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Development of Cooling Condensor Shell and Tube with Cooling Tower on the Distillation Equipment for the Making of RHUM Beverages

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Abstract

Distillation is a method of separating chemicals based on differences in the speed or ease of evaporation (volatility) of the material in distillation, the mixture of substances is boiled so that it evaporates, and this vapor is then cooled back into the form of a liquid. The condenser is a heat exchanger that functions as a medium for the condensation process. Cooling towers are able to lower the water temperature more than equipment that only uses air to dissipate heat. This study aims to observe the temperature of the shell and tube condenser with a cooling tower system on the alcohol content produced in the distillation apparatus. Experimental research method is testing the cooling tower cooling system on the shell and tube condenser for the distillation of rum drinks. The results of the development of a condenser cooling system distillation device with a cooling tower have an average temperature of Tu in 81.3°C and Tu out 41.0ºC in the condenser, the average water flow rate is 46 liters per minute. Meanwhile, the cooling water in the cooling tower has an average temperature of Tw in water 46.6°C and Tw out water 47.5°C. The results of distillation of molasses at a reactor temperature of 75°C, molasses capacity of 10 liters, alcohol content of rum drink 55%, 45% and 25% with a volume of alcohol produced 1.62 liters. The use of a cooling tower cooling system can stabilize the condenser temperature.

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1 Introduction

The process of making rum drinks using the distillation method from molasses through a heating process and condensation of molasses steam which is heated so that it becomes rum with an alcohol content. Molasses distillation into rum still uses a condenser cooling system of water that just flows without any flow regulation. The working principle of the condenser is the conversion process is carried out by flowing steam into the room containing the pipe arrangement and the steam will meet the outer surface of the pipe while the water that functions as a cooler will flow in the pipe (tube side), there will be contact between the two where the steam which has a hot temperature will be in contact with cooling water which serves to absorb heat from the steam, so that the temperature of the steam will drop and condense. The condenser is a heat exchanger that functions as a medium for the condensation process (Harby et al., 2016; Lee et al., 2006).

Cooling water in the condenser has an important role in the process of condensing steam into condensate water. circulating cooling water from a cooling tower to release heat to the atmosphere, or once-through water from a reservoir tube (Rochani et al., 2016). Shell and tube type heat exchangers are the most widely used heat exchangers in various industries and the simplest compared to other heat exchangers, this is because:

a. It only consists of a tube and a shell, where the tube is located concentrically inside the shell.
b. Ability to work under high pressure and temperature.
c. Its ability to be used on one large volume stream.
d. Its ability to work with working fluids that have a large volume flow difference.
e. Available in various materials or materials.
f. Sturdy and safe construction.
g. Mechanically it can operate properly and reliably. (Dewantara, 2019)

Rum is a type of alcoholic beverage made from fermented sugar cane juice, also known as molasses. The alcohol content in rum is as much as 40-60 percent. Rum is a traditional drink from the Caribbean that is thought to have existed for thousands of years. Currently, rum has been widely produced and consumed by people around the world. Not only drunk directly, rum can also be used as a mixture in various types of drinks and foods. For example, in cocktails, ice cream, cakes, to drinks or other sweet foods. The distillation method is usually taken if you want to increase the alcohol content in the fermented product, to separate ethanol from the ethanol mixture, the level is increased to a minimum of 29% and a maximum of 50%, distillation is the easiest and most efficient way to operate a solution consisting of each component. different boiling temperatures (Rochani et al., 2016). Through research on the development of a distillation device for a shell and tube condenser cooling system using a cooling tower on a rum beverage distillation apparatus, it is hoped that it can be one of the innovations in developing appropriate technology to support home industries, especially alcohol distillation (Milosavljevic & Heikkilä, 2001; Tsao et al., 2019).

