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Design of Environment Friendly Crude Oil Modular Refinery for Two Ends Products using Aspen Hysys Process Simulator

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Abstract

Nigeria is one of the oil-producing countries without adequate domestic refining capacity forcing the country to import petroleum products. The inadequacy and corruption in the importation of petroleum products have continually impacted negatively on Nigeria's economy. Therefore, the study aimed to design crude oil modular refinery that will confine prodigious expense on importation and corruption within the system. The designed modular refinery capacity processes1000 barrels of crude oil per day to produce diesel and kerosene based on the total deregulation of the two products and their high cost overall other petroleum products. Blended crude oil assay data was collected from OML-54, Ogbelle facility, Rivers State, Nigeria. The processing and simulation of crude oil assay data were carried out using the ASPEN HYSYS process simulator. McCabe Thiele method was used to determine the theoretical stages in the distillation column while, Peng Robinson method was used to determine the equation of state. The results of the simulation showed that diesel was produced on tray 10 at a temperature of 197.8ºF/92.1°C with a flow rate of 500 barrels per day while kerosene was produced on tray 5 at a temperature of 150ºF/66°C with a flow rate of 158 barrels per day. The material and energy balance established that total mass inflow and outflow were equal to 1.235e+004 lb/hr (2.723e+004 kg/hr) while the total energy inflow and outflow were equal to 3.503e+007 Btu/hr (3.693e+007 kJ/h). The study, therefore, concluded that the designed modular refinery is environment friendly as the total emission of carbon dioxide from both the inlet and outlet streamflow process is equal to 1.803e+3 which is insignificant when compared with IFPP (2007) and EPA (2009) standards

Keywords: Aspen Hysys simulator; Crude oil; Crude assay; Modular refinery

Abbreviations: NDPR: Niger Delta Petroleum Resources Limited; BPD: Barrel Per Day; EOS: Equation of State; NNPC: Nigerian National Petroleum Corporation; ADU: Atmospheric Distillation Unit

Introduction

According to Mamudu et al. [1], unrefined petroleum refinery is a handling plant that can be utilized to refine raw petroleum into increasingly reasonable items. The refineries owned by Nigerian government (Port Harcourt Phase 1 and 2, Warri and Kaduna) were constructed between 1965 and 1989 with combined refining capacity of 445,000 barrels per day [2,3].

These refineries were utilized to deliver around 89% of complete premium motor spirit consumed in the nation before the importation of this item started in 1997 because of a poor maintenance culture and inability of the Nigerian government to support the modern morals required for establishing new refineries [4,5]. As of June 2020, the corporation's three refineries processed no crude oil and the combined yield efficiency is 0.00% [6].

Since beginning of the importation of oil-based commodities, the average cost for basic items and hardship on average Nigerian residents have increased. Over the year, the Nigerian government has spent billions of dollars for the restoration of her refineries without valuable results [7]. This has resulted in inadequate fuel supply, surprising expense of living, debasement in subsidizing the items, etc. [8,9].

To tackle the above menace, government and private investors agreed to engage in the construction of large scale, medium-scale, and small-scale refineries. This development led to the decision of federal government to give licenses to private refineries with aim of improving daily production and distribution of oil-based commodities. Out of these private refineries only a few revalidated their licenses and Niger Delta Petroleum Resources is the only one functioning up to date [9,10].

The failure of the previous licensed refineries to work, give ways to the recent signing of MOU with intrigued state governments and private investors to set up modular or mini refineries in their areas. As of May 2018, the federal government had licensed to 13 private firms to set up modular or mini refineries [11].

Modular refineries are the refineries with smaller determined yield level and different from regular refineries that can produce different oil based finished products with large output [2,12]. It comes in different capacities varying from 500 to 30,000 barrels for per day [6,12]. The fundamental advantages of setting up modular refineries are to enhance local production of oil-based products, limit outrageous expense of importation removing benefactors, eradication of illegal refineries; assisting private investors with little capital and limit the level of oil-based products pollution [9,13].

The operational detail of any refinery operation differs from one location to another but practically all refineries share two essential procedures for separating petroleum into different components which include atmospheric distillation and cracking [14-16]. These two procedures must be simulated to study the genuine working system of the framework by using process simulation programming software [17,18].

