Assessment Of Complex Ii Fuel Oil Heat Exchanger Utilizing Heat Transfer Methodology

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Abstract.

The heating stage of oil and gas refining commences with a heat exchanger. Using the pressure drop method and dirt factor in conjunction with the utmost standard permissible limit is one method of evaluating the thermal efficiency of a heat exchanger. This is performed to ascertain the value of the pressure drop, or pressure drop, which is directed at the fluid passage in the shell and pipeline. Moreover, a dust factor value is necessary to account for the potential accumulation of impurities and scale on the walls outside the heat exchanger conduit. The dust factor value is the maximum value that the parameter permits to ascertain the feasibility of the heat exchanger. Heat Exchanger 011-E-112 in the Fuel Oil Complex Unit The results indicate that heat exchanger 11E-112 can still be utilized despite the necessity for design enhancements. The design data for the shell is 1.7 psi, and the tube is approximately 18.92 psi. The Dirt Factor values for the shell and tube are 0.017 BTU/hour ft2°F and 0.034 BTU/hour ft2°F, respectively. The tube pressure drop value is 130.32 psi, while the shell pressure drop value is 2.53 psi.

Keywords: *Fouling Factor, Heat Exchanger, Pressure Drop and Shell dan Tube.*

I. INTRODUCTION

The consumption of fuel oil (BBM) by the populace of the New Normal has increased in response to the COVID-19 pandemic. According to the Ministry of Energy and Mineral Resources (ESDM), the community consumed 48.56 million kiloliters of petroleum oil in September 2021, which is considerably high. The quantity of petroleum oil consumed must be proportional to the production amount to ensure that all requirements are adequately met [1]. There is a pressing need to address the requirements of numerous oil refineries in Indonesia. Refinery Unit IV is one of the refineries that produces fuel oil at a rate of 348,000 barrels per day. The conversion of petroleum oil into various products, including paraffinic oil, asphalt, and other aromatic products. A refinery unit customized to the equipment facilities is required to facilitate this production. One of the facilities in the refinery is the heat exchanger. This device is also a transfer unit in the distillation process, with kerosene and Heavy Diesel Oil (HDO) serving as the feedstock and heater. One of the heat exchangers that must be considered is its critical role in ensuring that the tool continues producing products that meet the intended specification criteria [2]. The heat transfer efficiency can also be used to evaluate the tool's effectiveness in making products that adhere to standards and specifications. Consequently, the author initiates the calculation and obtains the appropriate results by employing a quantitative approach.

A. How heat exchangers with shell and tube Work

The mechanism of the heat exchanger must facilitate heat transfer through both convection and conduction processes. This principle posits that the heat of the fluid is transferred to the fluid at a lower temperature when The hot fluid travels in tandem with the tube's direction, and the diapason fluid enters the shell. When hot fluid is in the feed tank or more in The heat of the fluid is transferred to the fluid with a lower temperature in the shell and tube-type heat exchanger. The heat exchanger can function as either a heat exchanger or a chiller customized to meet the application's specific requirements [3].The elements of the shell and tube heat exchanger. A heat transfer process system is defined by the temperature differential of a fluid, specifically the disparity between the temperature of the fluid within the tube and the temperature external to the tube (enclosed within the shell). It may lead to the transmission of heat between the fluid flow in the tube and the interior of the tube. Consequently, the tube side refers to specific area characteristics associated with the inside and inside of the tube, while the shell side refers to the outside. The heat exchanger also serves as a temperature controller in a system that can either add or remove thermal energy from one fluid to another. Two fluids typically affected by thermal conduction are separated by various heat exchangers, which contain elements in the form of tubes or plates. Subsequently, it is imperative to transfer heat energy to other elements [4].

