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Effectiveness Comparative of The AG-666 Condenser with Re-Design In Producing Distillate for The AT-460 Distillation Tower Feed

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ABSTRACT

PT. Sintas Kurama Perdana is the only formic acid production plant in Indonesia. The company places high attention on the daily operating conditions of its production process, ensuring that every parameter, such as flow rate, temperature, pressure, and components, is maintained according to the set point. In the production process of methyl formate and formic acid, optimization of operational conditions, especially in the heat exchanger unit, is the main focus. The shell and tube type heat exchanger, specifically with the code AG-666, is used to condense the AT-660 distillate vapor output. This study assesses whether the AG-666 is capable of total condensation without the need for the assistance of the AG-667 condenser in anticipation if the AG-667 does not function. The analysis is carried out based on the clean overall coefficient (Uc), design overall coefficient (Ud), fouling factor (Rd), efficiency, and effectiveness for actual design conditions and re-design. The data owned from the initial design of the survival is the Uc value of 1525 W/m2.K, Rd value of 0.00032 m2.K/W, efficiency of 82%, and effectiveness of 75%. The actual condition of the heat exchanger has a Uc value of 801.71 W/m2.K, Ud value of 104.62 Btu/ft.h.°F, Rd value of 0.000436 m2.K/W, efficiency of 74%, and effectiveness of 50%. Re-Design shows that increasing the number of passes (4 passes in the shell and 8 passes in the tube) allows single-stage condensation at an outlet temperature of 32 °C without non-condensable gases such as CO. Comparison between the initial design and the re-design results shows an increase in efficiency of 80% and effectiveness of 57.78%, with Uc 725.83 W/m2.K and Ud 102.27 Btu/ft.h.°F. The redesign provided better performance than the original design, although actual efficiency was slightly lower.

Keywords: Formic acid, heat excahnger (AG-666), effectiveness

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1. Introduction

PT Sintas Kurama Perdana is a company that produces chemicals in the form of formic acid in Indonesia and is the only factory in Southeast Asia as a producer and supplier of formic acid products in the region. This factory was established to meet the needs of formic acid from the needs of various industrial sectors including textile, rubber, pharmaceutical and others. Looking at the principles and methods of the process, this factory adopts the main system for making formic acid with the Kemira O.Y method from Finland, where all tools and engineering designs are fulfilled and characterized by Kemira to meet the flow of the formic acid production process at PT Sintas Kurama Perdana. In addition, the Kemira method outlines the principle of making formic acid by using methyl formate raw materials along with water where the process is called Methyl Formate Hydrolysis.

PT Sintas Kurama Perdana always pays attention to the operating conditions of the process every day to run in accordance with the set points and targets. Each stage of the process and process conditions must be well maintained, starting from the conditions of flow rate, temperature, components, pressure and optimization of each stage in accordance with the production design target. One of the important tools in the processing flow is a heat exchanger. This heat exchanger has a very crucial role in maintaining the temperature or setting the desired process temperature of each flow to match the set point set on each process equipment instrument.

In general, heat exchangers have two different types or models, namely double pipe heat exchangers and shell and tube heat exchangers. At PT Sintas Kurama Perdana, almost all heat exchanger models designed are shell and tube type. Therefore, it is important to analyze the design of the heat exchanger and the quality of the equipment that is still in use today with the plant operating conditions that are always full operation for 24 hours. In this particular assignment, special attention is given to the heat exchanger with tool code AG-666. The heat exchanger design is used to condense the vapor output from the AT-660 distillate, and the condensed liquid will be fed back into the condenser with the code AG-667.

The most common issues for heat exchanger design are effectiveness and efficiency. Such issues are useful for evaluating the performance of the exchanger [1]. Heat exchangers, if operated for a certain period of time, will experience a decrease in effectiveness. This can be caused by the formation of scale, corrosion, and leaks that occur in the heat exchanger [5]. The detection in the rating determines the heat transfer rate and fluid exit temperature for the specified fluid flow rate, inlet temperature, and pressure drop for the existing heat exchanger. Therefore, the heat transfer surface area and its dimensions are of interest to study and analyze [15] .