Previous studies revealed the uses of process stimulation programming in designing and planning refineries. Tijani et al. [19] developed software for designing atmospheric distillation column for proposed mini refineries in Nigeria. Nkazi & Ngwanza [20] carried out modelling and simulation of modular refinery for production of fuels with low environmental pollution. Idris et al [21] designed and developed modular crude oil refinery plant with capacity of 15,000 barrels per day (BPD).

Sotelo et al. [16] focused on dynamic simulation of a crude oil distillation plant using Aspen-HYSYS while Mamudu et al [1] carried out process design evaluation of an optimum modular topping refinery for Nigeria crude oil using HYSYS Software. Olugbenga & Arua (2018) based their research on the modification of outlet stream of the atmospheric distillation to improve products from heavy crude oil using Aspen Simulations.

Tsunatu et al [22] developed an optimal strategy for the design and operation of a crude petroleum distillation (topping) unit. However only few of these studies have considered the use of Aspen-HYSYS software in designing crude oil modular refineries for two ends products. The study therefore used Aspen-HYSYS software to forestall changes in the design and development of integrated long-term modular refinery in Nigeria.

Materials and Methodology

Description of the simulation process

The simulation process adopted for the study is Aspen HYSYS software. The software achieved process simulation by carrying out material and energy balances over the processing unit. Aspen HYSYS is an application that provides models for the analysis of the feasibilities of processes. The chosen simulation processes for the study are the McCabe Thiele method and the Peng-Robinson equation of state (EOS). The McCabe Thiele method was used to determine the theoretical stages in the distillation column of x-y diagram, rectifying and stripping section operating line and feed section operating line (q-line).

Meanwhile, the Peng Robinson method was used in the determination of hypothetical components (pseudo-components) which were coded parameters that used to streamline design construction and model fitting. The crude oil feed properties were provided as a crude assay which were the compilation of laboratory test and pilot plant data that defined the specific properties of the crude oil. The crude assay was extensively used in plant operation, development of product schedules, and examination of future processing ventures. As the crude oil feed specified in Aspen HYSYS, it passes through some pre-treatment processes before send to the atmospheric distillation tower.

In this study, the blended crude oil assay data with volume and temperature data were collected from wells 3 and 9 of the OML 54 in Ogbelle field as presented in Table 1 & 2. The OML 54 is located onshore in River's state within the Ogbelle field, and it was discovered in 1981 [23]. Nigerian National Petroleum Corporation [24] has the legal title to old OML 54 through a Farm-out agreement signed with Niger Delta Petroleum Resources Limited (NDPR) in 2000 which granted NDPR an equitable interest in the marginal reservoirs within the Ogbelle field. Ogbelle field development is focused on the production of crude oil and natural gas from the field, and the processing of the natural gas into higher-value products [23].

Table 1: Crude oil assay data.

Parameter	0API Gravity	Specific Gravity (@ 60 0F/16℃)	Reid Vapour Pressure	Salt Content	Sulphur Content
Value	35.6	0.847	4.9	10	0.098

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Table 2: Volume and temperature.

Volume Recovery (%)		IBP	10	20	30	40	50	60	70	80	EBP	Rec 82%	Residue 18%	Losses 1.8%
Temperature	(°C)	48	107	144	189	232	264	288	315	325	325	-	-	-
	(°F)	118	225	291	372	450	507	550	599	617	617	-	-	-

The crude oil was blended to get the best crude feed for the design of the modular refinery and to achieve maximum operating profit. The flexibility of the design is only peculiar to crude feeds whose assay is in the range of the crude assay data for the study.

Development of crude oil feed using ASPEN HYSYS software

The petroleum pseudo-components were defined from the crude assay data. The petroleum pseudo-components are the theoretical components that need to be defined since it is not readily available in the component library. In this study, the development of crude oil feed involved input of crude assay to characterise the crude oil for proper simulation of the modular refinery. The processes involved the selection of light components, selection of equation of state, selection of assay data type, selection of cut option and inputting of the crude properties.

Selection of light components: Set of pure chemical species to represent the light components of the crude oils were selected in the Aspen HYSYS software screen as presented in Figure 1.

