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Recommendation of Heat Exchanger as Refrigerant Cooler through Mass Balance Calculation in LNG Plant Process

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Abstract

The liquefaction unit is a process unit for processing the desired product from the gas phase to the liquid phase. The purpose of this unit is to facilitate the transportation process with the help of refrigerants. The disadvantage of this unit is that the heat transfer is less than optimal. In addition, this study can also maximize the storage system because it can reduce the specific volume of gas up to 1/600 times to increase energy efficiency in the LNG Plant. The potential for various options to increase the efficiency of the liquefaction cycle is tried to be calculated in this study. The calculation method between the mass balance and energy balance obtained the results of the design calculation that the type 2-4 heat exchanger, Carbon steel material, area 1023, 35m2, Rd 0.001-hour ft2 °F / Btu can be concluded that the design of the heat exchanger is safe and recommended.

Keywords: Energy Efficiency, Heat Exchanger, Liquefaction, LNG Plant, Materials.

1. Introduction

Natural gas is a vital energy source for the country, because it has clean, safe, and most efficient characteristics compared to other energy sources. Natural gas is widely used because it is a superior energy source compared to others in terms of technique and economy. Some of these advantages include having high combustion heat, abundant reserves in nature, and not causing too much air pollution [1]. In the manufacture of liquid natural gas (LNG) there are several series of processes that need to be carried out [2]. Before being processed, gas consisting of hydrocarbon gases such as methane, ethane, propane, butane, long hydrocarbon chains in small amounts and other impurity gases such as CO_2 and H_2S and water vapor need to be processed and cleaned first before being further processed. Initial processing of sales gas is very necessary to obtain natural gas specifications according to the desired criteria.

LNG cold energy heat exchanger (shell-and-tube type) is designed to recover cold energy for 0 °C ammonia cold storage applications. In order to conduct a more intuitive and detailed study of the effects of tube spacing and flow rate in each heat exchange tube in shell-and-tube heat exchanger, a

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double-tube heat exchanger is designed and provided. Liquid nitrogen and secondary refrigerant (antifreeze) are the cold and heat sources. Due to the effect of the tubes and refrigerant flow rate on the heat transfer coefficient, simulations and experiments on the antifreeze and tube speeds are carried out. The results show that increasing the antifreeze flow rate and reducing the tube spacing increase the amount of cold energy recovered. Based on the physical parameters of liquid nitrogen and LNG, the cold energy recovery ratio is 1.3. Predict the amount of cold energy that can be recovered from LNG in double-tube and shell-and-tube heat exchangers due to the cold energy recovery coefficient, cold energy recovery ratio, and heat exchange tubes. The recovery of cold energy from LNG in a shell-and-tube heat exchanger was applied to cold storage.

The number of impurities contained in sales gas has a very large influence on the selection of the process to be used for processing. The selection of the process for processing feed gas into LNG needs to be adjusted to the composition of the feed gas from the selected source and the desired product specifications [3]. The processes required for processing feed gas into LNG include preparation of raw materials in the acid gas removal unit and dehydration unit, then continued with the product manufacturing process, namely in the fractionation unit and refrigeration & liquefaction unit (Figure 1).