B. Specific Factors That Affect the Efficiency of Heat Exchangers

The efficacy of the heat exchanger can also be assessed by the evaluation that is derived from the calculation results during the formula stage, which is also influenced by a variety of factors, including [3]:

- Pressure Decrease

The decrease in pressure transpires in heat exchangers and has a substantial impact. The pumping process in the shell and tube heat exchanger type occurs when the pressure drop results in a significantly reduced power output for the pump. Consequently, efficiency values are enhanced, and operating costs are decreased to adjust the diameter between the shell and tube and the selection of baffles to the fluid being used.

- Logarithmic Mean Temperature Design (LMTD)

An inefficient heat exchanger results from the average value at a high design temperature, as the costs incurred are increasing. Consequently, reducing the number contained in the average design temperature is imperative. The pressure drop in the heat exchanger must be reduced by ensuring that the baffle is properly sized and that the shell and tube have a high diameter to complement the fluid flow.

- Dirt Factor

Additionally, heat exchangers exhibit resistance to impurities. D.Q. Kern posits that a heat exchanger has sufficient resistance if the value of Rd in calculations exceeds the minimal value of Rd by 0.005 hr.ft./btu [5]. Additional resistance to the conveyed energy can result in the minimum lower limit. Consequently, in order to elevate the Rd value, it is imperative to conduct routine cleanings of the heat exchanger, which is contaminated with impurities and scale.

- Actual Conditions Heat Exchanger Efficiency Value

The results of the efficiency calculation can be determined by the ratio of the heat absorbed in the tube to the total heat transferred from the shell. Increasing the percentage value to achieve maximum efficiency can be attained by equating the heat absorbed by the tube with the heat entirely transferred by the shell. [1]. This is also evident when comparing the heat exchanger's actual performance with its ideal performance. The efficacy of the field is also influenced by the heat exchanger's design, which is distinct in terms of its dimensions and type (plate, shell and tube). The subsequent formula illustrates the efficacy percentage:

$$\eta = \frac{qtube}{qshell} \times 100\% \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Besides actual heat transmission as a percentage of the maximum possible heat transfer, an ideal proportion exists contingent upon the specific application and the diverse types of heat exchangers employed. The range utilized varies from 70% to 90%, contingent upon the working conditions and maintenance of the heat exchanger.

C. Process Flow Diagram HE 011-E-112

The product stream entering the kerosene stripper is processed using a reboiler, removing lighter materials. Heavy Diesel Oil (HDO) serves as a heating medium and subsequently returns to the column. Subsequently, the product stream proceeds to the kerosene stripper, where it is processed with light material via a reboiler utilizing Heavy Diesel Oil (HDO) and subsequently returned to the column. The pump's function is to transfer the bottom product before it enters into the air cooler. The kerosene product is conveyed through the stream cooler before proceeding to storage. This is seen in Figure 1.

