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Mathematical Design of Shell-and-Tube Heat Exchanger for MEK Production

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Abstract
Purpose: This study aims to analyse and develop design a heat exchanger (HE) for the production of Methyl Ethyl Ketone (MEK) which will be compiled into a computational program for the design of shell-tube type HE.
Methodology: The problem with this HE is that the temperature of 2-butanol is 30˚C from the storage tank. While the HE reactor requires a temperature of 99.6˚C, HE plays a role in increasing the temperature from 30˚C to 99.6˚C. To be more energy efficient, researchers used heat of the product, MEK. Which is where to exchange heat from the product to the reactants. The design of a shell-tube two-pass exchanger with a working fluid in the form of 2-butanol as a hot fluid with water as a cold fluid.
Results: Thus, HE with shell and tube doesn't meet the requirements and standards of TEMA. Although the shell and tube type of HE doesn't conform to the criteria and standards specified in industrial applications, the analysis can be used as a learning tool for the design process, heme performance analysis, and operating mechanism of the HE.
Limitations: This research is focused on developing HE designs for the production of MEK.
Contribution: This research can provide a reference for designing HE in industrial development.
Conclusion: The designed shell-and-tube heat exchanger shows limited efficiency and does not comply with TEMA industrial standards. However, the study provides valuable insights into the design methodology and serves as a foundation for further optimization of heat exchanger systems to enhance performance, efficiency, and industrial applicability.

Keywords: *Education, Effectiveness, Heat Exchanger, Methyl Ethyl Ketone, Shell-Tube.*

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1. Introduction

Indonesia is a developing country. Industry in Indonesia is growing quite rapidly. The chemical industry is one of the most important industrial sectors and contributes to the country's foreign exchange (Sylvia & Sunitiyoso, 2024). Along with the development and progress of the times, people's need for chemicals continues to increase. However, it is very unfortunate that the fulfillment of domestic chemical needs has not been able to be done by the industry in Indonesia as a whole so Indonesia still has to import from other countries (Harisasono & Sunitiyoso). Therefore, to the needs of the community and support the process of industrialization, it is necessary to develop the chemical industry in Indonesia to reduce Indonesia's dependence on other countries (Machmud, Nandiyanto, & Dirgantari, 2018). One of them is by setting up factories to meet domestic needs. The establishment of the Methyl ethyl ketone factory is one of the efforts to reduce imports or dependence on an item from abroad (Grace, Nandiyanto, &

Kurniawan, 2022). This is indicated by the fairly rapid development of the chemical industry. The chemical industry is one of the industries that have good prospects because it can support human life, and improve the economy in the fields of health, security, production of goods and services, and education (Steinhäuser & Große Ophoff, 2025). One of the chemical industries that is considered prospective is the methyl ethyl ketone (MEK) industry. Until now, MEK is a chemical that still imports from other countries (Wuryanti, Hudalil, & Nugrahaeni, 2021).

The current modern era of energy is one of the important basic needs in human life. Where almost all human activities are related to energy. As time goes by the need for energy is getting longer and longer increase. With the increase in the price of energy needed, an effort is needed to make efficiencies in the energy. One way to increase efficiency is by taking energy from different sources to use (Veriyawan, Biyanto, & Nugroho, 2014). Energy is one of the most important factors that affect the stability of any system, and thus, dealing with different energy systems is very important to achieve the greatest possible benefit from energy sources (Alrwashdeh, Ammari, Madanat, & Al-Falahat, 2022). The most widely used type of heat exchanger in the world industrial is the shell and tube type because of its simple construction (Nuraeni, 2022).

A heat exchanger (HE) is a device used to transfer thermal energy (enthalpy) between two or more liquids, between solid surfaces and liquids, or between solid particulates and liquids at different temperatures and in thermal contact. Common examples of heat exchangers are shell and tube exchangers, car radiators, condensers, evaporators, air preheaters, and cooling towers (Muhammad & Yulianto, 2018). Heat exchangers are often used in engineering applications such as power generation, petroleum refining, chemical engineering processes, air conditioning, the food industry, and others. There are various types of heat exchangers, one of which is a shell and tube heat exchanger which is commonly used as a gas or liquid medium in a large temperature and pressure range (Purnamasari, Kurniawan, & Nandiyanto, 2021).

One of the most widely used types of heat exchangers is the Shell and Tube Heat Exchanger (Putra, 2017). The heat exchanger has a variety of types. HE that is often used is HE with a shell-and-tube type with segmental baffles (Vukić, Tomić, Živković, & Ilić, 2014). Shell and Tube Heat Exchanger is a type of heat exchanger that is widely used in oil mining and processing. However, the performance improvement of the heat exchanger needs to be done carefully due to its complex flow inside the shell. The heat exchanger design has a reference to the area of the heat transfer area, the larger the heat transfer area, the greater the heat exchanger made or designed (Banuwa & Susanti, 2021).

