International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 18 (2017) pp. 7372-7391

The Comparative Analysis of Bonny Light& Bonny Medum Crude Oil Using Simple Distillation and Preflash Model For Maximum Distillate Cuts Recovery (Crude Oil Topping Refinery)

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Abstract

Although Nigeria is currently ranked as the eleventh largest crude oil producing country in the world, scarcity of refined products still exists within the country due to the sub-optimum performance of the four conventional refineries as none can boast of working above 60 percent of its design capacity. In an attempt to curb this saddening state, the country is faced with setting up modular topping refineries at strategic locations within the country as other alternatives seem to yield little or no result. This paper makes a comparative analysis on the simple crude topping unit, the preflash added model and the preflash-stripping-pump around model for maximum distillate cuts yield using Bonny light and Bonny medium crude sample. Crude oil characterization with the use of Aspen Hysys was done to reveal the maximum liquid volume fraction of the different distillate at an ideal condition. The different crude assays were simulated against the different topping refinery models where variation between the characterized and stimulated volumetric cuts in barrel per day was observed and analyzed. The analysis shows that Bonny light favours the production of off gas, light naphtha and kerosene while Bonny medium favours the production of heavy naphtha, diesel, gas oil and atmospheric residue. The best scheme for different distillates was also determined. The results gotten from this research will help both Nigerian and foreign investors to determine the preferable model for individual distillate products in terms of maximum yield.

Keywords: Distillation**,** Preflash, Modular, HYSYS, Topping, Nigeria

INTRODUCTION

Although Nigeria has four full conversion refineries (Kaduna, Warri, Old Port- Harcourt and New Port Harcourt) with a total design capacity of 445,000 bpd (barrel per day), the sub-optimum performance of these refineries has led to the scarcity of refined products within the country. Year 2015, the Nigerian National Petroleum Corporation who solely controls these refineries for the federal government reported an estimated consumption rate of 35million and 10 million liters per day of Premium Motor Spirit (PMS) and kerosene respectively [NNPC Annual Bulletin, 2015]. In order to meet the deficit in supply, the country currently spends between $12 billion and $15 billion annually for the importation of petroleum products for domestic consumption.

[Ogedegbe, 2009] highlighted various reasons contributing to the low refining output as : bad maintenance culture, political instability, poor management, irregular feedstock supplies, non- implementation of the Petroleum Industry Bill (PIB), ineffective technical services department, vandalisation of the pipelines, obsolete technologies and delayed turn around maintenance but emphasized more on insufficient capital for establishing more conventional refineries on the part of private investors. Apart from the huge amount wasted on importing refined products, the low refining rate has also led to high rate of unemployment, under-utilization of crude oil feed and bad working condition for other industries that depend on finished or intermediate refined products.

In an attempt to curb this saddening state, other options have been attempted (establishment of more conventional refineries, legalization of illegal refineries and swapping of our crude with refined products from other countries) but to no avail. The country is now faced with the only feasible option of setting up modular refineries at strategic locations within the country, a concept that has successfully been applied in other parts of the world such as: Senegal, Cameroun, Congo, Niger Republic, Chad, Zambia, Gabon, Australia, Russia, Indonesia, Kurdistan and Siberia [The Citizens, 2015]. A modular refinery can be defined as a conventional refinery constructed in a fragmented way [Brown et al., 2003] or simply a big refinery in miniature form [Igwe, 2015].

Modular refineries are used in areas where crude oil and a ready market are available but low refining output is recorded or areas where there is a need to set up refineries which can easily be hidden or taken down when the need arises [Duncan, and Knox 1991]. These scenarios are prominent in Nigeria especially in the oil producing states where vandalisation of pipelines and other refining equipment seems to be the order of the day. With increasing level of complexities, the modular refinery comes in four different configurations namely: topping (atmospheric distillation) unit, hydro-skimming unit, vacuum added unit and the full conversion unit. Although these different configurations has successfully being used in different part of the world, the topping unit seems to be the most attractive option since the country is relatively new to the concept.

The presence of the two operational modular topping plant in Nigeria which include the Ogbelle 10000bpd Topping plant fully owned by the Niger Delta Petroleum Resources (NDPR) and university of Port Harcourt modular topping refinery has removed fear from individuals and private investors who were initially skeptical about venturing into the modular refinery business. The importance of setting up the modular refineries at strategic location within the country will assist in the following ways: the minimization or total eradication of shortage of refined products within the country, non- reliance on imported refined products, a full utilization of our crude oil feed which has a multiplier effect on the economy and most importantly motivation of private investor since start-up capital is low compared to a conventional refinery.

STATEMENT OF THE PROBLEM

Although a modular crude/topping refinery has an atmospheric distillation column, heat exchanger network, and furnace as its main equipment, [Brugma, 1941] has shown that it is possible to position a pre- flash drum or a pre-fractionation column before the heating stage. Evolution on the crude atmospheric distillation column also shows that there are optional features (strippers, pump around reflux and pump back reflux) which can be added to the distillation column to tackle various operational issues. Previous research has been carried out to ascertain the effects this addition has on the heat duty of the furnace and overall energy consumption of the unit, no comparative analysis has been carried out on the three different systems (simple crude oil topping unit, pre-flash added unit and pre- fractionation added unit) in terms of maximum distillate cuts recovery

AIM of STUDY

The aim of this study is to make a comparative analysis on the **simple crude topping unit** , **the preflash added model and the preflash-stripping-pump around model** for maximum distillate cuts yield using Bonny light and Bonny medium crude sample. The results gotten from this research will help both Nigerian and foreign investors to determine the preferable model for individual distillate products in terms of maximum yield.

LITERATURE REVIEW

CRUDE TOPPING (ATMOSPHERIC DISTILLAION) UNIT

A crude topping unit as shown in figure 1 below is designed to separate crude oil into different distillates fraction (off gas, light naphtha, heavy naphtha, kerosene, light diesel, heavy diesel, atmospheric gas oil and residue) based on their boiling units at a pressure slightly above atmospheric pressure. The crude oil passes through series of heat exchangers network before entering the de-salter which helps to remove water containing salts. Depending on the crude nature, it is heated (340-370 °C) until it attains the required percentage of vaporization (50 to 60 percent) which is being channeled to the distillation column via the flash zone [Bagajewicz and Ji, 2001]. .

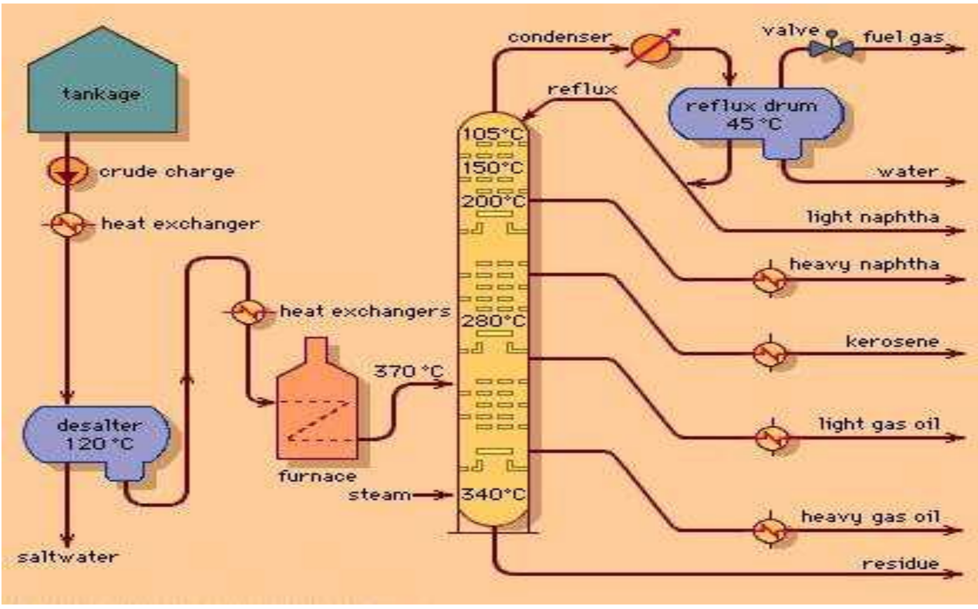


Figure 1: Atmospheric Distillation Unit. [Encyclopedia Britannica, 1999]

The overhead condenser helps to effectively remove heat within the column while the efficiency of the distillation/ separation process depends on the number of trays, the reflux ratio and the contact between the rising vapour and the falling liquid within the column. This process can be referred to as **SIMPLE DISTILLATION PROCESS -NO STRIPPING- NO PUMP AROUND REFLX- NO PUMP BACK REFLUX (MODEL A)**

EVOLUTION OF THE CRUDE ATMOSPHERIC DISTLLATION COUMN

In reality, during the separation process, some level of discrepancies where lighter components do not completely condense at their boiling point range and some times higher component tend to condense with lighter components is observed. This particular phenomenon causes un-standard refined products and was taken care of by [Miller and Osborne, 1938] who introduced side strippers to the system for the removal of light components in the product as shown in figure 2 below.

