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Software Development for the Design of Atmospheric Distillation Column for Proposed Mini-Refineries in Nigeria

[1]Tijani, Olamilekan E.; [2]Barivole, Nornubari B.; [3]Odike, Bright E.; [4]Dagde, Kenneth K.
[1 2 4]Department of Chemical/Petrochemical Engineering, Rivers State University, Nkpolu Oroworukwo, Port Harcourt, Nigeria
[3]Department of Petroleum Engineering, Rivers State University, Nkpolu Oroworukwo, Port Harcourt, Nigeria
[4]Corresponding Author Email: dagde.kenneth@ust.edu.ng

Abstract— *Nigeria is one of the largest oil producing countries with up to four (4) major refineries having a total design capacity of about 445,000 barrel per stream day, but none of these refineries is capable of producing up to 60% efficiency. Recent studies have indicated a low refining output obtained from Nigerian refineries, resulting to scarcity of various refined products within the country. This low refining output has led to the problem of spending large money on the importation of refined products. Therefore, it is imperative to propose mini-refineries for the thirty-six (36) states of the federation. The design of these mini-refineries is a repeating process except with the crude changing flow rate and crude type. This work is therefore focused on the development of a software for the provision of design parameters required for the fabrication of an Atmospheric Distillation Column. The design equations obtained from this work can also be used for the design of a Vacuum Distillation Column to provide feed for the Fluid Catalytic Cracking (FCC) unit. "GUI" (Graphical User Interface), "m.files" and "deploytool" functions of MATLAB 2018b were used in the development and building of this software, which can be easily installed and utilized on any standard computer. However, the examined crude type for this work is the Nigerian Bonny Light Crude. The software developed predicts accurate yields of the five different petroleum fractions (Naphtha, kerosene, LGO, HGO, and atmospheric residue), and also provides the feed point and points of collection of side streams. Results for only two case studies were highlighted in this work – considering a flow rate of 10,000 barrel per stream, 60% plate efficiency and reflux ratio of 2 in the 1st case study, and a flow rate of 150,000 barrel per stream, 45% plate efficiency and reflux ratio of 1.5 in the 2nd case study. However, in general, the column specification and side products parameters of an Atmospheric Distillation Column can be obtained for any flow rate of the examined crude type, plate efficiency and reflux ratio.*

I. INTRODUCTION

Refining of crude oils essentially consists of primary separation processes and secondary conversion processes. The petroleum refining process is the separation of the different hydrocarbons present in the crude oil into useful fractions, and the conversion of some of the hydrocarbons into products having higher quality performance (Anshuman, 2018). Atmospheric distillation and vacuum distillation of crude oils are the primary separation processes producing various straight-run products, from gasoline to lube oils. Petroleum refineries separate crude oil into constituent fractions by the process of distillation. The Atmospheric Distillation Unit is the first unit that separates petroleum crude in any refinery. Atmospheric distillation of crude oil is typically performed at pressures slightly above atmospheric pressure. At atmospheric pressure, low boiling fractions usually vaporize below 400°C without cracking the hydrocarbon compounds. Therefore, all the low boiling fractions of crude oil are separated by atmospheric distillation. Petroleum products are usually grouped into three categories: light distillates (LPG, gasoline and naphtha), middle distillates (kerosene and diesel), heavy distillates and residue (heavy fuel oil, lubricating oils, wax and tar). This classification is based on the methods employed in crude oil distillation and separation into fractions called distillates and residue (Ogbon *et al.*, 2018). These products, particularly the light and middle distillates (i.e., gasoline, kerosene, and diesel) are more in demand all over the world than their direct availability from crude oils. (Anshuman, 2018). Recent studies have indicated a low refining output obtained from Nigerian refineries, resulting to scarcity of various refined products within the country. This low refining output has led to the problem of spending large money on the importation of refined products. Also, pipeline contamination and the interference of flow assurance solids (salts, sands, sludge, hydrates, etc.) during the importation of refined petroleum products to depots across the country could result in the disruption of operations and economic losses. Hence, in order to provide solutions to the problems above, the country is tasked with the options of improving on the existing conventional refineries or establishing new and efficient refineries within the federation. Setting up of mini-refineries within the country is also a proposed option, making it possible for crude to be refined in the 36 states of the federation. A mini-refinery or a modular skid unit is often the perfect solution if only a small space is available because it arrives at the jobsite pre-assembled and contained within a frame. The unit arrives as a single piece or as multiple pieces that can be connected. Some of the advantages of these mini-refineries are in their flexibility to meet demand (easy to add modules), high level of quality control, efficient use of space and pre-delivery testing to ensure ultimate functionality, lower capital requirements/short payback period, minimal space/land requirements, quick and easy installation. Although the configuration of a mini-refineries comes in different packages, this work focuses on the development of a software used in the design of an Atmospheric distillation column for all the proposed mini-refineries to be built in Nigeria.

