JOURNAL OF MECHANICAL ENGINEERING, SCIENCE, AND INNOVATION

Research Article

Calculation Study of Double Pipe Type Heat Exchanger in LNG Plant Pre-Design with Capacity 250 tons/hour

Journal of Mechanical Engineering, Science, and Innovation
e-ISNN: 2776-3536
2024, Vol. 4, No. 1
DOI: 10.31284/j.jmesi.2024.v4i1.5164
ejurnal.itats.ac.id/jmesi

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Abstract

In industrial processes, heat exchangers are very important tools and are always needed. Heat exchangers can be used to increase and decrease the temperature. The most widely used type of heat exchanger is the Double Pipe or DPHE type. The LNG (Liquified Natural Gas) plant is one of the industries that uses a heat exchanger in the process of lowering the initial temperature of the LNG to change the gas phase to liquid. The aim of this study is to obtain better efficiency in the LNG manufacturing process, so it is necessary to carry out a heat exchanger design study. Based on the design calculation results, it was found that Heat Exchanger type 2-4, material Carbon steel, area 2076, 16 m2, Rd 0.005 hr ft2 oF/btu and ΔP of 4.4051 psi. It can be concluded that the heat changer design is feasible to operate safely and without any obstacles.

Keywords: *Double pipe, heat exchanger, design, LNG*

Received: October 10, 2023; Received in revised 1: November 6, 2024; Received in revised 2: April 24, 2024; Accepted: May 2, 2024
Handling Editor: Ika Nurjannah

INTRODUCTION

The LNG (Liquified Natural Gas) industry is a process of processing natural gas into liquid fuel through several processes including the distillation process[1], [2]. In this distillation unit, heat transfer occurs either by heating or cooling. This heat transfer process occurs due to a temperature difference, where the temperature of the hot fluid moves to the cold fluid, or vice versa, either directly (without separation) or indirectly (with separation)[3], [4].

The heat transfer device that is generally used is a Shell and Tube Heat Exchanger (STHE) type Heat Exchanger[5], [6]. This type has many advantages, including having the capacity to work at high temperatures and the design can be adapted to the production process[7], [8]. STHE performance can be reduced due to impurities, so it needs to be redesigned.

Many heat exchanger design studies have been carried out by varying the pipe diameter, baffles, number of pipes, pipe pitch and pipe arrangement in order to obtain good performance and suit needs[9], [10]. In addition, this design study can minimize problems in the field such as pressure drops, the transfer process has not been maximized, which can have an impact on costs[11], [12]. In the factory pre-design process, all equipment is carried out with initial design studies according to capacity, so that with the steps contained in [13] different heat exchanger specifications and different types will be produced.

In this calculation study, it is used to find out the right dimensions to have good performance so that the transfer process can be maximized. The performance of the heat exchanger that will be studied is the heat exchanger in the LNG industry, which plays a role in lowering LNG so that it can change the gas phase to liquid.

METHODS AND ANALYSIS

The initial stage in conducting a heat exchanger planning study is collecting specific primary and secondary data to simplify calculations. Primary data required includes hot and cold fluid flow rates, inlet and outlet temperatures, and operating pressure. Figure 1 shows the Heat Exchanger code used, namely E-510. This heat exchanger functions to reduce the temperature of LNG with the help of PMR (Pre-Cooling Mix Refrigerant). Meanwhile, secondary data is a heat exchanger design size table, which is obtained from reference books, journals or mechanical data sheets, mechanical drawing units, and the design steps are presented in Figure 2. To calculate the amount of heat transfer using equation 1:

$$Q = U \times A \times \Delta T_{lmtd} \tag{1}$$

Where, Q is heat released/received (W), U is heat transfer coefficient (W/m^2.^{o}C), A is heat transfer surface area (m^2), and Δ_{lmtd} is average temperature difference (^{o}C).

To calculate the temperature difference between the two fluids, it can be calculated using equation 2:

$$\Delta T_{lmtd} = \frac{\Delta T_{max} - \Delta T_{min}}{ln\frac{\Delta T_{max}}{\Delta T_{min}}} \tag{2}$$

Where, ΔT_{max} is $T_1 - t_2$ (^{o}C), ΔT_{min} is $T_2 - t_1$(^{o}C), T_1 is inlet hot fluid temperature (^{o}C), T_2 is out hot fluid temperature (^{o}C), t_1 is inlet cold fluid temperature (^{o}C), t_2 is temperature of the cold fluid leaving (^{o}C).

