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Simulation of the Blends of Different Types of Sudanese Heavy Crude Oil

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ABSTRACT: A detailed simulation of an atmospheric distillation column was performed using Aspen Hysys V.10 software. The model was based on data from the actual plant located in El Obeid refinery in North of Kordofan. Crude oils were described using True Boiling Point (TBP) assays and a Peng-Robinson package was used to predict thermodynamic properties. Three different types of crude oils (Nile Blend, Rawat, Thargath), and 7 blends with different proportions were selected from the previous crudes oil. The simulation results agree well with those of the industrial plant in the case of the Nile blend and the validity of the model is confirmed. The conversion ratio to high-value light products in the Atmospheric distillation tower of the Nile Blend was 31%vol, Rawat was 39.7%vol, Thargath was 24.22%vol, Mix 1 was 30.51%vol, Mix 2 was 26.62%vol, Mix 3 was 31.23%vol, Mix 4 was 28.96%vol, Mix 5 was 30.47%vol, Mix 6 was 27.97%vol and Mix 7 was 27.81%vol. The simulation results show that the blend (66.7%Nile Blend+13.3%Rawat+20%Thargath) will increase product of Off-Gas and Kerosene more than pure Nile Blend, and the blend (60%Nile Blend+20%Rawat+20%Thargath) will increase product of Off-Gas and Light Naphtha more than pure Nile Blend, and The conversion ratio to high-value light products in the Atmospheric distillation tower was converged to Nile Blend in most blends.

KEYWORD: *Heavy crude oil, Simulation, Aspen Hysys, Atmospheric distillation, El Obeid refinery.*

I. INTRODUCTION AND PREVIOUS STUDY

Crude oil composed of thousands of hydrocarbons varying from methane to very high molecular weight components, with varying proportions of paraffins, naphthenes, and aromatics (Juma Haydary and Tomáš Pavlík., 2009). A distillation column is the main unit in a petroleum refinery that is used to fractionate crude oil into desired products (Salah M. Ali et al., 2018).

(Lekan et al., 2012), proposed a model to optimize the atmospheric distillation column of a crude oil. The proposed optimization model is applicable for the change in feed stock, market situations and products prices. (Akba and Umuze., 2013), make steady state MESH model to simulate crude oil distillation column. Their model is capable of predicting the concentrations and temperature of any component on the column trays.

(Sayed et al., 2013), simulate a crude oil distillation unit using nonlinear steady-state model embedded in the Aspen Hysys V.10 to process different crudes blended in specific proportions. (Shankar et al., 2015), simulate of a real crude plant using Aspen Hysys. Experimental and simulated true boiling point for kerosene, light gas oil and atmospheric residue were taken into account in analysis of the crude distillation unit. (Dhallia et al., 2014), used Aspen Hysys to study the effect of trays number, feed tray location and reflux ratio on residue and naphtha yield They observe that the naphtha yield decrease with increasing the trays number and reflux ratio. The naphtha yield also increases and residue yield decrease if the feed stage moved up in the column. The properties of crude oils are varying making achieving the products specifications in distillation unit is difficult. Petroleum refining in the Sudan face several challenges in the last few years, one of these challenges is increase the demand to light fractions while decrease the ratio of exploited light crude oils. Most of previous studies include applying simulation results to optimize operating conditions of atmospheric distillation column. This study is important as it includes simulations and blending the heavy Sudanese crudes, studying its properties and predicting the amount of light products. The purpose of this study is to simulate and create a new blends from heavy Sudanese crudes using Aspen HysysV.10 software and compare the simulation results with real results for distillation for Nile Blend in El Obeid refinery to validate the model.

II. CASE STUDY

The crude oil distillation unit described in this study was originally designed to fractionate 10,000 barrels per day, and the design was modified to accommodate 15,000 barrels per day of Nile Blend. The products obtained are gas, light naphtha, kerosene, atmospheric gas oil and atmospheric residue. The atmospheric distillation column consists of 36 trays with partial condenser, and three side strippers. The drawer numbers are arranged from bottom 1 to top 36. The furnace is used to heat the crude oil to desired temperature (371.1°C), then the crude oil is pumped to the atmospheric distillation column at the tray 4 from bottom. The column operates with pressure 105.5 kPa at top and 310.3 kPa at the bottom and partial condensation at pressure drop 27.58 kPa. The side- strippers which used to separate heavy Naphtha, kerosene and atmospheric gas oil contains 4 trays each. Over flash 3.5% vol. is used in order to reach sufficient fractionation efficiency.