Shell and tube heat exchangers generally have two flow directions, namely counter-current flow and concurrent flow (Wicaksono, Wijanarko, Simanullang, & Tahad, 2018). The above fluid flow occurs in shell and tube construction heat exchangers and is often called tubular exchanger equipment while in the direct contact group there is no grouping of flow types (Putra, 2017). In this study, a computational program for the design of shell and tube-type heat exchangers will be compiled. A heat Exchanger is a tool for the process of transferring energy (heat), using a fluid medium, both gas, hot, and cold, from one region to another due to the difference in temperature and temperature. Therefore, it is necessary to design and design a shell and tube-type heat exchanger and fabricate thermal and mechanical component components into a heat exchanger. In addition, for the design to be well-directed, several things must be done such as the calculation of the main components of the shell and tube and the process of designing heat exchangers (Taware, Patil, & Arakerimath, 2017).

This study aims to analyse and develop design a heat exchanger for the production of Methyl Ethyl Ketone (MEK) which will be compiled into a computational program for the design of shell and tube-type heat exchangers (Grace et al., 2022). The problem with this heat exchanger is that the temperature of 2-butanol is 30˚C from the storage tank. While the heat exchanger reactor requires a temperature of 99.6 degrees, so HE plays a role in increasing the temperature from 30˚C to 99.6˚C. To be more energy efficient, researchers used heat of the product, Methyl Ethyl Ketone. Which is where to exchange heat from the product to the reactants (Kolios, Gritsch, Glöckler, & Eigenberger, 2005).

2. Literature Review

2.1 Methyl Ethyl Ketone

Methyl ethyl ketone (MEK) is a ketone compound of the aliphatic group that has the molecular formula $CH_3COCH_2CH_3$ or C_4H_8O. MEK has synonyms : butanone, 2-butanon, butane-2-on, methyl propanone, MEETCO, methyl acetone (Shen, Deng, Yang, & Deng, 2024). MEK is a colorless organic liquid that has a sharp odor like acetone and has a low boiling point of 79.6˚C. Methyl ethyl ketone is produced by dehydrogenation of 2-butanol using copper, zinc, or bronze catalysts at a temperature of 400-500˚C with a conversion from 2-butanol 80-95%, where the purity of the MEK is more than 95% (Keuler, Lorenzen, & Miachon, 2001). Methyl ethyl ketone has many uses in everyday human life because it can dissolve many substances. This compound is widely used as a solvent in processes related to gum, resins, cellulose acetate coating, and nitrocellulose. In addition, this compound is also widely used in the manufacture of plastics, and household products such as varnishes, textiles, in the production of paraffin wax, and household products such as varnishes, paint removers, denaturing agents for alcohol denaturation, glue and as cleaning agents (Luttrell & Bellcock, 2015).

2.2 Heat Exchanger

A heat exchanger is a heat transfer device that exchanges heat between two or more process fluids. Heat exchangers have widespread industrial and domestic applications. Many types of heat exchangers have been developed for use in steam power plants, chemical processing plants, building heat and air conditioning systems, transportation power systems, and refrigeration units (Zohuri, 2017). In practice, the function of heat exchangers used in industry is preferred to exchange the energy of two fluids (can be the same substance) of different temperatures. Energy exchange can take place through a plane or heat displacement surface separating the two fluids or in direct contact (mixed fluids) (Granados-Ortiz & Ortega-Casanova, 2020). The energy exchanged will cause changes in fluid temperature (calorific sensible) or sometimes used to change phases (latent heat). The rate of energy transfer in a heat exchanger is influenced by many factors such as fluid flow speed, physical properties (viscosity, thermal conductivity, specific calorific capacity, etc.), temperature difference between the two fluids, and the surface properties of the heat displacement field that separates the two fluids (Chalimah et al., 2024). Based on the surface construction profile, heat exchangers that are widely used in the industry include shell and tube construction, tubes with extend surfaces/fins and tubes, and plate heat exchangers (SEPTIAN, Rey, & AZIZ, 2021).

3. Method

3.1 Zero-lift drag coefficient C_{D0}

The process of making MEK can be done with several processes, including (Chadwick, 1988):

a. Liquid phase n-butane oxidation process.
b. The direct oxidation process of n-butene (Hoechst Wacker Process).
c. The process of gas-phase catalytic dehydrogenation of 2-butanol.