In order to anticipate unwanted things such as AG-667 damage to the heat exchanger at PT. Sintas Kurama Perdana, then with anticipation if the chilled water stock is insufficient to meet the process needs at AG-667, alternative efforts need to be made through these things. Choosing the right heat exchanger will save daily operational costs and maintenance. If the heat exchanger is new, then the metal surface of the heating pipes is still clean after the device has been operating for some time, a layer of dirt or crust forms on the surface of the pipe. The heat exchanger is designed as much as possible so that heat transfer between fluids can take place efficiently. Heat exchange occurs due to contact, either between fluids there is a separating wall or both are mixed directly (direct contact) [6].

Through its function, it is necessary to analyze whether the AG-666 condenser can perform phase change events in condensation only on the tool and not use the AG-667 tool as a condensation perfector [3]. Therefore, by looking at the performance of the heat exchanger performance, it is necessary to analyze and identify the heat exchanger with distillation output in the form of light organic vapor. Analysis and identification based on the clean overall coefficient of the net overall heat coefficient (Uc), the value of the design overall coefficient or gross overall heat coefficient (Ud), the fouling factor (Rd), and the re-design schematic to find out if the AG-666 condenser can condense the entire steam yield without the need for a further condenser device, namely AG-667 in anticipation if at any time the AG-667 condenser does not function properly or completely dies.

2. Methodology of Research

Data collection is needed for the analysis and identification process on the condenser heat exchanger (AG-666) for the formic acid section in acid distillation I. The data used is data on the working conditions per day of the condenser heat exchanger at PT Sintas Kurama Perdana starting on February 19, 2024 until February 23, 2024. The data collection method here is divided into two, namely the primary data collection method and secondary data collection.

As additional information that the current conditions at the output of AT-660 distillate do not contain CO gas due to the recycle of CO gas that has occurred in the methyl formate section and in the design calculation, CO gas does not really affect the mass flow involved so that its value can be ignored for the calculation of actual conditions and condenser re-design.

2.1 Primary Data

Primary data collection in this special assignment takes the main design data for the AG-666 condenser as a basis for determining in analyzing and identifying the calculation needs of this shell and tube heat exchanger.In addition, this primary data serves as a reference material in evaluating the value of the temperature output from the AT-660 distillation which will enter AG-666 and the value of the outlet temperature of the condenser. The data is used to identify whether the heat exchanger that is being used is still within safe limits or there are anomalies in the results obtained.

2.2 Secondary data

Secondary data collection is data that is needed as a calculation material in the analysis and identification of the condenser heat exchanger (AG-666) in the formic acid process section in the acid distillation column I. Data obtained from field data and data from various kinds of literature.Field study data was obtained by taking and reviewing the direct operating conditions and actual process flow in the condenser heat exchanger (AG-666) from February 19, 2024 and February 23, 2024, namely by taking data on field conditions directly and monitoring with the DCS (Distribution Control system) control room in the form of in and out temperatures in the condenser, volume flow, and pressure of each flow rate of each fluid flowing, both in the shell and in the tube.

In the literature study, the data obtained are the calculation steps of the heat exchanger and the graphs and tables used. The literature used are (Kern, 1950), [Walker, 2011], [J.P Hollman, 1986] and (Yaws, 1999) [7], [8], [1], and [4].

2.3 Data Analysis

The actual data obtained by going to the field to be processed requires data in the form of:

1. Inlet temperature data to the distillation tower to obtain its mass flow value per component.
2. Temperature data in the field at temperatures in and out of the AG-666 condenser.
3. Volume flow data into the distillation and out of the distillate column in the upper flow.
4. Data on the mass fraction of the distillation inlet and outlet to determine the need for a comparison of the composition of the flow in each component.

Data was taken within a period of 5 working days a week and taken from February 19 to February 23, 2024.

