

Fore				
	1S 16991 CBM	**2S** 22611 CBM	**3S** 22762 CBM	**4S** 21638 CBM
	1P 16991 CBM	**2P** 22611 CBM	**3P** 22762 CBM	**4P** 21638 CBM

Figure 1. Overview and Capacities of Tank

Based on Figure 1, the ship has 8 tanks arranged 4 starboard side and port side. The volume of gas that can be loaded is about 168004 CBM. Reliquefaction process is the topic that will be studied in this research.This research was conducted by implementing the stages summarized in Figure 2 as the following.

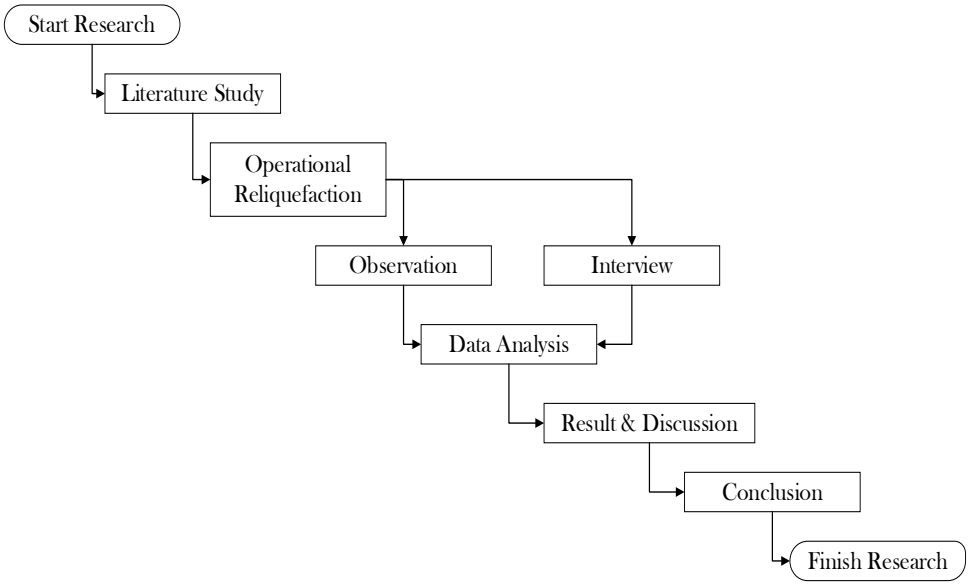


Figure 2. Research Flowchart

As presented in the Figure 2 the present research focused on reliquefaction system available on board. During the proces loading cargoes, observation was performed to the system to examine various important parameters which included pressure and temperature on tanks. Observation is needed to answer complex questions about phenomena that occur (Jia, 2023). Those parameters greatly affected the amount of Boil off Gas (BOG), tank conditioning, and condensation in heat exchangers. Observation results and data obtained were presented qualitatively. Observations became more complete with the addition of interviews conducted with the senior officers on board as research informants. The results of observations and interviews will be analysed with previous literature and presented in a qualitative descriptive approach.

The chief officer being resposible for cargoes on vessel and the chief engineer being responsible for engine area were considered as competent parties. The interview process was conducted based on pre-determined guidelines. The determination of the interview guide is based on relevant research that discusses the reliquefaction process. The parameters on which questions are based include, operating processes, problems, performance improvement, and operator proficiency (Morozyuk et al., 2022). The guidelines included questions related to the requification system on MT. Chinagas Legend. The interview instructions used by the researchers were presented on **Table 1** as the following.

Table 1. Interview Items

Questions Poin
How does the reliquefaction system work in MT. Chinagas Legend ?
What the obstacles are encountered in the reliquefaction process ?
How to use the reliquefaction system to make it more optimal ?
How can the cargo compressor as a reliquefaction system work properly when used ?
How can the crew use the cargo compressor easily
How can the ship's crew be able to carry out cargo compressor maintenance at MT. Chinagas Legend ?

RESULT AND DISCUSSION

Reliquefactionis a process of converting the Boil off Gas (BOG) from storage tank back into liquid form. The term reliquification refers to the same process of liquefying gas vapor. Reliquefaction System is only found on LPG transporting vessels that have cargo tanks of Fully-Refrigerated type. This kind of vessel transports its cargoes at atmospheric pressure and are designed for large-sized cargoes. The liquefaction system has the main principle of cargo liquid being sprayed at the top of the tank. Reliquefaction system installed on tanker gas carriers presented on Figure 3 as the following.

