Reliquification of Boil of Gas by using BOG Compressor

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ABSTRACT
Liquefied natural gas (LNG) is a prominent clean energy source available in abundance. LNG has high calorific value, while lower price and emissions. Vapors generated from LNG due to heat leak and operating-condition-changes are called boil-off gas (BOG). This paper discusses complexities and challenges of managing boil off gas (BOG) in lique ed natural gas (LNG) liquefaction plants. The advantages and disadvantages of different options and compressor systems are covered and the concept of dynamic simulation as an analysis tool is addressed. The study would help proper handling of BOG problems in terms of minimizing flaring at LNG exporting terminals, and thus reducing waste, saving energy, and protecting surrounding environments.
Keywords*: BOG, LNG, etc.*

Introduction

Natural gas currently supplies approximately 23% of the world energy production. According to the BP energy outlook, LNG represents a growing share of gas supply. Global LNG supply is projected to grow 4.5% per year to 2030. More than double the growth rate of total global gas production (2.1% per year). LNG contributes 25% of global supply growth 2010-2030compared to 19% for 1990-2010. The reason of converting the LNG natural gas to liquid is to ease transport to markets and storage since liquefied LNG is the most economical mean to transport the natural gas for long distance. The volume of LNG is around 1/600 the volume of natural gas under gaseous state. The processes to liquefy LNG all involve some refrigeration process that sequentially extracts heat from the feed gas resulting in its liquefaction.

As heat leaks into the tank. The LNG boils and has to be accommodated somehow to keep the tank pressure under control. This is typically done in a BOG compressor which transports the vapor to the liquefaction system or utilizes it in some other form depending on the liquefaction process. The LNG tank is in a constant boiling state. The total BOG flow is a combination of the entire vapor generated from rundown flash, heat leak. Barometric pressure changes pump energy, and net hydraulic grade. If this vapor is not drawn off by the BOG compressor, the tank pressure will increase to the point when venting will be required.

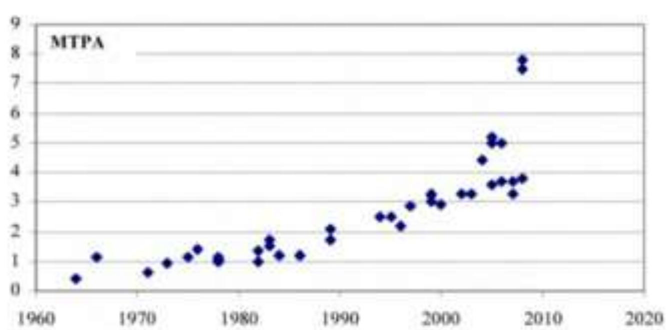

Fig.1:Consumption of Natural gas

1. BOG Generation in LNG Liquefaction Plants.

The overall generation and transport of BOG is shown in Fig.LNG liquefaction processes, always results in the generation of BOG. This BOG produced is generally the result of staged ashes that are used to produce LNG at near atmospheric pressure in the tanks as well as the BOG produced due to heat leak into the LNG tank and associated piping during "HOLD "mode (nonslip loading) of operation.

BOG resulting primarily from rundown flash is generated and is returned to the methane loop by the BOG compressor. However, during ship loading there is a significant incremental quantity of BOG generated due to vapor displacement at ship loading rates, system heat leak (in loading lines, etc.) and flashing of the LNG at ship cargo

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storage pressure. This BOG generated during ship loading is generally warmer than the BOG generated during "HOLD" mode due to additional superheat from the ship blowers, vapour return lines, etc. Consequently, during ship loading, the tanks are forced to operate at higher pressures. Below which shows ship BOG vapor versus tank pressure.

In a multitrain LNG facility, depending on the different operating scenarios involving ship loading, and hold of the different trains, the tank pressure can vary significantly. BOG from the ship vapour return header is normally mixed with the BOG from the tanks and then compressed by BOG compressors which, depending on the LNG process, compress the BOG back to the process or compress it to be used as high pressure fuel gas in the plant.

