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## Contents

### Editorial

### English Papers

### Arabic Papers

# Review of Reliquefication Plant System for Liquified Natural and Petroleum Gas Carriers

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## المستخلص:

تؤثر كفاءة عملية تسييل الغاز الطبيعي والبترولي بشكل كبير على القدرة الإنتاجية الإجمالية لسلسلة التوريد، واستخدام الطاقة، والاقتصاد، والسلامة. طور العديد من الأكاديميين عددًا من الأساليب التقليدية وأجروا عددًا من الأبحاث حول مختلف عمليات الغاز الطبيعي المسال/غاز البترولي المسال. تم تلخيص ومناقشة تصميم وتحسين عمليات تسييل الغاز الطبيعي والبترولي خلال السنوات القليلة الماضية في هذه الدراسة ومقارنة وبيان فوائد وعيوب طرق التسييل المختلفة. علاوة على ذلك، تم تسليط الضوء على التطورات السريعة الأخيرة في تكنولوجيا التسييل المضغوط وتطبيقاتها المتوقعة.

## Abstract:

The effectiveness of the liquefaction process for natural and petroleum gas is crucial to the supply chains overall production capacity, energy use, economics, and safety. Many academics have developed several traditional methods and undertaken a lot of research on various LNG/LPG processes. The optimization and design of petroleum and natural gas liquefaction processes during the last few years are summarized and discussed in this study. Comparing and contrasting the benefits and drawbacks of various liquefaction methods. Furthermore, highlighted are the recent fast advancements in pressurized liquefaction technology and its anticipated applications.

**Keywords:** liquefied natural and petroleum gas (LNG/LPG); liquefaction processes; liquefaction plant.

## 1. Introduction

Due to the rising demand for alternative fuels, the marine transport industry for liquefied gases has grown in importance and the number of gas carriers has increased. Because of the greater material costs associated with transporting the resulting amounts of compressed gases, the gas supply in a liquefied condition is more profitable (Lee et al., 2014).

The energy potential of liquefied petroleum gases (LPG) is substantial. LPG shipping circumstances might change based on the needs of the client and the thermo-physical characteristics of the cargo. The most typical cargoes are butane ($C_3H_8$) and propane ($C_4H_{10}$). Charterers and other parties with business interests are increasingly asking ship-owners to mix LPG before entering the destination nation's territorial waters. In this instance, the International Maritime Organization (IMO) criteria might be followed by mixing the components either during unloading or loading or in tanks aboard the ship itself during transit. The majority of the containers used for component mixing are typically chilled vessels (Rossios, 2015).

Due to a variety of variables, including population expansion and rising living standards, there is an apparent rise in energy consumption. By 2040, it is projected that the world's energy consumption will have increased by nearly one-third, with fossil fuels serving as the primary energy source (Lim et al., 2013). Nevertheless, the burning of these fuels would result in significant emissions of greenhouse gases (GHG), particularly carbon dioxide (CO2). Natural gas (NG) decreases CO2 emissions per unit of energy by about 29% to 44% when compared to coal and oil (Howarth et al., 2011). In addition, because of its reduced air pollution emissions, natural gas is sometimes referred to be a "bridge fuel" for future renewable energy. It has grown to be a desirable energy source and is regarded as one of the cleanest fossil fuels. As a result, NG now supplies approximately 24% of the world's energy, contributing much more to the total demand for primary energy (Nawaz et al., 2019).

The key aspects and most recent findings of the NG/PG liquefaction process will be presented in detail in this review, along with a summary of the state of the science, an analysis of the difficulties in designing and optimizing the process, and recommendations for future study. NG/PG liquefaction process is examined from 2 perspectives: traditional liquefaction process and pressured liquefaction process. As is well known, the liquefaction pressure and temperature have a significant influence on the structure of liquefaction process. The traditional liquefaction procedure is examined. The pressurized liquefaction process' most current developments, application prospects, and some recommendations are displayed. To encourage future study and optimization of the LNG/LPG process, several key results are outlined to assist designers in the LNG/LPG business in making better judgments.