III. PROCESS SIMULATION

Process modelling and simulation enables the designer to explore the process behavior and select the optimum operating conditions to operate the process with maximum products at low cost. Simulation can save a lot of money and time also it was cheaper and much faster than making a series of experiments (Aspen Hysys, 2014). Aspen Hysys is a powerful tool for chemical processes modelling, simulation and optimization. Aspen Hysys can be used for both steady state and dynamic simulation of complex crude oil distillation system (Shankar et al., 2015). The crude oil refineries are complex, non-linear and integrated system. A rigorous distillation model includes solving equilibrium, mass and energy equations to calculate the temperatures, flow rates and compositions within the distillation column. For simulation of atmospheric crude oil distillation unit Aspen Hysys was usually used. The first step after component list selection for a successful simulation is correct choice of the thermodynamic model that will be used in the calculations of the Vapour-liquid properties. The Peng-Robinson equation of state is normally accepted for the compounds in the crude distillation unit. The second step is the characterization of crude oil and input data design and operating conditions. The Oil Characterization property view allows to create, modify, and otherwise manipulate the Assays and Blends for simulation case. When the property view for a new Assay is opened, the property view contains minimal information. Depending on the Assay Data Type, the property view is modified appropriately. For this experimental, the Assay is defined based on TBP data. Then bulk properties data was chosen After that, the distillation curve data (TBP) were inserted, auto blend option was used for cut option, when the output blend is choosing we can click to add and transferred this assay for oil flow information and insert the flowrate to calculate new component (hypothetical components). The Cut Distributions table shows the Fraction of each product in the Blend. Since Liquid Volume is the current Basis in the Table Control group, the products are listed according to liquid volume fraction, these fractions can be used to estimate the products flow rate for the fractionation column. The last step in the oil characterization procedure is to install and rename the oil.

- The petroleum hypocomponents are added to the fluid package.
- The calculated Light Ends and Oil composition are transferred to a material stream for use in the simulation.

By applying the same method, all the properties and proportions were calculated of Rawat, Thargath, and 7 mixtures crudes, these mixtures were made in different proportion of the three previous crudes as follow as table 1:

Table1: showing the contents of blends

Type of crude	Blending proportion
Mix 1	(60%Nile Blend+20%Rawat+20%Thargath)
Mix 2	(40%Nile Blend+20%Rawat+40%Thargath)
Mix 3	(66.7%Nile Blend+13.3%Rawat+20%Thargath)
Mix 4	(20%Nile Blend+20%Rawat+60%Thargath)
Mix 5	(53.33%Nile Blend+13.33%Rawat+33.33%Thargath)
Mix 6	(66.7%Nile Blend+20%Rawat+13.3%Thargath)
Mix 7	(80%Nile Blend+10%Rawat+10%Thargath)

In general, the first task in the Simulation environment is to install one or more feed streams, however, the stream Preheat Crude was already installed during the oil characterization procedure, the preheated crude enters the fractionation column at 371.1°C and 482.6 kPa. for this reason, the first step is to

Create a new Heater on the flow sheet for heating the crude oil because the normal condition for crude temperature 31.5°C and pressure 101.3 kPa. Four steam streams were creating (Bottom steam, Heavy Naphtha steam, Kerosene steam, Atmospheric Gas Oil steam) and energy stream (Trim Duty), An absorption column is constructed on the flow sheet and the previously mentioned basic information has been filled in, Although HYSYS does not usually require estimates to produce a converged column, the good estimates result in a faster solution.

Monitor page was selected to view the Specifications matrix, there are some specifications which are currently Active that we want to use as Estimates only, we make the following final changes to the specifications, we can Activate the over flash and Vapour Production Rate specifications by selecting its Active checkbox, Deactivate the Reflux Ratio and Waste Water Rate specifications. Before any calculation, the side-stripers feed stage location must be specified, beside product flow, specification of the steam flow and parameters, withdraw and return stages, and the number of striper stages are entered.