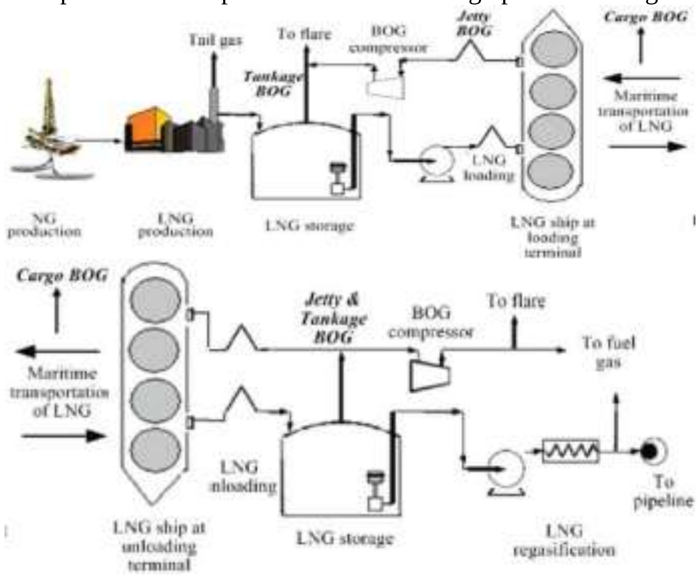

Fig.2. Loading and Unloading of LNG

2. BOG recovery strategies.

2.1 Use BOG as fuel gas

LNG plants need a huge amount of energy for compression of refrigerants and to run other units. BOG can be used as the fuel to drive compressor and power generation turbines. Fuel gas pressure requirements may vary significantly. Power required to compress BOG can be calculated.

2.2 Use BOG as feed gas

BOG can also be used as feed gas for the existing LNG plant. In this case, the main feed flow rate needs to be reduced to maintain the total feed rate within the plant processing capacity. The original natural gas feed should be reduced such as to have the total mass flow rate constant at about 600,000 kg/h. During the LNG ship loading mode, the total maximum amount of BOG generation approaches about 10% of the natural gas feed rate by mass according to the base case considered. Before the BOG can be used as the feed gas, the BOG stream needs to be compressed to about 50 bar to match the pressure of natural gas stream in the inlet of the LNG plant. This requires additional energy. The BOG will be compressed, air cooled, water cooled, and then recycled to the plant.

2.3 Liquefy BOG on berth

If the BOG liquefaction facility can be installed on the berth area, jetty BOG can be liquefied and added immediately to the ship tanks being loaded. This will avoid transportation of BOG back to the shore. However, ship loadings are in batch operations. Thus, the corresponding start-up and shut-down of BOG liquefaction frequently might cause problems. Further storage of the refrigerants will add complexity to the problem. Transfer of on-shore refrigerant to berth area has been considered, and energy required for transportation and heat loss due to additional piping is calculated.

2.4 Use BOG as makeup gas

During the loading mode, LNG storage tank needs some gas feed to maintain its pressure and avoid vacuum operations. The BOG generation rate in storage tanks is much lower than the volume of LNG being withdrawn from the tanks during the LNG ship loading. The BOG can be used as make-up gas for the storage tanks. BOG colder than ambient temperature will add less heat as compared to using other gases at the ambient temperature. The BOG generation rate is not constant with time, however, JBOG generation rate is higher than the make-up gas required for storage tanks as buffers. Therefore, a necessary amount of BOG can be diverted to storage tanks and the remaining is utilized in other recovery processes. This strategy cannot be simulated using steady state simulation.

3. Reliquefaction process by using BOG Compressor.

Generally, LNG is stored in a container during transportation and absorbs the heat from the surrounding environment, which makes the LNG boil and evaporate. As the boil-off gas (BOG) increases, the pressure in the container rises quickly. If the pressure in the container exceeds its design pressure, it will become a serious threat to the transportation, as well as the receiving system. Burning and recovering the energy is the traditional method of dealing with the extra BOG. Another method is to liquefy the BOG the BOG is pressurized by a compressor first and liquefied in a condenser by the super cooled LNG. After that, the pressure of LNG is raised by a liquid pump, and the LNG passes through a vaporizer to the pipelines. Therefore, the boil-off compressor is a key device in safely handling the BOG.BOG compressors in LNG systems are usually classified as either vertical labyrinth or horizontal piston, which are oil-free reciprocating compressors. The temperature of the BOG can be as low as -162°C; therefore, there is a huge difference between the suction temperature and ambient temperature.