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II. Materials And Methods

The materials used for this work are MATLAB 2018b and research data. MATLAB 2018b was used to develop the software from its functions; GUI (Graphical User Interface) to design the software interface, "m.file" for writing the codes, and "deploytool" which was used to package and build the software into a folder for redistribution purposes.

Research data from literatures for characterization of Nigerian Bonny Light Crude and its petroleum fractions were also used for this work.

Table 1: Thermodynamic property of components

Components	Molar mass	Boiling point (°C)	Crude composition (volume fraction)	Specific gravity	Vapour pressure (kpa)	Specific heat capacity(J/gK)	Latent heat of vaporization (J/g)	Distillate composition	Bottom composition
Naphtha	98	150	0.299	0.76	1.0781@20°C	2.2055	330		0.01
Kerosene	130	250	0.13	0.85	0.7@20°C	2.0	251		0.03
Light Diesel Oil (LDO)	172	300	0.126	0.86	0.5@20°C	1.75	250		0.18
Heavy Diesel Oil (HDO)	188	345	0.125	0.87	0.4@38°C	1.7	238		0.21
Atmospheric residue	218	370	0.335	0.94	0.3@183°C	1.65	220	0	0.57
References	Victor, et al. (2015)	Victor, et al. (2015)	Angela, et al. (2019)						

Table 2: Column specification

Column specification	Value	References
Bottom Temperature	407.295988°C	Angela, et al. (2019)
Bottom pressure	243.67108kpa	Angela, et al. (2019)
Operating pressure	Slightly above atmospheric pressure (1.1atm is used)	
Operating Temperature	377.295988°C	Angela, et al (2019)
Plate spacing	0.5m	Commonly used in literatures
Weir height h_w	50mm	Richardson, et al. (2002)
Hole diameter d_h	5mm	Richardson, et al. (2002)
Plate thickness (carbon steel)	3mm	Richardson, et al. (2002)

The backbone of the software lies in the design equations, which were developed using the basic principles in designing multi-distillation columns and plates (sieve plate is considered).

2.1 Determination of Flow Rates and Compositions

Let A, B, C, D and E represent naphtha, kerosene, light gas oil, heavy gas oil and atmospheric residue respectively.

2.1.1 Molar flow rate of feed

The flow rate of crude oil from oil well is mostly given in volumetric flow rate (barrel per day). This value has to be converted to molar flow because the flow rate in the codes of the software is considered as molar.

$$F = \frac{\rho_{mix}}{M} V_o \qquad (1)$$

where ρ_{mix} is density of mixture of components (g/m^3), M is molecular weight of mixture and V_o is the volumetric flow of feed in m^3/sec.