Figure (1) Show the flow diagram of atmospheric crude oil distillation unit were the atmospheric distillation column is described in detail as shown in figure (2)

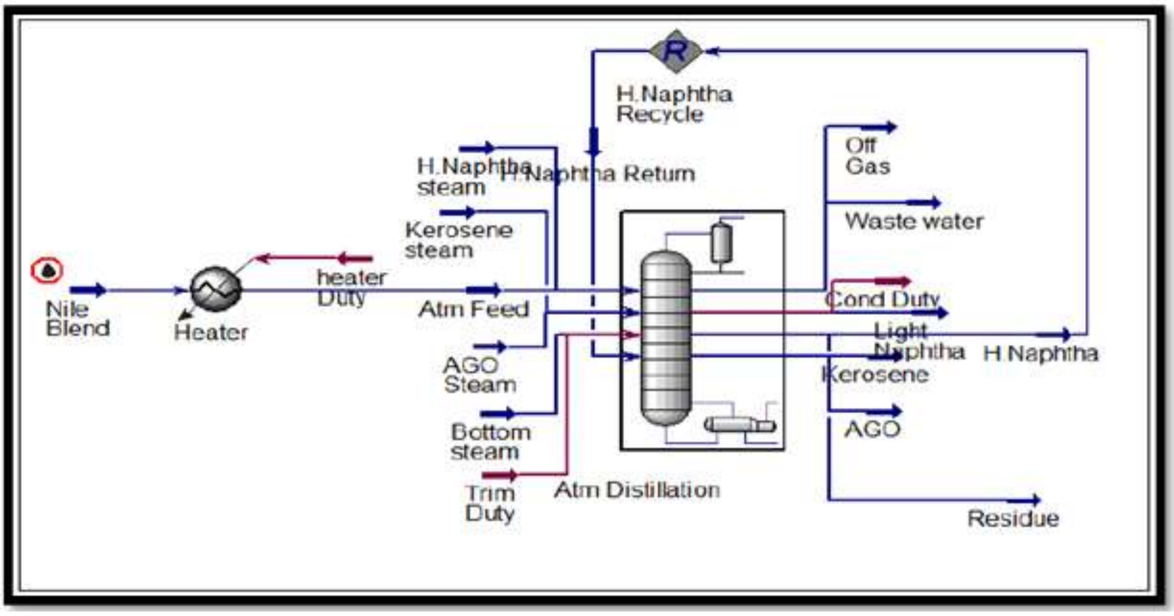

Figure 1: Flow diagram of atmospheric crude oil distillation unit

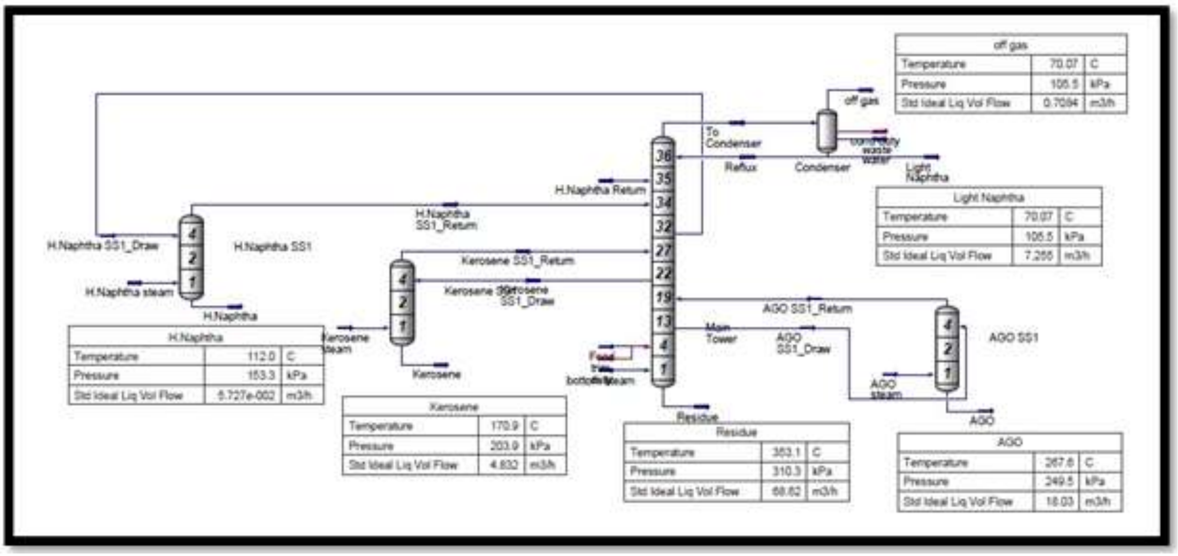

Figure 2: Flow diagram of atmospheric crude oil distillation column

IV. CRUDE OIL PROPERTIES

Crude oils classified as light, Medium, Heavy and extra Heavy depending on API gravity ranges as shown in table (2).