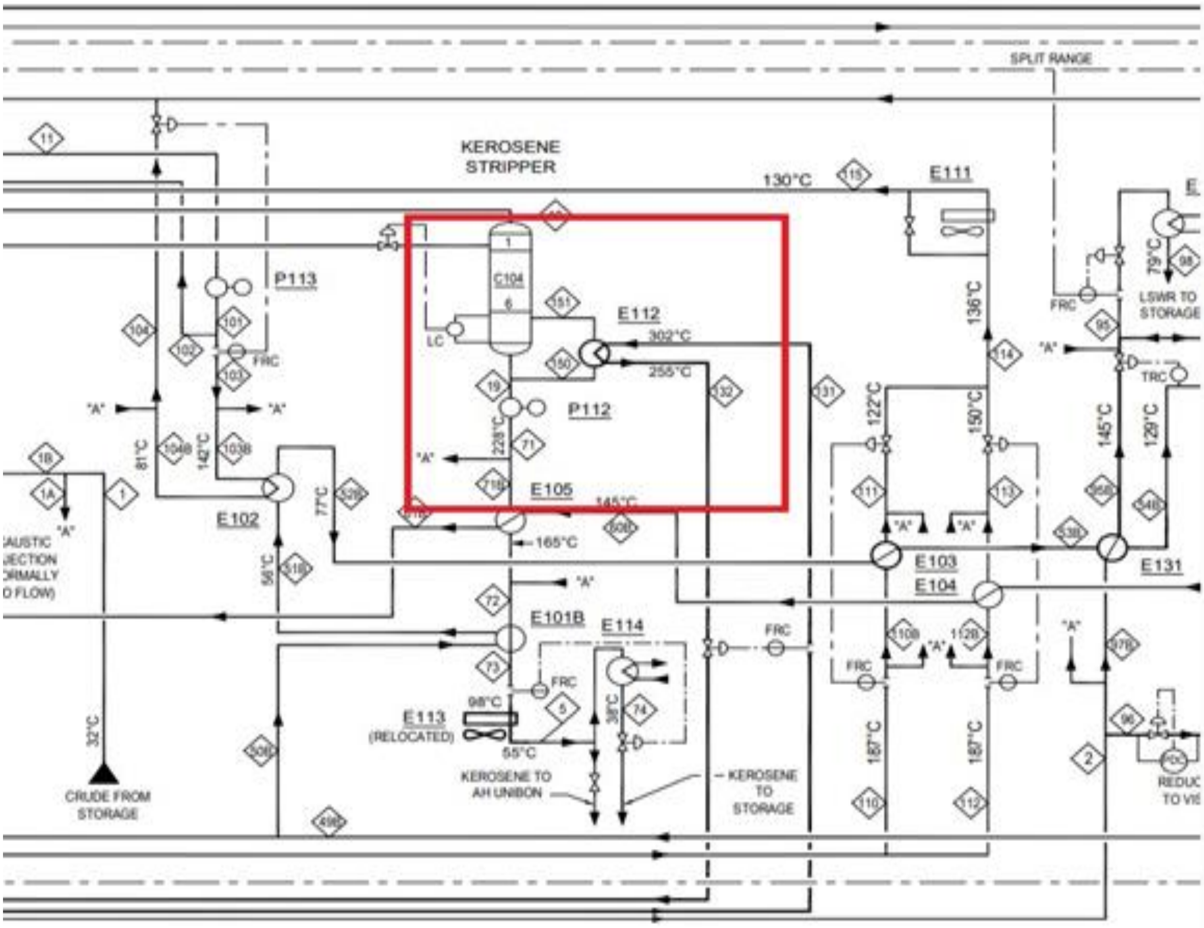


Fig 1. Flow Chart of Heat Exchanger 011-E-112 at Crude Distillation Unit Fuel Oil Complex II

The accumulator under the tray, number 43, is the source of the heavy diesel oil (HDO) flow, which has been demonstrated to be divided into three critical components. The Heavy Diesel Oil heat pump is refluxed back into the column by another pump with the code 011P-105A/B. The Heavy Diesel Oil heat pump is divided into two parallel streams that pass through the exchanger. The second stream is combined and enters the air chiller, where it is returned to the column.Researchers are still drawing attention to enhancing heat transfer through shell and tube exchangers [6]. Universal Oil Product (UOP) has developed Fuel Oil Complex II (FOC II), which is primarily responsible for the production of fuel oil (BBM) for domestic use and certain products for export, including LPG and Naphta. The refinery's processing process is divided into two stages: first- and second-level. Crude oil is physically separated into fractions using heat power at the first level.

The second-level processing is performed to enhance the quality of the first-level products, which are typically processed chemically.The heat exchanger with stand 011-E-112 is a piece of equipment that is designed to transfer heat energy, which is commonly referred to as enthalpy, between two or more fluids of varying temperatures. This is achieved by establishing thermal contact between solid surfaces with fluids or certain solid particulates with fluids [7]. How heat exchange occurs is the basis for classifying heat exchangers into multiple categories. The heat exchanger's shell and tube configuration, which operates with a counter-current flow, is a popular choice in XY. A cold fluid, kerosene, and a heated fluid, HDO, are employed in this exchange process. The heat transfer procedure significantly influences the sustainability of the CDU II unit within the heat exchanger. Consequently, studies and observations were used to evaluate the 011-E-112 heat exchanger's effectiveness.