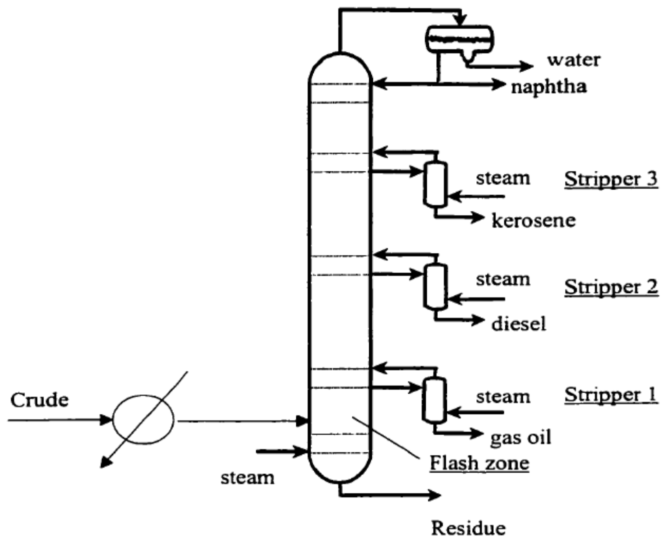


Figure 2: Atmospheric Distillation Column with the Addition of Strippers [Watkins, 1979]

Although [Watkins, 1979] saw how productive the addition of strippers is, he highlighted the increasing vapour and liquid traffic experienced within the distillation column due to all heat regulated by the condenser alone. [Bagajewicz, 1998] then suggested that the diameter of the top section has to be large enough to accommodate this traffic.

This led to the addition of both pump around reflux and pump back reflux. Pump back reflux refers to the removal of liquid from a tray within the distillation column which is then cooled and pumped back into the column at several points below the withdrawal point. The pump around reflux with side strippers which is widely used in the industry today uses an externally circulated cooled stream for the partial removal of heat as shown in figure 3 below

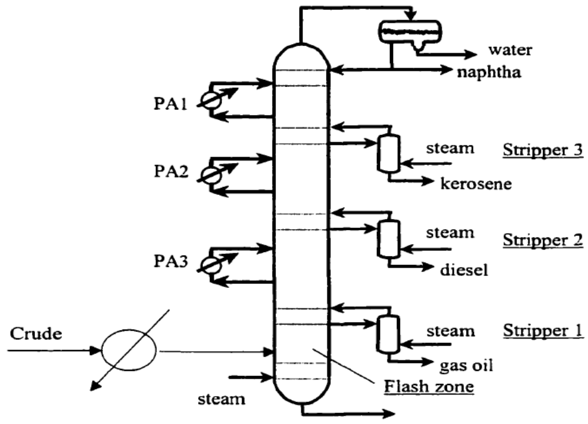


Figure 3: Pump Around Reflux added to an Atmospheric Distillation Column [Watkins, 1979]

THE INTRODUCTION OF THE PRE- FLASH DESIGN

[Brugma, 1941] introduced the addition of a pre- flash vessel to the conventional topping unit when it was observed during the pre-heat stage of light crude oil that above certain temperature, a high pressure is required to suppress any tendency of vaporization. The pre-flash scheme helps to avoid un-necessary heating of light components in the furnace, short-circuiting them to be injected at an appropriate tray in the column for further separation process. [Shuncheng, 2001] also introduced another variation whereby part of the vapor coming out from the pre- flash drum is passed through the heating furnace as shown in figure 4 below

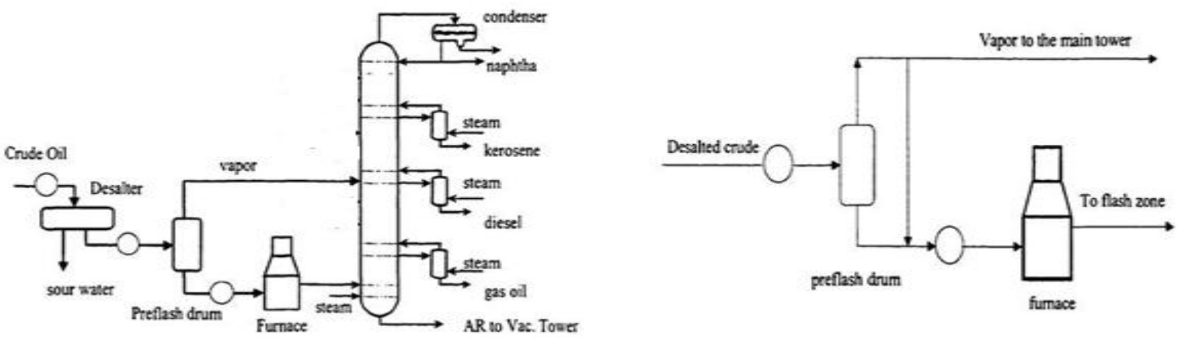


Figure 4: Pre- Flash Vessel added to an Atmospheric Separation Process [Watkins, 1979]

[Bagajewicz and Ji, 2001] showed that the introduction of the vapor feed from the flash drum simply changes the heat load distribution in the column thereby affecting the heat duty of the pump around circuits while [Shuncheng, 2001] proved that for a light crude with no pump around circuits, the vapor and liquid traffic decrease as a result of decreased heat input in the feed.

Modular Crude Topping Refinery Configuration

As earlier stated, a crude topping refinery can be in the form of a simple distillation, pre-flash or pre-fractionation scheme with optional features such as stripping, pump around reflux and pump back reflux. This particular study will look at a comparative analysis of **BONNY LIGHT AND BONNY MEDIUM CRUDE SAMPLE** ON **SIMPLE DISTILLATION-NO STRIPPNG-NO PUMP AROUND REFLUX- NO PUMP BACK RELUX (MODEL A), PRE-FLASH-NO STRIPPNG-NO PUMP AROUND REFLUX-NO PUMP BACK RELUX (MODEL B) and PRE-FLASH- STRIPPNG- PUMP AROUND REFLUX (MODEL C) FOR MAXIMUM DISTILLATE CUTS.**

Methodology

- Based on their true boiling points, bonny light and bonny medium crude assays as shown in table A1-A2 were characterized using Aspen Hysys Simulator version 8.6. The result revealed the maximum liquid volume fraction of the different distillate that can be gotten from the crude at an ideal condition as recorded in figure 5-6.
- 10000bpd of bonny light and bonny medium crude assay were simulated through model A-C **(Simple Distillation-No Stripping-No Pump Around Reflux- No Pump Back Reflux, Pre-Flash- No Stripping- No pump Around Reflux- No Pump Back Reflux and Pre-Flash-Stripping with Pump Around Reflux)** as shown in figure 7-9 .The design capacity of 10000bpd was kept constant with a fixed temperature of 358.31ºC and pressure of 700kpa of crude entering the main distillation column. Other operating conditions are highlighted in table A1-A4 as at when converged
- Variation between the characterized and stimulated volumetric cuts in barrel per day was observed and analyzed
- Based on the analysis, the best scheme for different distillates were determined

RESULT AND DISCUSSION

Crude Oil Characterization based on their True Boiling Point

Bonny Light Crude Characterization

Bonny light crude characterized based on its true boiling points produces 0.039,0.05 ,0.21 ,0.13 ,0.126 , 0.125,0.065 and 0.27 liquid volume fraction of off gas, light naphtha, heavy naphtha, kerosene, light diesel, heavy diesel, AGO and residue respectively as shown in figure 5 . These values expressed in percentage form shows 4% off gas, 26% naphtha, 13% kerosene, 31% diesel and 26% atmospheric residue of the total liquid volume fraction. These values represent the maximum liquid volume fraction of the different distillate that can be gotten from the crude at an ideal condition

Bonny Medium Crude Characterization

Bonny medium crude characterized based on its true boiling points produces 0.02, 0.01, 0.085, 0.12, 0.14, 0.175, 0.1, and 0.365 liquid volume fraction of off gas, light naphtha, heavy naphtha, kerosene, light diesel, heavy diesel, AGO and residue respectively as shown in figure 6. Expressed in percentage form reveals 2% off gas, 9% naphtha, 12% kerosene, 41% diesel and 36% atmospheric residue of the total liquid volume fraction. These values represent the maximum liquid volume fraction of the different distillate that can be gotten from the crude at an ideal condition