Table.2: Crude oil classification according API

Crude Oil	**API**
Light	30-40
Medium	22-29.9
Heavy	10-21
Extra heavy	Less than 10

API gravity is calculated as:

$$API^{o} = \frac{141.5}{Sp.Gr.} - 131.5 \rightarrow 1$$

For any crude oil analysis, the True Boiling Point (TBP) curve is essential for prediction quantities of petroleum fractions. The true boiling point curve is a plot of the boiling point of the mixture as a function of volume fraction or cumulative weight distilled. Tables (3) represents typical crude oil cut points.
Table (4) showing the TBP assays of main Three Sudanese crudes and blend used in this study.

Table.3: Typical crude oil cut points

Cut	Initial Boiling Point [C°]				End Boiling Point [C°]
	Nile Blend	Rawat	Thargath	Mix	
Off Gas	34.4	33.84		35.45	59
Light Naphtha	59	59	92.99	59	175
Heavy Naphtha	175	175	175	175	180
Kerosene	180	180	180	180	260
Atm Gas Oil	260	260	260	260	380
Residue	380	380	380	380	1014

Table.4: True Boiling Point of the main Sudanese crude oils

Nile Blend		**Rawat**		**Thargath**	
Temperature [C°]	**Volume %**	**Temperature [C°]**	**Volume %**	**Temperature [C°]**	**Volume %**
60	0.70	35	0.6	70	0.19
75	1.29	50	1.3	85	0.3
90	2.31	70	2.2	100	0.46
105	3.16	90	2.7	115	0.65
120	4.14	120	3.7	135	0.92
135	5.09	140	4.5	150	1.16
149	6.20	155	5.6	170	1.64
165	7.42	170	6.3	185	2.08
180	8.45	185	7.2	205	2.74
195	9.85	200	8.6	225	3.66
210	10.63	220	10.3	245	5.21
225	12.98	240	12.4	265	7.33
232	13.91	260	14.7	285	9.79
240	14.68	280	17.5	305	12.59

255	15.44	300	20.4	325	15.62
270	17.77	320	21.8	345	18.74
285	19.47	330	24.6	365	21.82
300	22.91	350	27.7	385	25.00
315	25.24	370	39.4	400	27.50
330	27.59	435	45	415	30.12
345	29.72	450	50.9	430	32.82
360	32.51	470	57.8	445	35.53
369	33.91	500	65	460	38.23
400	34.73	565	100	475	40.94

V. RESULTS AND DISCUSSION

Nile Blend characterization by Liquid volume at ideal condition based on its true boiling points produces 0.7084 m^3/h, 7.255 m^3/h, 4.832 m^3/h, 18.03 m^3/h, and 68.62 m^3/h of off gas, light naphtha, kerosene, AGO and residue, respectively.