3.2 Calculation of Mechanical

The study of mechanical aspects in this heat exchanger is very broad including shell, stationary head, rear, head, baffle, tube layout, tube pitch, tube, pass of flow, nozzle, drain, and venting (Putra, 2017). The best heat exchanger is the shell and tube. The shell-and-tube heat exchangers are still the most common type in use (Prasad & Anand, 2020). The advantage of shell and tube heat exchangers is that they are most widely used in industrial processes because they can provide a fairly small ratio of the heat transfer area to the volume and mass of the fluid. in addition, it can also accommodate thermal expansion, is easy to clean, and the construction is also quite cheap among others (Costa & Queiroz, 2008).

3.3 Use of Standards in Studies

The standards include design problems, manufacture, selection of construction materials, shell and tube testing, seats and supports, floating heads, nozzle channels, tube plates, and others. Standards regarding heat exchangers use TEMA (Tubular Exchanger Manufactures Association) standards (Krisdiyanto, Fikri, Adi, & Nugroho, 2021). The standard that is widely used in the issue of heat exchangers is TEMA (Tubular Exchanger Manufacturer Association), an association of heat exchanger makers in America (Yang, Fan, Liu, & Jacobi, 2014). TEMA discusses more types of heat exchangers, methods of calculating their performance and strength (design process), the terms of parts of heat exchangers (parts), and the basis of selection in the application of heat exchangers in everyday life, especially in industry (Gawande, Wankhede, Yerrawar, Sonawane, & Ubarhande, 2012a).

The procedure aims to protect users from the danger of damage, failure of the operation, and where and for what reason there is a "complaint" to the problem that occurs. This is understandable because in general heat exchangers work at high temperatures and pressures Gawande, Wankhede, Yerrawar, Sonawane, and Ubarhande (2012b), but also not only refer to TEMA but also follow generally accepted standards. Usually used standards from America such as ASME, API, ASTM, and others. Based on the TEMA, the types of heat exchangers are broadly divided into two large groups based on their use in industry, namely:

- Class R: for use with heavy working conditions, for example for the oil industry and the heavy chemical industry.
- Class C: which is made for general use, whose production basis pays more attention to economic aspects with a small heat transfer size and capacity. This class is used for general use in the industry (Morris, 2011).
- With a standard operating effectiveness of 60%-80% (Ham, Kim, You, & Cho, 2023).

The properties of the fluid are density, viscosity, temperature, pressure, specific volume, specific weight, specific gravity, surface tension, vapor pressure, capillarity, and cavitation. Even the factors that must be considered to determine the type of fluid in the tube (tube side) or outside the tube (shell side) are:

- Ability to clean up (cleanability)
  When compared to how to clean the tube and shell, then side cleaning. The shell (outside the tube) is much more difficult. For this reason, clean fluid usually flows next to the shell (outside the tube), and dirty fluids the tube.
- Corrosion
  Corrosion or hygiene problems are greatly affected by the use of alloy. Metal alloys are expensive, due to which dirty fluid is drained through the tube to save costs that occur due to shell damage.
- Working pressure
  A high-pressure shell, a large with e diameter, will require a thick wall which will be expensive. To overcome this, when the high-pressure fluid is better flowed through the tube.
- Temperature
  High-temperature fluids better flow through the tube. High-temperature fluids will also reduce allowable stress on the equipment material, this requires a thick shell wall.
- Amount of fluid flow
  Good planning will be obtained a small amount of fluid flow carried out on the side next to the shell. It affects the number of passes but the consequence is losses and pressure drops.
- Viscosity
- The limit of the critical number of Reynolds numbers for turbulent flow on the shell side is 200 therefore the laminar flow in the tube can be turbulent when it flows through the shell. If the laminar fixed flow flows through the shell then the flow should flow through the tube.

3.4 Mathematical models for designing a heat exchanger

Table 1 shows the assumptions used for the characteristics of fluids operating in a Heat Exchanger. This assumption will use a shell and tube-type Heat Exchanger design. The cold fluid used is C_4H_9OH as Heavy Organics (HO), while the hot fluid used is C_4H_8O as Light Organics (LO) with An Overall Up of 10-40. The thermal analysis is in the form of manual calculations using basic Microsoft Office applications based. Table 2 shows the calculated heat exchange parameters.