2 Research Methods

This research includes experimental research through testing the shell and tube condenser cooling system using a cooling tower on a distillation apparatus with a reactor tube heater using an LPG stove. Before carrying out the test (distillation process), molasses is treated with the sample material by fermentation for 3 weeks, so that the molasses/raw material for the sample to be tested includes good quality molasses. Furthermore, tests were carried out on the shell and tube condenser temperature and the water temperature in the cooling tower to obtain the alcohol content (Olujić et al., 2009; Moutsatsou et al., 2003).

Distillation Equipment Test

1. Setting the heating temperature on the reactor tube with a gas solenoid valve to regulate the flame of the stove so that it gets a temperature of 75°C in the reactor tube so that the molasses heating temperature can be controlled
2. Data collection of shell and tube condensers with cooling tower cooling is as follows:
   a. Operating time (t) in minutes

b. Condenser inlet steam temperature (Tu.in) in ºC
c. Condenser outlet cooling water temperature (Tw out) in ºC
d. Temperature of condenser out rum liquid (Tu out) in ºC
e. Temperature of cooling water entering condenser (Tw in) in ºC
f. Condenser cooling water flow rate in L/min
g. Take a sample of alcohol/rum to be tested with an alcoholmeter in (%)
h. Volume of rum drink (V) in ml

3. Measurement of the percentage of alcohol content. To get the alcohol content using an alcoholmeter measuring instrument.

Alcohol Level

The instrument used to measure alcohol content is an alcoholmeter. The measurement of alcohol content is carried out after each distillation and the measurement is stopped when the measured alcohol content is 90% (alcohol content according to ASTM D5501 for liquid fuel) and the ethanol content is 94%. The measurement step using an alcoholmeter is to insert 100 ml of distillate into a measuring cup, then the alcoholmeter is dipped into the distillate. The immersed boundary on the surface of the distillate indicates the alcohol content of the sample being tested (Waisnawa & Sudana, 2021).

Shell and Tube Condenser

This type of heat exchanger is one type of heat exchanger which according to its construction is characterized by a set of tubes mounted on a cylindrical shell in which two types of fluids exchanging heat flow separately, each through the tube side and the shell side (Mustiadi et al., 2020). As Figure 1.

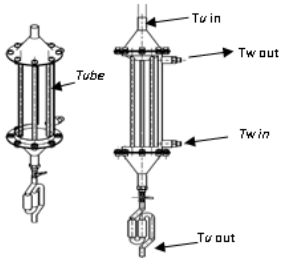

Figure 1. Shell And Tube Condenser

Cooling Tower

Cooling tower as a heat exchanger whose working fluid is water and air which functions to cool water by direct contact with air which causes a small part of the water to evaporate. In most cooling towers the air cooling system uses a centrifugal pump to move water vertically up across the tower. All working cooling towers will release heat through the condenser, the hot steam will release the heat in the cooling tower so that the water becomes hot. Cooling towers in general function to absorb heat from the water and provide a relatively cool amount of water to be reused in a cooling installation or in other words the cooling tower functions to lower the temperature of the water flow by extracting heat from the water and emitting it into the atmosphere. Cooling towers can solve the temperature drop problem, because they are able to lower the water temperature more than equipment that only uses air to dissipate heat. Cooling tower construction (Yohana et al., 2019). Like Figure 2.

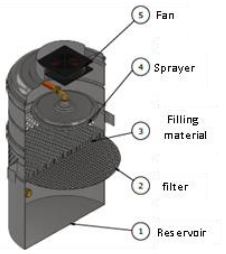

Figure 2. Cooling Tower Construction

The working principle of the distillation condenser shell and tube cooling tower cooling system. The distillation apparatus for rum drinks uses a Shell and tube condenser designed with a controlled heating and cooling system, the heating system uses a gas stove with a solenoid valve controlled by thermocontrol in order to stabilize the temperature in the reactor tube as a place for heating molasses. The reactor tube is cylindrical in shape which is equipped with a conical cap so that it can close the gap for the steam to escape from the reactor tube so that the process of flowing steam into the condenser tube is more optimal. When steam flows from the reactor tube to the shell and tube condenser tube, a condensation process will occur. In the condenser cooling system using a cooling tower aims to maintain the temperature of the cooling system on the shell and tube condenser to remain stable. In this process, the vapor will change phase to liquid where the liquid is the result of distillation, namely rum that drips out of the condenser tube channel. The distillation apparatus uses a shell and tube condenser with a cooling tower (Mohamad & Harwan, 2020). Like Figure 3.