Table 5: showed the crude oil Derivatives produce

Crude / products	Blend1 Nile Blend 15000 bbl/Day 99.37 m^3/h	Blend2 Rawat 3000 bbl/Day 19.87 m^3/h	Blend3 Thargath 15000 bbl/Day 99.37 m^3/h	Blend4 Mix1 15000 bbl/Day 99.37 m^3/h	Blend5 Mix2 15000 bbl/Day 99.37 m^3/h	Blend6 Mix3 15000 bbl/Day 99.37 m^3/h	Blend7 Mix4 15000 bbl/Day 99.37 m^3/h	Blend8 Mix5 15000 bbl/Day 99.37 m^3/h	Blend9 Mix6 15000 bbl/Day 99.37 m^3/h	Blend10 Mix7 15000 bbl/Day 99.37 m^3/h
Reflux Ratio	5.609	2.230	22.22	4.453	8.434	5.931	6.923	7.083	5.955	5.159
Light Naphtha	7.255 m^3/h	3.00 m^3/h	1.8 m^3/h	7.867m^3/h	4.751 m^3/h	6.586 m^3/h	4.500 m^3/h	5.465 m^3/h	6.47 m^3/h	6.148 m^3/h
Reflux Rate	44.67 m^3/h	7.422 m^3/h	40.00 m^3/h	38.60 m^3/h	44.68 m^3/h	43.85 m^3/h	37.5 m^3/h	44.00 m^3/h	40.00 m^3/h	38.88 m^3/h
OFF GAS	0.7084 m^3/h	0.3287 m^3/h	0.00 m^3/h	0.8007m^3/h	0.5463 m^3/h	0.8070 m^3/h	0.9169 m^3/h	0.7474 m^3/h	0.2471 m^3/h	1.389 m^3/h
Residue	68.62 m^3/h	12.02 m^3/h	75.33 m^3/h	69.12 m^3/h	72.97 m^3/h	68.40 m^3/h	70.68 m^3/h	69.15 m^3/h	71.61 m^3/h	71.83 m^3/h
Waste Water Rate	0.8833 m^3/h	0.9682m^3/h	0.9827 m^3/h	0.8907m^3/h	0.9515 m^3/h	0.9297m^3/h	0.8931 m^3/h	0.9350 m^3/h	0.9693 m^3/h	0.8872m^3/h
Heavy Naphtha	0.05727m^3/h	0.07462m^3/h	0.09937m^3/h	0.030 m^3/h	0.03829m^3/h	0.0367m^3/h	0.05703m^3/h	0.04242m^3/h	0.02286m^3/h	0.3438m^3/h
Kerosene	4.832 m^3/h	0.585 m^3/h	4.869m^3/h	4.76 m^3/h	5.872 m^3/h	6.916 m^3/h	5.96 m^3/h	7.043 m^3/h	6.00 m^3/h	5.136 m^3/h
Atm Gas Oil	18.03 m^3/h	3.999 m^3/h	17.4 m^3/h	16.92 m^3/h	15.3 m^3/h	16.75 m^3/h	17.44 m^3/h	17.05 m^3/h	15.09 m^3/h	15.00 m^3/h

The following table 5 and Figure 3 showing all streams values.