Table 1. Temperature of Flow 22 PT. Sintas Kurama Perdana to distillation tower

Date	$T_{act,in}$ flowrate (*flow* in)°C
19 February 2024	45
20 February 2024	47
21 February 2024	48
22 February 2024	44
23 February 2024	44
Average	**46**

Table 2. Inlet And Outlet Flow Temperature At AG-666 Condenser

Date	T_{in} *condenser* °C	T_{out} *condenser*°C	$T_{cw,in}$ (*Cooling water*)°C	$T_{cw,out}$ (*Cooling water*)°C
19 February 2024	50	42	31	36
20 February2024	52	42	31	36
21 February2024	51	39	30	37
22 February2024	51	38	31	38
23 February2024	51	42	31	37
Average	**51**	**41**	**31**	**37**

Table 3. Distillation Tower Inlet Flow Volume And AT-660 Distillate Output

Date	*Flow in* (m^3/hour)	*Flow Out Top Distilate* (m^3/hour)
19 February 2024	5	2,8
20 February 2024	4,5	2,67
21 February 2024	5,25	3,2
22 February 2024	5,25	3,13
23 February 2024	5,25	3,2
Average	**5,05**	**3,00**

Table 4. Mass Fraction In AT-660 Distillation Tower

Date	Inlet Mass Fraction (%)				Top Distillate Mass Fraction (%)	
	MF	AF	MeOH	H_2O	MF	MeOH
19 February 2024	81,3	2,3	4,4	12	68,7	31,3
20 February 2024	61,7	2,8	4,1	31,4	68,2	31,8
21 February 2024	70,6	2,7	11,9	14,8	70,4	29,6
22 February 2024	69,1	3,7	13,8	13,4	65,7	34,3
23 February 2024	76,2	3,1	7	13,7	64,9	35,1
Average	**71,78%**	**2,92%**	**8,24%**	**17,06%**	**67,58%**	**32,42%**

3. Result and Discussion

3.1 Data Calculations and Data Collection

The calculation results are divided into 3 comparison results, where there are initial data sheets as the main reference, actual data, and re-design calculation data as a new proposal from the author to design. Actual data and re-design data use the calculation of the average value on 5 working days at PT Sintas Kurama Perdana with consideration of the conditions and factory operations running normally without any start-up or shut down constraints. Especially for re-design data, there is a consideration of new numbers taken which are not from the initial design data or from actual data.

Based on the data obtained from PT Sintas Kurama Perdana through the company's process flow guidebook, it is found that the total condensation point of all liquids except CO gas which is not contained in the distillate output mixture is at 32°C or 89.6°F.

The calculation results can be seen in the table below.

Table 5. Initial Design Data Sheet of AG-666 Condenser

Variable	Design Data
Shell Side	Water
Tube Side	Metil Format, Metanol, CO
Suhu (in/out) shell (°C)	33/43
Suhu (in/out) tube (°C)	51/40
Shell Passes	1
Tube Passes	1
Velocity in shell (m/s)	0,4
Velocity in tube (m/s)	6,3
Transfer Rate (W/m^2.K)	1525
Heat Exchanged (ΔTlm) (°F)	44,06
Fouling Resistance (m^2.K/W)	0,00032
Tube Count	1267
Tube Length (mm)	5760
OD tube (mm)	19,05
ID tube (mm)	15,75
Thickness (mm)	1,65
Pitch (mm)	23,81
Shell ID (mm)	965
Material	SS316L
Seg Baffle Cut (%)	25
Support Tube	U-Bend
TEMA Class	B
Design Temperature	120°C
Efficiency (%)	82
Effectiveness (%)	75

Table 6. Calculation Results of Actual Condition of AG-666 Condenser Design

Variable	Design Data
Shell Side	Water
Tube Side	Metil Format, Metanol, Non CO
Suhu (in/out) shell (°C)	31/37
Suhu (in/out) tube (°C)	51/41
Shell Passes	1
Tube Passes	1
Transfer Rate Clean (W/m^2.K)	801,71
Heat Exchanged (ΔTlm) (°F)	19,69
Fouling Resistance (m^2.K/W)	0,000436
Tube Count	1267
Tube Length (mm)	5760
OD tube (mm)	19,05
ID tube (mm)	15,75
Thickness (mm)	1,65
Pitch (mm)	23,81
Shell ID (mm)	965
Material	SS316L
Seg Baffle Cut (%)	25
Support Tube	U-Bend
TEMA Class	B
Design Temperature (°C)	120
Efficiency (%)	74
Effectiveness (%)	50,00

Heat exchanger is a device that produces heat transfer from a fluid, both used in the heating process and the cooling process. The right conditions can produce products that match what is desired in a process [1]. The operating conditions considered in this discussion include temperature (in, out) and incoming feed flow in finding variables in the form of Overall Coefficient Clean Heat Transfer (Uc), Dirt Coefficient Heat Transfer (Ud), Fouling factor (Rd), efficiency value (η) and effectiveness (ε). The heat transfer carried out in this heat exchanger tool is counterflow type with 1.1 passes shell and tube [6].