Table 1. The assumption for Fluid Properties working on HE

	Shell Side	**Tube Side**

	LO	HO
Inlet Temperate T_{in} (˚C)	120	99.60
Outlet Temperature T_{out} (˚C)	99.60	30
Fluid Flow Area (ft^2)	0.52	0.76
Operating Pressure (atm)	1	1
Density (kg/m^3)	1012.57	765.22

Table 2. Heat exchanger parameter calculation

Section	**Parameter**	**Equation**	**Eq**
Basic parameters	The energy transferred (Q)	$Q_{in} = Q_{out}$ $$m_c \times Cp_c \times \Delta T_c = m_h \times Cp_h \times \Delta T_h$$ where, Q: the energy transferred (Wt) M: the mass flow rate of the fluid (Kg/s) Cp: the specific heat ΔT: the fluid temperature difference (°C).	(1)
	Logarithmic mean temperature differenced (LMTD)	$$LMTD = \frac{(T_{hi} - Tc_o) - (T_{ho} - Tc_i)}{ln\frac{(T_{hi} - Tc_o)}{(T_{ho} - Tc_i)}}$$ where, T_{hi}: temperature of the hot fluid inlet (°C) T_{ho}: temperature of the hot fluid outlet (°C) Tc_i: temperature of the cold fluid inlet (°C) Tc_o: temperature of the cold fluid outlet (°C)	(2)
	Correction factor	$$R = \frac{T_{hi} - T_{ho}}{T_{co} - T_{ci}}$$ $$S = \frac{T_{co} - T_{ci}}{T_{hi} - T_{ci}}$$ $$F_t = \frac{\sqrt{R^2 + 1}\ \ln[\frac{1-P}{1-PR}]}{(R-1)\ln(\frac{2-P(R+1-\sqrt{R^2+1}}{2-P(R+1+\sqrt{R^2+1}})}$$ $$\Delta T_{lm} = \frac{\Delta T_2 - \Delta T_1}{\ln(\frac{\Delta T_2}{\Delta T_1})}$$ $$\Delta T_m = F_t\ \Delta T_{lm}$$	(3) (4) (5) (6)
	Heat Transfer Field Area (A)	$$A = \frac{Q}{U \times LTMD}$$ where, Q: the energy transferred (W) U: the overall heat transfer coefficient *LMTD*: the logarithmic mean temperature difference.	(7)
	Number of Tubes (N)	$$N = \frac{A}{\pi \times D_o \times l}$$ where, N: the number of tubes A: the area of the heat transfer area (m^2), π: 3.14 D_o: tube diameter (m) l: tube length (m).	(8)

Tube	Surface Area of Total Heat Transfer in Tube (a_t)	$$a_t = N_t \frac{a'_t}{n}$$ where, a_t: the total heat transfer surface area in the tube (m^2) N_t: the number of tubes a'_t: the flow area in the tube (m^2) n: the number of passes.	(9)
	Mass Flow Rate of Water in Tube (Gt)	$$Gt = \frac{m_h}{a_t}$$ where, Gt: the mass flow of water in the tube (kg/m^2s) m_h: the mass flow rate of the hot fluid (Kg/s) a_t: the flow area tube (m^2)	(10)
	Reynold number (Re,t)	$$Re_t = \frac{di_t \times Gt}{\mu}$$ where, Re_t: the Reynolds number in tube di_t: the inner tube diameter (m), Gt: the mass flow of water in the tube (m^2) μ: the dynamic viscosity (Kg/ms).	(11)
	Prandtl Number (Pr,t)	$$Pr = (\frac{C_p \times \mu}{K})^{\frac{1}{2}}$$ where, Pr: Prandtl number Cp: the specific heat of the fluid in the tube μ: the dynamic viscosity of the fluid in the tube (Kg/ms) K: the thermal conductivity of the tube material (W/m°C).	(12)
	Nusselt number (Nu,t)	$$Nu = 0.023 \times {Re_t}^{0.6} \times Pr^{0.33}$$	(13)
	Inside coefficient (h_i)	$$h_i = \frac{Nu \times K}{d_i, t}$$ where, h_i: the convection heat transfer coefficient in the tube ($W/m^2°C$) K: the thermal conductivity of the material (W/m°C) d_i, t: the inner tube diameter (m).	(14)
Shell	Shell flow area (A_s)	$$A_s = \frac{d_s \times C \times B}{P_t}$$ $$D_b = d_o(\frac{N_t}{k_1})^{\frac{1}{n_1}}$$ where, d_s: shell diameter (m) C: clearance (P_t-d_o) B: a shell bundle P_t: tube pitch (1.25× d_o) (m).	(15) (16)
	Mass Flow Rate of Water in Shell (Gs)	$$Gs = \frac{m_c}{A_s}$$ m_c: the mass flow rate of the cold fluid (Kg/s) A_s = the shell flow area (m^2).	(17)