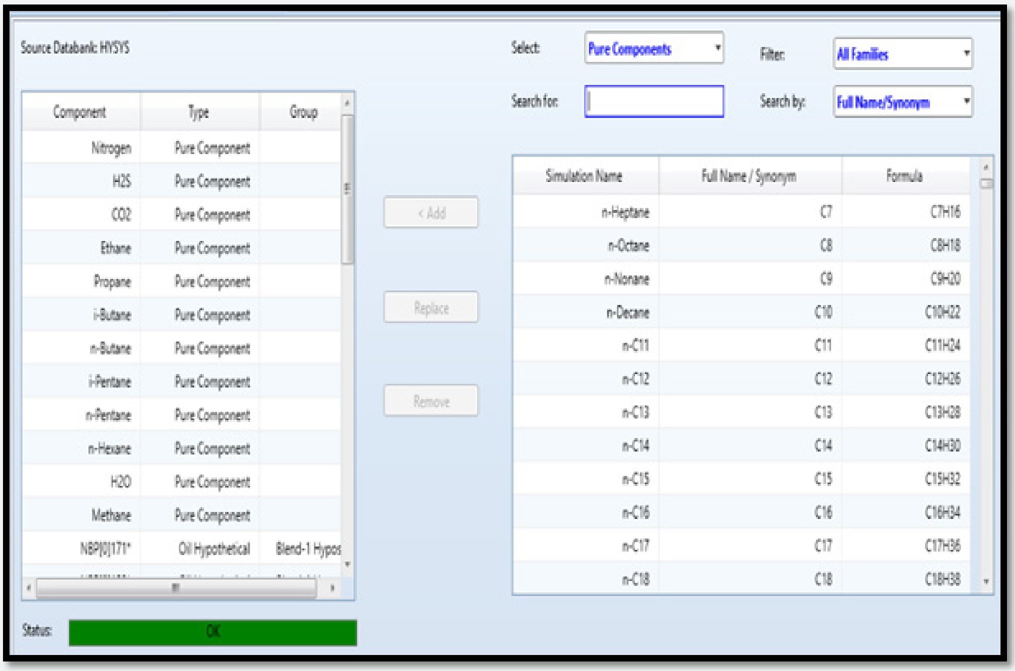

Figure 1: Selection of light components.

Selection of equation of state: To pick a fluid property package, the Peng Robinson option was chosen from the fluid packages screen of the software as presented in Figure 2.

Selection of assay data type and cut option selection (auto blend): The assay data type was selected by using chromatograph option to define the crude oil assay to be used for the simulation while the auto cut option (auto blend) was selected as shown in Figure 3.

Inputting of the crude properties: The bulk properties, light end composition, paraffinic composition, aromatic composition, and naphthenic composition data were input into the software as shown in Figures 4 & 5.

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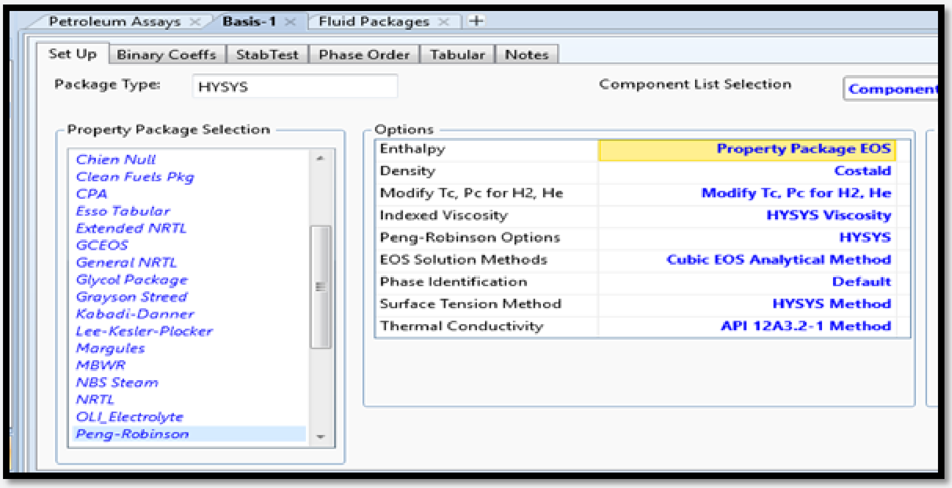

Figure 2: Selection of Peng Robinson equation of state.