## 2. Review of literature

Typically, pipelines or liquefied natural gas are the two major alternatives for transporting NG from producing sites to consumers (LNG). Pipelines provide little transportation loss, good security, and are simple to operate. They are also appropriate for continuous operation. Yet, the transit of long-distance pipelines frequently goes via several locations. There are several drawbacks for pipelines in the face of varied geological conditions and barriers, such as the complexity of construction, the rising construction and maintenance cost with the lack of flexibility, and increased transit distance. The usage of pipelines is prohibited in several nations and areas, such as Korea, Taiwan, and a few European nations. Because of the tremendous challenges involved in building pipelines, LNG has emerged as the standard method for resolving all issues related to the storage and shipping of NG across the world (Song et al., 2019).

On the other hand, the abundance of NG in the ocean has sped up the rate of its excavation and consumption in order to satiate the expanding need for natural gas. The Offloading and LNG-Floating Production Storage (FLNG for short or LNG-FPSO), integrates the NG storage, offloading function units, and production. Given the severe offshore circumstances, the limited space, and the high costs associated with transferring natural gas from an offshore extraction platform to an onshore liquefaction facility, may be the best option (Wang et al., 2014). The long-distance transport option that decreases the amount of delivered NG by around sex hundred times through liquefaction is more dependable for reasons related to economics, technology, politics, and security. The "Liquefied Natural Gas (LNG) Forecast Report" from Shell projects that by 2040, there will be 700 million tons of LNG in use worldwide. The quantity of LNG-fueled cargoes is also rising concurrently. By 2021, it is predicted that there will be 45 LNG bunkering boats operating worldwide (Shell LNG Outlook, 2021).

The sector is anticipated to reach an all-time competitive level as a result of the worldwide development of LNG production and rising environmental concerns. Roman-White et al. (2021) ooks at all of the new technologies that have been added to the LNG production line. The writers talk about the need for creativity throughout the full LNG supply chain, from production and liquefaction to shipping, regasification, and sales. They talk about new technologies, such as improvements to gas turbines, floating storage and regasification units (FSRUs), and digitalizing and automating LNG ports.

The study shows how important innovation is for lowering energy use, boosting efficiency, and making the LNG business more profitable. The writers also talk about the possibilities of new technologies like small-scale LNG, carbon capture and storage (CCS), and making hydrogen from natural gas. Up to 60% of the reservoir's capacity may be extracted using such techniques, which include steam, chemical, and water injection. Following extraction, natural gas (NG) is transported to a treatment facility to remove impurities like carbon dioxide, water, nitrogen, oxygen, and hydrogen sulfide to avoid equipment damage or internal corrosion brought on by particulates created during the cooling process. NG may be liquefied using a variety of processes after pretreatment. NG is carried to the receiving station after being liquefied, where it is then gasified once again and brought to the user side (Mazyan et al., 2016).

Refrigeration and liquefaction technologies account for forty-two percent of the total LNG supply chain cost. This is primarily due to the fact that the liquefaction process is carried out in cryogenic temperatures and requires sophisticated refrigeration systems and other equipment. The consumption of large energy caused by the refrigeration cycle compressed power entry has an additional influence on the cost and consumption of high energy of LNG liquefaction production. Hence, if the cost and consumption of the compression power of the liquefaction process can be decreased, the increase in trade growth rate and global competitiveness for LNG would be greatly boosted (Gao et al., 2022).

Operational improvements at various supply chain points can result in significant benefits. For instance, increasing energy efficiency to lower the quantity of fuel needed for conversion of NG in various supply chain activities, resulting in more LNG output with little additional resource use and environmental effect. In addition to being one of the most important thermodynamic processes in the cryogenic natural gas business, NG liquefaction is also the most energy-intensive and expensive link in the supply chain. Gas expansion cycles and Vapor compression cycles are typically the cycles involved in the liquefaction process. The primary difference between these two cycles is that the refrigerant changes phases during the vapor compression cycle, but the refrigerant does not change states during the gas expansion cycle (Katebah et al., 2020).