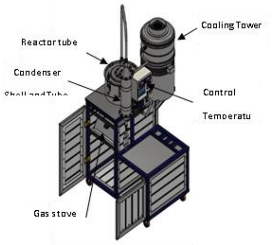

Figure 3. Cooling Tower Distillation System

3 Results and Discussions

The molasses distillation process into rum drinks is carried out using a shell and tube condenser cooling tower system equipped with cooling water temperature control, and heating the reactor tube using a barner stove fueled by LPG.

Discussion

Analysis of the steam temperature in the shell and tube condenser on the cooling tower water flow rate. In Figure 4.

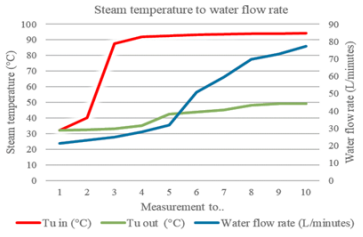

Figure 4. Graph of steam temperature against the flow of water.

The movement of steam temperature entering through the pipe to the Tu in condenser continues to increase rapidly, while the Tu out temperature in the condenser gradually increases slowly, this is influenced by the flow of cooling water in the cooling tower with temperatures of Tw in and Tw out. there is no increase in water temperature in the cooling tower reservoir. While the temperature of the cooling tower water on the flow of water can be seen in Figure 5 (Giler & Cedeño, 2020; Vallejo et al., 2019).

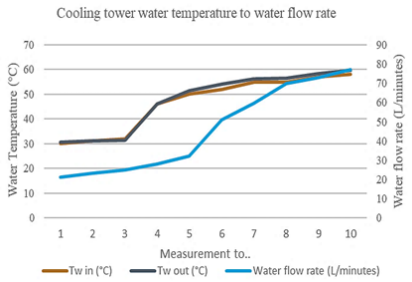

Figure 5. Graph of Cooling tower water temperature against water flow

Based on the graph of the Tw in and Tw out temperature measurements, the water flowing from the cooling tower to the condenser tube has a very small ratio of around 1.2 degrees. And the temperature rise of the cooling tower water is very low, so the cooling tower work can be said to be effective in cooling the condenser tube. The process of cooling the shell and tube condenser tubes in the distillation apparatus using a cooling tower system can be stated as stable, namely the average temperature Tu in 81.3°C and Tu out 41.0ºC in the condenser and the average water flow rate of 46 liters per minute, while cooling water in the cooling tower has an average temperature of Tw in 46.6°C and Tw out 47.5°C. When compared to a condenser using a reservoir cooling system, the temperature of the steam inlet and the temperature of the outlet is very small, with an average of Tu in 80 °C and Tu out 57ºC (Arimi et al., 2014; Najafpour & Shan, 2003).

Analysis of testing the molasses distillation process into rum drinks

Based on the results of testing the distillation apparatus using a cooling tower cooling system on the alcohol content of rum drinks. in table 1.