II. METHODS

The research methods employed are as follows: data collection, literature review, and flowchart, as illustrated in Figure 2.

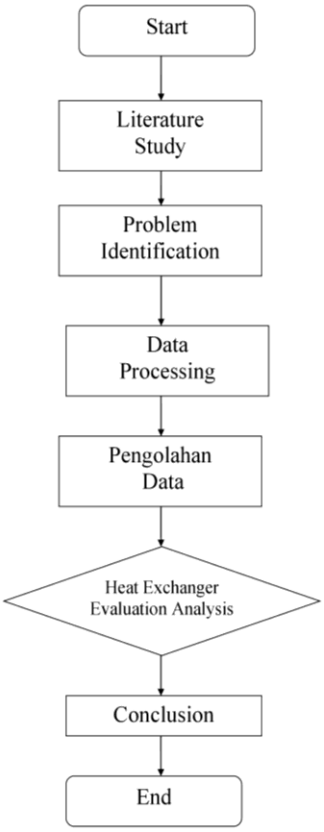


Fig 2. Flowchart of Heat Exchanger Evaluation

Examining heat exchangers employs several methods, including Log Mean Temperature Difference (LMTD), effectiveness-NTU approach, heat transfer technique, thermal efficiency comparison method, fouling factor method, pressure drop method, and visual and physical inspection methods. The assessment methods provide a more precise understanding of the heat exchanger's performance. Consequently, each method possesses distinct advantages and limits, which may lead to inefficiencies in calculating, necessitating selecting a method that yields more thorough findings. The assessment is contingent upon the type of heat exchanger, operational parameters, and the aims to be attained. The performance of heat transfer equipment can be assessed by calculations derived from formulations designed to evaluate heat exchangers, including [5]:

1. Heat Transfer Calculation
   $Qc = mc \times (t_2 - t_1)$
   $Qc = mh \times Cph \times (T_2 - T_1)$ .... (2)
2. Logarithmic Mean Temperature Difference (LMTD)
   $$\Delta T\ LMTD = \frac{(T1-T2)-(T2-t1)}{In\left(\frac{(T1-t2)}{(T2-t1)}\right)}\Delta T \quad \text{(3)}$$
   ΔT LMTD bisa disesuaikan dengan persamaan di bawah ini:
   Δt = ΔT LMTD × Ft .... (4)
3. Calorific Temperature (Tc and tc)
   $$\mathbf{Tc} = \frac{T1+T2}{2}$$
   $$\mathbf{tc} = \frac{t1+t2}{2} \quad \text{(5)}$$

4. *Flow Area* in *Shell* and *Tube*
   a. Shell Flow Area

   $$\boldsymbol{as = \frac{IDs \times C \times B}{144 \times Pt}} \dots\dots\dots \quad (6)$$

   b. Flow Area Tube

   $$\boldsymbol{at = \frac{Nt \times art}{144 \times n}} \dots\dots\dots \quad (7)$$

5. Mass Flow Velocity in Shell and Tube
   a. Shell Mass Velocity

   $$\boldsymbol{Gs = \frac{W}{as}} \dots\dots\dots \quad (8)$$

   b. Tube Mass Velocity

   $$\boldsymbol{Gt = \frac{W}{at}} \dots\dots\dots \quad (9)$$

6. Reynold Number
   Reynold's number is utilized to ascertain the nature of fluid flow. Shell Reynolds number employs viscosity at calorific temperature, whereas tube Reynolds number utilizes viscosity at the calorific temperature of the hot fluid [5]. The shell diameter is derived from Figure 28 of Kern. In contrast, the tube diameter is taken from Table 10 of Kern, which is predicated on the external diameter and BWG in the heat exchanger design data [8]:
   a. Reynold Shell Number

   $$\boldsymbol{as = \frac{IDs \times C \times B}{144 \times Pt}} \dots\dots\dots \quad (10)$$