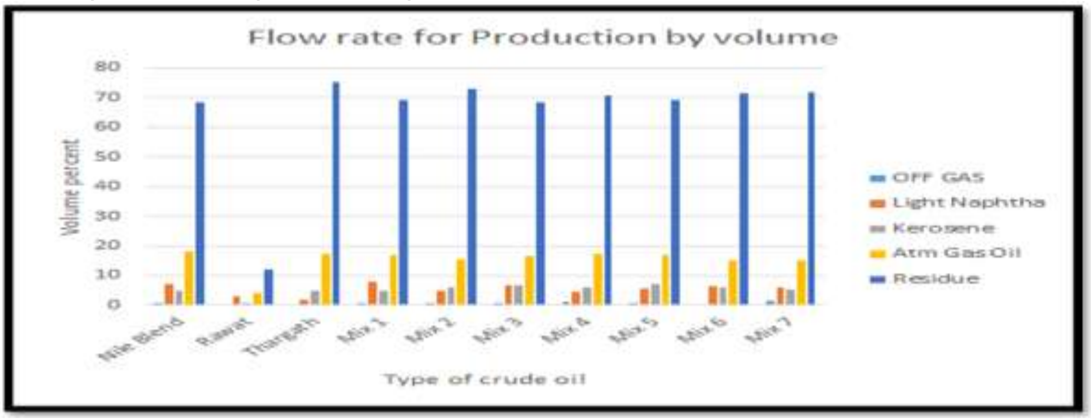

Figure 3: showing the derivatives petroleum of the different crudes

Correlation between type of crudes and values for different products

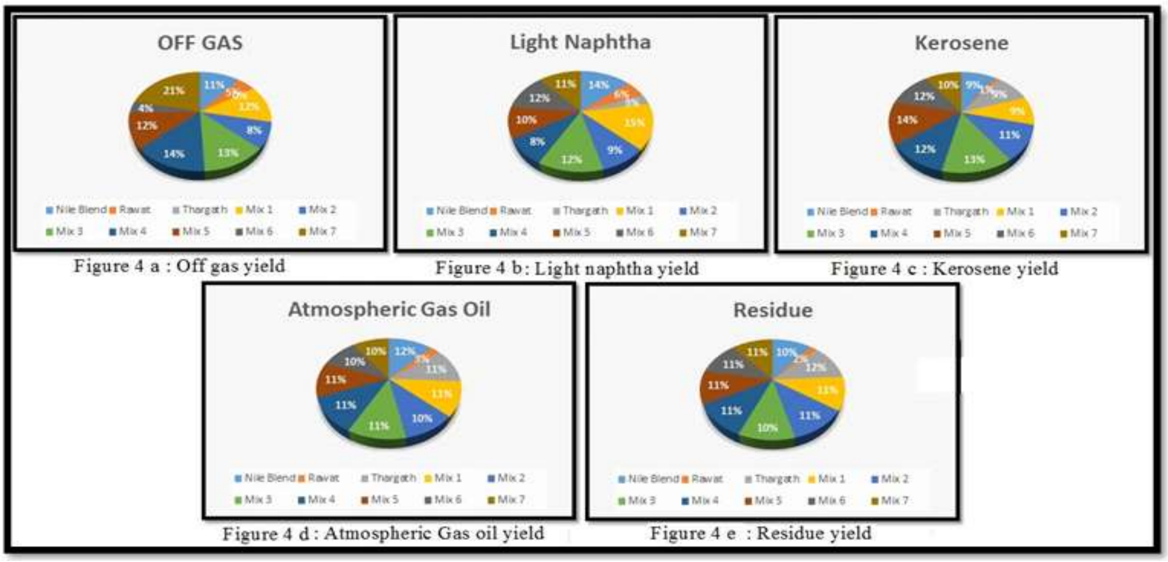

Figure 4 a : Off gas yield

Figure 4 b: Light naphtha yield

Figure 4 c : Kerosene yield

Figure 4 d : Atmospheric Gas oil yield

Figure 4 e : Residue yield

Figure 4: correlation between products and proportion of different crudes

Figure 4 shows correlation between products and proportions of different crudes that under normal distillation conditions as following:

Figure 4a showing off gas yield, Mix 7 crude produce more volume of off gas while Thargath crude give the least, furthermore the converged crudes with the Nile Blend crude for produce off gas are mix 1, mix 3 and mix 5, also figure 4b showing light naphtha yield, Mix 1 crude produce more volume of light naphtha while Thargath crude give the least, the most converged crudes with the Nile Blend crude for produce Light Naphtha are mix 3, mix 6 and mix 7,alsofigure 4c showing kerosene yield, Mix 5 crude produce more volume of Kerosene while Rawat crude give the least, the most converged crudes with the Nile Blend crude for produce Kerosene are Thargath, mix 1 and mix 7.

Figure 4d showing atmospheric gas oil yield, Nile Blend crude produce more volume of Atmospheric gas oil while mix 7 crude give the least, the most converged crudes with the Nile Blend crude for produce Atmospheric gas oil are Thargath, mix 4 and mix 5, and figure 4e showing residue yield, Thargath crude produce more volume of Residue while Rawat crude give the least, the most converged crudes with the Nile Blend crude for produce Residue are mix 1, mix 3 and mix 5.

All previous comparisons were made with the Nile Blend crude.

Steady state simulation

Ten different blends for crude oils were selected to provide the model validity. These crude oils are Nile Blend, Rawat, Thargath, mix1, mix2, mix3, mix4, mix5, mix6 and mix7. The products yield for any crude oil depends on crude characterization and the cut points temperatures. The predicted products volume fractions for (off gas, light naphtha, kerosene, Atmospheric gas oil and residue) agree very well with real results. Figures (5, 6 and 7) showing temperature profile, pressure profile and net molar flow versus tray position from bottom respectively.