The volume fraction can be converted to molar fraction using

$$\text{Molar fraction of component (i)} = \frac{(\rho_i * V_i/M_i)}{(\sum_i^n(\rho_i * V_i/M_i))} \qquad (2)$$

where M_i is the molecular weight of i, ρ_i is the density of component i (g/m^3), V_i is the volume fraction of component i, and i= A, B, C, D, E

$$\rho_{mix} = x_{fA}\rho_A + x_{fB}\rho_B + x_{fc}\rho_c + x_{fD}\rho_D + x_{fE}\rho_E \qquad (3)$$

$$M = x_{fA}M_A + x_{fB}M_B + x_{fc}M_B + x_{fD}M_D + x_{fE}M_E \qquad (4)$$

2.2 Compositions of Feed, Distillate and Bottom Products

The feed and bottom compositions of products can be found in Table (1) above, but that of distillates are unknown, so determined by following principle of conservation of mass.

2.2.1 Component balance

The bottom compositions are known (i.e. x_{BA}, x_{BC}, x_{BD}, x_{BE}), F is known and its compositions are known, also x_{DE} is known.

For component A; $$x_{DA} = \frac{x_{fA}F - x_{BA}(F-D)}{D} \qquad (5)$$

For component B; $$x_{DB} = \frac{x_{fB}F - x_{BB}(F-D)}{D} \qquad (6)$$

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For component C; $$D = \frac{(x_{fc} - x_{Bc})}{x_{DC} - x_{BC}} F \quad (7)$$

where $$x_{DC} = \frac{x_{fC}\, F - x_{BC}\,(F - D)}{D} \quad (8)$$

For component D; $$x_{DD} = \frac{x_{fD} F - x_{BD}\,(F-D)}{D} \quad (9)$$

where x_{Di} is the mole fraction of i in the distillate from the distillation column, x_{Bi} is the mole fraction of i in the bottom product from the distillation column, x_{fi} represents mole fraction of i in the feed into the distillation column, F is the molar flow rate of the feed into the distillation column (mol/s), D is the molar flow rate of the distillate from the distillation column (mol/s), and B is the molar flow rate of the bottom products from the distillation column (mol/s).

2.3 Determination of Number of plates, Feed Point and Height of Column

2.3.1 Number of plates

There are various methods of solving for the number of plates, but we will consider just two methods in this work.

2.3.1.1 Method 1: Lewis – Matheson's Method

Step 1: Determine the operating line equations with respective to all components in the distillation column.

Upper Operating Lines For component A;

$$y_{nA} = \frac{R}{R+1} x_{nA} + \frac{1}{R+1} x_{DA} \quad (10)$$

where R- reflux ratio

For component B; $$y_{nB} = \frac{R}{R+1} x_{nB} + \frac{1}{R+1} x_{DB} \quad (11)$$

For component C; $$y_{nc} = \frac{R}{R+1} x_{nc} + \frac{1}{R+1} x_{Dc} \quad (12)$$

For component D; $$y_{nD} = \frac{R}{R+1} x_{nD} + \frac{1}{R+1} x_{DD} \quad (13)$$

For component E; $$y_{nE} = \frac{R}{R+1} x_{nE} + \frac{1}{R+1} x_{DE} \quad (14)$$

Lower Operating Lines

For component A; $$y_{mA} = \frac{L_m}{L_m - B} x_{mA} - \frac{B}{L_m - B} x_{BA} \quad (15)$$

For component B; $$y_{mB} = \frac{L_m}{L_m - B} x_{mB} - \frac{B}{L_m - B} x_{BB} \quad (16)$$

For component C; $$y_{mC} = \frac{L_m}{L_m - B} x_{mC} - \frac{B}{L_m - B} x_{BC} \quad (17)$$

For component D; $$y_{mD} = \frac{L_n}{L_n + D} x_{mD} - \frac{B}{L_n - B} x_{BD} \quad (18)$$

For component E; $$y_{mE} = \frac{L_n}{L_n + D} x_{mE} - \frac{B}{L_n - B} x_{BE} \quad (19)$$