   $$\boldsymbol{Re\ s = \frac{De\ Gs}{\mu h}} \dots\dots\dots \quad (11)$$

   $$\boldsymbol{Re\ s = \frac{4 \times ({}^{1}\!/_{2}\, pT \times 0.86\, PT - \frac{{}^{1}\!/_{2\pi d2o}}{4}}{{}^{1}\!/_{2}\mu d0}} \dots\dots\dots \quad (12)$$

   b. Reynold Tube Number

   $$\boldsymbol{Re\ t = \frac{De\ Gt}{\mu c}} \dots\dots\dots \quad (13)$$

7. Heat Transfer Factor (Jh)
   Determination of Jh by reading the graph at ho and hi

   $$\boldsymbol{ho = jH \frac{kh}{De} (\frac{ch\ \mu h}{kh})^{1/3}\, \theta s}$$

   $$\boldsymbol{hi = jH \frac{kc}{De} (\frac{cc\ \mu c}{kc})^{1/3}\, \theta c} \dots\dots\dots \quad (14)$$

   $$\boldsymbol{hio = hi \times \frac{ID}{OD}} \dots\dots\dots \quad (15)$$

8. Tube Wall Temperature

   $$\boldsymbol{tw = tc + \frac{ho}{hio+ho}(Tc - tc)} \dots\dots\dots \quad (16)$$

9. Determining the Convection Coefficient of Heat

   $$\boldsymbol{ho = \left(\frac{ho}{\theta a}\right) \times \theta atw} \dots\dots\dots \quad (17)$$

   $$\boldsymbol{hio = \left(\frac{hio}{\theta p}\right) \times \theta ptw} \dots\dots\dots \quad (18)$$

10. Determining the Net Whole Coefficient of Heat (U_c)

    $$\boldsymbol{Uc = \frac{ho \times hio}{ho+hio}} \dots\dots\dots \quad (19)$$

11. Gross heat coefficient when moving (U_d)

    $$\boldsymbol{Q = UdA\ (\Delta T_{LMTD})} \dots\dots\dots \quad (20)$$

12. Determination of Dirt Factor (R_d)

    $$\boldsymbol{Rd = \frac{Uc - Ud}{Uc \times Ud}} \dots\dots\dots \quad (21)$$

13. Pressure Difference

The pressure drop on the shell side of the heat exchanger involves a proportion of the distance the fluid needs to cross the tube bundle between the baffles. So, the isothermal effect on the extent of the pressure reduction is when the two fluids are cooled or heated.

a. Shell pressure drop.

$$\Delta Ps = \frac{f\, G_s^2\, De\, (N+1)}{5{,}22 \times 10^{10}\, Des\, \theta s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

b. Tube pressure that drops.

$$\Delta Pt = \frac{f\, G_s^2\, De\, Ln}{5{,}22 \times 10^{10}\, Des\, \theta s} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

$$\Delta Pr = \frac{4n}{s} \times \frac{V^s}{g'} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

Total pressure drop on the tube:

$$\Delta Pt = \Delta Pt + \Delta Pr \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (25)$$

III. RESULT AND DISCUSSION

A. Shell and Tube Heat Exchanger Specification Data

The author requires actual data on shell and tube heat exchangers to calculate the thermal efficiency of Heat Exchanger 011-E-112 at the Crude Distillation Unit Fuel Oil Complex II (FOC II). This efficiency is used as an indicator to determine whether the Heat Exchanger is still suitable for use [2]. In the industry, shell and tube-type heat exchangers are the most prevalent and extensively used due to their straightforward design and ability to handle high pressure, temperature, and fluid flows. It is necessary to have specifications in place to evaluate performance and ensure that the design is appropriate for the application.The primary specifications of shell and tube heat exchangers are as follows: the heat exchanger type, which can be either single-pass or multi-pass, is contingent upon the fluid flow through the tube. The number of tubes and their sizes, determined by the length, number of tubes, and diameter, each impacts the surface area, heat transfer, and fluid flow rate. The coefficient of heat transfer (U-value) is a metric that estimates the heat efficiency that corresponds to the value transferred through the tube wall.