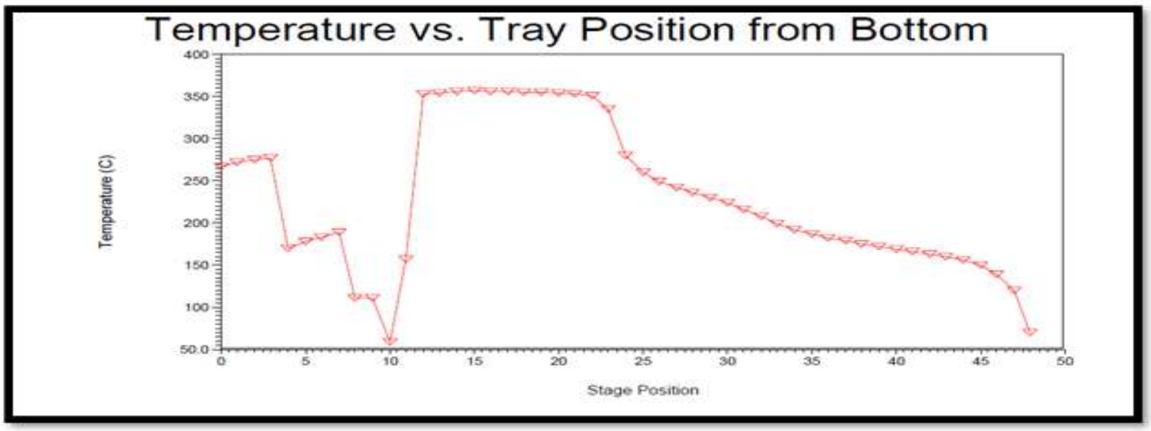

Figure 5: Temperature Profile

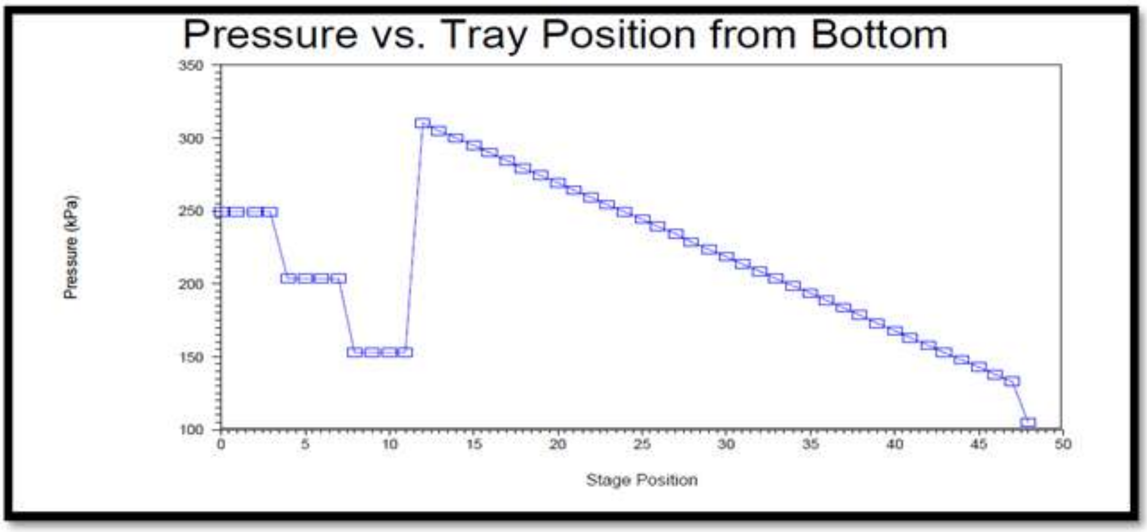

Figure 6: Pressure Profile

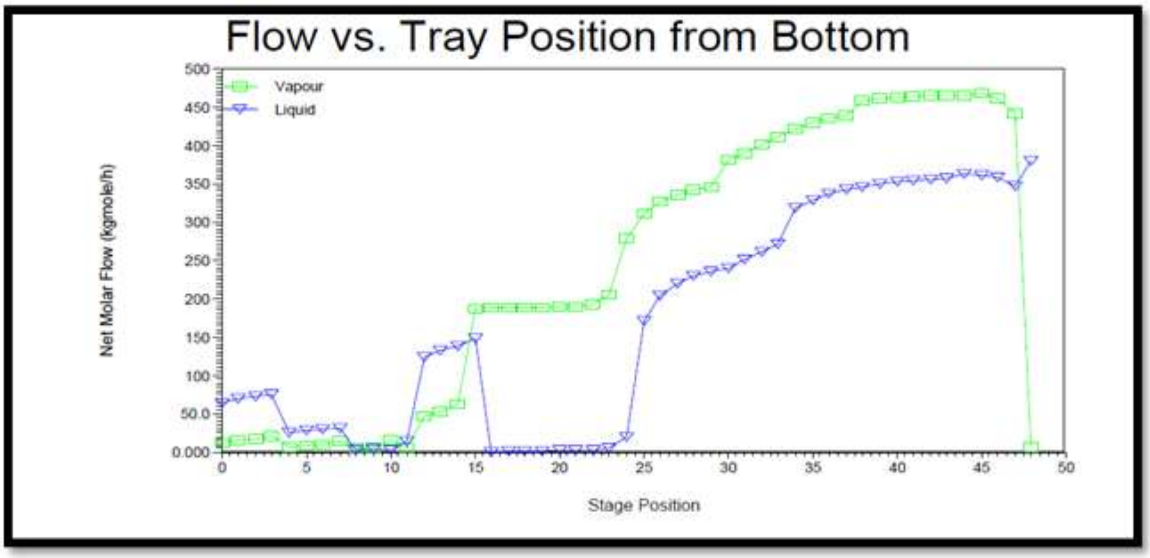

Figure 7: Net flow (Vapour and Liquid) Profile

VI. CONCLUSION

The simulation results agree well with those of the El Obeid Refinery Company in the case of the Nile blend and the validity of the model is confirmed. user could predict the effect of feed variable on the petroleum products quality and quantity. The conversion ratio to high-value light products in the Atmospheric distillation tower of the Nile Blend was 31%vol, Rawat was 39.7%vol, Thargath was 24.22%vol, Mix 1 was 30.51%vol, Mix 2 was 26.62%vol, Mix 3 was 31.23%vol, Mix 4 was 28.96%vol, Mix 5 was 30.47%vol, Mix 6 was 27.97%vol and Mix 7 was 27.81%vol. The simulation results show that the blend (66.7%Nile Blend+13.3%Rawat+20%Thargath) will increase product of off gas and kerosene more than pure Nile Blend, also the blend (53.33%Nile Blend+13.33%Rawat+33.33%Thargath) will increase product of off gas and kerosene more than pure Nile Blend, and the blend (60%Nile Blend+20%Rawat+20%Thargath) will increase product of off gas and light naphtha more than pure Nile Blend, and the conversion ratio to high-value light products in the Atmospheric distillation tower was converged to Nile Blend in most blends.

REFERENCES

[1]. Juma Haydary, Tomáš Pavlík, (2009). "Steady-State and Dynamic Simulation of Crude Oil Distillation Using Aspen Plus and Aspen Dynamics", Institute of Chemical and Environmental Engineering, Faculty of Chemical and Food Technology.