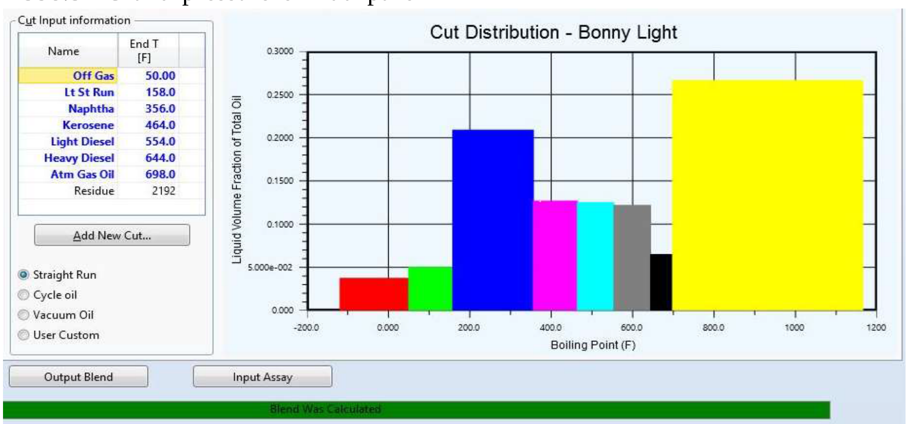


Figure 5: Bonny Light Crude Characterization

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 18 (2017) pp. 7372-7391

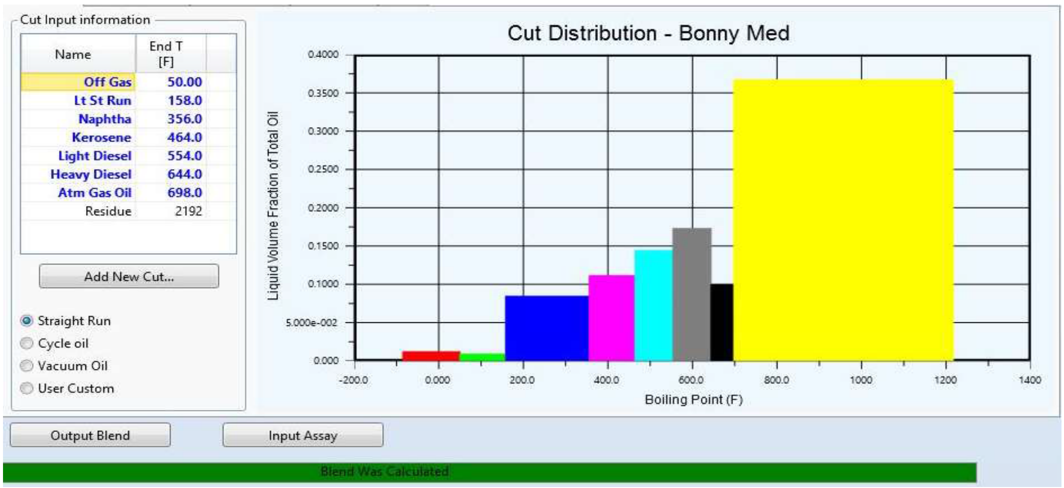


Figure 6: Bonny Medium Crude Characterization

Crude Oil Simulation and Operating Conditions

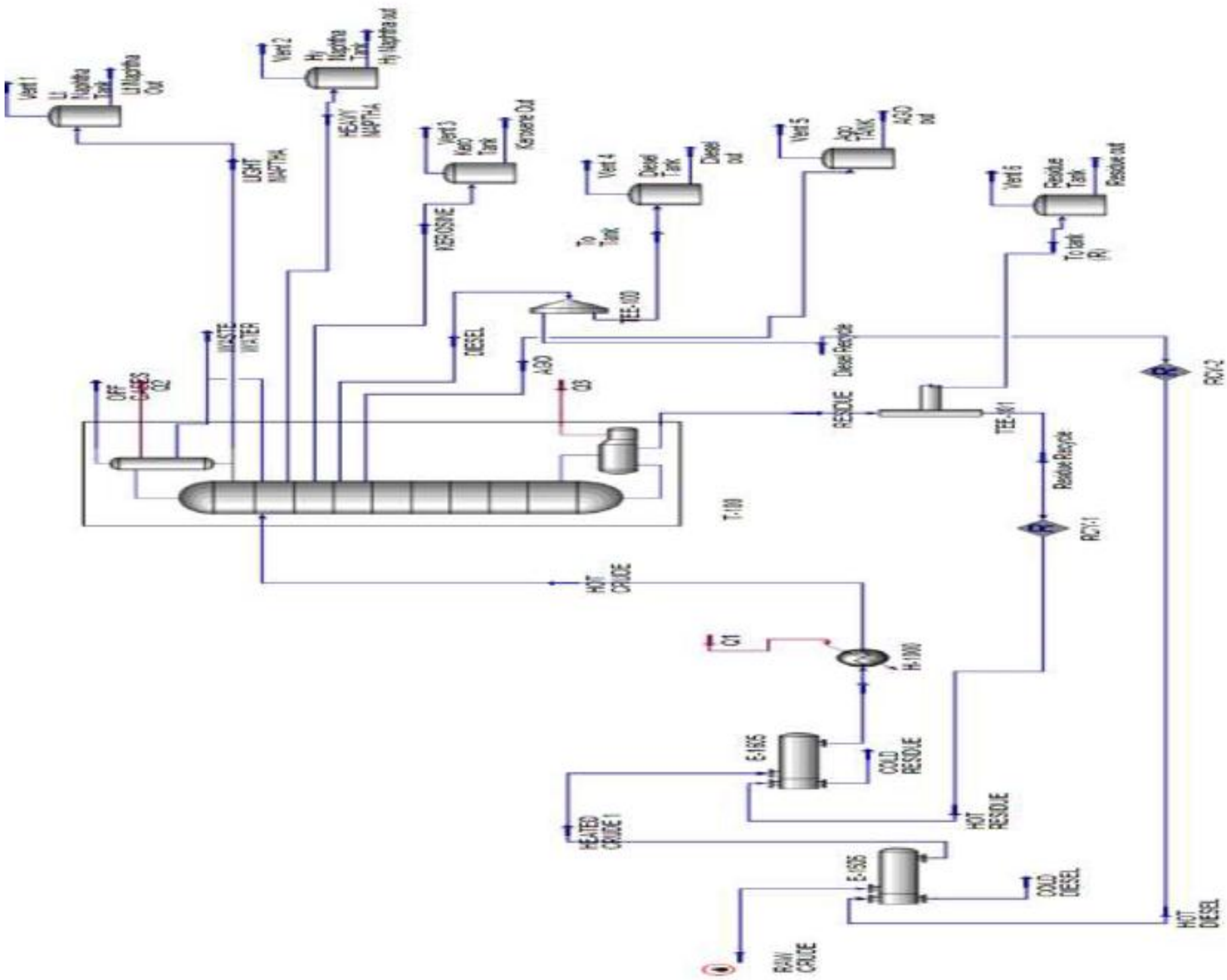


Figure 7: Simple Distillation Process [No Stripping, No Pump Around and No Pump Back Reflux]