The maximum operating pressure and temperature that The alignment can be used to ascertain the heat exchanger's capacity to overcome of certain applications with their limits. The fouling factor also denotes the quantity of impurities or deposits that impact heat transfer efficiency. Additionally, the shell and tube's construction material, typically stainless steel or copper, is selected or adjusted to the existing material to prevent corrosion and resistance to fluid pressure and temperature [9]. To ensure optimal performance and safety of operation in the heat exchanger, it is also necessary to meticulously correct existing specifications and eliminate any potential obstacles. The redesign of process equipment is employed to facilitate and comprehend that heat exchangers can also serve as an alternative method of reducing or increasing the capacity of fluid flow and mass liquids. Consequently, the capacity of heat exchangers is a component of the process equipment implemented in the bimi oil fluid lifting industry sector [2]. The Heat Exchanger's design specifications, as obtained from Field Work Practices, are as follows:

1. Design Specifications for Shell Side Heat Exchangers, as illustrated in Table 1

Table 1. Shell Specification Design Data

No	Description	Unit	HE 011-E-112
1	Inside Diameter (ID)	mm	1346
2	Outside Diameter (OD)		1346
3	Number of Baffles (N)	inch	
4	Distance Between Baffles (B)	inch	
5	Number of Passes (N)		Divided Flow
6	Fluid Type		Kerosene
7	Temperature in	C	227
8	Temperature out	C	233

2. Table 2 illustrates the design specifications for the Tube Side Heat Exchanger.

Table 2. Design Data for Tube Specifications

No	Description	Unit	HE 011-E-112
1	Outside Diameter (OD)	mm	25,4
2	Tube Length (L)	ft	1998,03156
3	Number of Tube (Nt)	Buah	1010
4	Inlet Temperature	C	302
5	Outlet Temperature	C	255
6	BWG		12
7	Tube Arrangement, Pitch	mm	31.75
8	Distance Between Tubes (C")	inch	
9	Number of Passes (N)		6
10	Fluid Type	Heavy Diesel Oil	

3. Specification of Heat Exchanger Tube Side as outlined in Table 3

Table 3. Actual Data of Tube Specifications

HE 011-E-112				
Flowrate	**Flowrate**	**Flowrate (Kl/Day)**	**temp In (°C)**	**Temp out (°C)**
Hot Fluid (HDO)	447,01	(m^3/hr)	319	266
Flowrate	**Flowrate**	**Flowrate (Kl/Day)**	**temp In (°F)**	**Temp Out (°F)**
Hot Fluid (HDO)	447,01	(m^3/hr)	606	510

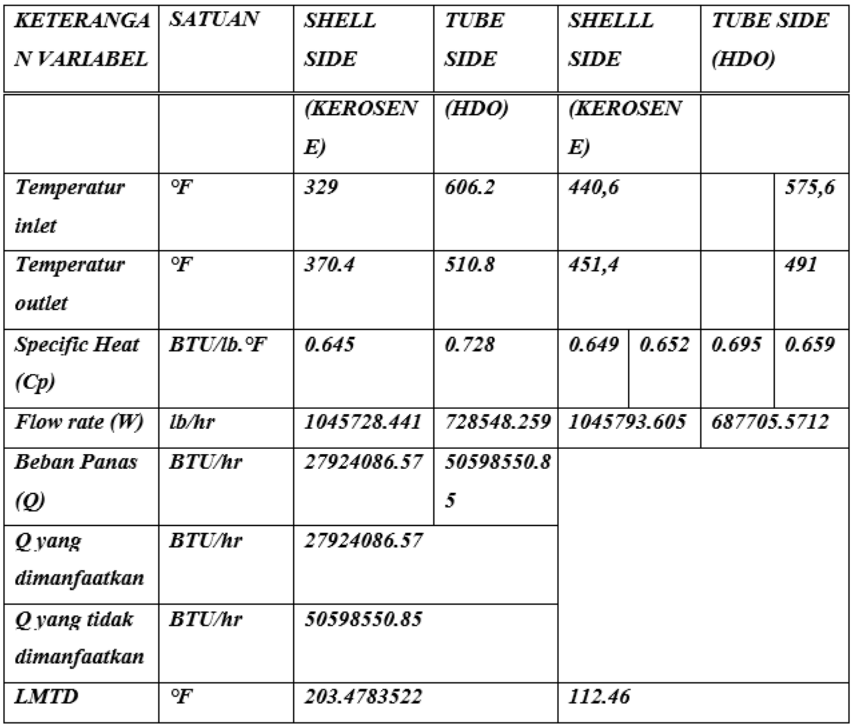
4. Specification of Heat Exchanger Tube Side as outlined in Table 4