Determining the type of heat exchanger can be based on the results of calculating the heat transfer surface area using equation 3.

$$A = \frac{Q}{U_d \times \Delta T_{lmtd}} \tag{3}$$

Where, U_d is design overall heat transfer coefficient (W/m^2.^{o}C).

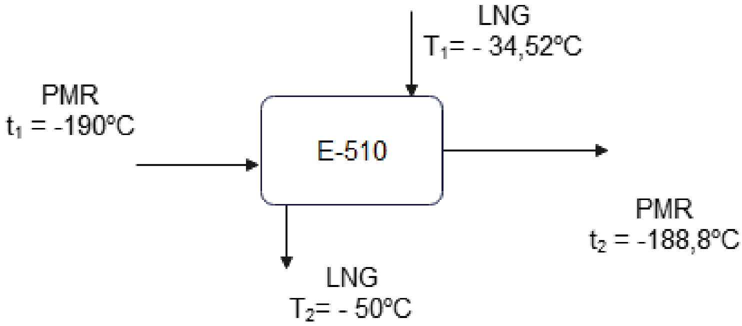

Figure 1. Heat Exchanger Design Scheme.

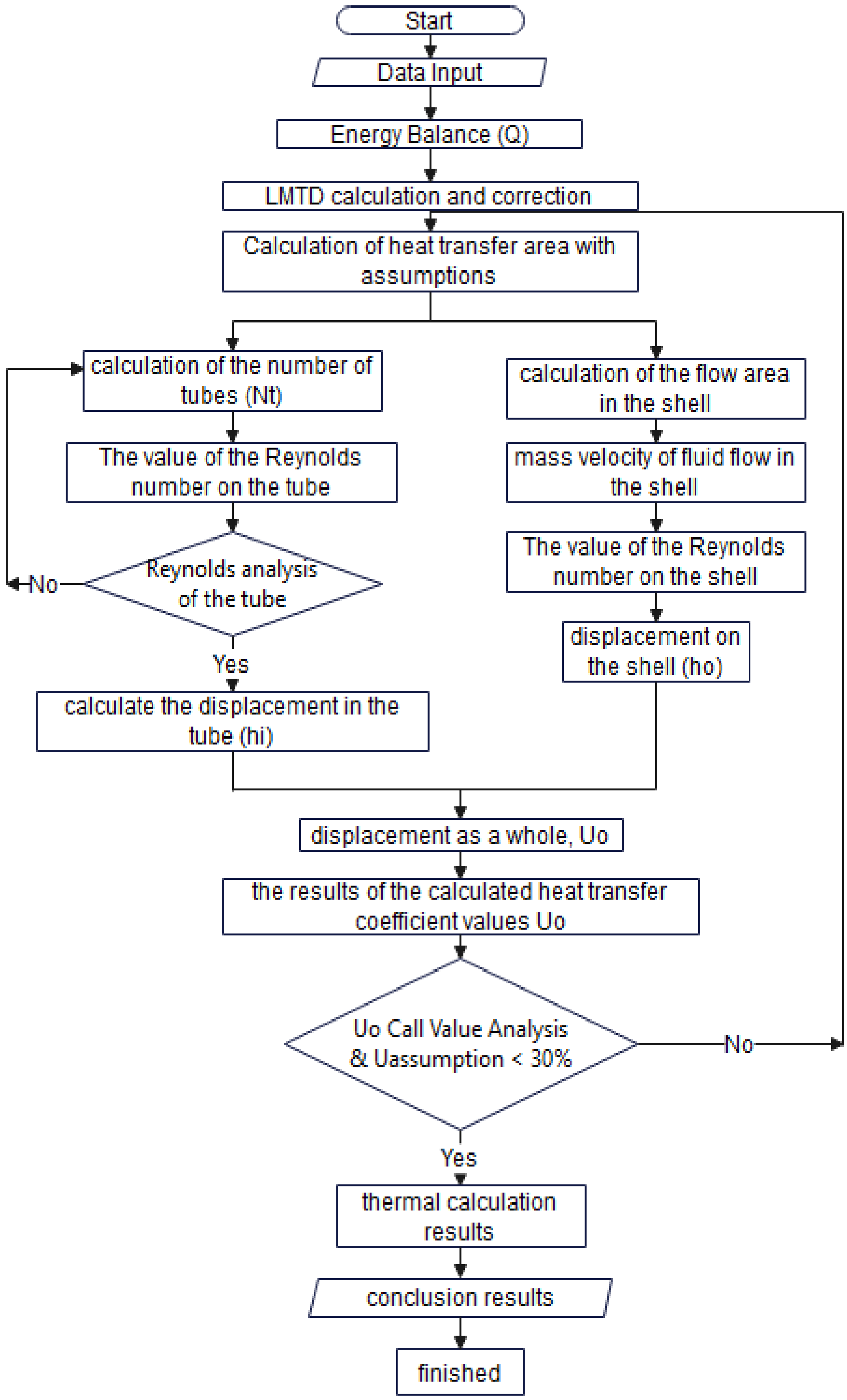

Figure 2. Heat Exchanger (HE) designs flow diagram.