	Equivalent diameter (d_e)	$$d_e = \frac{4(\frac{Pt}{2} \times 0.87\ Pt - \frac{1}{2} ð \frac{d_{o,t}}{4})}{\frac{1}{2} ð d_{o,t}}$$ where, P_t: tube pitch (1.25× d_o) (m) π: 3.14 $d_{o,t}$: tube outside diameter (m).	(18)
	Reynold number (Re,s)	$$Re_s = \frac{di_t \times Gt}{ì}$$ Re_s: ReyReynold'smber di_s: inner tube diameter (m) Gs: the mass flow of water in the shell (Kg/m^{2}s) ì: the dynamic viscosity (Kg/ms).	(19)
	Prandtl Number (Pr,s)	$$Pr = (\frac{C_p \times ì}{K})^{\frac{1}{2}}$$ Pr_s: Prandtl number Cp: specific heat capacity (kJ/kg°C) ì: dynamic fluid viscosity (Kg/ms) K: thermal conductivity (W/m°C).	(20)
	Nusselt number (Nu,s)	$$Nu_s = 0.023 \times {Re_s}^{0.6} \times Pr^{0.33}$$ Re_s: Reynold number Pr: Prandtl number	(21)
	Convection Heat Transfer Coefficient (ho)	$$ho = \frac{Nu \times K}{d_e}$$ ho: convection heat transfer coefficient (W/m^2°C) K: thermal conductivity (W/m°C) d_e: equivalent diameter (m).	(22)
Shell and Tube	Actual Overall Heat Transfer Coefficient (U_{act})	$$U_{act} = \frac{1}{\frac{1}{h_i} + \frac{\Delta r}{k} + \frac{1}{h_o}}$$ where, hi: inside heat transfer coefficient (W/m^2°C) ho: outside heat transfer coefficient (W/m^2°C), Δr: wall thickness (m) K: thermal conductivity(W/m°C)	(23)
Heat rate	Hot Fluid Rate (C_h)	$$C_h = m_h.Cp_h$$ where, C_h: hot fluid rate (W/°C) Cp_h: specific heat capacity (J/Kg°C) m_h: mass flow rate of hot fluid (Kg/s).	(24)
	Cold Fluid Rate (C_C)	$$C_C = m_c.Cp_c$$ C_c: cold fluid rate (W/°C), Cp_h: specific heat capacity (J/Kg°C), m_c: mass flow rate of cold fluid (Kg/s). $$Q_{max} = C_{min}(T_{h,i} - T_{c,i})$$ Q_{max}: maximum heat transfer (W) C_{min}: minimum heat capacity rate (W/°C) $T_{h,i}$: temperature of the hot fluid inlet (°C) $T_{c,i}$: temperature of the cold fluid inlet (°C).	(25) (26)

Effectiveness	Heat Exchanger Effectiveness (å)	$$å = \frac{Qact}{Qmax} \times 100\%$$ where, Q_{act}: actual energy transferred (W) Q_{max}: maximum heat transfer (W)	(27)
	Number of Transfer Unit (NTU)	$$NTU = \frac{U \times A}{C_{min}}$$ where, U: overall heat transfer coefficient (W/m^2°C A: heat transfer area (m^2) C_{min}: minimum heat capacity rate (W/°C).	(28)
	Fouling factor (Rf)	$$Rf = \frac{U_a - U_{act}}{U_a \times U_{act}}$$ where Rf: fouling factor U_a overall heat transfer coefficient (W/m^2°C) U_{act}: actual overall heat transfer coefficient (W/m^2°C)	(29)

4. Result and Discussion

The results of the study on the design of a Heat Exchanger using a Vaporizer with the function of heating and evaporating (2-butanol) using product heat (MEK) from 30°C to 100°C, with the type Shell and Tube Heat Exchanger, counter flow. The heat balance is used to determine the heat transfer efficiency in the pre-design of the plant. Energy Balance Equation:
(energy in)-(out going energy)+(energy generation)-(energy consumption)=(energy accumulation) (Kristiana & Manurung, 2021)