Table 4. Actual Data for Shell Specifications

HE 011-E-112				
Flowrate	**Flowrate**	**Flowrate (Kl/Day)**	**temp In (°C)**	**Temp out (°C)**
(Kerosene)	447,36	(m^3/hr)	165	188
Flowrate	**Flowrate**	**Flowrate (Kl/Day)**	**temp In (°F)**	**Temp Out (°F)**
Kerosene	1539874	(m^3/hr)	319	370

B. Result

The thermal efficiency of Heat Exchanger-3 is determined using the Dirt factor/fouling factor (Rd) in conjunction with the Pressure Drop method. The dirt factor (Rd) indicates the fouling factor, specifically the dirt resistance, which is essential for preventing the accumulation of crust on both the inner and outer walls of the heat exchanger tube [10]. Fouling can lead to increased back pressure and elevated pump power requirements. Therefore, it is essential to clean the heat exchanger components. Options for mitigating the fouling factor include the application of chemicals or the replacement of parts. Heat loss may also be considered a maintenance activity, as it enables heat and energy to contribute to an extended service life of process equipment [11]. The calculated Dirt factor (Rd) values for the tube and shell are 0.017 BTU/hr ft^2 °F and 0.03 BTU/hr ft^2 °F, as referenced from the book by D.Q. Kern regarding the Dirt factor (Rd) limit. Kern, the allowable Dirt factor (Rd) limit is 0.005 BTU/hr ft^2 °F. The impurities in the liquid consistently adhere to and accumulate on the walls of the heat exchanger. This accumulation leads to scaling, which hinders the efficacy of heat transfer within the heat exchanger, thereby failing to meet various process requirements. Empirical equations serve as a viable option for conducting calculations with simulation programs, such as HTRI and Heat Transfer Research Inc. This approach facilitates a significant reduction in problem-solving time. The heat transfer mechanism between the fluids, specifically HDO and kerosene, is necessary. Tube and Shell. Figure 3 illustrates the results pertaining to the dirt factor and pressure drop.



KETERANGAN VARIABEL	SATUAN	SHELL SIDE	TUBE SIDE	SHELLL SIDE		TUBE SIDE (HDO)	
		(KEROSENE)	(HDO)	(KEROSENE)			
Temperatur inlet	°F	329	606.2	440,6			575,6
Temperatur outlet	°F	370.4	510.8	451,4			491
Specific Heat (Cp)	BTU/lb.°F	0.645	0.728	0.649	0.652	0.695	0.659
Flow rate (W)	lb/hr	1045728.441	728548.259	1045793.605		687705.5712	
Beban Panas (Q)	BTU/hr	27924086.57	50598550.85				
Q yang dimanfaatkan	BTU/hr	27924086.57					
Q yang tidak dimanfaatkan	BTU/hr	50598550.85					
LMTD	°F	203.4783522		112.46			