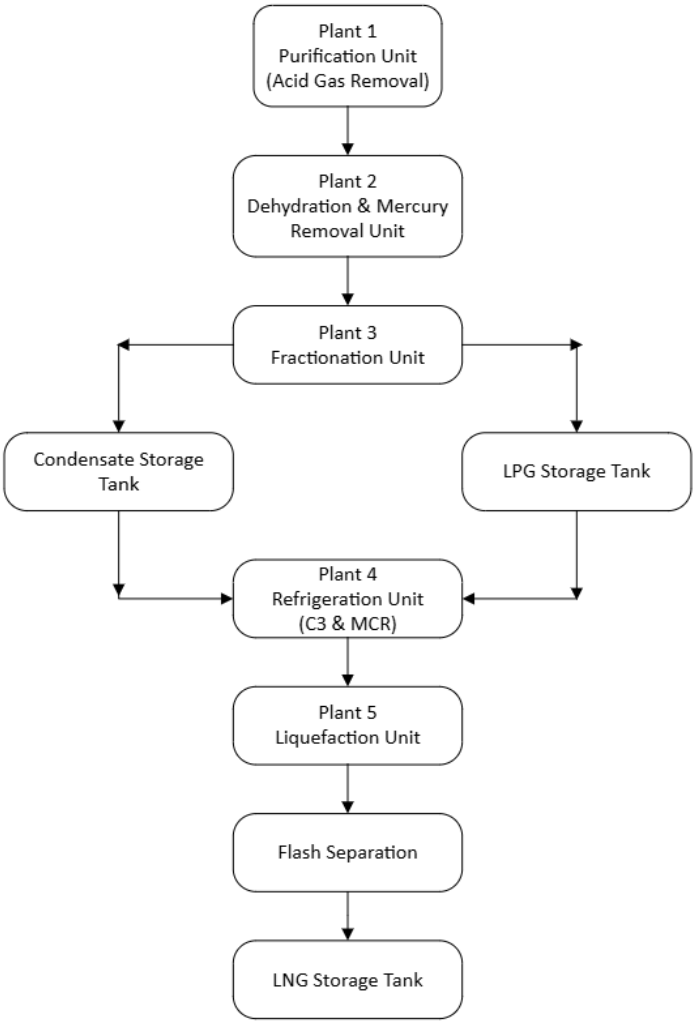

Figure 1. LNG Manufacturing Process Block Diagram

The propane precooled mixed refrigerant (C3-MR) process, developed by air products & chemicals inc (APCI), is the most widely used liquefaction process today. It has dominated the LNG technology base since the late 1970s and accounts for approximately 75% of natural gas liquefaction processes. The C3-MR process consists of a multistage propane precooling system followed by liquefaction using a mixed refrigerant system (consisting of nitrogen, methane, ethane, and propane) and dual mixed refrigerant (DMR) processes. However, the DMR process, which uses a mixed refrigeration cycle instead of a propane precooling cycle, has larger train capacity and higher

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liquefaction efficiency than C3MR [4], [5]. cooling system is needed in the NGL recovery process and liquefaction so that there is a correlation or integration of the two process configurations. The integration concept is applied by Elliot et al. [6] to produce a significant reduction in overall capital costs and increase product capacity.

Research on process efficiency improvement is the basis for the classification of integrated groups of NGL and LNG. An integrated process for this product was introduced by Ghorbani et al. which included no nitrogen. The process applied C3MR for cooling, and the results showed reasonable specific power with NGL recovery of more than 90% [7]. Three integrated processes applying cascade refrigeration cycles were applied by Mehrpooya et al. [8] where mixed fluid refrigeration (MFC), DMR and C3MR. This configuration has high ethane recovery and lower specific power consumption with previous studies [8]. This scheme utilizes a double mixed refrigeration cycle for liquefaction and shows good efficiency and NGL recovery examined by Vatani et al. [9] which can be applied to large-scale LNG plants. An integrated process using SMR and coupled distillation was presented by Khan et al. [10] where this scheme showed remarkable improvement in compression power compared to previous models. Wang and Xu reported that integrated NGL recovery with LNG regasification process shows great potential for energy saving and product production [11]. Efficient performance can be achieved by integrating liquid recovery with the liquefaction process introduced by Hudson et al. [12]. Based on previous research mentioned above for the integrated LNG recovery and liquefaction scheme, the use of heat exchangers through calculations only focuses on increasing process efficiency, not increasing overall efficiency. For long-term operations, it is necessary to consider the right heat exchanger dimensions to have good performance so that the transfer process can be maximized. The performance of the heat exchanger to be studied is the heat exchanger in the LNG industry which plays a role in the liquefaction process in LNG so that it can change the gas phase into liquid.