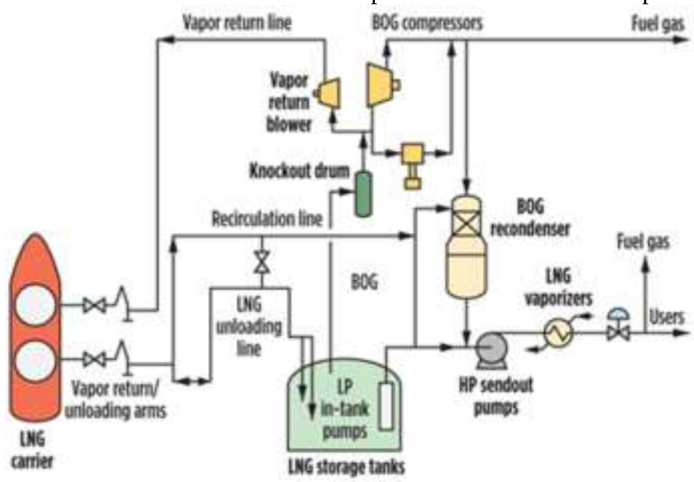

Fig. 3. Reliquefaction process by using BOG Compressor

In this case, the heat exchange from the surrounding environment to the BOG through the suction pipe or cylinder, which is ignored in general reciprocating compressor design, has a significant influence on the thermodynamic process in the working operation. Many studies focusing on the thermodynamic process and heat transfer in a reciprocating compressor have been conducted in the past.

4.Physical factors consideration for BOG compressor

4.1 Expose to cryogenic temperature

LNG at barometric pressure boils off at minus 160°C. This temperature is well below the limit where some of the common engineering materials alter their properties. For example, the loss of ductility of most unalloyed carbon steels within a temperature span from 0°C to about minus 50°C.

4.2 Bone dry gas

Natural gas in form of boil-off is virtually free from water vapour as the dew point is as low as minus 160°C. 0n the one hand it is a matter of experience that moisture in a tribological system is an important parameter. Together with a number of other factors it has a distinct bearing on wear rates under non-lubricated conditions. If one decides to employ dry-running self-lubricating materials for piston rings, one must also accept their mechanical and thermal constraints under bone-dry running conditions. Consequently, the stroke and speed of the machine is set in accordance with the gas conditions. so that the wear rate of the sealing and guiding elements can be held within acceptable limits. Already the initial choice of the dry-running material is itself subject to error because the designer is faced with a multitude of available types.

4.3 Preheat

At low temperatures the heat transfer from the cylinder to the gas affects the thermodynamic process in the compression chamber. This directly determines the design method and the parameters of BOG compressors. The large temperature difference between the low-temperature suction chamber and the surrounding environment leads to thermal stresses on the cylinder, influencing the structure and materials of the cylinder and the heat treatment process. As the piston is in direct contact with the freezing gas, the piston rings must be oil-free, and the selflubricated material must have appropriate friction and wear characteristics. For these reasons, the heat transfer in the cylinder and the thermodynamic process in the compression chamber are critical issues in the design of BOG compressors. Rare research were done on the characteristics of BOG compressor, As mentioned above, preheat is one of the most important design parameter of BOG compressor because it strongly affects the actual flow rate of BOG compressor.

5. Materials selection and design of BOG Compressor

5.1 Piston and cylinder

For the first stage cylinders with exposure to the lowest temperatures resulted in the choice of 666 Ni35. This is a nodular cast iron containing 35% of nickel, also known under the trade name of Ni Resist US. This alloy simultaneously exhibits remarkable ductility at low temperatures and one of the lowest thermal expansion coefficients known in metals. The corresponding pistons were made of nickel-alloyed cast iron with laminar graphite.The less severe temperatures in the second stage allowed the use of ferritic nodular cast iron with good fracture toughness down to minus 100°C and bronze for the piston. The third stage cylinder consists of normal cast iron grade 662.

5.2 Suction and discharge valves

The most suitable type of valve is employed for the operating condition. Valve seats and guards are made of austenitic stainless steel, and the gas tight face contacting with the valve plate is super finished.

Valve plates and valve springs are made of special alloy steel having excellent low temperature tenacity and fatigue strength, and are given a special finish treatment after machining.