Step 2: Determine the composition of vapour on each component and this is given by:

$$\boldsymbol{y_i = \frac{x_{Bi}\alpha_{iB}}{\sum(\alpha_{iB} x_{Bi})}} \quad (\mathbf{20})$$

where $i = A, B, C, D, E$, x_{Bi} is bottom composition of component i, $\alpha_{i,B}$ is the relative volatility of i relative to base component. Hence, let D→base component.

$$\alpha_{iD} = \frac{P_i^{sat}}{P_D^{sat}} \quad (21)$$

where P_i^{sat} is the vapour pressure of i

Composition of corresponding liquid is gotten from the operating line of component i. Calculating for the above, we can start fom bottom to top or top to bottom.

Starting from bottom to top, = composition of liquid in the below plate.

The above procedure carried for all components until the composition on a plate converges to the composition of feed, and that plate is termed feed plate. Counting the number of iterations up to this point gives the feed point. While calculating earlier, lower operating lines were used. After determining the feed plate, upper operating lines were used and calculation only stops when the composition on a plate converges to that of the distillate. The number of plates is thus, the total number of iterations carried out.

2.3.1.2 Method 2

This involves the combination of Fenske's equation, Gillard correlation (1940) and Kirkbride (1944) equation. The key components are important factors in using this method. Thus, Let A → light key component D-Heavy key component

2.3.2 Minimum Number of Plates Required

This is given by Fenkse's equation as shown below:

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$$\text{Nm} = \log \frac{\left[\frac{X_{DA}}{X_{DD}}\right]\left[\frac{X_{BD}}{X_{BA}}\right]}{Log\alpha_{AD,av}} \quad (22)$$

$$\alpha_{AD,av} = \sqrt{\alpha_{AD,B} \times \alpha_{AD,D}} \quad (23)$$

where $\alpha_{AD,av}$ represents the average volatility of component A relative to D, $\alpha_{AD,B}$ is the average volatility of component A relative to D in the bottom product, $\alpha_{AD,D}$ is the average volatility of component A relative to D in the Distillate, and Nm indicates the minimum number of plates.

2.3.3 Actual Theoretical Number of Plates

Gilliland correlation (1990) gives the equation to determine actual theoretical number of plates as shown in equation (24) and (25):

$$N = \frac{1 - \exp\left[\left(\frac{1+54.4\Psi}{11+111.72\Psi}\right)\left(\frac{\Psi-1}{\Psi \wedge 0.5}\right)\right] + N_M}{\exp\left[\left(\frac{1+54.4\Psi}{11+111.72\Psi}\right)\left(\frac{\Psi-1}{\Psi \wedge 0.5}\right)\right]} \quad (24)$$

$$\Psi = \frac{R - R_m}{R+1} \quad (25)$$

where N is the actual number of plate and R_m is the minimum reflux ratio

2.3.4 Feed Point Location

The feed point location is given by Kirkbride (1944) using equations (26) and (27) as shown below:

$$Log\left(\frac{N_r}{N_s}\right) = 0.206\log\left[\left(\frac{B}{D}\right)\left(\frac{X_{fD}}{X_{fA}}\right)\left(\frac{X_{BA}}{X_{DD}}\right)^2\right] \quad (26)$$

$$N_r + N_s = N \quad (27)$$

Solving equations (26) and (27) simultaneously gives:

$$N_S = \frac{N}{10\left(0.206\log\left[\left(\frac{B}{D}\right)\left(\frac{X_{fD}}{X_{fA}}\right)\left(\frac{X_{BA}}{X_{DD}}\right)^2\right]\right)+1} \quad (28)$$

where Ns is feed point while counting from top to bottom, Nr is feed point while counting from bottom to top.

2.3.5 Height of Column

Height of column is gotten from the fundamental equation as shown below:

Height of column = Number of plate $*$ Plate spacing.