Aside from the heat burden being distributed over the temperature range from room temperature to LNG's low temperature, the cycle in this operation is essentially comparable to a closed refrigeration cycle. Also, an exergy study demonstrates that temperature difference is the main cause of cryogenic heat exchanger’s exergy damage, as it is the factor that determines the larger compression stress in the LNG main heat exchanger. To minimize such differences, refrigerant composition, flow rate, and operating pressure may all be optimized in LNG cryogenic heat exchangers. Various liquefaction methods need varied energy-using machinery, operations, and financial investments. Several academics have examined the fundamental theories and operating principals of numerous NG liquefaction technologies, along with diverse refrigeration cycle characteristics, and produced several NG liquefaction methods (Wang et al., 2014).

These procedures are broken down into three groups based on the types of refrigeration cycles and equipment that are now on the market: expander liquefaction, cascade liquefaction, and mixed refrigerant liquefaction. The three refrigeration cycles that make up the cascade liquefaction process often have different temperatures. The most common refrigerants are ethylene, methane, and pure propane. In the mixed refrigerant liquefaction process, there is just one refrigerant cycle made out of a light hydrocarbon combination. Moreover, the refrigerant in the expander liquefaction process is often pure nitrogen or methane. Although these refrigerants can achieve the low temperature needed for single-loop LNG, they are less efficient than cascade liquefaction and mixed refrigerant liquefaction processes. In general, these three types of liquefaction processes are improved upon or combined in actual liquefaction operations. Based on their features, several NG liquefaction methods are applied in various NG liquefaction unit types (Zhang et al., 2020). Here are some of the most commonly used NG liquefaction methods and the unit types in which they are applied:

Cascade liquefaction: In this method, the natural gas is cooled in a series of heat exchangers where it is cooled by a refrigerant, usually nitrogen or methane, which is itself cooled in a separate cycle. This method is commonly used in large-scale liquefaction plants, such as those used for baseload LNG production.

Mixed refrigerant liquefaction: This method uses a mixture of refrigerants, typically propane, ethylene, and methane, to cool the natural gas. The refrigerant mixture is cooled in a separate cycle and then circulated through the heat exchangers to cool the natural gas. This method is commonly used in medium-sized to large-scale LNG plants.

Single mixed refrigerant liquefaction: In this method, a single refrigerant, such as methane or ethylene, is used to cool the natural gas. This method is suitable for small to medium-sized LNG plants.

Expander liquefaction: In this method, the natural gas is expanded through a turbo-expander, which cools it to produce LNG. This method is commonly used in small-scale LNG plants, such as those used for peak-shaving or remote power generation.

Nitrogen cycle liquefaction: This method uses a nitrogen refrigeration cycle to cool the natural gas. This method is typically used in small-scale LNG plants.

LNG hybrid liquefaction: This method combines two or more of the above liquefaction methods to optimize efficiency and reduce costs. For example, a hybrid liquefaction plant may combine a nitrogen cycle with a mixed refrigerant cycle to produce LNG.

The choice of liquefaction method and unit type depends on various factors such as the scale of production, the location of the plant, and the availability of refrigerants. By selecting the most appropriate NG liquefaction method and unit type, LNG producers can optimize efficiency, reduce costs, and meet the growing demand for natural gas.

Onshore production and offshore production are two categories for natural gas liquefaction units based on the manner of production. They may also be divided into peak-shaving type, base-load type, and other small-scale liquefaction units, depending on the application. The drastically varying operating conditions, production capacities, and operating procedures result in different requirements for the liquefaction process depending on the production method and application. The mature cascade liquefaction procedure was mostly employed in the early 1960s for building NG liquefaction units. It changed to a much-streamlined mixed refrigerant liquefaction technique in the 1970s. Following the 1980s, the APCI-proposed propane pre-cooled mixed refrigerant liquefaction technique was primarily used in the newly constructed and extended base-load NG liquefaction facilities. The subsequent development of small-scale NG liquefaction units, peak-shaving liquefaction units, offloading units and offshore FLNG production storage, etc., has focused on all the requirements of NG liquefaction aspects, continuously challenging the optimization and design of NG liquefaction processes. According to the literature, few research have investigated the safety of the liquefaction process, with most LNG supply studies concentrating on lowering energy usage and increasing economics. The optimization of the liquefaction process, the recovery of heavy hydrocarbons, a comparison of the proportioning content of refrigerants, a safety study of LNG and FLNG leaks, and other difficulties may be classified as the major concerns in the LNG supply chain **(Gao et al., 2022).**

## 3. Data collection

The key aspects and most recent findings of the NG/PG liquefaction process will be systematically presented in detail in this review, along with a summary of the current state of the research, an analysis of the difficulties in designing and optimizing the process, and recommendations for future study. The compressive search was conducted by using the databases: MEDLINE/PubMed and the following free keywords e.g.: liquefied natural and petroleum gas (LNG/LPG), liquefaction processes, liquefaction plant.