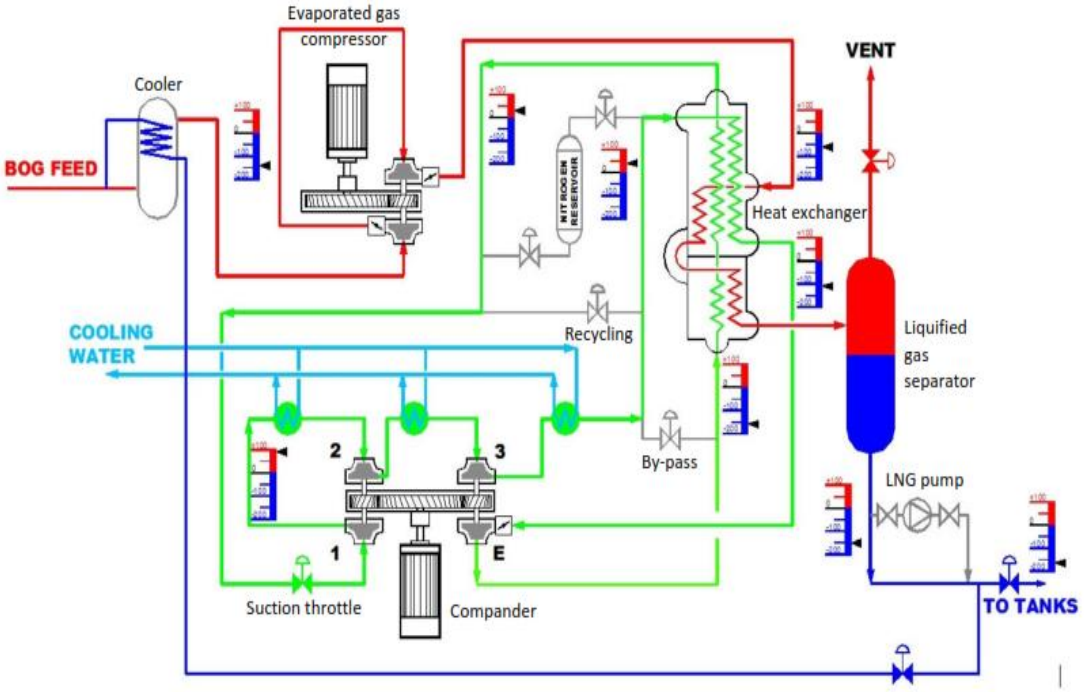
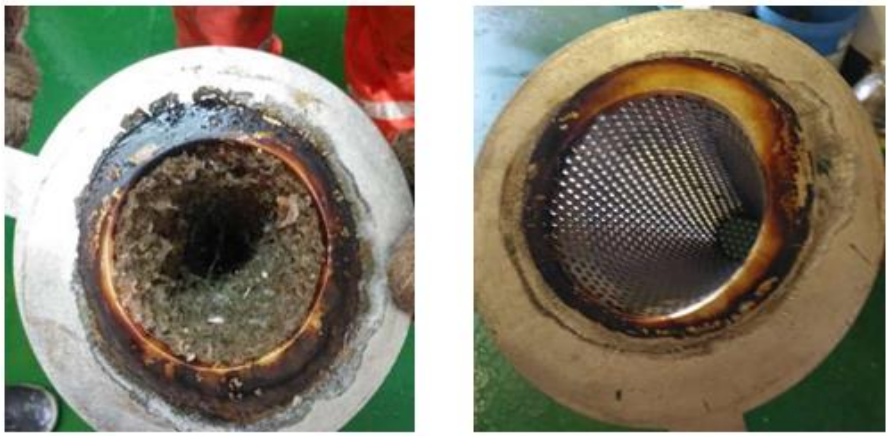