Table 1
Measurement of Alcohol Concentration in Rum Drinks

No Observation	Molasses temperature in the reactor (ºC)	Alcohol Volume (ml)	Distillate/ alcohol (%)
1	54	0	0
2	57	0	0
3	61	0	0
4	64	0	0
5	70	250	55%
6	73	350	45%
7	74	275	45%
8	75	375	25%
9	75	193	15%
10	75	175	15%
Total		1618	

Based on the measurement results in the distillation process of making rum drinks made from 10 liters of molasses. In table 1, it is found that the molasses temperature in the reactor tube continues to increase to the temperature control limit of 75ºC, while the cooling tower water flow to the condenser flows continuously to cool the condenser

so that the temperature remains stable. In the 5th observation, there were already drops of alcohol/rum coming out of the condenser pipe, the alcohol content was 55% with a volume of 250 ml of alcohol, the 6th observation had an alcohol content of 45% with a volume of 350 ml of alcohol, the 7th observation had an alcohol content of 45% with a volume of 275 ml of alcohol and the observation to 8th alcohol content 25% alcohol volume 375ml while for the 9th observation, and 10th alcohol content 15% alcohol volume 378ml. Testing the rum distillation apparatus with a cooling tower on the condenser tube can be concluded that the condensation process becomes more stable with the alcohol content of rum drinks 55%, 45% and 25% and the volume of alcohol produced is 1.62 liters (Henderson, 1976; Palacz, 1985).

4 Conclusion

The development of a distillation device for making rum drinks using a cooling tower cooling system on a shell and tube condenser is as follows:

1. Cooling the condenser tube in the distillation apparatus using a cooling tower system can be stated as stable, namely the average temperature Tu in 81.3°C and Tu out 41.0ºC in the condenser, the average water flow rate is 46 liters per minute, while the cooling water on the cooling tower the average temperature Tw in 46.6°C and Tw out 47.5°C.
2. Distillation equipment for rum drinks with cooling tower cooling in shell and tube condenser tubes can be concluded that the condensation process becomes more stable with alcohol content of rum drinks 55%, 45% and 25% and the volume of alcohol produced is 1.62 liters.

The results of the development of a distillation apparatus with a cooling tower cooled condenser can be used for the home industry to produce fruit-based alcohol.

Conflict of interest statement
The authors declared that they have no competing interest.

Statement of authorship
The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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References

Arimi, M. M., Zhang, Y., Götz, G., Kiriamiti, K., & Geißen, S. U. (2014). Antimicrobial colorants in molasses distillery wastewater and their removal technologies. *International Biodeterioration & Biodegradation*, *87*, 34-43. https://doi.org/10.1016/j.ibiod.2013.11.002

Dewantara, D. (2019). Analysis and calculation of the mass flow rate of water in the cooling tower in the heat chamber machine. Journal of Mechanical Engineering: Vol. 08. No.2

Giler, J. J. G., & Cedeño, C. N. P. (2020). Elaboration of bovine manure biodigester for biogas transformation to electric power. *International Research Journal of Management, IT and Social Sciences*, *7*(5), 32-37. https://doi.org/10.21744/irjmis.v7n5.967

Harby, K., Gebaly, D. R., Koura, N. S., & Hassan, M. S. (2016). Performance improvement of vapor compression cooling systems using evaporative condenser: An overview. *Renewable and sustainable energy reviews*, *58*, 347-360. https://doi.org/10.1016/j.rser.2015.12.313

Henderson, P. (1976). Reaction trends shown by chrome-spinels of the Rhum layered intrusion. In *Chromium: its Physicochemical Behavior and Petrologic Significance* (pp. 1035-1044). Pergamon. https://doi.org/10.1016/B978-0-08-019954-2.50024-X

Ihsan, S. (2015). Optimasi Kondensor Shell And Tube Berpendingin Air Pada Sistem Refrigerasi Nh3. *AL-ULUM: JURNAL SAINS DAN TEKNOLOGI*, *1*(1).

Lee, T. S., Liu, C. H., & Chen, T. W. (2006). Thermodynamic analysis of optimal condensing temperature of cascade-condenser in CO2/NH3 cascade refrigeration systems. *International journal of refrigeration*, *29*(7), 1100-1108. https://doi.org/10.1016/j.ijrefrig.2006.03.003

Marjuni, M., Minarto, O., & Wahyono, S. C. (2021). Modifikasi Sirkulasi Air Pendingin Alat Destilasi pada Proses Pembuatan Akuades. *Jurnal Fisika Flux: Jurnal Ilmiah Fisika FMIPA Universitas Lambung Mangkurat*, *18*(1), 16-24.