## 4. Comparative review based on traditional and advanced liquefaction techniques

Several review papers have examined the progress of NG liquefaction technologies, with varying review emphases **(He et al., 2018; Zhang et al., 2020; Katebah et al., 2020)**. **Ros-Mercado et al. (2015)**, for example, addressed the NG transportation system. Chang (2015) investigated how to improve the structural efficiency of refrigeration cycles using NG liquefaction technology. Similarly, Lim et al. (2013) focused on the commercial refrigeration cycles of the LNG process. Other evaluations, such as those on FLNG technology or the mixed refrigerant liquefaction process, only summarized one kind of LNG process.

The extensive categorization and explanation of the LNG process by **Khan et al. (2017)** neglected the application variations between onshore and offshore liquefaction as well as their respective optimization needs. **Mazyan et al. (2016)** also highlighted emerging technologies like solar energy, NG solidification, and thermoacoustic that improve the efficiency of the liquefaction and regasification processes. The significance of LNG technology optimization was not addressed in **Zhang et al.'s (2020)** recent in-depth examination of the condition of numerous LNG process types. Several scientific groups from several countries have conducted research on the methods used in gas reliquefication systems.

Saputra and Supramono considered the LPG carrier reliquefication facility with a capacity of 20 tons per day in 2019. The ship carries cryogenic liquids as well as LPGs (butane and propane) and ethane, ethylene, and methane. A cascade refrigeration machine is used in the refrigeration system. The thermodynamic analysis of a reliquefication plant utilizing the exergy technique has been explored experimentally. Nanowski (2013) published the results of an investigation of the butane reliquefication plant in order to evaluate the probable loading rate.

Gómez et al. (2013) investigated numerous BOG reliquefication processes on the LNG ships' board based on economic factors and energy efficiency. Many technologies were described, analyzed, and discussed. This enabled the operational and technical elements, as well as the selection criteria for the reliquefication plant, to be highlighted. Several re-liquefaction facilities have been compared based on their effectiveness and performance, as well as other technical facts. Kwak et al. (2018) investigated the Boil-Off Gas (BOG) reliquefication facility, which decreases methane losses on small-scale LNG carriers. The gas turbine is a closed-cycle model using nitrogen as the operating fluid.

Tan et al. (2018) proposed an upgraded BOG reliquefication system for LNG ships. Two mixed refrigerant cascade cycles (also known as dual mixed refrigerant cycles, or DMR) are used to provide the reliquefication of BOG cooling capacity. The energy efficiency of the new system is assessed using the exergy approach of thermodynamic analysis for stationary modeling in Aspen HYSYS. It is recommended that any changes to operating parameters that affect system performance be considered. To improve the performance of LNG BOG reliquefication units on gas carriers, Kochunni and Chowdhury (2021) proposed adding a 2-stage transcritical CO2 refrigerating machine to LNG reliquefication systems powered by the Claude and Brayton thermodynamic cycles. Their efficiency is equivalent to that of reliquefication systems, which compress flammable refrigerant gases such as ethylene or propylene while operating in cascade cycles. The researchers discovered that the new technology reduces weight and size while enhancing energy efficiency and providing reliable fire protection.

A review of the aforementioned studies revealed that while there aren't many articles on the subject of systems for the study of reliquefication of petroleum gas, researchers concentrate on LNG transportation systems because they believe they are the most in demand.