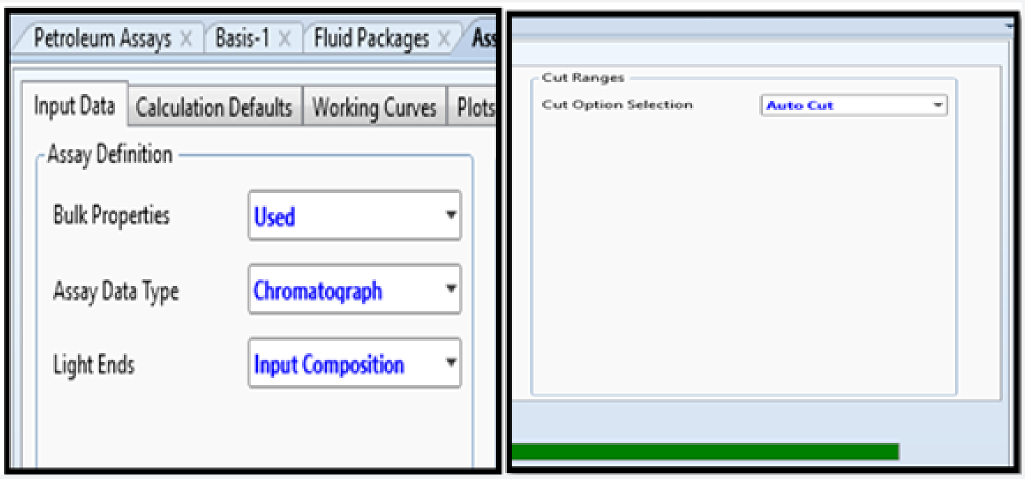

Figure 3: The assay data type and cut option selection (auto blend).

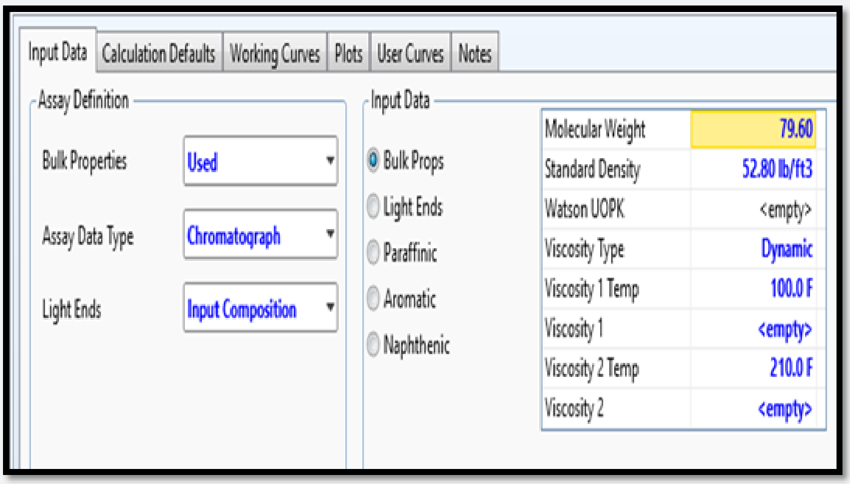

Figure 4: Bulk properties data.