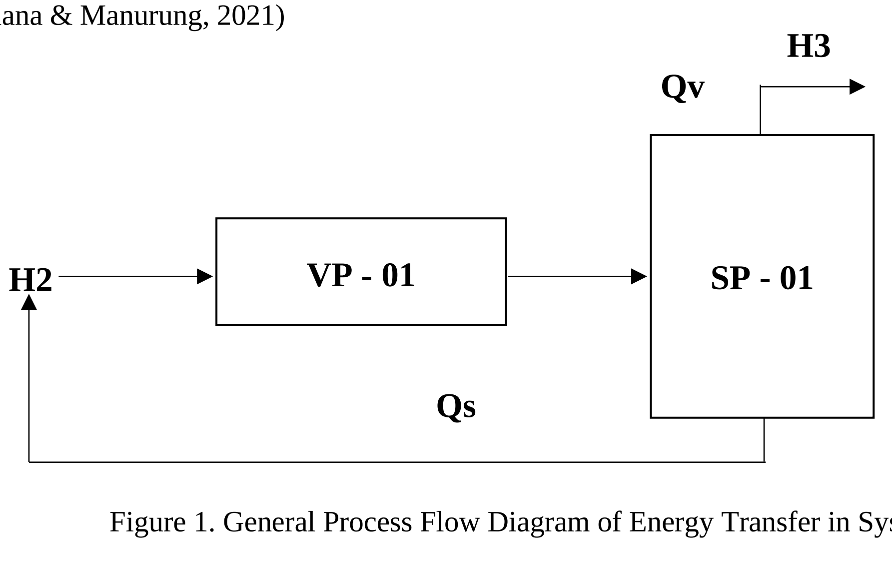

Figure 1. General Process Flow Diagram of Energy Transfer in System

The heat load value (Q) on the HE (Vaporizer) on the shell and tube type is 1181584.74150033 kcal/hr. Table 3 explain the result of the calculation of the calculation of enthalpy in and out and heat loads from C_4H_9OH.

Table 3. Results of enthalpy and heat load calculations

Component	In	Out
	kcal/hr	kcal/hr
In Enthalpi	414801.4160	0.0000
Out Enthalpi	0.0000	1596386.1575

Heat Load (Q)	1181584.7415	0.0000
Total	**1596386.1575**	**1596386.1575**

In this Heat Exchanger (Vaporizer) design, preheating of cold fluids has an initial temperature of 30°C and a final temperature of 99.6°C, while the hot fluid has an initial temperature of 120°C and a final temperature of 99.6°C. Table 4 explains the comparison of hot fluids and cold fluids.

Table 4. Comparison of hot fluids and cold fluids

Hot Fluid			**Cold Fluid**		**Difference**
°C	**°F**		**°C**	**°F**	
120	248	Higher Temp	99.60	211.28	36.71
99.60	211.28	Lower Temp	30	86	125.28
20.39	**36.72**	**Difference**		**125.28**	**88.56**

Delt Weighted's data calculation results are 66,347°F and the heat transfer area value is 1185,410 ft^2, while the heat exchanger (Vaporizer) trial layout is 450,141 with a number close to 302 tubes. The speed of mass velocity greatly affects the heat transfer coefficient. With the increase in mass velocity then the pressure drop will rise faster than the heat transfer coefficient. Pressure to know the extent to which the fluid can maintain the pressure it has during the fluid flow. In this study, the mass velocity (Gs) for the shell side cold fluid was obtained at 7257,942 lb/hr.ft^2 and the inner diameter of the shell was 1.2381 using the Reynold number of 361,477 (turbulent). The heat transfer factor (jh) value is 38. Meanwhile, in the tube side hot fluid, a mass velocity (Gt) value of 29134.0 lb /hr.ft^2 was obtained. then for condensing steam of 1500 Btu/hour.ft^2.F on clean overall coefficients Up of 162.8172 ft^2 while Uv at 162.8172 ft^2. And clean surface required Ap of 8.0169 ft^2 and Av of 426.0416 ft^2. Then the total clean surface result is 434.0584 ft^2. The effective value of 14%. Thus, it can be described in table 5 the specifications of the Heat exchanger (VP-01).

Table 5. Heat exchanger Specifications (VP-01)

	Data Result
Function	Evaporate the feed before entering the reactor
Type	*Shell and Tube Condenser*
Sum	1 pc
Material	*Plate Steel SA.283 Grade C*
Shell Size	
IDs	27.00 in
Baffle Spacing	20.25 in
Passes	4 pc
Pressure Drop	4.9959-06 psia
Tube Size	
Odt	1.25 in
Idt	1.12 in
BWG	16
Structure	*Triangular Pitch*
Number of Tube	302 pc
Passes	4 pc
Flow Area	0.0068 ft^2
Tube length	12.00 ft

Surface per in fit	0.3271 ft^2
Pressure Drop	2.6650E-04 psia
Uc	162.8172 Btu/hr.ft^2. ˚F
Ud	59.62 Btu/hr.ft^2.˚F
Rd	0.010632 hr.ft^2. ˚F/Btu

5. Conclusions and Suggestions

5.1 Conclusions

HE reactor requires a temperature of 99.6°C, HE plays a role in increasing the temperature from 30°C to 99.6°C for the production of Methyl Ethyl Ketone. So the specifications obtained in the HE design in increasing the temperature to 99.6 °C for the production of MEK, at the shell size for IDs is 27.00 in, baffle spacing is 20.25 in, passes is 4 pieces, the pressure drop is 4.9959E-06 psia and the heating flow rate is 6824.7534 kg/hr, while the tube size for Odt is 1.25 in, Idt is 1.12 in, passes are 4 pieces, the pressure drop is 2.6550E-04 psia and the cooling flow rate is 11000 kg/hr. The effectiveness value of this HE design is 14%, while that recommended by the TEMA standard is 60%-80%. However, the results show that the designed HE does not meet the requirements of the TEMA standard. This research can be used as a reference for the next Heat Exchanger design research.