### 4.1 Reliquefication plants

#### 4.1.1 LNG reliquefication plants basics

The evaporated gas circle and the nitrogen cooling circuit are the two primary circles of a reliquefication facility. The LPG separator, LNG pump, evaporated gas cooler, compressors, heat exchangers, and evaporated gas circle are all parts of the evaporating gas system (when the system pressure is lower than the pressure in the cargo tanks, pump is used in these special circumstances). The circle of nitrogen cooling is made up of heat exchangers, a nitrogen dryer, a nitrogen booster compressor, a compressor, a nitrogen receiver, and nitrogen.

The main purpose of an evaporated gas cooler is to keep the gas entering a heat exchanger at a consistent temperature. The efficiency of the compressor is increased by the gas cooling, which raises gas density and increases the gas mass flow by the compressor. A cargo tank recirculating and cooling pump is used to pump liquefied natural gas into the evaporated gas cooler for cooling purposes ("spray"). The capacity of a centrifugal two-stage compressor for evaporating gas is often modified by rotating the first and second stage's blades. In this manner, the pressure on the compressor discharge side is maintained while only the capacity changes.

Maintaining the default cargo tank pressure and raising the gas pressure before it enters the heat exchanger are the major duties of the evaporated gas compressor. The temperature of condensation rises with increased pressure, enhancing the plant's total efficiency. By exchanging heat with cool nitrogen, the heat exchanger's primary job is to de-liquefy evaporated gas. A three-stage radial compressor, the compressor is powered by an electric motor through a gear or gear box.

### 4.1.2 Natural gas reliquefication plant main characteristics

The LNG reliquefication facility of ship needs to adhere to the following standards (Mokhatab et al., 2013):

•The capacity of the reliquefication plant is typically designed to handle a certain percentage of the cargo boil-off, rather than 100% of the boil-off gas, particularly in cases where the boil-off rate is high or the size of the reliquefication plant would be prohibitively large.

•Installing a gas combustion unit (GCU) is a necessary alternative for reliquefication plants.

•Since the nitrogen in evaporated natural gas cannot be deliquefied, the nitrogen concentration in natural gas decreases. Combustion in the gas combustion unit removes non-condensed nitrogen,

•The system must be capable of stopping the reliquefication when the cargo pumps are operating, eliminating the need for extra generators, and it must have automated capacity management.

• Mokhatab et al. (2013) use a nitrogen generator to produce the nitrogen, which is employed as a refrigerant and maintains its gaseous form during the whole cooling operation.

### 4.1.3 Natural gas liquefaction Thermodynamic basics and optimization

The typical components of the liquefaction system installed aboard ships for the transportation of natural gas include:

– closed refrigeration cycle and
– Cargo cycle.

Mixed Refrigerants (MR) in the Joule-Thomson circle (JT) in a closed refrigeration cycle may often reduce the temperature difference with a minimal number of built-in components. Nevertheless, because such mixes are difficult to install on board ships, only pure cooling media are present in the systems on board for the liquefaction of natural gas. Pure media are simple to use, but they require more cooling in terms of degrees. The reverse Brayton nitrogen cycle has been shown to be the best option for a closed refrigeration cycle for ship systems. The benefits include the capability of manufacturing nitrogen in a ship's nitrogen generators, cheap acquisition costs, safe operation, and non-flammability at pressures more than hundred bar (Vorkapić et al., 2016).

One drawback is that an expansion turbine cannot function in a two-phase environment (gaseous and liquefied phase). The turbine may sustain irreparable damage in the event of partial liquefaction when droplets penetrate the blades, which are rotating at a periphery speed of 200–300 m/s. Thus, it is important to take precautions while developing a process to make sure the liquid phase never reaches the turbine.

As a result, the Brayton cycle is unable to create liquid; as a result, the cycle's cooling impact is constrained, and boil-off temperature control is diminished. Another issue is that the turbine demands a large amount of coolant flow even with the lowest rotor diameter, which lowers the system's cooling capacity to just approximately 500 W. The shipboard installations are unaffected by this restriction, though. It is crucial to lessen the entropy produced by the difference in temperature (T) in a cryogenic heat exchanger since natural gas is mostly a combination of hydrocarbon gases, and the specific heat varies with temperature at different times in the liquefaction process. As in the T-s diagram in Figure 1 Nitrogen refrigeration cycle (Vorkapić et al., 2016):