6. Types of compressors used in industry

6.1 Centrifugal compressor

Centrifugal compressors are normally used when the boil off gas volume is quite large. However, the inlet gas temperature must be controlled within a certain level to maintain a consistent density, and to keep the centrifugal compressor from approaching surge, which would then recycle, thus further heating the gas.

Control range is limited (by design) to approximately 80 100%, and the intake gas temperature and specific gravity should not vary since the centrifugal compressor must operate on its design curve, and only operate at least 10% above the surge or recycle point.

6.2 Reciprocating compressor

Step type capacity control is available in up to five steps. In this manner, a wide, smooth, capacity control range, i.e. (0 25% 50% 75% 100%) is supplied by the reciprocating compressor.

Reciprocating compressor design is the most suitable compressor to be used for LNG BOG service in both LNG receiving terminals, as well as for LNG storage facilities The reciprocating compressor controls can correspond sufficiently to changes in the boil off gas volume, and thus reduce the overall operating costs; they are always adopted for LNG BOG service at LNG.

The centrifugal compressor is usually only required when the boil off gas volume becomes quite large during actual LNG receiving operations. These events are quite limited in duration, and may only occur once or twice per month, when the tanker is connected to the unloading arms.

Occasionally, when several LNG storage tanks are filled and established, an additional boil off gas demand may be called for during the course of normal holding operations, as well as during LNG receiving. For this type of dual operation, a centrifugal compressor for base load conditions handles large volumes, and the reciprocating compressor handles the fluctuating portion of the LNG boil off gas volume.

	Reciprocating	**Centrifugal**
Capacity	Small-Middle	Middle-Large
Disch. Pressure	High	Low
Space	Large	Small
Suction Temp. Range	Wide	Narrow
Capacity Control	25,50,75,100%	80,100%
Efficiency	High	Middle
Driver Output	Small	Large

Table showing comparison between reciprocating and Centrifugal Compressor

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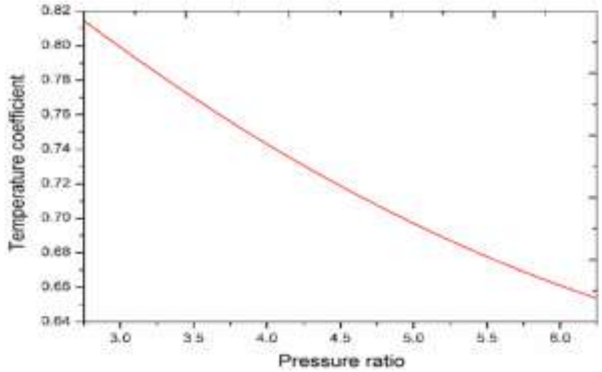
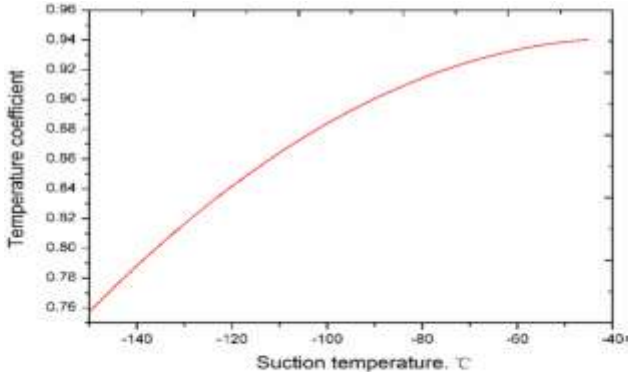
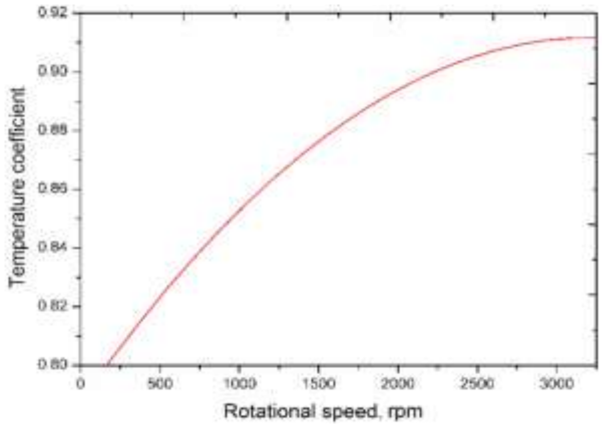
7. Performance characteristics of BOG

7.1Temperature coefficient

The temperature coefficient can reveal the influence of suction heating on a BOG compressor. The temperature coefficient increased with increasing suction temperature or compressor rotational speed, but decreased with pressure ratio.