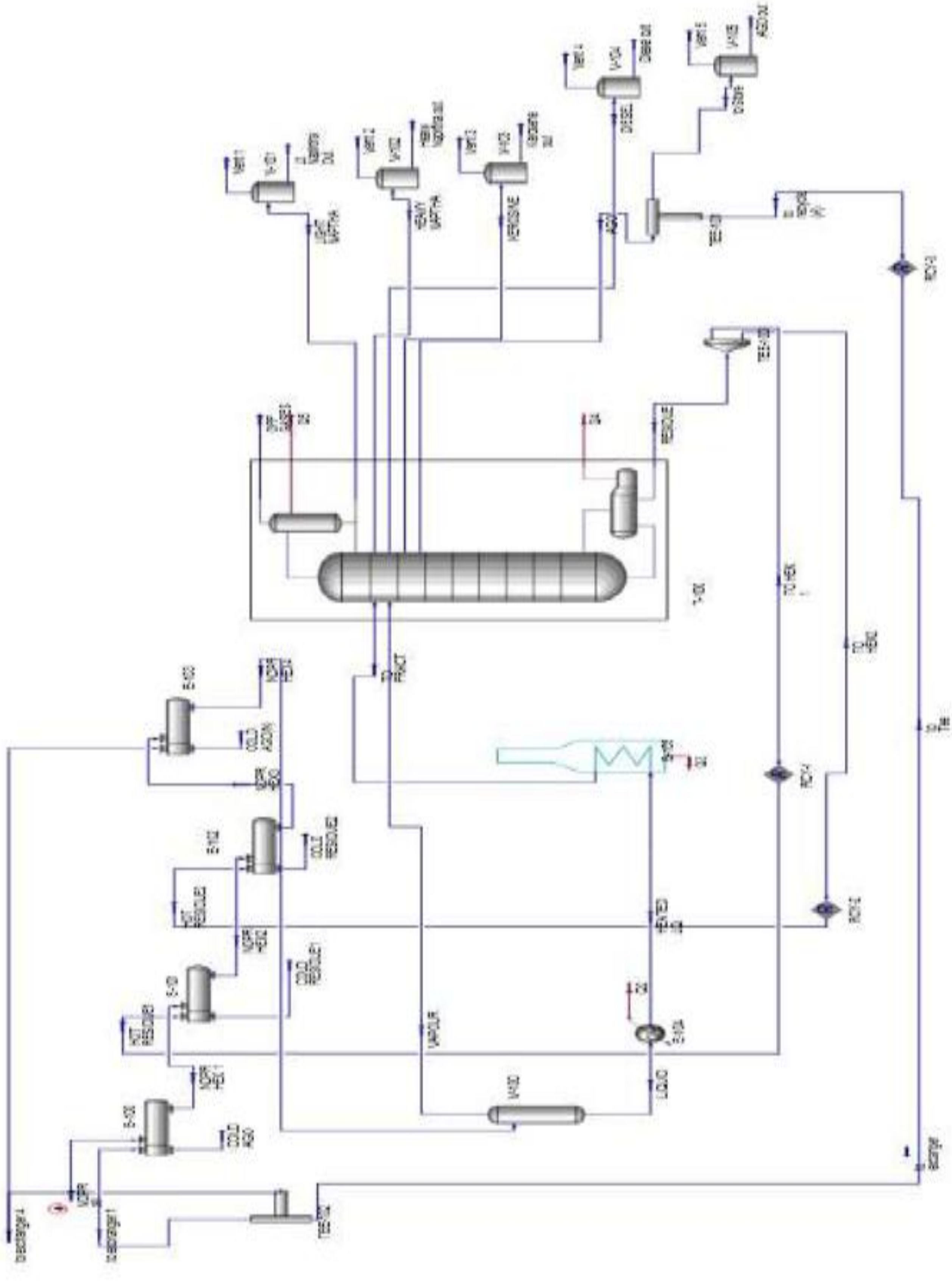


Figure 8: Preflash Process [No Stripping, No Pump Around and No Pump Back Reflux]

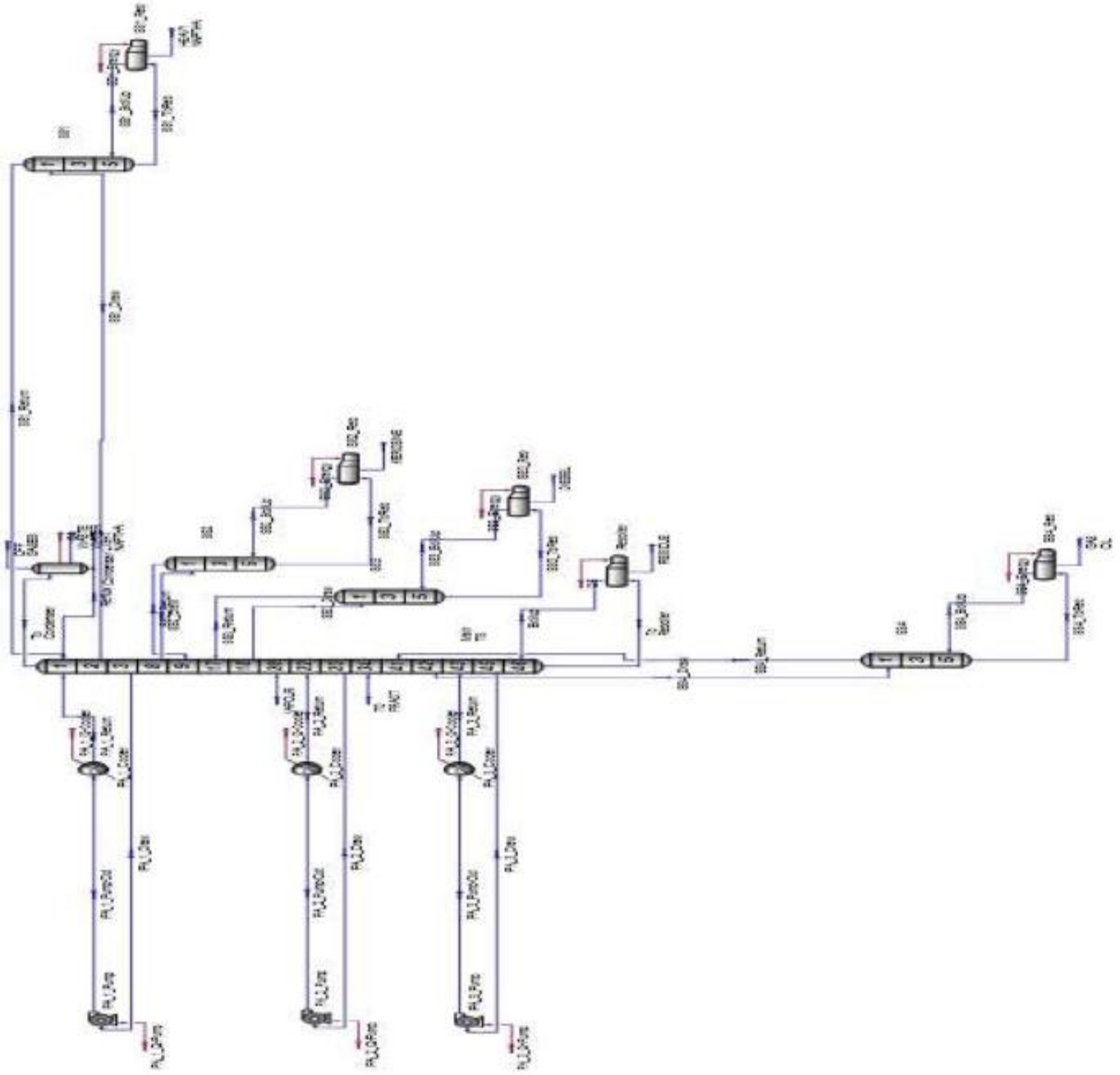


Figure 9: Preflash Process [Distillation Column and Stripping Environment]

Variation between Characterized and Simulated Volumetric Cuts

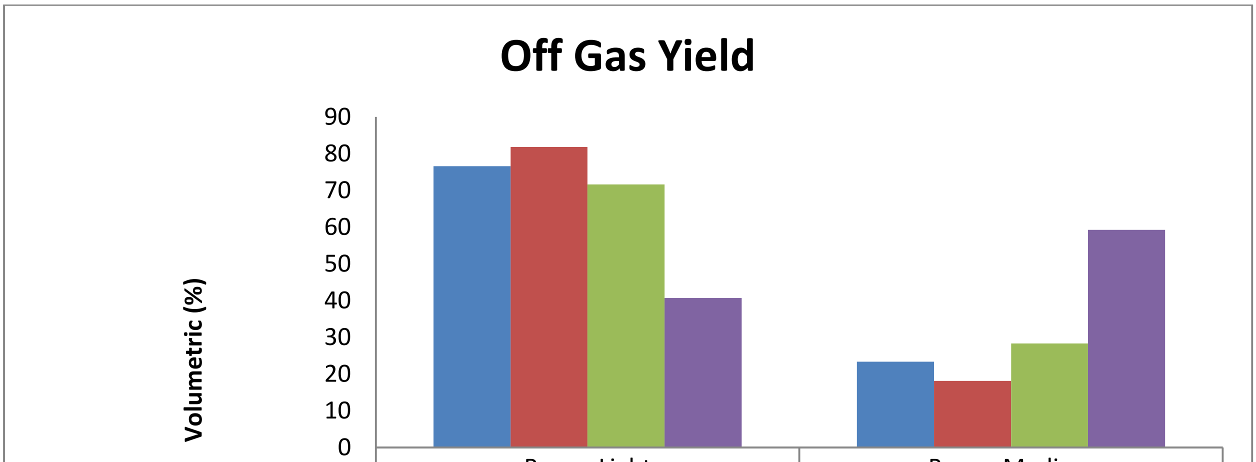
Off Gas

During the refining of a barrel per day of crude oil, table 1 shows the different volume of off gas that will be produced when the different streams of crude are simulated against the simple, pre- flash and the pre- flash with pump around reflux. Figure 10 expresses these values in percentage form which shows that under normal distillation, Bonny light should produce more volume of off gas or liquefied petroleum gas (77%) condition while bonny medium produces the remaining (23%)

The use of the simple distillation (82%) and preflash (72%) scheme will favor off gas production for bonny light while preflash with pump around scheme will favor the production of off gas for bonny medium (59%). For the maximum production of off gas, bonny light crude oil with either simple distillation or preflash scheme should be used. For cost savings, the use of an additional pump around reflux is not necessary.