2. Method

The initial stage in conducting a heat exchange planning study is collecting specific primary and secondary data to simplify calculations. Variable in this study is about the temperature includes hot and cold fluid flow rates, inlet and outlet temperatures, and operating pressure. The balance energy and the calculation before making sure about temperature effective in the natural gas liquefaction unit aims to change the phase of gas which mostly consists of fractions C_1 and C_2 from multiphase to liquid. Gas from the deethanizer column (D-420) fractionation process with a temperature of -71.13 °C and a pressure of 35 bar is initially reduced in pressure to 5.1 bar using the MR Inlet Valve (K-511) as shown in Figure 2.

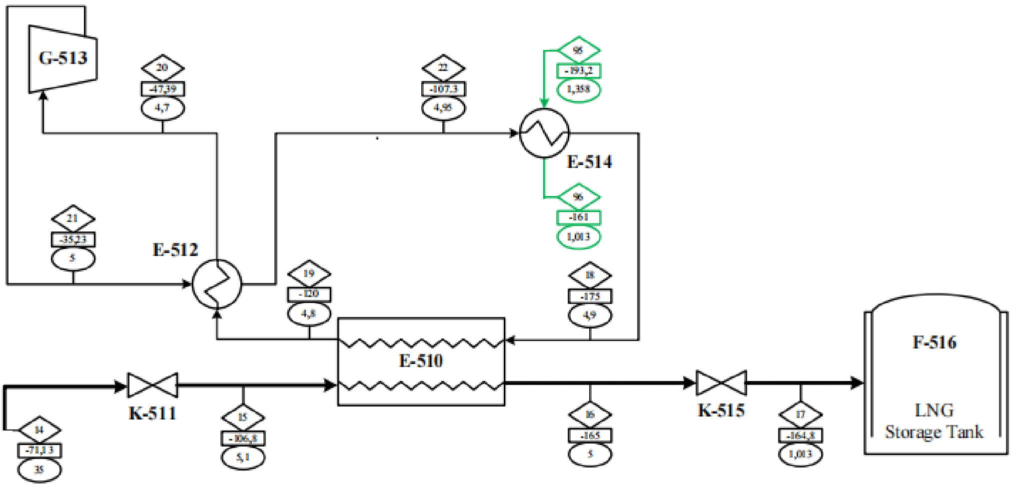

Figure 2. Process Flow Diagram

This pressure reduction process is also accompanied by a decrease in the temperature of natural gas to -106.8 °C. The temperature of natural gas is then reduced again using the mixed refrigerant cool box (E-510) until the temperature reaches -165 °C. After that, the LNG will be reduced in pressure again to reach atmospheric using the LNG product valve (K-515) to adjust the storage conditions in the LNG Storage Tank (F-516). The mixed refrigerant used consists of 25% mol methane, 60% mol ethane, 10%

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mol propane, and 5% nitrogen. The cooling cycle using this mixed refrigerant [13] starts from the MR output of the mixed refrigerant cool box (E-510) with a temperature of -120 °C and a pressure of 4.8 bar which is first heated until its phase changes to vapor using the MR exchanger (E-512) so that its temperature changes to -47.39 °C.

Table 1. Composition of Products Produced

Component	Amount (kg/hr)	%wt
	LNG End Product	
Methane(C_1)	179,471.79	0.85
Etane (C_2)	27,823.02	0.13
Propane (C_3)	55.16	0.0003
Nitrogen (N_2)	1,737.39	0.0083
Amount	209,093.75	1
	LPG End Product	
Etane (C_2)	83.71	0.003
Propane (C_3)	18,331.07	0.69
i-Butane (iC_4)	3,353.16	0.12
n-Butane (nC_4)	4,500.48	0.17
i-Pentane (iC_5)	14.64	0.0006
Amount	26,283.86	1

The product composition in Table 1 does not include water and acid gas components because the recovery and liquefaction processes occur after treatment in the acid degassing unit and the dehydration process. It is important to determine common key parameters for a fair comparison of different process schemes because these parameters can significantly affect the process performance.