N/B: In the course of this work, Method 2 was used to determine the number of plates and feed point, while Method 1 was used to determine the composition on each plate so as to know the point where the side products will be withdrawn. Other important design parameters were also determined below:

- Molecular weight of bottom component, MW

$$(MW) = \sum_{i=1}^{N} MW_i * y_{wi}$$

$$\overline{MW} = M_A \frac{P_A^{sat}}{P} x_{BA} + M_B \frac{P_B^{Sat}}{P} x_{BB} + M_C \frac{P_c^{Sat}}{P} x_{BC} + M_D \frac{P_D^{Sat}}{P} x_{BD} + M_E \frac{P_m^{Sat}}{P} x_{BE} \quad (29)$$

where P=P_B is known as bottom pressure, and y_i - composition of vapour, mass flow rate of bottom product, $W = \overline{MW} * B$

- Vapour density, ρ_V

$$\rho_V = \frac{P_B \overline{MW}}{RRT} \quad (30)$$

where RR is the Universal gas constant, and T is the bottom temperature

- Liquid density, ρ_l

$$\rho_L = \sum_{i=1}^{n} \rho_i x_i$$

$$\rho_l = \rho_A \frac{P_A^{sat}}{P_B} x_{BA} + \rho_B \frac{P_B^{sat}}{P_B} x_{BB} + \rho_c \frac{P_c^{sat}}{P_B} x_{BC} + \rho_D \frac{P_D^{sat} x_{BD}}{P_B} + \rho_E \frac{P_E^{sat} x_{BE}}{P_B} \quad (31)$$

- Vapour velocity, Uv

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$$U_v = \left(-0.171 l_t^2 + 0.27 * l_t - 0.047\right)\left[\frac{\rho_l - \rho_v}{\rho_v}\right]^{1/2} \quad (32)$$

- Column diameter, D_c

$$D_c = \sqrt{\frac{4\dot{w}}{\bar{\wedge}\rho_v u_v}} \quad (33)$$

- Thickness of column, t_c

$$t_c = \frac{P_i * D_c}{4f_D - Pi} \quad (34)$$

where P_i is the design pressure, l_t is the plate spacing, and f_D is the design stress

- Outside Diameter of column, OD_c

$$OD_c = D_c + 2 * t_c \quad (35)$$

2.4 Design of Sieve Plate for the Column

The active area, hole area, downcomer area, and weir length were determined using their respective conventional formula.

2.4.1 Number of holes on plate

$$N_h = \frac{Ah}{Area\ of\ one\ hole} \quad (36)$$

$$\text{Area of one hole} = \frac{\pi d_h^2}{4} \quad (37)$$

where N_h is the Number of holes, and A_h is the hole area

2.4.2 Determination of Hole Pitch (Distance between Two Holes)

$$A_p = A_a + A_{up} + A_{cz} \quad (38)$$

where A_p is the area of perforation, A_{up} is the area of unperforated edge, and A_{cz} is the area of calming zone.

$$A_{up} = L_{up} * W_{up} \quad (39)$$

where L_{up} is the length of unperforated edge, W_{up} is the width of unperforated edge equal to 50mm {standard atmospheric column design, (Richardson, et al.(2002)}.

$$L_{up} = (D_c - W_{up})\pi\left(\frac{180 - \theta_c}{180}\right) \quad (40)$$

Where $\theta_c = 99$ for all distillation processes, since it is obtained using $\frac{Lw}{Dc} = 0.76$(constant design equation, {Richardson, et al. (2002)}

$$A_{cz} = L_{cz} * W_{cz} \quad (41)$$

where L_{cz} is the length of calming zone, W_{cz}- width of calming zone equal to 50mm(Richardson, et al. (2002)) and l_w –weir length.

$$L_{cz} = l_w + W_{up} \quad (42)$$

$\frac{Ah}{Ap}$ is related to $\frac{lp}{dh}$ by a graph

But the graph is solved to get it equation by taking some values provided in Table (3).