When the fluid flows along the heat exchanger, some impurities and other fluids will stick to the walls of the shell and tube which in a long period of time will form scale and cause obstruction to the heat transfer rate and obstruction to the fluid flow in the heat exchanger. Obstructed heat transfer will load the heat transfer process and make the desired temperature inappropriate [14]. So with the current condition that has been running for almost 38 years from the establishment of the factory, it is necessary to analyze the Clean overall coefficient (UC), Design overall coefficient (Ud), fouling factor (Rd), and efficiency value (η). In addition, continuous identification will also be carried out to obtain findings and other alternatives if the AG-667 condenser is not running properly due to the condition of each equipment that has been operating for a very long time. Therefore, the identification of the effectiveness value becomes the main comparison medium to anticipate undesirable things to happen by always considering the old design or construction to counteract the waste of costs from the AG-666 condenser heat exchanger in the formic acid distillation section I.

Table 7. Calulation Results of AG-666 Condenser Re-Design ondition

Variable	Design Data
Shell Side	Water
Tube Side	Metil Format, Metanol, Non CO
Suhu (in/out) shell (°C)	22,5/29
Suhu (in/out) tube (°C)	45/32
Shell Passes	4
Tube Passes	8
Transfer Rate Clean ($W/m^2.K$)	725,83
Heat Exchanged (ΔTlm) (°F)	22,00
Fouling Resistance (m2.K/W)	0,000344
Tube Count	1267
Tube Length (mm)	5760
OD tube (mm)	19,05
ID tube (mm)	15,75
Thickness (mm)	1,65
Pitch (mm)	23,81
Shell ID (mm)	965
Material	SS316L
Seg Baffle Cut (%)	25
Support Tube	U-Bend
TEMA Class	B
Design Temperature (°C)	120
Efficiency (%)	80
Effectiveness (%)	57,78

3.2 Identification of New Mini Re-Design Needs

In the new design, the proposal was made considering the aging condition of the plant equipment and has not been replaced at all with a new process device due to very high shipping and cost considerations from Kemira O.Y., Finland. Alternatively, the re-design identified that AG-666 should be modified slightly in the design of its passes to its existing condition and not require any additional cost other than routine maintenance [13]. Also, the re-design considered that the distillation output should be at a temperature around 45℃ (mixture component/light organics) which is at the boiling point of the mixture and the output of AG-666 should be fully condensed at 32℃. This condition based on field data will be very helpful and a solution in the absence of non-condensable gas in AG-666 (Non CO content), in the sense that CO gas conditions do not exist at the output of AT-660 distillation. This is in accordance with field data, because CO gas is negligible and only minimal CO content in the distillate output is around 0.0001% based on Lab analysis at PT. Sintas Kurama Perdana. Therefore, the leftover gas can be optimized back to the recyle flow in GE-380, the compressor in the methyl formate formation section. The new design made has a type of 4.8 passes shell and tube exchanger in order to have a longer residence time with consideration of the heat transfer conditions obtained from the calculation results (Table 7).

This decrease in temperature will indeed have an effect because it has not reached the perfect dew point value (saturated vapor) of the methyl formate and methanol components [11]. However, this value will also greatly affect the total condensation value of the mixture component so that it is easier to condense by reaching the boiling point value first. If the re-design value has the same input output value as the actual data, both from the incoming feed and the incoming coolant, it will have a drastic temperature drop in the displacement that occurs and affects the value of the LMTD results. Based on actual conditions, according to the rules in the book [7] that the temperature range in the heat transfer device is a maximum of 10 ℃ for the input and output flow from the sheel and tube sides. However, actual conditions cannot be applied to the AG-666 condenser for one condensation stage only. This is because the output temperature in actual conditions is 41℃, which is still far from the condensed value of the mixed components of methyl formate and methanol, so it has not reached the perfect condensation temperature of 32℃. Therefore, it is necessary to adjust the output of the distillation tower to the AG-666 condenser with the upper output temperature set point at 45 ℃ with the help of DCS on the system monitor. This condition will reduce the distillation load as well if applied.