Table 1: Off Gas Variation

OFF GAS (BBL/DAY)				
	Characterization	**Simple Distillation**	**Pre-Flash**	**Pre-Flash With Pump Around**
Bonny Light	**0.03705**	**0.1545**	**0.1876**	**0.1076**
Bonny Medium	**0.0113**	**0.03429**	**0.0742**	**0.1568**



	Bonny Light	Bonny Medium
Characterization	76.62874871	23.37125129
Simple Distillation	81.8369617	18.1630383
Preflash	71.65775401	28.34224599
Preflash with Pumparound	40.69591528	59.30408472

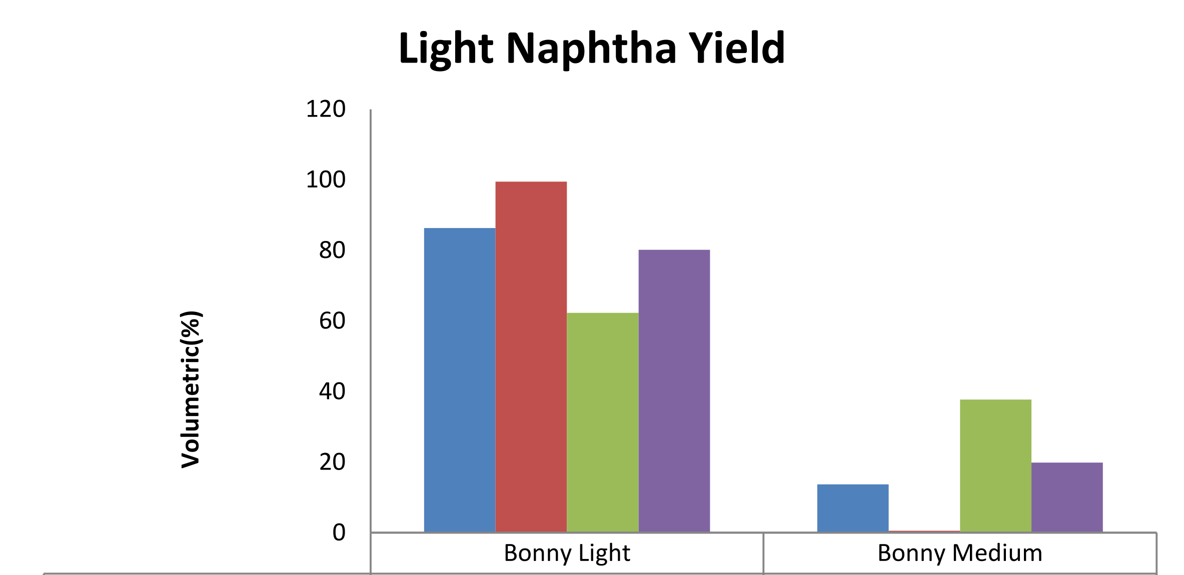
Figure 10: Off Gas Yield

Light Naphtha

Table 2 below highlights the volume variation of light naphtha from a barrel of crude oil per day. From figure 11, it is observed that ideally bonny light crude favours the production of light naphtha (86%) more while bonny medium gives the least (14%). The simple distillation (99%) and preflash with pump around scheme (80%) favours the production of light naphtha for bonny light crude (the preferred crude for the production of light naphtha). Although bonny medium does not favor the production of light naphtha, the preflash scheme without the addition of pump around reflux will optimize its yield

Table 2: Light Naphtha Variation

LIGHT NAPHTHA (BBL/DAY)				
	Characterization	**Simple Distillation**	**Pre-Flash**	**Pre-Flash With Pump Around**
Bonny Light	**0.05038**	**0.001859**	**0.0335**	**0.0873**
Bonny Medium	**0.00798**	**0.0000098**	**0.0203**	**0.0216**



	Bonny Light	Bonny Medium
Characterization	86.32625086	13.67374914
Simple Distillation	99.47559932	0.524400685
Preflash	62.26765799	37.73234201
Preflash with Pumparound	80.16528926	19.83471074

Figure 11: Light Naphtha Yield

Heavy Naphtha

From table 3 and figure 12 below, it is observed that bonny medium (93%) will always favor the production of heavy naphtha when compared to bonny light (38%). For an investor with bonny medium crude the use of both preflash (38%) and preflash-pump around (40%) scheme will optimize the yield. For bonny light crude, simple distillation (99%) scheme without the additional cost of a preflash drum (61%) and pump around reflux (60%) should be used for maximum productivity and cost savings.

Table 3: Heavy Naphtha Variation

HEAVY NAPHTHA (BBL/DAY)				
	Characterization	**Simple Distillation**	**Pre-Flash**	**Pre-Flash With Pump Around**
Bonny Light	**0.0059**	**0.0007374**	**0.0213**	**0.009**
Bonny Medium	**0.08376**	**0.00000618**	**0.0132**	**0.0059**

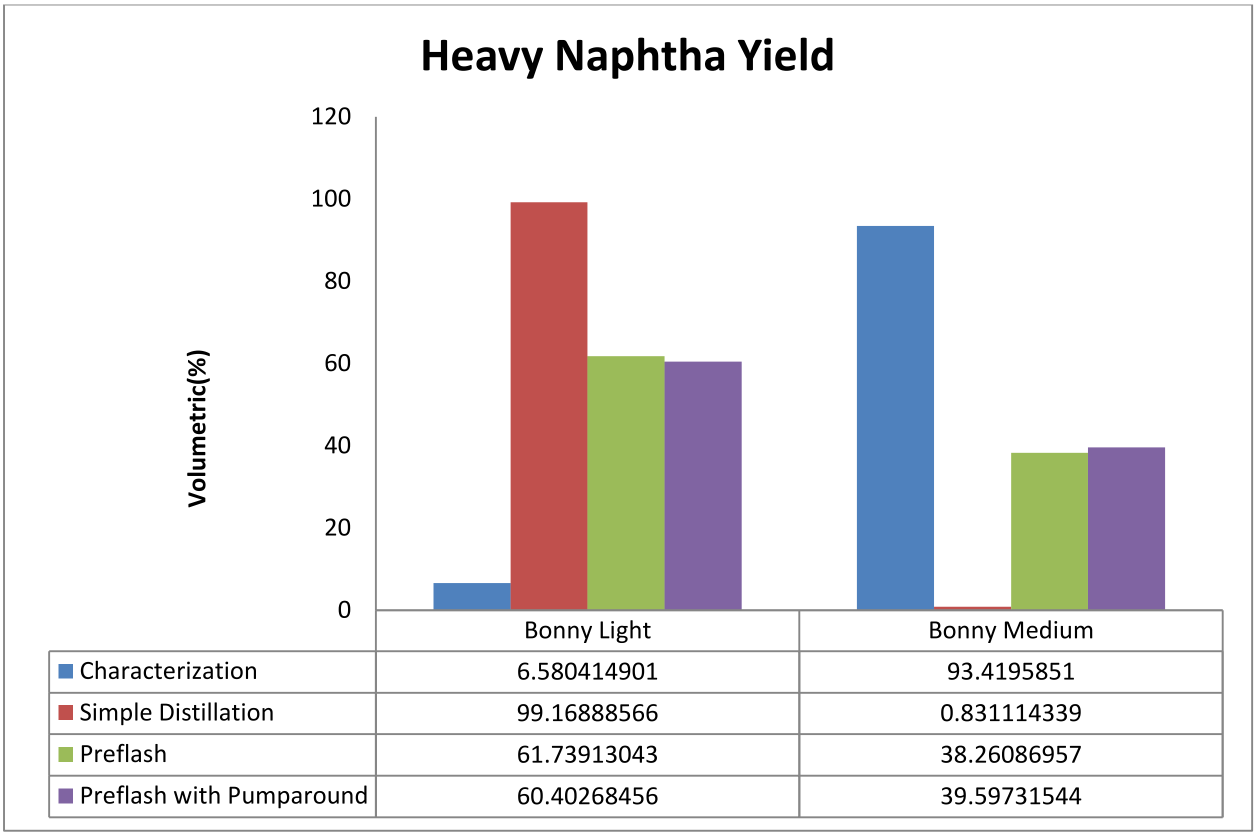


Figure 12: Heavy Naphtha Yield

Kerosene

For the maximum production of kerosene, the use of bonny light crude (53%) with simple distillation (52%) scheme is preferable. The addition of a preflash drum (45%) with pump around reflux (48%) is not necessary as it reduces its characterized value. Bonny medium crude is relatively not bad as it has a close range to that of bonny light (47%). Both the preflash scheme and the preflash with pump around will help actualize this value with 54% and 51% respectively as shown in table 4 and figure 13 below.