Let $\frac{Ah}{Ap} = x$ and $\frac{lp}{dh} = y$

Table 3: Extracted data from literature {Richardson, et al. (2019)}

Y	2.0	2.5	2.7	3.5	4.0
X	0.25	0.15	0.12	0.065	0.06

By plotting the values of Table 3 on excel, the equation obtained is shown below:

$$l_p = \left[59.511\left(\frac{Ah}{Ap}\right)^2 - 27.868\left(\frac{Ah}{Ap}\right) + 5.2587\right] d_h \quad (43)$$

2.5 Determination of Boiler and Condenser Load

$$Q_C = V_n \lambda_{ave,top} = V_n \sum_{i-1}^{n} \lambda iyi$$

$$Q_C = V_n \left(\frac{P_A^{Sat}}{P} X_{DA}\lambda_A \times \frac{P_B^{Sat}}{P} X_{DB}\lambda_B \times \frac{P_C^{Sat}}{P} X_{DC}\lambda_C \times \frac{P_D^{Sat}}{P} X_{DD}\lambda_D \times \frac{P_E^{Sat}}{P} X_{DE}\lambda_E\right) \quad (44)$$

$$Q_B = V_m \lambda_{ave,bottom} = V_m \sum_{i-1}^{n} \lambda iyi$$

$$Q_B = V_m \left(x_{BA}\lambda_A + x_{BB}\lambda_B + x_{BC}\lambda_C + x_{BD}\lambda_D + x_{BE}\lambda_E \right) \quad (45)$$

where V_m is the vapour flow rate of product from bottom of column, V_n is the vapour flow rate of products from top of distillation column, Q_C is the amount of heat removed by condenser (J/s), λi is the latent heat of vapourisation of component i, and Q_B is the amount of heat added by boiler (J/s).

2.5.1 Amount of Cooling Water Required by Condenser

$$m_w = \frac{c}{c_{Pw}(T_2 - T_1)} \quad (46)$$

Where m_w is the amount of cooling water required by condenser (g/s), (T_2-T_1) indicates the rise in temperature of cooling water used in the condenser (°C), and C_{Pw} is the specific heat capacity of component i.

2.5.2 Amount of Steam Required by The Boiler

$$m_{Bw} = \frac{Q_B}{\lambda_w} \quad (47)$$

Where m_{Bw} is the amount of steam required by boiler (g/s), and λ_w is the latent heat of vapourisation of water (J/mol).

III. Results

Table 4: 1st Case Study - Considering a flow rate of 10,000 barrel per stream, 60% plate efficiency and reflux ratio of 2

Column Specification	Values	Unit
Column Diameter	5.5066	m
Column Area	23.8184	m^2
Downcomer Area	2.8582	m^2
Active Area	18.102	m^2
Net Area	20.9602	m^2
Hole Area	1.8102	m^2
Weir Length	4.185	m
Hole Diameter	0.005	m
Number of holes	92181	
Hole Pitch	0.015476	m
Number of plates	33	
Height of column	16.3278	m
Feed Point Counting from top plate	29	
Boiler load	24804827.24	J/sec
Condenser Load	541907.62	J/sec
Steam required by boiler	6095.60	g/sec
Cooling Water Required by condenser	4300.85	g/sec
Thickness	0.00772	m
Outside diameter	5.522	m
plate for kerosene removal from bottom	12	
Height for kerosene removal	5.833	m
Plate for light gas oil removal from bottom	7	
Height for Light gas oil removal	3.33	m
plate for Heavy gas oil removal from bottom;	5	
Height for Heavy gas oil removal	2.5	m

Composition of Components on Plates for Side Products Removal

	Naphtha	Kerosene	LGO	HGO	Atmospheric Residue
Kerosene plate	0.24015	0.15424	0.18569	0.12379	0.29613
LGO plate	0.080536	0.0903	0.2454	0.224	0.359
HGO plate	0.043984	0.06844	0.23734	0.23213	0.41811

The input parameters for the software were volumetric flow rate of crude oil in barrel per stream day, plate efficiency, and the desired reflux ratio. The output parameters from the software obtained were – column diameter, outside diameter, thickness, area of column, net area, height and number of plates required by mechanical engineers to fabricate the atmospheric distillation column, hole pitch, number of holes and hole area required for the plate fabrication, condenser duty and amount of condenser's cooling water for condenser fabrication and boiler and amount of steam required for fabrication of boiler.