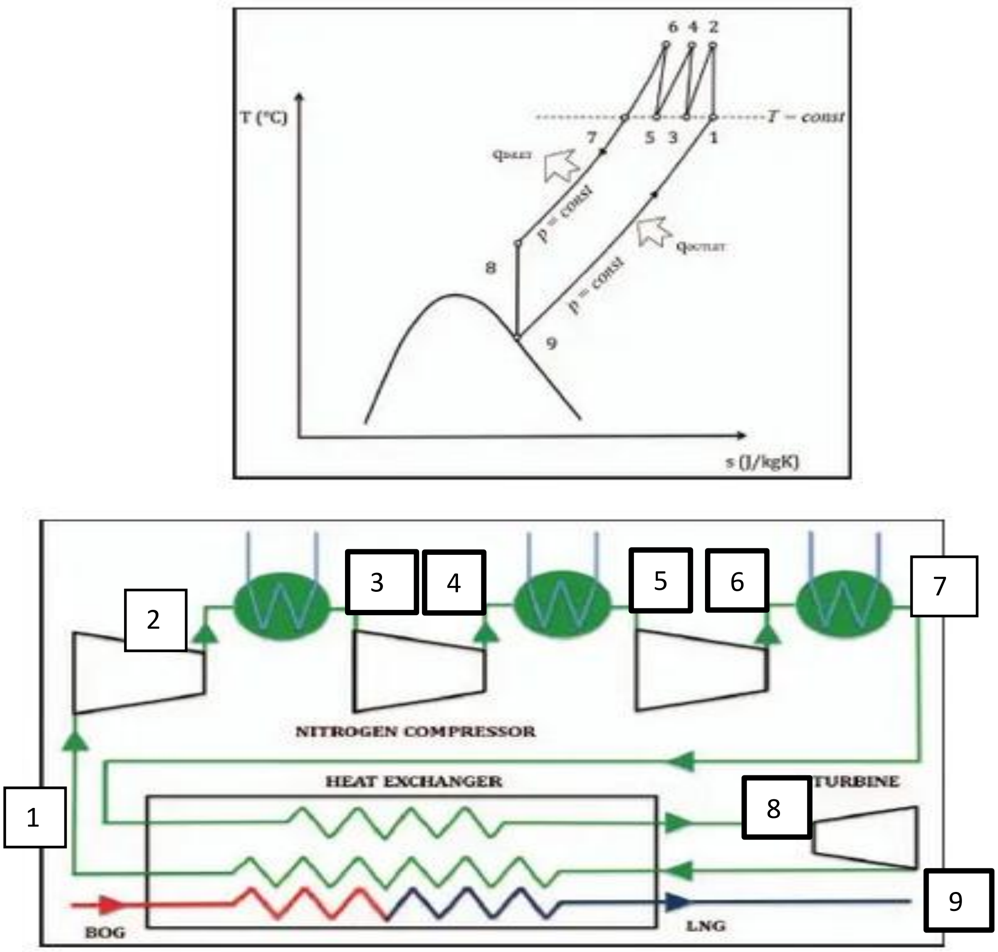

**Figure (1):** Refrigeration cycle of Brayton closed nitrogen.

Three-stage adiabatic compression of nitrogen with heat removal in coolers between stages one–seven, further cooling of gas at constant pressure between stages seven-eight, adiabatic expansion in the cryogenic expansion turbine between stages eight–nine, and cargo expansion at constant pressure between stages seven-nine. Once the first and second compression stages are completed, the gas goes through intermediate coolers (two-three; four-five), and the 3rd compression stage is completed with a cooler (six-seven). The compressor consists of a 3-stage compressor that is powered by an electric motor mounted on the same axis as the cryogenic turbine. When gas expands, some of the energy it has already used is partially recovered, which lowers the amount of electricity needed to run the compressor. A cascade refrigeration cycle using ethylene and propylene is an alternative to the Brayton nitrogen refrigeration cycle.