Table 4: Kerosene Variation

KEROSENE (BBL/DAY)				
	Characterization	**Simple Distillation**	**Pre-Flash**	**Pre-Flash With Pump Around**
Bonny Light	**0.1275**	**0.3993**	**0.2809**	**0.2265**
Bonny Medium	**0.1113**	**0.3638**	**0.3378**	**0.2436**

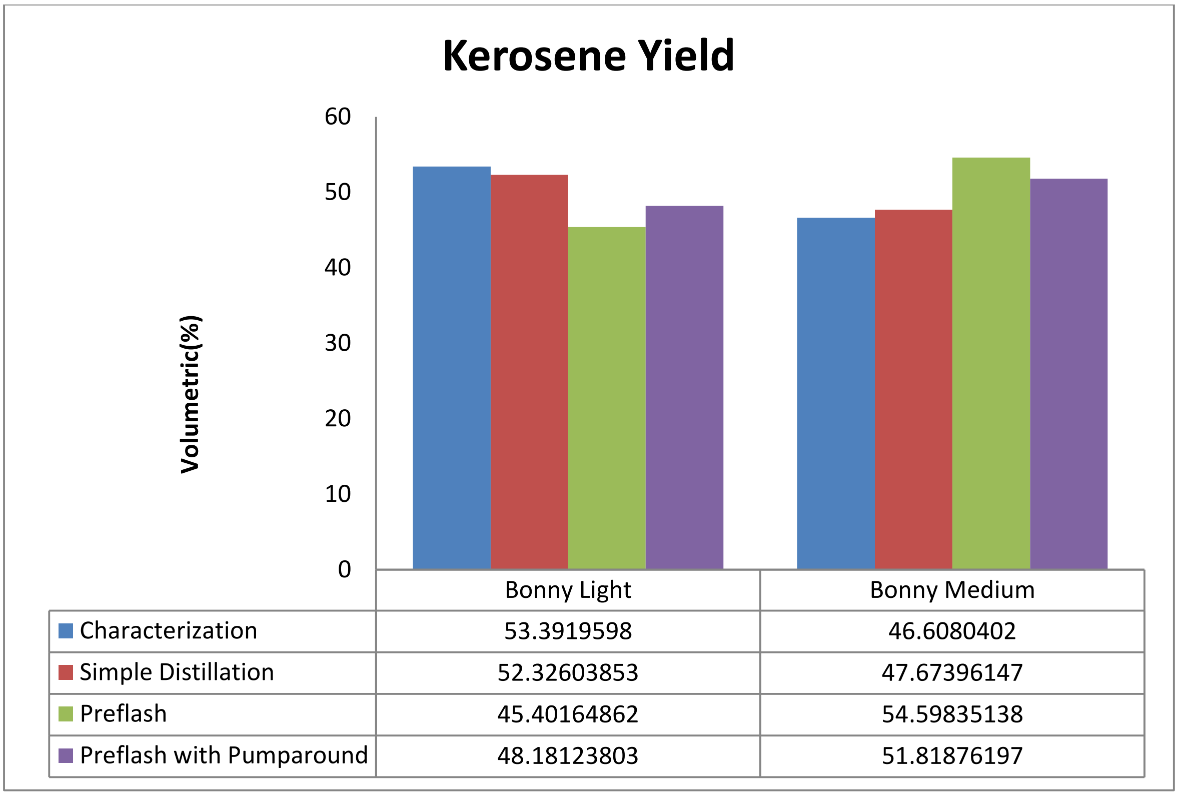


Figure 13: Heavy Naphtha Yield

Diesel

For maximum production and profitable operations, the use of bonny medium crude (56%) with a preflash pump around scheme (57%) should be employed, although the use of a pre flash (50%) and simple distillation scheme (48%) can serve as an alternative. For bonny light crude oil (43%), a simple distillation scheme (51%) can be used without the addition of a preflash (49%) or pump around reflux (42%)

Table 5: Diesel Variation

DIESEL (BBL/DAY)				
	Characterization	**Simple Distillation**	**Pre-Flash**	**Pre-Flash With Pump Around**
Bonny Light	**0.2485**	**0.19**	**0.3067**	**0.2579**
Bonny Medium	**0.3169**	**0.1791**	**0.3176**	**0.3457**

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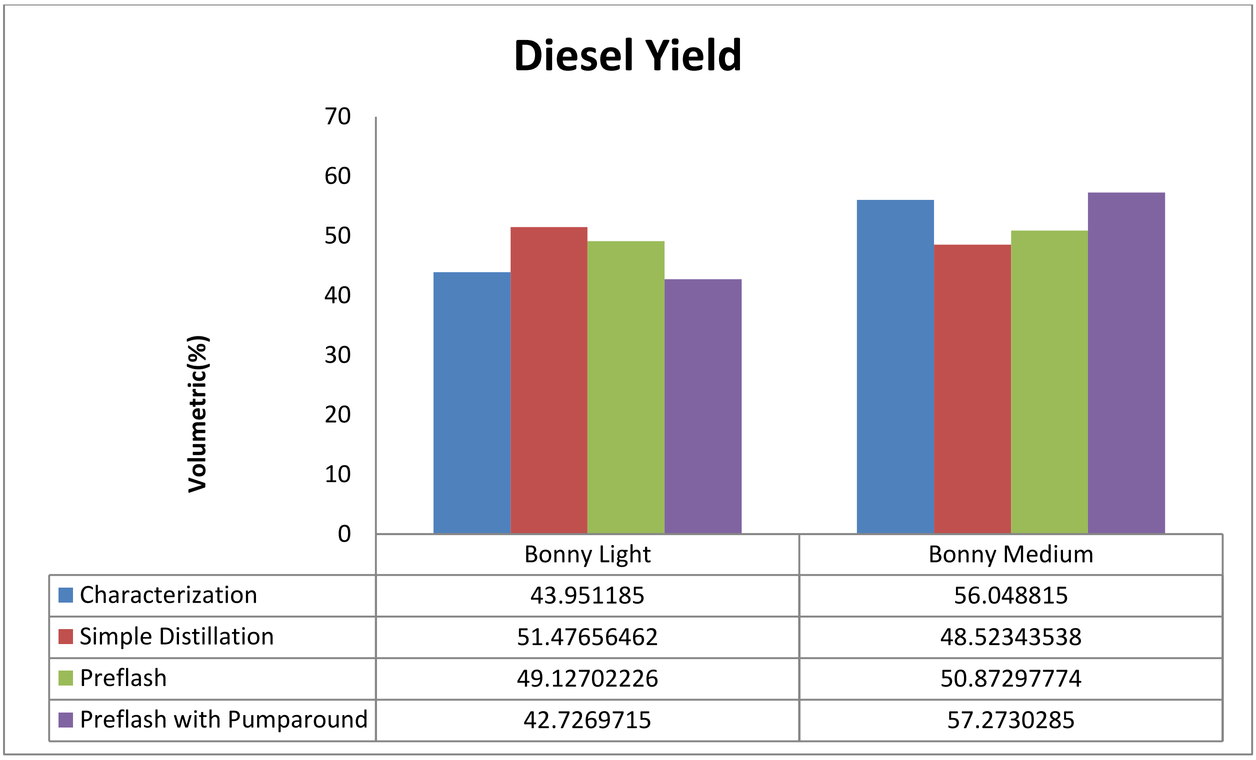


Figure 14: Diesel Yield

Gas Oil

For maximum production and profitable operations, the use of bonny medium crude (60%) with a simple distillation scheme (71%) should be employed without the use of preflash (54%) or pump around scheme (28%) whose values are below the characterized values. For bonny light crude oil (39%), a preflash with a pump around reflux scheme (71%) should be used.