3. Result and Discussion

The results of the calculation of the specifications and dimensions of the pre-design heat exchanger equipment are shown in Table 2. Design considerations are based on the provision that the fluid that will flow has the largest mass rate is LNG, the fluid with a large mass will flow through the Nitrogen pipe. The parameters as an indication that this heat exchanger is feasible or not are the dirt factor (Rd) and pressure drop (ΔP). The indicator of the length or shortness of the maintenance time is seen from the value of the dirt factor. The cause of the dirt factor is the presence of dirt which can be in the form of mud carried along with the flowing fluid, polymers, and deposits (corrosion crust) [14]. The fluid flow rate is a parameter that affects the value of the dirt factor for both hot and cold fluids where increasing the fluid flow rate can reduce the value of the dirt factor. Thus, the heat exchange process can take place perfectly [15].

Table 2. Specification of MR Cool Box

Code	E-510	
Inlet gas temperature	Flow (15)	-106.8 °C
	Flow (18)	-175 °C
Outlet gas temperature	Flow (16)	-165 °C
	Flow (19)	-120 °C
Dirt factor		0.001 jft^{2}F/Btu
Pressure drop liquid		10 psia
Pressure drop gas		10 psia
Shell	ID	39 in
	Baffles	12 in

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	Passes	2
	Pressure drops	1.35 psia
Tube	OD	1.25 in
	ID	1.12 in
	Pitch	1.56 in
	Length	20 ft
	Amount	425
	Passes	4
	Pressure drops	1.95 psia
Area	A	1023.35 ft^2
Amount		5 pieces

The efficiency of the basic APCI cycle can be improved by implementing the right heat exchanger design. The temperature points on the HX E-510 with the aim of lowering the temperature, E-512 to reheat the TEG solvent and E-512 to lower the temperature of the Mixed refrigerant are presented in Figure 3. Liquid turbines or hydraulic turbines are well-established technologies. These turbines are available with efficiencies of more than 90% [16] and can easily replace the expansion valves used in the MR cycle and LNG expansion process. To apply it to the propane cycle, the propane must be cooled first before entering the turbine. Two-phase expanders are currently being developed with current efficiencies of around 80% [17] and can easily replace the expansion valves used in the vapor compression cycle. The MR will be pressured using the MR compressor (G-513) (Table 3) from 4.7 bar to 5 bar. Furthermore, the MR will be cooled using the MR exchanger (E-512) until its temperature reaches -151 °C. After that, the MR will be cooled again using the MR Cooler (E-514) until the phase becomes liquid and the temperature reaches -175 °C, then the MR is ready to be used again to cool natural gas into LNG.

Table 3. Specification of Mixed Refrigerant Compressor

Code	G-513
Type	Centrifugal Compressor
Capacity	887,731.70 kg/hour
Amount	1
Suction Temperature	-47.39 °C
Suction Pressure	4.7 bars
Discharge Temperature	-35.23 °C
Discharge Pressure	5 bars
Amount of stage	1
Casing	Cast steel
	Carbon steel (AISI-C1405)
Piston	Cast steel
Diaphragm	Uncooled, cast iron
Efficiency	70%
Power	1,525.3 kW
Cylinder selection	12,958.8 cfm

The heat exchanger design is placed on the liquefaction unit. This heat exchanger acts as an initial cooler for ethane which is the output of the deethanizer column from a temperature of -34 °C to 50 °C using PMR (pre-cooling mix refrigerant). In this process, there is a change in the gas phase from the overhead product the deethanizer to a liquid phase called LNG, so that gradual cooling is required using a refrigeration system [18], [19]. In this design, consideration of the fluid that will flow through the annulus is based on the provision that the fluid with the largest mass rate is LNG. The results of the

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calculation of the specifications and dimensions of the heat exchanger design equipment are shown in Table 2 while the fluid that has a large mass rate will flow through the pipe, namely nitrogen.