Then, the required incoming cooling water value is 22.5℃, this value is still within the safe range of provisions in the supply of cooling water flow in the cooling tower [12]. The cooling water value determined based on the output value of the shell side water is 29 ℃, where the range is still within safe limits because the incoming water is quite cold and the difference between the incoming and outgoing water is 6.5 ℃. Under these conditions, the value obtained from the re-design calculation results for the AG-666 condenser can be applied at PT Sintas Kurama Perdana, supported by the entire construction of the equipment at PT is very efficient and sophisticated with Kemira Oyj technology from Finland. However, these conditions must also be accompanied by continuous equipment maintenance, at least 6 months once.

The provision of a total condensation temperature of 32℃ is given by PT Sintas Kurama Perdana as an effort to solve the current problem so that the effectiveness and efficiency of the condenser can be compared and become a benchmark for loss of function in AG-667 to reduce the electricity load or existing chilled water needs.

3.3 Comparison of Clean Overall Coefficient (UC) and Design Overall Coefficient (Ud) Values In Actual Design and Re-Design

Tables 5, 6 and 7 show that the value of clean overall coefficient (UC) or overall heat transfer when clean is greater than the value of design overall coefficient (Ud) or heat transfer when dirty. This is in accordance with Kern's theory stating that the value of clean overall heat transfer coefficient (Uc) must be greater than the design overall heat transfer coefficient (Ud).

From the calculation of the Uc value and the Ud value obtained in the actual data conditions, it is found that it is 801.71 $W/m^2.K$ while the design overall heat transfer coefficient (Ud) value is 104.62 Btu/ft.h.°F (British units adjust to the provisions of the kern book) which is still within the range of provisions for obtaining heat exchanger design values with cold fluid (water) and hot fluid (light organics) inflow types. The results obtained are in accordance with the provisions, namely the value of Uc> Ud [11]. However, the value of clean overall coefficient (Uc) has decreased along with the production process that continues to run and without stopping for 24 hours. This is due to factors of tool conditions, especially those that are aging and have not been over-treated so that they can carry out heat transfer events properly like design data. The design data shows a clean overall coefficient (Uc) value of 1525 $W/m^2.K$. Therefore, there is a decrease of about 723.29 W/m2.K in heat transfer from the shell side (water) to the tube side (methanol and methyl formate) to cool down the temperature on the tube side.

Calculation analysis of Uc and Ud values was carried out on the new condenser design. Where a value of 725.83 $W/m^2.K$ (Uc) is obtained and the Ud value is obtained at 102.27 Btu/ft.h.°F which shows that the value is very conditional with the current equipment conditions [12].

3.4 Comparison of Fouling Factor (Rd) Values

The value of Rd (fouling factor) is a value used to indicate the size of the impurity factor contained in the heat exchanger. Fouling factor affects the heat transfer coefficient because the greater the fouling on the tube, it will cause an increase in heat transfer resistance which results in obstruction of the heat transfer rate on the tube so that the heat transfer coefficient decreases. This Rd parameter is used to determine whether the heat exchanger needs to be cleaned by engineering process tools or not. If the design Rd < actual Rd then the heat exchanger needs to be cleaned. The average value of Rd (fouling factor) in the AG-666 condenser heat exchanger in the formic acid section on February 19, 2024 to February 23, 2024 is 0.000436 $m^2.K/W$ while the design Rd is 0.00032 $m^2.K/W$ the difference between design and actual values is around 0.000116 m2.K/W. So from these results the design Rd value < actual Rd, the heat exchanger needs to be cleaned because the impurities in the AG-666 condenser are quite high. Fouling that occurs in the heat exchanger is caused by the accumulation of dirt or residue carried by components (methanol and methyl formate) that come from the AT-660 distillate output [13]. In addition, the age factor of the heat exchanger installation is very old and the dirt has stuck to the outer wall of the shell and tube, causing the heat transfer from the hot fluid (mixture component) to the cold fluid to be not maximized and resulting in a decreased efficiency value. If the cleaning engineering tools process and monthly or maybe annual maintenance, then AG-666 can still run properly even though the condition of the tool is very old and needs to be rejuvenated on the walls of the heat exchanger in the form of re-painting or coating anti-corrosion material again.