Three cycles make up the liquefaction process: natural gas, propylene (C3), and ethylene (C2). To lessen the temperature disparity in the exchanger, natural gas is compressed in 3 Stages as opposed to the two stages used in closed ethylene and propylene cycles. The closed refrigeration cycles C2 and C3 are shown in **Figure 2**, and they include adiabatic compression in 2 stages (one-two and three-four), intermediate cooling at constant pressure (two-three) and condensation (four-five at C3), expansion in the valve-Joule Thompson (five-six) along the heat transfer, and constant enthalpy curve at constant pressure in the primary heat exchanger (six-one). The Brayton cycle's thermodynamic efficiency can be increased by adding an extra pre-cooler and expansion turbine **(Vorkapić et al., 2016).**

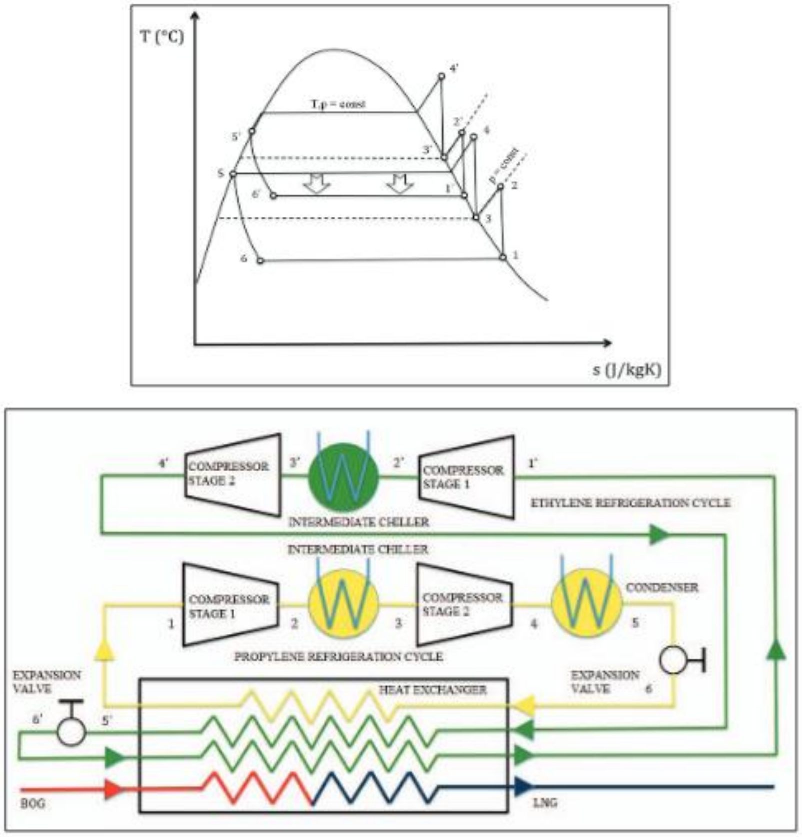

**Figure (2):** ethylene and propylene Cascade refrigeration cycle

While the Brayton concept with the expansion turbine is thermodynamically more effective, Joule-Thomson expansion is useful for cycles when it is important to produce lower temperatures. The Claude cycle, which liquefies natural gas with outstanding results, combines turbine expansion with damping. The Kapitza cooling cycle, which is characterized by lower costs and better operability, is created when the 3rd heat exchanger is removed after the nitrogen compressor (Vorkapić et al., 2016).

#### 4.1.4 Liquefaction systems

While developing the ship's liquefaction systems, the following factors should be considered when selecting an appropriate system:

- Possibility of use in certain navigational situations (rolling, pitching)
- The liquefaction technology previous experience
- Restricted installation space
- Possibilities of stopping and sudden starting up
- Simplicity of installation
- Simple to use
- crew, cargo, environment, and ship Safety
- Cost
- recommended redundancy

There are still 4 more operational criteria that have an impact on the choice in addition to the primary requirements mentioned above:

- Boil-off cargo Liquefaction pressure
- Cargo system
- Boil-off gas Temperature
- capacity of System

### 4.2 Pressurized Liquefied Natural Gas Process

In comparison to traditional liquefaction technology, the idea of pressurized liquefied natural gas (PLNG) technology has been put forth. In order to raise the LNG storage temperature and sustain greater pressures across the whole LNG transportation transport chain, it is necessary to chill natural gas (NG) to an intermediate temperature for liquefaction. The purification and liquefaction of natural gas using PLNG technology is both technically and economically advantageous, although storage and transportation cost more money. The entire project cost can be decreased, the benefits of PLNG technology can be completely utilized, and the application scope can be increased by planning and optimizing transportation costs and production costs through a suitable PLNG process.