Fig 3. HE 011-E-12's Actual and Design Calculation Results

The Pressure Drop indicates the reduction in pressure during fluid flow within the Shell and the Tube. The author's calculations for the Pressure Drop figure yielded 2.0062 Psi in the Shell section, referencing references from the D.Q. book. The allowable pressure drop limit is ten psi [12]. This illustrates the internal fluid flow (lb/hr) within the shell section at each mass flow rate, which exhibits minimal variation. The pressure drop measured in the tube is significantly higher than the design specifications, influenced by the flow rate, with a recorded value of 130.32 Psi, which deviates considerably from the design data [13].The discrepancy between the observed high-pressure drop in the tube and the design specifications may signify a misalignment or operational issue within the system. A potential cause is the collection of dirt, scale, or deposits within the tube, which obstructs the flow and substantially elevates the pressure drop relative to the intended value. Furthermore, any deformation or impairment of the tube, including constriction or obstruction, may result in the actual pressure drop exceeding anticipated levels. Simulations conducted with HYSYS software yielded flow velocities and pressure decreases closely aligned with actual measurements, indicating that elevated temperatures can exacerbate fouling formation, resulting in instability [14].

Pressure reductions that surpass this design threshold can impair overall system performance, diminish efficiency, and elevate energy demands to sustain the required flow. If not promptly rectified, this condition can expedite the deterioration of system components like pumps or compressors and heighten the chance of tube failures, including leaks or ruptures. Consequently, it is essential to perform frequent inspections and maintenance to guarantee that the system functions in accordance with its design parameters and to avert undesirable increases in pressure drop [15]. Consequently, pressure drop and dirt factor dictate The heat exchanger's efficiency. The outcomes of these two parameters influence the heat transmission process within this heat exchanger. Impurities, including deposits from continuously flowing fluids, may also arise from the corrosion of heat exchanger components influenced by the fluid type. Similar to other instruments, the continued operation of this heat exchanger will inevitably result in fouling of the fluid kind. An increase in contaminants adversely impacts performance, hence influencing the overall The heat transfer coefficient is influenced by the temperature of the fluid that is circulating. As a result, the most critical component of an assessment is to determine the effectiveness of each heat exchanger variable.

IV. CONCLUSION

Recommendations for enhancing the heat exchanger's performance include the addition of a temperature indicator to ensure that the current at the heater output is calculated with more accuracy, aligning it more closely with actual data. Evaluations of the performance of shell and tube heat exchangers should be conducted to ensure optimal heat transfer while maintaining minimal performance thresholds. Furthermore, if fouling is present on the shell and tube walls, frequent cleaning of the equipment can be performed to uphold the heat exchanger's function. The computation of each factor must be systematically organized as a fundamental reference for calculating and employing equations tailored to the chosen boundary conditions in the assessment of shell and tube heat exchangers.The assessment of the heat exchanger can be finalized following calculations that juxtapose design and actual results alongside an analysis of the heat exchanger's characteristics. Based on the analysis of HE 011-E-112 in the Crude Distillation Unit II of the Fuel Oil Complex II Oil and Gas Company XY during July-August 2024, it is concluded that the dirt factor (Rd) for Heat Exchanger 011-E-112 in FOC II exceeds the fouling factor specified in the data specification sheet.

- Rd shell, design specification = 0.0003 BTU/hour per square foot.
- Actual shell Rd July-August 2024 = 0.0170 BTU/hour.ft^2.°F
- Rd shell, design specification = 0.0005 BTU/hour·ft^2·°F
- Actual shell Rd July-August 2024 = 0.0342 BTU/hour·ft^2·°F

Consequently, the heat exchanger necessitates maintenance to enhance its performance significantly. Calculations of pressure drop to determine the operational efficiency of the heat exchanger 011-E-112. This pertains to the numerous contaminants present in the shell and tubes of the heat exchanger. The results of the pressure drop calculation are as follows: permissible pressure drop for the shell (ΔP shell) is 1.7 Psi, the allowable pressure drop for the tube (ΔP tube) is 18.92 Psi, the actual pressure drop for the shell in August 2024 (ΔPshell) is 2.006 Psi, and actual pressure drop for the tube in August 2024 (ΔPtube) is 130.32 Psi.

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