In [13] (table 6.2 and table 11), as well as the type of heat exchanger, specific data is obtained for calculating NRe, heat factor and heat coefficient.

From the trial and specific data obtained, calculations can be made on the annulus and pipe. Related calculations can be found in equations 4 to 13.

Displacement evaluation calculations

Hot fluid

$$G_t = M/at \tag{4}$$

Where, G_t is mass velocity in tube (kg/m^2), M is mass rate hot fluid(kg/h), at is tube surface area (m^2).

Cold fluid

$$G_s = m/as \tag{5}$$

Where, G_s is mass velocity in shell (kg/m^2), m is mass rate cold fluid(kg/h), as is shell surface area (m^2).

Calculation of Clean Overall Coefficient (Uc)

$$U_C = \frac{h_o \times h_{io}}{h_o + h_{io}} \tag{6}$$

Where, Uc is Clean Overall Coefficient, h_o is convection heat transfer coefficient outside diameter, hio is convection heat transfer coefficient inside diameter.

Calculation of Design Overall Coefficient (U_D)

$$U_D = \frac{1 + (R_d \times U_c)}{U_c} \tag{7}$$

Where, Ud is Design Overall Coefficient, Rd is fouling factor.

Calculation of the actual area

$$A = \frac{Q}{U_D \times LMTD} \tag{8}$$

Calculation of the required pipe length

$$L = \frac{A}{a''} \tag{9}$$

Where, L is pipe length, a'' is pipe surface area.

Calculation of the number of hairpins required.

$$\sum hairpin = \frac{required\ pipe\ length}{available\ pipe\ lengths} \tag{10}$$

Calculation of the length of the new pipe

$$L\ new = \sum hairpin \times available\ pipe\ lengths \tag{11}$$

Pressure Drop Calculation

For the annulus

$$\Delta Pa = \frac{f\ Gs^2\ IDs\ (N+1)}{5.22\ 10^{10} de\ Sg\ fs} \quad (12)$$

Where, ΔPa is Pressure Drop in shell psi, IDs is inside diameter m, de is diameter effective m, sg is specific gravity, fs is friction factor in shell.

For pipes

$$\Delta Pn = \frac{4 \times n \times v^2 \times 62.5}{sg \times 2gc \times 144} \quad (13)$$

Where, ΔPn is Pressure Drop in pipe psi, n is number of pipes m, v is velocity fluid, gc is conversion gravity.

RESULTS AND DISCUSSIONS

The process of making LNG from natural gas is divided into 4 main areas, namely acid gas removal, dehydration, fractionation and liquefaction, overall presented in Figure 3.

The design study designed is a heat exchanger located in the liquefaction unit. This heat exchanger acts as an initial coolant 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 Deethanizer overhead product into a liquid phase called LNG, so it is needed gradual cooling using a refrigeration system[14], [15].

The results of calculating the specifications and dimensions of the heat exchanger pre-design equipment are shown in tables 1. In this design, consideration of the fluid that will flow through the annulus is based on the provision that the fluid has a mass speed The largest is LNG, while the fluid that has a large mass rate will flow through the pipe, namely Nitrogen.

Parameters as an indication that this heat exchanger is suitable or not are the fouling factor (Rd) and pressure drop (ΔP). The fouling factor value is an indicator of short or long maintenance times. The cause of the impurity factor is the presence of dirt, which can be in the form of mud that is carried along with the flowing fluid, polymers, and deposits (crust from corrosion)[16]. The fouling factor value is influenced by the fluid flow rate, both hot and cold fluids, where increasing the fluid flow rate can reduce the fouling factor value. Thus, the heat exchange process can take place perfectly[17]. From the calculation