Milosavljevic, N., & Heikkilä, P. (2001). A comprehensive approach to cooling tower design. *Applied thermal engineering*, *21*(9), 899-915. https://doi.org/10.1016/S1359-4311(00)00078-8

Mirzayanti, Y. W., & Kurniayati, R. (2021). Produksi Etanol Berbahan Baku Molasses Melalui Proses Fermentasi Menggunakan Ragi Roti. *Journal of Industrial Process and Chemical Engineering (JOICHE)*, *1*(1), 1-6.

Mohamad, A., & Harwan. (2020). Analysis of environmental temperature on the performance of cooling tower type induced draft unit 2 At pt. X. Sainstech Vol. 30 No. 1, ISSN :1410 -7104

Moutsatsou, A., Chalarakis, E., & Zarangas, G. (2003). Influence of raw materials and distillation equipment on the heavy metal content of waste from an alcoholic anis-type beverage. *Journal of hazardous materials*, *96*(1), 53-64. https://doi.org/10.1016/S0304-3894(02)00145-0

Mustiadi, L., Astuti, S., & Purkuncoro, A. E. (2020). BUKU AJAR DISTILASI UAP DAN BAHAN BAKAR PELET ARANG SAMPAH ORGANIK.

Najafpour, G. D., & Shan, C. P. (2003). Enzymatic hydrolysis of molasses. *Bioresource Technology*, *86*(1), 91-94. https://doi.org/10.1016/S0960-8524(02)00103-7

Olujić, Ž., Jödecke, M., Shilkin, A., Schuch, G., & Kaibel, B. (2009). Equipment improvement trends in distillation. *Chemical Engineering and Processing: Process Intensification*, *48*(6), 1089-1104. https://doi.org/10.1016/j.cep.2009.03.004

Palacz, Z. A. (1985). SrNdPb isotopic evidence for crustal contamination in the Rhum intrusion. *Earth and Planetary Science Letters*, *74*(1), 35-44. https://doi.org/10.1016/0012-821X(85)90164-5

Rochani, A., Yuniningsih, S., & Ma'sum, Z. (2016). Pengaruh konsentrasi gula larutan molases terhadap kadar etanol pada proses fermentasi. *Reka Buana: Jurnal Ilmiah Teknik Sipil dan Teknik Kimia*, *1*(1), 43-48.

Tsao, H. F., Scheikl, U., Herbold, C., Indra, A., Walochnik, J., & Horn, M. (2019). The cooling tower water microbiota: Seasonal dynamics and co-occurrence of bacterial and protist phylotypes. *Water research*, *159*, 464-479. https://doi.org/10.1016/j.watres.2019.04.028

Vallejo, R. S. R., Gámez, M. R., Espinales, A. M. S., & Pérez, A. V. (2019). Effects of thermal radiation using wood stoves on population health: Casas Viejas community, Jipijapa Canton. *International Research Journal of Management, IT and Social Sciences*, *6*(5), 1-8. https://doi.org/10.21744/irjmis.v6n5.656

Waisnawa, I. S., & Sudana, I. M. (2021, November). The Effect of Heating Temperature and Duration Process of Nira Fermentation by the Content of Alcohol in the Process of Arak Distillation. In *International Conference on Innovation in Science and Technology (ICIST 2020)* (pp. 297-300). Atlantis Press.

Yohana, E., Farizki, B., Sinaga, N., Endy Yulianto, M., & Hartati, I. (2019). Analisis Pengaruh Temperatur dan Laju Aliran Massa Cooling Water Terhadap Efektivitas Kondensor di PT. Geo Dipa Energi Unit Dieng.