Table 6: Gas Oil Variation

GAS OIL (BBL/DAY)				
	Characterization	**Simple Distillation**	**Pre-Flash**	**Pre-Flash With Pump Around**
Bonny Light	**0.06467**	**0.09551**	**0.0688**	**0.1765**
Bonny Medium	**0.09985**	**0.2372**	**0.0827**	**0.0689**

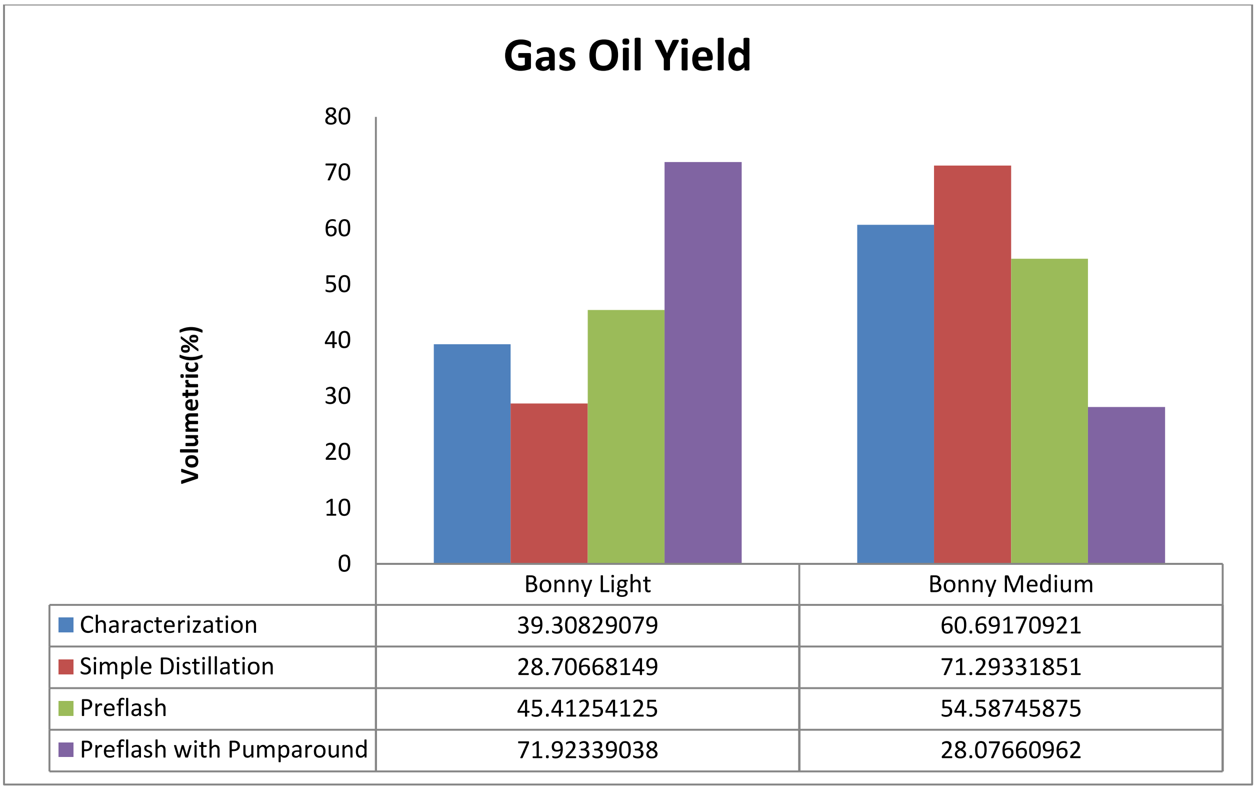


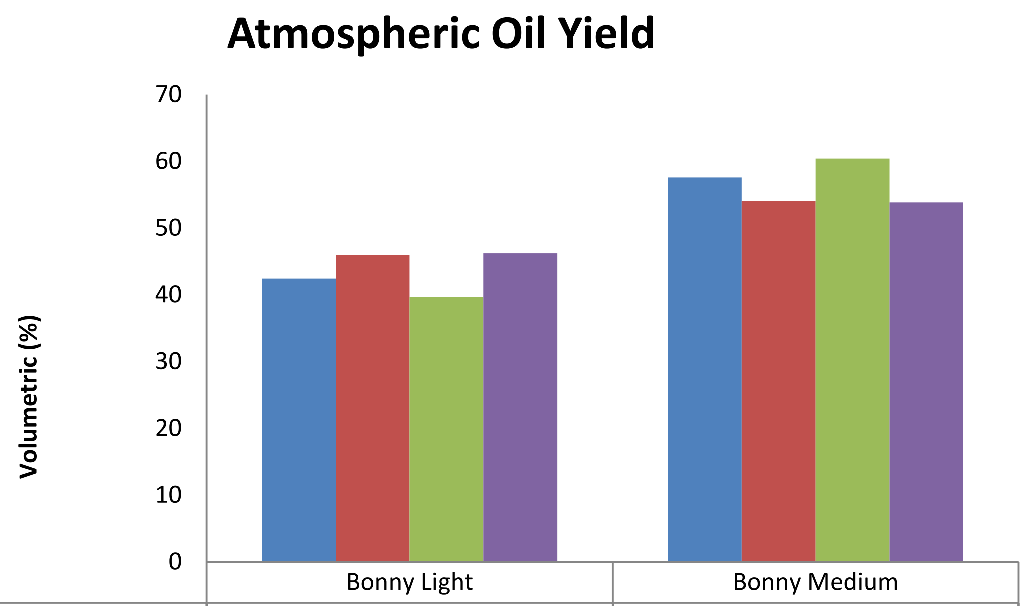
Figure 15: Gas Oil Yield

Atmospheric Residue Variation

Table 7 highlights the volume variation of atmospheric residue from a barrel of crude per day. This is achieved when the different streams of crude are simulated against the simple, pre-flash and pre-flash with pump around scheme. As shown in figure 16 below bonny medium (60%) favours the production of residue when compared with bonny light. For maximum efficiency, bonny light should be combined with a preflash scheme which will result to 60% of its volumetric value.

Table 7: Residue Oil Variation

RESIDUE OIL (BBL/DAY)				
	Characterization	**Simple Distillation**	**Pre-Flash**	**Pre-Flash With Pump Around**
Bonny Light	**0.2666**	**0.1581**	**0.1012**	**0.1352**
Bonny Medium	**0.3618**	**0.1857**	**0.1542**	**0.1575**



	Bonny Light	Bonny Medium
Characterization	42.42520687	57.57479313
Simple Distillation	45.98603839	54.01396161
Preflash	39.62411903	60.37588097
Preflash with Pumparound	46.19063888	53.80936112

Figure 16: Gas Oil Yield

CONLUSION

The following conclusions can be drawn when bonny medium and bonny light crude oil are comparatively analyzed within the simple, pre-flash and pre-flash pump around modular topping refinery scheme

- Bonny light favours the production of off gas, light naphtha and kerosene
- Bonny medium favours the production of heavy naphtha, diesel, gas oil and atmospheric residue
- Simple distillation scheme favours the production of off gas, light naphtha, heavy naphtha , kerosene, diesel and gas oil for bonny light crude oil
- Preflash with pump around scheme favours the production of gas oi and atmospheric residue for bonny light crude
- Simple distillation favours the production of gas oil for bonny medium crude oil
- Preflash scheme favours the production of light naphtha, heavy naphtha, kerosene and atmospheric residue for bonny medium crude
- Preflash with pump around favours the production of off gas, diesel for bonny medium crude

REFERENCES

[1] Nigerian National Petrochemical Corporation. (2013). Annual Statistical Bulletin. Availableat:http://www.nnpcgroup.com/Portals/0/Monthly%20Performance/2013%20ASB%201st%20edition.pdf [Accessed 29 Sep. 2015].