#### 4.2.1 PLNG Process and traditional LNG Process Comparison

NG that has been cooled to around one hundred eleven K is transformed into products of LNG for storage at a pressure of about 0.1 MPa using the conventional LNG process. With a pressure range of 1.0–7.6 MPa, the PLNG process can produce products of LNG with a temperature range of 150–211 K, which is roughly thirty-nine–hundred K higher than that of traditional LNG products.

When considering the storage and liquefaction as well as overall costs technical requirements, it is more appropriate to use a pressure of one-two MPa for pressurized liquefaction, where the comparable temperature of natural gas liquefaction is around 153-173 K (Xiong et al., 2016). When pressurized NG is cooled to an intermediate temperature for conventional liquefaction, the goal of liquefaction storage may be realized, which allows for a considerable reduction in liquefaction operation costs and energy consumption for the PLNG process. When compared to traditional liquefaction, the PLNG method requires less pretreatment of the input gas and offers a novel way to lower CO2 emissions throughout the LNG process. The CO2 concentration in LNG products should be kept below fifty ppm because, in the case of the traditional liquefaction process, CO2 must be rigorously eliminated from input gas in the event that it solidifies at low temperatures and causes blockages (Lee et al., 2018). Temperature greatly affects CO2 solubility in methane. As the increase in temperature dramatically increases the solubility of CO2 in LNG products. The higher temperature also makes aromatics and other heavy hydrocarbons more soluble in LNG products, enhancing the PLNG process's tolerance for these elements in input gas (Xiong et al., 2016). By lowering the required CO2 content in the input gas, the PLNG method helps to eliminate the necessary auxiliary equipment for traditional liquefaction, such as CO2 removal equipment and heavy hydrocarbon scrubbing towers, which streamlines the manufacturing process and uses less energy. The process structure can be made simpler by raising the liquefaction and storage temperatures. And because there are fewer pieces of equipment, the accompanying expenses are around half those of a traditional LNG facility. Also, the PLNG process is crucial in preserving occupied parts of the LNG production system, opening the door to LNG production in a constrained space. The increase in product storage pressure in the PLNG process creates more demands on the transportation and storage linkages than does the traditional liquefaction process. Small, thick-walled storage tanks are typically used for PLNG storage in order to provide appropriate pressure-bearing capability; however, because these tanks are carried in clusters, their weight and production costs are increased. Moreover, after being heated and pressurized, LNG loses density, necessitating greater storage space in order to carry goods of the same quality while also raising the cost of transportation. The economic benefits of the PLNG process in liquefaction and purification, as well as their impact on costs of transportation, should be carefully considered when comparing and weighing the advantages and disadvantages of various pressure liquefaction methods.

## 5. Conclusion

The robust growth of LNG/LPG production has been encouraged by the high demand in the market for natural and petroleum gas consumption on a worldwide scale. The level of liquefaction technology has a direct impact on both the commercial profitability of natural gas providers and the cost of usage for customers. The potential for using LNG/LPG processes has expanded due to related advancements including boosting onshore LNG/LPG production capacity, enhancing the exploitation of sporadic small gas sources, and researching novel methods to transition from shallow to deep waters. This paper examines the discrepancy between liquefaction process research and practical operating needs based on current liquefaction process development. It also defines the primary issues encountered as well as potential future development paths. This makes it possible for the next researchers to produce better optimization and design outcomes for real-world projects and advance LNG/LPG applications.

## 6. Recommendations

- The production of LNG involves many feed gas liquefaction components. Attention must be given to both the overall improvement in combination with BOG cycle re-liquefaction process and the NGL recovery process as well as consumption of energy at all stages of the natural gas cooling process to increase the liquefaction process's energy efficiency.

- The author suggests conducting more searches of best evidence, current contents, and previous reviews, personal contact and examination of cited reference sources, and discussion with several experts in the field.

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