5.2 Suggestions

This research is limited to the analysis of research developments related to the design of shell-tube heat exchangers for producing Methyl Ethyl Ketone so deeper exploration is needed. For subsequent research, assumptions can be given that will increase the effectiveness of the heat exchanger.

References

Alrwashdeh, S. S., Ammari, H., Madanat, M. A., & Al-Falahat, A. a. M. (2022). The effect of heat exchanger design on heat transfer rate and temperature distribution. *Emerging Science Journal, 6*(1), 128-137. doi:http://dx.doi.org/10.28991/ESJ-2022-06-01-010

Banuwa, A., & Susanti, A. N. (2021). Analisis kebutuhan pelatihan ASN Penyuluh Keluarga Berencana (PKB) di provinsi Lampung. *Jurnal Ilmiah Widyaiswara, 1*(1), 35-43. doi: https://doi.org/10.35912/jiw.v1i1.240

Chadwick, S. S. (1988). Ullmann's encyclopedia of industrial chemistry. *Reference Services Review*.

Chalimah, S., Maulana, I., Setyobudi, R., Sandrina, A., Anggoro, R., Buana, E., . . . Alhalim, M. A. (2024). Analysis of Efficiency and Heat Transfer Coefficient in the Performance Evaluation of Shell and Tube Heat Exchanger. *BIOMEJ, 4*, 1-9. doi:https://doi.org/10.33005/biomej.v4i2.129

Costa, A. L., & Queiroz, E. M. (2008). Design optimization of shell-and-tube heat exchangers. *Applied thermal engineering, 28*(14-15), 1798-1805. doi:https://doi.org/10.1016/j.applthermaleng.2007.11.009

Gawande, S. H., Wankhede, S. D., Yerrawar, R. N., Sonawane, V. J., & Ubarhande, U. B. (2012a). Design and development of shell & tube heat exchanger for beverage. *Modern Mechanical Engineering, 2*(4), 121-125. doi:http://dx.doi.org/10.4236/mme.2012.24015

Gawande, S. H., Wankhede, S. D., Yerrawar, R. N., Sonawane, V. J., & Ubarhande, U. B. (2012b). Design and development of shell & tube heat exchanger for beverage.

Grace, V., Nandiyanto, A., & Kurniawan, T. (2022). Design Heat Exchanger Type Shell-Tube Mathematically With 2-Butanol Hot Fluid and Cold Fluid Steam for the Production of MEK. *Jurnal Ilmiah Widyaiswara, 2*, 1-11. doi:https://doi.org/10.35912/jiw.v2i1.1777

Granados-Ortiz, F.-J., & Ortega-Casanova, J. (2020). Mechanical characterisation and analysis of a passive micro heat exchanger. *Micromachines, 11*(7), 668. doi:https://doi.org/10.3390/mi11070668

Ham, J., Kim, E., You, N., & Cho, H. (2023). Comparison of thermal performance in solution heat exchangers with different chevron angles in absorption system. *Case Studies in Thermal Engineering, 51*, 103598. doi:https://doi.org/10.1016/j.csite.2023.103598

Harisasono, T. Y., & Sunitiyoso, Y. The Road towards a Resilient Base Petrochemical Industry in Indonesia: A Transformative Scenario Planning Approach. doi:https://doi.org/10.47191/ijcsrr/V5-i12-22

Keuler, J. N., Lorenzen, L., & Miachon, S. (2001). The dehydrogenation of 2-butanol over copper-based catalysts: Optimising catalyst composition and determining kinetic parameters. *Applied Catalysis A: General, 218,* 171-180. doi:https://doi.org/10.1016/S0926-860X(01)00639-1

Kolios, G., Gritsch, A., Glöckler, B., & Eigenberger, G. (2005). Enhancing Productivity and Thermal Efficiency of High-Temperature Endothermic Processes in Heat-Integrated Fixed-Bed Reactors. *Integrated Chemical Processes: Synthesis, Operation, Analysis, and Control*, 1-43. doi:https://doi.org/10.1002/3527605738

Krisdiyanto, K., Fikri, M., Adi, R., & Nugroho, A. (2021). Stress Analysis on Tubesheet Referring to TEMA Standard. *JMPM (Jurnal Material dan Proses Manufaktur), 5*, 52-57. doi:https://doi.org/10.18196/jmpm.v5i1.12340

Kristiana, L., & Manurung, A. (2021). An Energy Balance Model for a Small Educational Thermal Device. *ELKOMIKA: Jurnal Teknik Energi Elektrik, Teknik Telekomunikasi, & Teknik Elektronika, 9*(2), 333-343.