[2] Ogedegbe, A., 2009, “The Nigerian Petroleum Refineries: History, Problems and Possible Solutions,” A lecture delivered at the Induction Ceremony for New Fellows of the Nigerian Academy of Engineers, http://www.businessdayonline.com/NG/index.php/oil/3203-nigerian-refineries-history-problems-and-possible-solutions-1

[3] The Citizens, 2015, “DPR, make modular refineries count – Punch,” Available at: http://thecitizenng.com/public-affairs/dpr-make-modular-refineries-count-punch/ [Accessed 30 Sep. 2015]

[4] Brown, K.B., Maxwell, B.L., Rick, R.V., and Shumway, M.D., 2003, "Modular Oil Refinery," WO 2003031012A1

[5] Igwe, G.J., 2014, “Modular refineries will address perennial shortage of petroleum products,” Available at:http://businessnews.com.ng/2014/09/08/modular-refineries-will-address-perennial-shortage-petroleum-

products-igwe/ [Accessed 2 Oct. 2015]

[6] Duncan, J.W., and Knox, L., 1991, "Overland Petroleum Processor," US Patent 4983259

[7] Brugma, A. J., 1941, "The Brugma Process, Refinery and Natural Gasoline Manufacturer". 20(9), 86

[8] Bagajewicz, M., and Ji, S., 2001, "Rigorous Procedure for the Design of Conventional Atmospheric Crude Fractionation Units-Part I," Industrial & Engineering Chemistry Research. 40(2):617-626

[9] Miller, W., and Osborne, H., 1938, "The Science of Petroleum," Volume II, Oxford University Press, London

[10] Watkins, R. N., 1979, "Petroleum Refinery distillation," Gulf Publishing Company, Book Division

[11] Bagajewicz, M., 1998, "On the Design Flexibility of Atmospheric Crude Fractionation Units," Chemical Engineering Communications. 166(1), 111 — 136

[12] Shuncheng, J.I., 2001, "Optimal Design of Crude Oil Distillation Plants," Ph.D. thesis, University of Oklahoma College

APPENDIX A

CRUDE ASSAY

Table A1: Bonny Light Crude Assay

BONNY LIGHT									
Whole Crude	IBP(C)	FBP(C)	Cut Yield By Volume (%)	Cumulative	Whole Crude	IBP(C)	FBP(C)	Cut Yield By Volume (%)	Cumulative
Cut 1	IBP	8.89	3.75553	3.75553	Cut 12	336.4706	369.4118	7.167108	73.2676
Cut 2	8.89	40	1.44626	5.20179	Cut 13	369.4118	402.3529	6.240062	79.50766
Cut 3	40	72.9412	4.16132	9.36311	Cut 14	402.3529	435.2941	5.272611	84.78027
Cut 4	72.9412	105.882	5.51549	14.8786	Cut 15	435.2941	468.2353	4.260537	89.04081
Cut 5	105.882	138.824	6.49861	21.3772	Cut 16	468.2353	501.1765	3.395835	92.43664
Cut 6	138.824	171.765	6.57074	27.948	Cut 17	501.1765	534.1176	2.494532	94.93118
Cut 7	171.765	204.706	6.63064	34.5786	Cut 18	534.1176	567.0588	1.801154	96.73233
Cut 8	204.706	237.647	7.08015	41.6588	Cut 19	567.0588	600	1.253993	97.98632
Cut 9	237.647	270.588	8.28133	49.9401	Cut 20	600	650	1.623034	99.60936
Cut 10	270.588	303.529	8.12986	58.0699	Cut 21	650	FBP	0.390642	100
Cut 11	303.529	336.471	8.03056	66.1005					

IBP: Initial Boiling Point FBP: Final Boiling Point

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 18 (2017) pp. 7372-7391

Table A2: Bonny Medium Crude Assay

BONNY MEDIUM									
Whole Crude	IBP(C)	FBP(C)	Cut Yield By Volume (%)	Cumula tive	Whole Crude	IBP(C)	FBP(C)	Cut Yield By Volume (%)	Cumulative
Cut 1	IBP	8.89	0.99	0.99	Cut 11	303.5294	336.4706	11.53751	52.13421
Cut 2	8.89	40	0.10066	1.09066	Cut 12	336.4706	369.4118	10.97139	63.1056
Cut 3	40	72.9412	0.92714	2.0178	Cut 13	369.4118	402.3529	9.90231	73.00791
Cut 4	72.9412	105.882	1.53157	3.54937	Cut 14	402.3529	435.2941	8.333446	81.34135
Cut 5	105.882	138.824	2.39273	5.9421	Cut 15	435.2941	468.2353	6.457033	87.79839
Cut 6	138.824	171.765	3.50726	9.44936	Cut 16	468.2353	501.1765	4.793043	92.59143
Cut 7	171.765	204.706	4.935	14.3844	Cut 17	501.1765	534.1176	3.139406	95.73084
Cut 8	204.706	237.647	6.71059	21.0949	Cut 18	534.1176	567.0588	1.979641	97.71048
Cut 9	237.647	270.588	8.88744	29.9824	Cut 19	567.0588	600	1.162335	98.87281
Cut 10	270.588	303.529	10.6143	40.5967	Cut 20	600	FBP	1.127187	100

IBP: Initial Boiling Point   FBP: Final Boiling Point

Table A1: Parameters for Storage Tank and Distillation Column (Simple Distillation)

Storage Tank						
Parameters	Heavy Naphtha	Residue	Kerosene	Diesel	Gas Oil	Light Naphtha
Vessel Diameter (M)	3.2004	3.6576	5.6388	4.8768	3.6576	2.7432
Vessel Height (M)	1.3716	1.524	2.4384	2.1336	1.524	1.2192
Design Gauge Pressure (Kpa)	103	243.6711	243.67108	243.671	243.671	103
Design Temperature (C)	125	426.836	178.594182	304.775	368.473	125

Distillation Column	
Parameters	
Diameter Bottom Section (M)	191.5668
Bottom Tangent To Tangent Height (M)	31.242
Design Gauge Pressure Bottom (Kpa)	243.67108
Design Temperature Bottom (C)	416.39827
Operating Temperature Bottom (C)	386.39827
Number Of Trays Bottom Section	46
Bottom Tray Type	Sieve
Bottom Tray Spacing (Mm)	609.6

m (meters), kpa (kilopascal), c (celsius) and mm (millimetres)

Table A2: Parameters for Heat Exchangers (Simple Distillation)

Heat Exchangers					
Parameters	E-1505	H-1000	E-1605	Re-boiler	Condenser
Heat Transfer Area (m^2)	5.13055	7.947231	0.667274	1367557.1	785534.976
Tube Design Gauge Pressure (Kpa)	769.0306	3001.561	745.337747	745.33775	413.67108
Tube Design Temperature (C)	304.7752	259.2	426.827702	426.8277	125
Tube Operating Temperature (C)	274.7752	229.2	396.827702	396.8277	35
Tube Outside Diameter (mm)	25.4	25.4	25.4	25.4	25.4
Shell Design Gauge Pressure (Kpa)	1204.21	1967.264	1168.67108	325.64767	242.004413
Shell Design Temperature (C)	125	230	126.586147	125.236	125
Shell Operating Temperature (C)	77.5	200	96.586147	70.346	61.510536
Tube Length Extended (m)	6.096	6.096	6.096	6.096	6.096
Tube Pitch (mm)	31.75	31.75	31.75	31.75	31.75
Number Of Tube Passes	1	1	1	1	1
Number Of Shell Passes	1	1	1	1	1

m (meters), kpa (kilopascal), c (celsius) and mm (millimetres)

Table A3: Parameters for Storage Tank and Preflash Vessel (Preflash with/no Pump around)

	Pre- Flash Column	Storage				
Parameters	V-100	V-102	V-103	V-101	V-104-2	V-104
Liquid Volume (m^3]	11.436982					
Vessel Diameter (m)	1.6764	6.096	5.6388	2.895	5.9436	9.906
Vessel Height (m)	5.1816	2.7432	2.4384	1.2192	2.5908	4.4196
Design Gauge Pressure (Kpa)	1018.67108	103	103	103	243.67108	103
Design Temperature (C)	125	125	140.29485	125	377.19719	212.355555
Operating Temperature (C)	85.621451					

m (Meters), kpa (Kilopascal), c (Celsius) and mm (Millimeters)

Table A4: Parameters for Distillation Column and Strippers (Preflash with Pump around)

Distillation Tower					
Parameters	SS4_@T-100	Main TS_@T-100	SS1_@T-100	SS3_@T-100	SS2_@T-100
Diameter Bottom Section (m)	0.4572	58.9788	0.4572	0.4572	0.4572
Bottom Tangent To Tangent Height (m)	6.2484	31.242	6.2484	6.2484	6.2484
Design Gauge Pressure Bottom [kpa]	243.67108	243.67108	103	103	103
Design Temperature Bottom (C)	377.060834	407.295988	125	210.302439	139.924223
Operating Temperature Bottom (C)	347.060834	377.295988	86.548606	180.302439	109.924223
Number Of Trays Bottom Section	5	46	5	5	5
Bottom Tray Type	Sieve	Sieve	Sieve	Sieve	Sieve
Bottom Tray Spacing (mm)	609.6	609.6	609.6	609.6	609.6

m (Meters), kpa (Kilopascal), c (Celsius) and mm (Millimeters)