In the re-design condition, the fouling factor value is 0.000344 $m^2.K/W$. The fouling factor value obtained is almost similar to the initial design with only a difference of 6.98%. With this value, the new design conditions can be applied with a calculation not exceeding 10% of the initial design and not less than the initial design data, meaning that the design is acceptable (allowable) [6].

3.5 Efficiency Of AG-666 Heat Exchanger Performance

The efficiency value shows to assess the efficiency of the condenser's performance during operation by comparison of design data and actual current data. This efficiency has certain reasonable limits, generally this efficiency value ranges from 70%-90% of the heat exchanger design. Therefore, in order to know this value, it is necessary to analyze and see how far the decline has occurred for approximately 36 years the factory has been established.

The initial design shows an efficiency value of 82% in the heat transfer process that occurs in this AG-666 condenser. Whereas in the actual data with the same design, the efficiency value decreased to 74%. This indicates a decrease in the performance of the heat exchanger due to the old design and will automatically affect the current process conditions [14].

Based on table result by analysis, the new design made efficiency reached 80%, with it still in the feasible category to be carried out and applied in the acid distillation section 1 for the AT-660 output. This value is still within reasonable limits for the efficiency of heat exchangers that generally exist in industry.

3.6 Effectiveness of AG-666 Heat exchanger

A high effectiveness value indicates that the heat exchanger can transfer heat flux per unit mass of fluid in large quantities. Heat exchanger devices that have low effectiveness must be further investigated based on what is the cause and main obstacle in reducing the performance of heat transfer per unit of heat in the heat exchanger [15]. Heat transfer will change the temperature of the two fluids coming out of the heat exchanger. Changes in the temperature of the two fluids will be able to determine the effectiveness value of the heat exchanger by using the ratio of heat transfer between one of the fluids to the minimum heat transfer between the two fluids [16].

The results obtained show that the actual data has a decreased heat transfer effectiveness value with the initial design data. This can be caused by the difference in incoming and outgoing temperatures between the shell and tube. This temperature value is very influential because it will have an impact on the ΔTLMTD value obtained. In the initial effectiveness value of the design made, it was found to be 75%, while in actual conditions it was found to be 50%. The reasonable limit in general the effectiveness value of the heat exchanger tool in charge of heat transfer is 30% as a minimum limit, so that its performance can still be tolerated [17]. The new design data meets the existing reasonable limit value with a value of 57.78% and is still within safe limits [5].

Based on the data from the calculation results in tables 5, 6, and 7, it was found that the effectiveness value of the initial, actual, and redesigned conditions still met. However, the results of the calculation and analysis of the re-design are more suitable for use with the current conditions, with an effectiveness value of 57.58%

4. Conclusion

The need for 2-stage condensation at the AT-660 distillate output is due to the fact that the total condensation value of the mixture has not yet been reached, which is 32℃. The condensation temperature of 32℃ is obtained with data from the company with a note that there is no CO content in the output distillate which indicates the presence of non-condensable gas compounds in the AG-666 condenser. While the design data is only at an output temperature of around 40 ℃ as distillate at the output of the out heat exchanger and in the presence of CO content. The design data is designed to anticipate the presence of non-condensable gas that has not been condensed with the coolant in the form of chilled water at 8℃. Therefore, it is necessary to carry out the condensation stage twice at the output of the AT-660 to maximize the liquid produced in the distillate later.

Comparisons of the overall coefficient value (Uc), gross overall heat coefficient (Ud), fouling factor value (Rd), efficiency (η), and effectiveness (ε) provide significant differences. The initial design value with good conditions has very high performance compared to the new re-design value. However, when looking at the current conditions, the value obtained from the re-design has higher effectiveness and efficiency than the actual design data value. Where the efficiency value obtained in the re-design is 80%, effectiveness is 57.78%, Uc value is 725.83 $W/m^2.K$ and Ud value obtained is 102.27 Btu/fft.h.°F. While for the actual design data, the efficiency value obtained is 74%, effectiveness 50%, UC value 801.71 $W/m^2.K$, while the design overall heat transfer coefficient (Ud) value is 104.62 Btu/ft.h.°F.