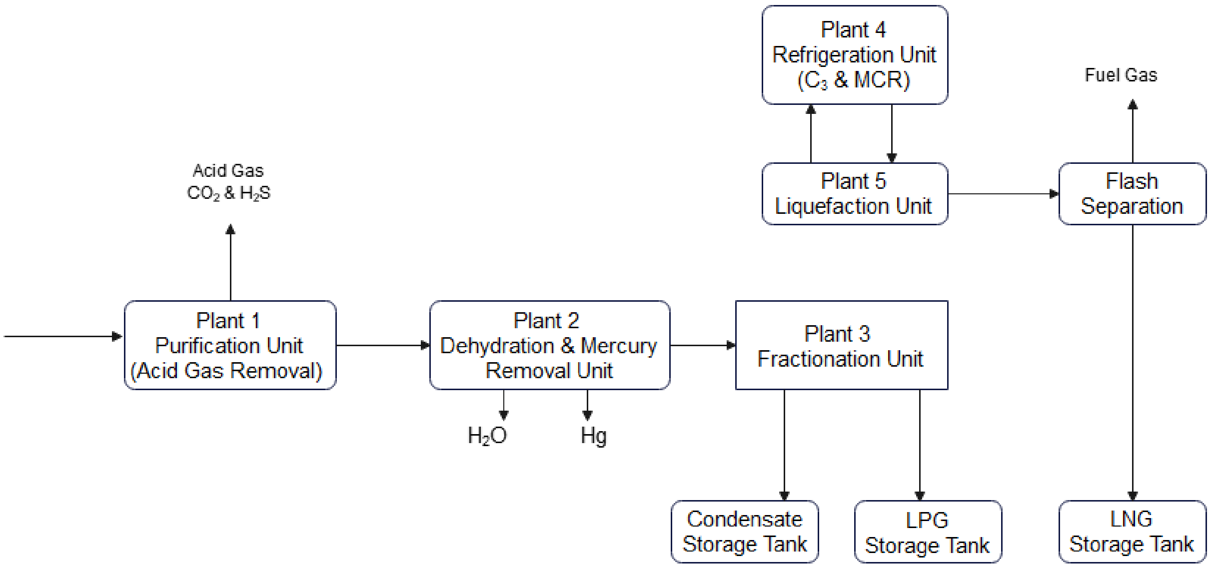

Figure 3. Block Diagram of LNG Plant

Table 1. Data from calculations of double pipe type heat exchanger specifications

Specification	**Information**			
No.Code	E-510			
Fuction	Initial temperature reduction of LNG before entering the main heat exchanger			
Provision	2 – 4 Exchanger			
Material	Carbon steel			
Inlet temperature	Current 58	=	-35	^{o}C
	Current 62	=	-190	^{o}C
Exit temperature	Current 59	=	-50	^{o}C
	Current 60	=	-188.8	^{o}C
Provision	Rd	>	0.001	$(hr)(ft^2)(^{o}F)/(btu)$
	ΔP Liquid	<	10	psi
	ΔP Gas	<	2	psi
Shell	ID	=	0.8	m
	Baffle	=	0.2	m
	Passes	=	2	
	ΔP	=	0.062	psi
Tube	OD	=	0.0254	m
	ID	=	0.0217424	m
	BWG	=	15	
	Pitch	=	0.03175	m triangular
	Long	=	36.48	m
	Amount	=	430	
	Passes	=	4	
	ΔP	=	4.4051	psi
Rd			0.005	$(hr)(ft^2)(^{o}F)/(btu)$
Area			2076.164622	m^2
Amount			1	piece

results, the fouling factor value is 0.005 hr ft^2 ^{o}F/btu, this shows that the heat exchanger design study is suitable or feasible.

The second indicator is pressure drop (ΔP) which is the standard for determining whether a heat exchanger is designed properly or not[18]. In addition, pressure drop has a fundamental role in the performance of the heat exchanger. One thing that influences pressure reduction is the connection (baffle and tube). The type and arrangement of baffles used can produce a pressure drop[19]. The calculation results show that the pressure drop for the shell is 0.062 psia and for the tube it is 4.4051 psia. Meanwhile, the specified value for the pressure drop on the annulus is less than 2 psi and on the pipe is less than 10 psi, so it can be concluded that this design meets.

CONCLUSIONS

In pre-designing the LNG plant, the recommended type of heat exchanger is 2 – 4 with carbon steel material. The Heat Exchanger design that has been carried out is suitable for operation based on the Rd (Fouling Factor) and ΔP (Pressure Drop) values. The value obtained meets the requirements with an Rd value of 0.005 hr ft^2 ^{o}F/btu and a ΔP of 4.4051 psi (<10 psi).

ACKNOWLEDGEMENTS

DECLARATION OF CONFLICTING INTERESTS

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FUNDING

The author(s) disclosed receipt of no financial support for the research, authorship, and/or publication of this article.

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