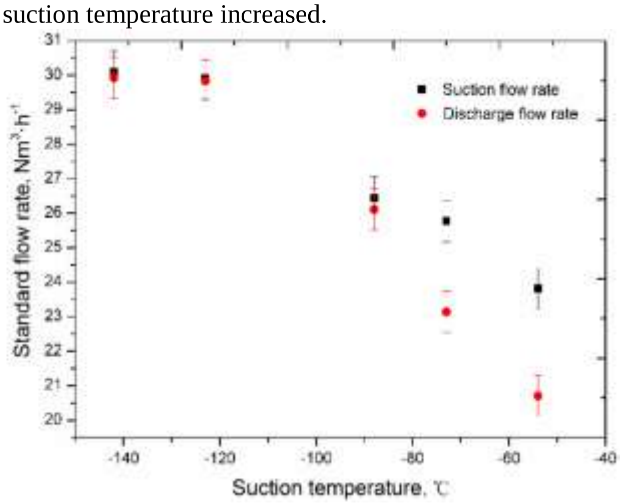






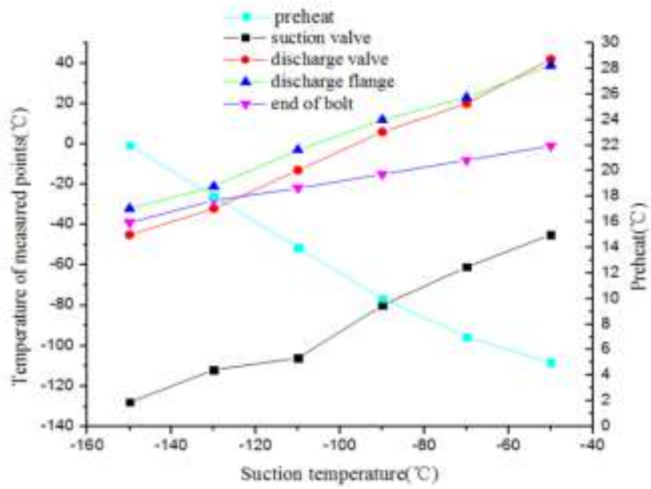
7.2 Suction temperature

Therefore, the clearance between cylinder and piston increased with increasing suction temperature, as well as the leakage from the clearance the flow rate difference between the suction and discharge increased rapidly while the suction temperature increased.



7.3 Efficiency, power consumption and pre heat

According to the experimental results of the temperature distribution, preheat increased with the decrease of suction temperature and increased with the increase of pressure ratio. The pressure-time diagrams at low suction temperature showed the suction pressure loss were higher than those of ambient suction temperature which resulted in the increase of the actual pressure ratio and power consumption and the decrease of flow rate. In addition, the flow rate and power consumption were recorded and the specific power consumption were calculated. The calculated results showed the power consumption of suction temper low suction temperature is less than that of ambient temperature.



Conclusion

1. As LNG liquefaction plant sizes grow and multiple trains are linked together, the BOG management problem becomes more complex. The problem is one of hydraulics, turndown, transient behaviour, and compressor selection.
2. This generated BOG is used for different purpose in liquefaction plant by pressurizing with BOG compressor.
3. The temperature coefficient can reveal the influence of suction heating on a BOG compressor. The temperature coefficient increased with increasing suction temperature or compressor rotational speed, but decreased with pressure ratio.
4. The largest temperature difference in the different parts of the cylinder did not occur in the final stable stage, but instead occurred in the first ten minutes of operation. Pre-cooling the cylinder is probably a necessity to reduce this temperature difference.
5. The temperature coefficient can reveal the influence of suction heating on a BOG compressor. The temperature coefficient increased with increasing suction temperature or compressor rotational speed, but decreased with pressure ratio.
6. Centrifugal compressors are normally used when the boil off gas volume is quite large, whereas Reciprocating compressor design is the most suitable compressor to be used for LNG BOG service in both LNG receiving terminals, as well as for LNG storage facilities.

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