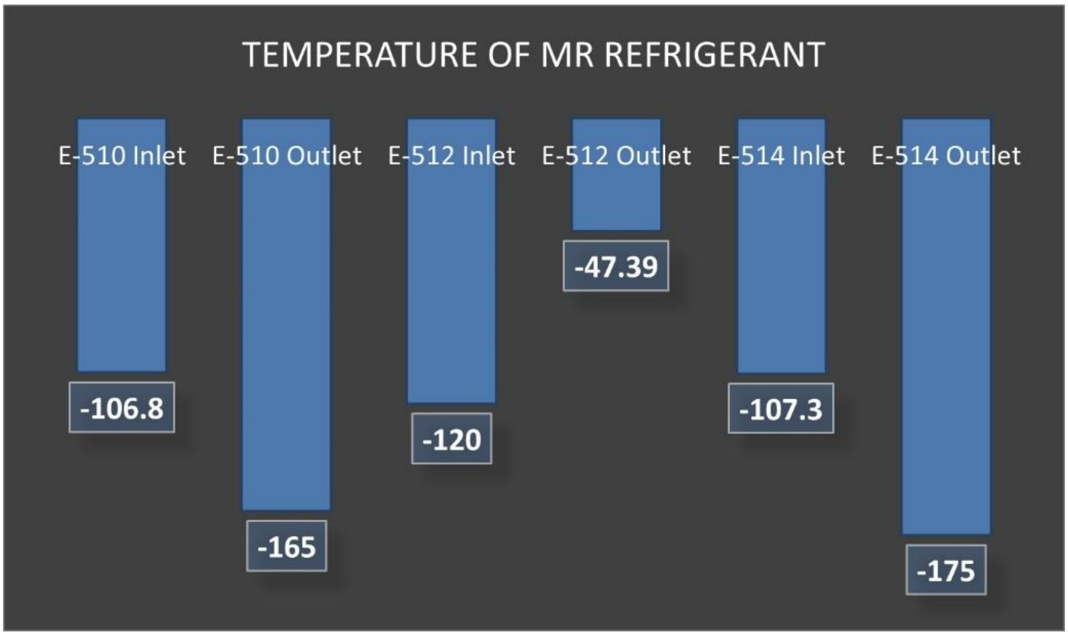

Figure 3. Temperature of MR Refrigerant

The parameters as an indication that this heat exchanger is feasible or not are the fouling factor (Rd) and pressure drop (ΔP). The fouling factor value is an indicator of the length or shortness of the maintenance time. The cause of the occurrence of the contamination factor is the presence of dirt which can be in the form of mud carried along with the flowing fluid, polymers, and deposits (crust due to corrosion) [14]. factors that influence the heat exchange process so that it can be called perfect when the fluid flow rate increases so that it can reduce the value of the contamination factor [15].

4. Conclusion

From this study, it can be concluded that the recommended type of heat exchanger is 2–4 with carbon steel material in pre-designing the LNG plant, The Heat Exchanger design that has been carried out is suitable for operation based on the Rd (Fouling Factor). The value obtained meets the requirements with an Rd value of 0.001 hr ft2 °F/Btu. Based on the comparison results, the best refrigerant is C3-MR or propane precooled mixed refrigerant. C3-MR was chosen because it has high thermal efficiency, low specific power (12.2 kW/ton LNG/day) and has a capital investment that is not too much and the number of equipment is not too much. C3-MR which will be used uses a license from APCI with cooling media in the form of nitrogen, methane, ethane and butane until the phase becomes liquid and the temperature reaches -175°C, then the MR is ready to be used again to cool natural gas into LNG. And by changing the composition of MCR with a methane content of 25%, ethane 60%, propane 10%, nitrogen 5%. The implification of this research is The HX modules of commercial process simulators often carry unstated assumptions regarding the physics of the process. The present study has uncovered several of those unstated assumptions and has proposed several simple methods for overcoming those assumptions. The corrected this model was then extended to include other aspects of a typical regasification terminal and used to study the design and operation of regasification terminals under several simple but relevant contexts.

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