[2]. Salah M. Ali*, Dr. Hareth Sh. Moshref*, Saad K. Ibrahim*, Harith A. Mohammed*, Dr. Zaidoon M. Shakor**, Dr. Shaker Mohmud***(2018),''Studies and Modeling for Upgrading Units for Heavy Oil Refineries", Journal of Petroleum Research & Studies, No.19.

[3]. Lekan T. P., Jamiu A. A., and Solomon O. A., (2012). "Investigations into Optimization Models of Crude Oil Distillation Column in the Context of Feed Stock and Market Value", Advances in Chemical Engineering and Science, 2, pp 474-480.
[4]. Akpa, J. G. and Umuse, O. D., (2013). "Simulation of a Multi-Component Crude Distillation Column", American Journal of Scientific and Industrial Research.
[5]. Sayed F. A., Nooryusmiza Y., Saibal G., Mardhati Z. A., and Khairiyah S., (25 - 27 June 2013). "Profit Maximization of a Crude Distillation Unit", Proceedings of the 6th International Conference on Process Systems Engineering (PSE ASIA), Kuala Lumpur.
[6]. Shankar N., Aneesh V. and Siva Subramanian V, (Aug 2015). "Aspen Hysys based Simulation and Analysis of Crude Distillation Unit", International Journal of Current Engineering and Technology, Vol.5, No.4.
[7]. Dhallia, M. B., Sumaya A. M. and Ali A. R., (2014). "Effect on naphtha and Residue Yield Through Different Operating and Design Variables in Atmospheric Distillation Column", Journal of Petroleum Technology and Alternative Fuels 5(4), pp 31-37
[8]. Aspen-Hysys Software, 2014. Version 8.4. Aspen Tech Inc, USA.