Figure 3. Reliquefaction System
Source: Kukuljan et al., 2012

Figure 3 shows that compressed vapor is connected to condenser. The condensor heat exchangeris a component in which seawater flows as a cooling medium. The vapor exhaust flows from the compressor to the condenser system in compressed form, with the aim of cleaning the manifold ducts and facilitating the heat exchange process. The reliquefaction system provide two options, the 2-stage or 3-stage mechanisms.The former type of system passes two stages for butane cargoes(C_4H_{10}), while the latter type passes through three stages for Propane cargoes(C_3H_8). The reliquefaction system used on board is different from that used on shore. shipboard systems require smaller, simpler devices with maximum performance (Gómez et al., 2013). The process of inerting and freeing gasses directly from ventilation to the atmosphere is performed only in emergency situations. This action is the final solution in handling the load when other options are unavailable. The referred emergency situations are where the tank pressure is too low. The pressure limit cannot be more than 0.45 bar during loading and unloading operations. During normal voyage, the pressure limit is less than 0.27 bar and the pressure cannot be increased by means of reliquefaction. Improve the design of the expansion device using the replacement of the throttle device with the ejector to increase efficiency system (Sokolovska-Yefymenko et al., 2023).

Temperature handling is extremely important with the aim that the LPG cargoes entering the tank will not evaporate quickly. The boiling point for Propane LPG gas (C_3H_8) is at a temperature of - 42.3°C and butane LPG gas (C4H10) is at a temperature of - 50°C.

These temperature are in accordance with the provisions of the rules according to international rules (SIGTTO, 2013). The regulation stipulates that the tanks on fully-refrigerated LPG vessels have a temperature limit of -50°C. The problem during the process of cooling the cargo after going through the compression process is that the cooling system does not work properly due to the seawater filter being dirty. Usually this happens because there are dirts or wastes from the seawater suction system, such as; shells, barnacles, silt, sand, and others. The amount of water entering the condenser is greatly influenced by the condition of the filter. A clean seawater filter will facilitate the flow of water so that heat transfer for liquefaction can be optimized. Gas transportation using carrier gas vessels requires good cooling in the reliquefaction system (Shakrina et al., 2021). Previous studies that sea water in normal flow gives COP values of 0.22 and an exergetic efficiency of 37%, such values being 22.22% and 19.35% greater than on problem (Romero Gómez et al., 2015). Figure 4 shows the condition of cloged seawater filter (a) and cleaned seawater filter (b), as the following.



(a) (b)

Figure 4. Filter Condition, (a) Cloged, (b), Cleaned

Another problem that occurs and hinders is the presence of leaks. Leaks in the valve lead to condensation or vapor pressure becomes low. Compressor cargo suction pressure that does not work as expected can affect the reliquefaction process. This resulted in the reliquefaction process being longer than usual (Sumali et al., 2021). Therefore, to overcome the problems experienced during the operation of the reliquefaction system, routine machine maintenance is required. Provision of lubricating oil on a regular basis as well as providing information and familiarization to gas engineers in maintaining engine cleanliness are necessary actions.

Based on the observations and interviews with informants, it is known that engine maintenance follows the Plan Maintenance System (PMS). Maintenance is carried out periodically (weekly and monthly) by referring to the DNVGL Classification. Apart from the periodic maintenance, the gas engineer at MT. Chinagas Legend had gone through a training process. Experience in operating and maintaining reliquefaction systems and compressors on fully-refrigerated ships is an extremely valuable asset to become a good gas engineer.

CONCLUSION

Reliquefaction is a process where Boil off Gas (BOG) from a storage tank is converted back into liquid form. The term reliquification is the same as the process of liquefying gas vapor. The Reliquefaction System is only found on LPG vessel type that

have cargo tanks of Fully-Refrigerated type. Handling the temperature really needs to be done with the aim that the LPG cargo that enters the tank when loading does not evaporate quickly. The boiling point for LPG gas prophane type is (C3H8) is at a temperature of -42.3°C and LPG butana type (C4H10) is at a temperature of -50°C. The problem during the process of cooling the cargo after going through the compression process is that the cooling system does not work properly because the seawater filter is dirty. Another problem that occurs and hinders is the presence of leaks. Leaks in the valve so that the condensate or vapor pressure becomes low. Meanwhile, to overcome the obstacles or problems experienced during the operation of the reliquefaction system, routine machine maintenance is required. Provision of lubricating oil on a regular basis as well as providing knowledge and familiarization to gas engineers in maintaining engine cleanliness.

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