Table 4 shows the result obtained when the input parameters are flow rate of crude of 10,000 barrel per stream day, 60% plate efficiency and reflux ratio of 2, while Table 5 shows the result obtained when the input parameters are flow rate of crude of 150,000 barrel per stream day, 45% plate efficiency and reflux ratio of 1.5. Results obtained from table 5 can be compared to New Port Harcourt Refinery because the same flow rate is considered. Also, the number of plates and feed point counting from bottom in the Port Harcourt refinery are 48 and 43 respectively. For this software, number of plates equals 45 and feed point counting from bottom is 40. In general, the result obtained from this software is fully tested and reliable.

Table 5: 2nd Case Study - Considering a flow rate of 150,000 barrel per stream, 45% Plate efficiency and Reflux ratio of 1.5

Column Specification		Values		Unit
Column Diameter		21.327		m
Column Area		357.2767		m^2
Downcomer Area		42.8372		m^2
Active Area		271.5303		m^2
Net Area		314.4035		m^2
Hole Area		27.153		m^2
Weir Length		16.2085		m
Hole Diameter		0.005		m
Number of holes		1382713		
Hole Pitch		0.015674		m
Number of plates		45		
Height of column		22.34		m
Feed Point Counting from top plate		40		
Boiler load		3720724188.6		J/sec
Condenser Load		8128484.11		J/sec
Steam required by boiler		91434.011		g/sec
Cooling Water Required by condenser		64511.78		g/sec
Thickness		0.0299m		m
Outside diameter		21.39m		m
plate for kerosene removal from bottom		16		
Height for kerosene removal		7.78m		m
Plate for light gas oil removal from bottom		9		
Height for Light gas oil removal		4.44m		m
plate for Heavy gas oil removal from bottom;		7		
Height for Heavy gas oil removal		3.33m		m
Composition of Components on Plates for Side Products Removal				

	Naphtha	Kerosene	LGO	HGO	Atmospheric Residue
Kerosene plate	0.26245	0.11585	0.19031	0.16319	0.2682
LGO plate	0.08581	0.08581	0.2415	0.2242	0.3738
HGO plate	0.041865	0.066184	0.23427	0.23109	0.42659

IV. CONCLUSION

The developed software was efficient in providing the fundamental parameters for the design of an Atmospheric Distillation Column, height of removal of side products and feeding of crude. The principle of operation of the developed software is well simplified, and the equations obtained in this work can also be used to design a Vacuum Distillation Column to provide feed for the Fluid Catalytic Cracking (FCC) unit. This can be achieved by excluding component E, and taking A as a mixture consisting of fuel gas, slop oil and sour water, B as Light Vacuum Gas Oil (LVGO), C as Heavy Vacuum Gas Oil (HVGO), and E as vacuum residue.

The software is however, precisely developed for the design of the major component (Atmospheric Distillation Column) in a Crude Distillation Unit of a mini-refinery. Improvement on this work can be made by including other components (e.g. heat exchanger, de-salter and furnace) in the Crude Distillation Unit and all other respective units of a mini-refinery. This work is also primarily based on the evaluation of the physical and chemical properties of Nigerian Bonny Light Crude. However, it is consequential to note that the developed software provides a benchmark for the design of an Atmospheric Distillation Column, irrespective of the crude type in consideration. Hence, an improvement on the developed software can therefore make provision for all Nigerian crude types.

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