Based on the results of identification and further review, the changed process conditions of the re-design are to change the inlet and outlet flow temperatures of the heat exchanger. Then all designs do not change following the existing design data, only a few modifications need to be made. The inlet temperature of the condenser depends on the output of the AT-660 top distillate which must be at 45℃ at the boiling point of the mixture. Then the output temperature of the condenser must be at 32℃ considering that the entire output has become a whole liquid phase without any CO content. The inlet temperature of the cooler is at 22.5℃ and the output is at 29℃. With the conditions and design of the AG-666 heat exchanger, condensation can be carried out in only 1 stage and does not require AG-667.

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References

[1] J. P. Holman, "Heat Transfer Sixth edition". 1986.

[2] T. Kuppan, "Heat Exchang€R Design Handbook."

[3] Green, Don W, Southard, and Marylee Z, "Perry's Chemical Engineers' Handbook."

[4] C. L. Yaws, "Chemical Properties Handbook: Physical, Thermodynamic, Enviromental, Transport, Safety, and Health Realted Properties for Organic and Inorganic Chemicals".

[5] Khairunnisa, E. Naryono and M. A. Ismail, "Evaluasi Efektivitas Alat Heat Exchanger 11e-25 pada Kilang Fuel Oil Complex (Foc) I di PT Pertamina Ru-Iv Cilacap," vol. 2021, no. 2, pp. 288–296, [Online]. Available: http://distilat.polinema.ac.id

[6] R. Nugraha , R. Setiawan2 , and R. D. Anjani, "Analisa Perhitungan Kerja Alat Penukar Kalor Berdasarkan Data Desain dan Data Aktual", vol.17, no. 3, September, pp. 155-162. EKSERGI. https://jurnal.polines.ac.id/index.php/eksergi

[7] D. Q. Kern, "Process Heat Transfer".

[8] J. Walker, "Fundamentals of Physics." [Online]. Available: www.wileyplus.com. 2011.

[9] T. V. Andrushkevich *et al.*, "A new gas-phase method for formic acid production: Tests on a pilot plant," *Catal Ind*, vol. 6, no. 1, pp. 17–24, 2014, doi: 10.1134/S2070050414010024.

[10] W. X. Chua, S. da Cunha, G. P. Rangaiah, and K. Hidajat, "Design and optimization of Kemira-Leonard process for formic acid production," *Chemical Engineering Science: X*, vol. 2, May 2019, doi: 10.1016/j.cesx.2019.100021.

[11] C. J. Geankoplis, "Transport Process and Unit Operations".

[12] S. Mokhatab, W. A. Poe, and J. Y. Mak, "Utility and Offsite Systems in Gas Processing Plants," in *Handbook of Natural Gas Transmission and Processing*, Elsevier, 2019, pp. 537–578. doi: 10.1016/b978-0-12-815817-3.00018-6.

[13] R. Nugraha, R. Setiawan, and R. D. Anjani, "Analisa Perhitungan Kerja Alat Penukar Kalor Berdasarkan Data Desain dan Data Aktual," 2021.

[14] A. Sekarayu Permanajati, E. Nurrohmah, B. Nainggolan Program Studi Teknik Konversi Energi, J. Teknik Mesin, P. G. Negeri Jakarta Jl Siwabessy Kampus Baru UI, and K. Depok, “Analisis Efektivitas Heat Exchanger Generator Thrust Bearing Oil Cooler Unit 7 PLTA Cirata”.

[15] R. Mukherjee, “Effectively Design Shell-and-Tube Heat Exchangers.”

[16] F. G. dkk Sasmita, “Efektivitas Kinerja Heat Exchanger Shell and Tube 1- 2 dengan Variasi Flow Rate Natural Gas pada Shell dan Reformer pada Tube di Unit Hydrogent Plant 8 PT Pertamina (Persero) Ru V Balikpapan”.

[17] R. K. Sinnott, “Chemical Engineering Design Volume 6.”