Luttrell, W. E., & Bellcock, L. R. (2015). Methyl ethyl ketone. *Journal of Chemical Health and Safety, 22*(4), 33-36. doi:https://doi.org/10.1016/j.jchas.2015.06.007

Machmud, A., Nandiyanto, A., & Dirgantari, P. (2018). Technical efficiency chemical industry in indonesia: Stochastic frontier analysis (SFA) approach. *Pertanika Journal of Science and Technology, 26*, 1453-1464.

Morris, M. (2011). Mechanical Design of Heat Exchangers *Thermopedia*: Begel House Inc.

Muhammad, I., & Yulianto, S. (2018). REDESIGN PLATE HEAT EXCHANGER PADA CLOSED COOLING WATER SYSTEM PLTGU KAPASITAS 740 MW. *Prosiding Semnastek*.

Nuraeni, A. H. (2022). Simplified Analysis of Environmental Permits Integrated through OSS (Online Single Submission). *Jurnal Ilmiah Widyaiswara, 1*(1), 45-54. doi: https://doi.org/10.35912/jiw.v1i1.678

Prasad, A. K., & Anand, K. (2020). Design and analysis of shell and tube type heat exchanger. *Int. J. Eng. Res. Technol.*, 524-539.

Purnamasari, H. N., Kurniawan, T., & Nandiyanto, A. B. D. (2021). DESIGN OF SHELL AND TUBE TYPE HEAT EXCHANGER FOR NANOFIBRIL CELLULOSE PRODUCTION PROCESS. *International Journal of Research and Applied Technology (INJURATECH), 1*(2), 318-329.

Putra, I. (2017). Studi perhitungan heat exchanger type shell and tube dehumidifier biogas limbah sawit untuk pembangkit listrik tenaga biogas. *Jurnal Polimesin, 15*(2), 42-49.

SEPTIAN, B., Rey, P. D., & AZIZ, A. (2021). Desain dan rancang bangun alat penukar kalor (heat exchanger) jenis shell dan tube. *Baut dan Manufaktur, 3*(01), 52-60.

Shen, M.-X., Deng, C.-Q., Yang, J., & Deng, J. (2024). Preparation of methyl ethyl ketone from biomass-derived levulinic acid using a metal-free photocatalytic system and life cycle assessment study. *Green Chemistry, 26*(19), 10290-10298. doi:https://doi.org/10.1039/D4GC02798A

Steinhäuser, K. G., & Große Ophoff, M. (2025). The Need for Change: A Roadmap for the Sustainable Transformation of the Chemical Industry. *Sustainable Chemistry, 6*(2), 16. doi:https://doi.org/10.3390/suschem6020016

Sylvia, E., & Sunitiyoso, Y. (2024). A system dynamic model for Indonesian petrochemical industry emission reduction. *International Journal of Energy Sector Management, 18*(1), 1-25. doi:https://doi.org/10.1108/IJESM-07-2022-0006

Taware, M., Patil, D., & Arakerimath, R. (2017). Design, Fabrication and Testing of Shell and Tube Heat Exchanger for Heat Recovery from Hydraulic Oil. *International Journal of Engineering Research and, V6*. doi:https://doi.org/10.17577/IJERTV6IS070289

Veriyawan, R., Biyanto, T., & Nugroho, G. (2014). Optimasi Desain Heat Exchanger Shell-And-Tube Menggunakan Metode Particle Swarm Optimization. *Jurnal Institut Teknologi Sepuluh Nopember (ITS), Surabaya*.

Vukić, M., Tomić, M., Živković, P., & Ilić, G. (2014). Effect of segmental baffles on the shell-and-tube heat exchanger effectiveness. *Hemijska industrija, 68*, 171-177. doi:https://doi.org/10.2298/HEMIND130127041V

Wicaksono, C., Wijanarko, E., Simanullang, O. H., & Tahad, A. (2018). Perancangan Eco Heat Exchanger Type 1-2 Shell And Tube dan Pengaruh Jumlah Baffle Terhadap Transfer Panas. *Jurnal Chemurgy, 1*(1), 27-30.

Wuryanti, S., Hudalil, A., & Nugrahaeni, I. (2021). Gambaran kompetensi Widyaiswara dalam mengelola pembelajaran di Pusat Pendidikan dan Pelatihan Kesejahteraan Sosial Kementerian Sosial. *Jurnal Ilmiah Widyaiswara, 1*(1), 27-34. doi: https://doi.org/10.35912/jiw.v1i1.233

Yang, J., Fan, A., Liu, W., & Jacobi, A. M. (2014). Optimization of shell-and-tube heat exchangers conforming to TEMA standards with designs motivated by constructal theory. *Energy conversion and management, 78*, 468-476. doi:https://doi.org/10.1016/j.enconman.2013.11.008

Zohuri, B. (2017). *Compact heat exchangers*: Springer.