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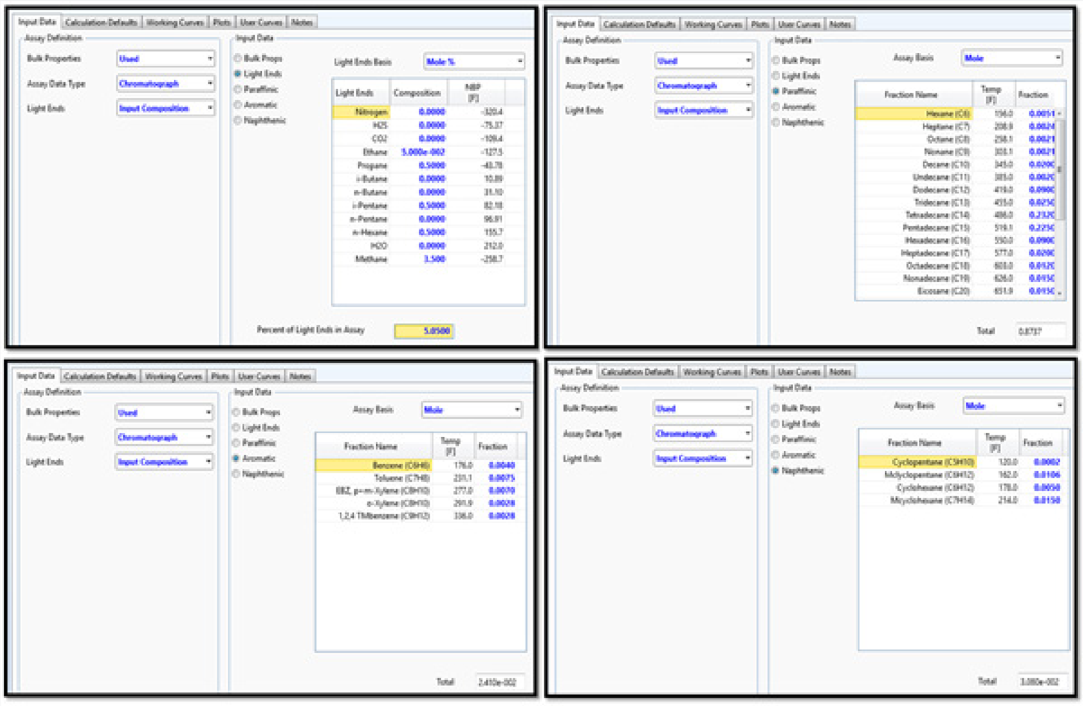
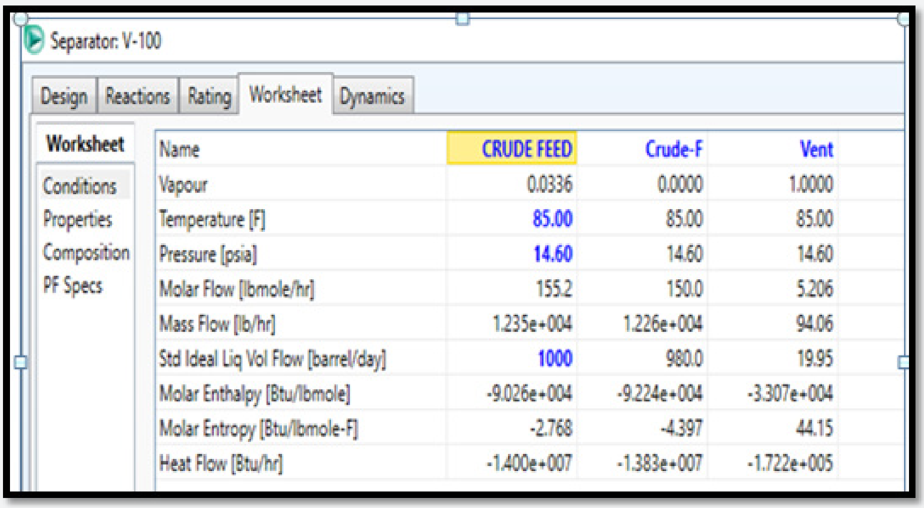


Figure 5: Light ends, paraffinic, aromatic and naphthenic composition.

Design of components of modular refinery using ASPEN HYSYS software

After the assay of the crude oil was completely defined, the data to design each of the components of modular refinery were selected from the software. The components of the modular refinery that were designed are: crude separator, heat exchangers (crude/residue heat exchanger and crude/diesel heat exchanger), crude heater and atmospheric distillation unit (ADU).

Design of crude separator: A crude separator (V-100) is a device used to separate vapour-liquid mixture (crude feed). It works based on the principle of gravity to cause liquid to settle to the bottom of the vessel where it is withdrawn from the liquid outlet as Crude-F. The design of crude separator depends on the type of crude feed. In this study, the major input values of crude feed were the temperature (85ºF/29°C), pressure (14.6psia/0.101 MPa) and the liquid flow (1000 bbl/day) as presented on the worksheet in Figures 6a & 6b.



Name	CRUDE FEED	Crude-F	Vent
Vapour	0.0336	0.0000	1.0000
Temperature [F]	85.00	85.00	85.00
Pressure [psia]	14.60	14.60	14.60
Molar Flow [lbmole/hr]	155.2	150.0	5.206
Mass Flow [lb/hr]	1.235e+004	1.226e+004	94.06
Std Ideal Liq Vol Flow [barrel/day]	1000	980.0	19.95
Molar Enthalpy [Btu/lbmole]	-9.026e+004	-9.224e+004	-3.307e+004
Molar Entropy [Btu/lbmole-F]	-2.768	-4.397	44.15
Heat Flow [Btu/hr]	-1.400e+007	-1.383e+007	-1.722e+005

Figure 6a: Worksheet and crude separator.

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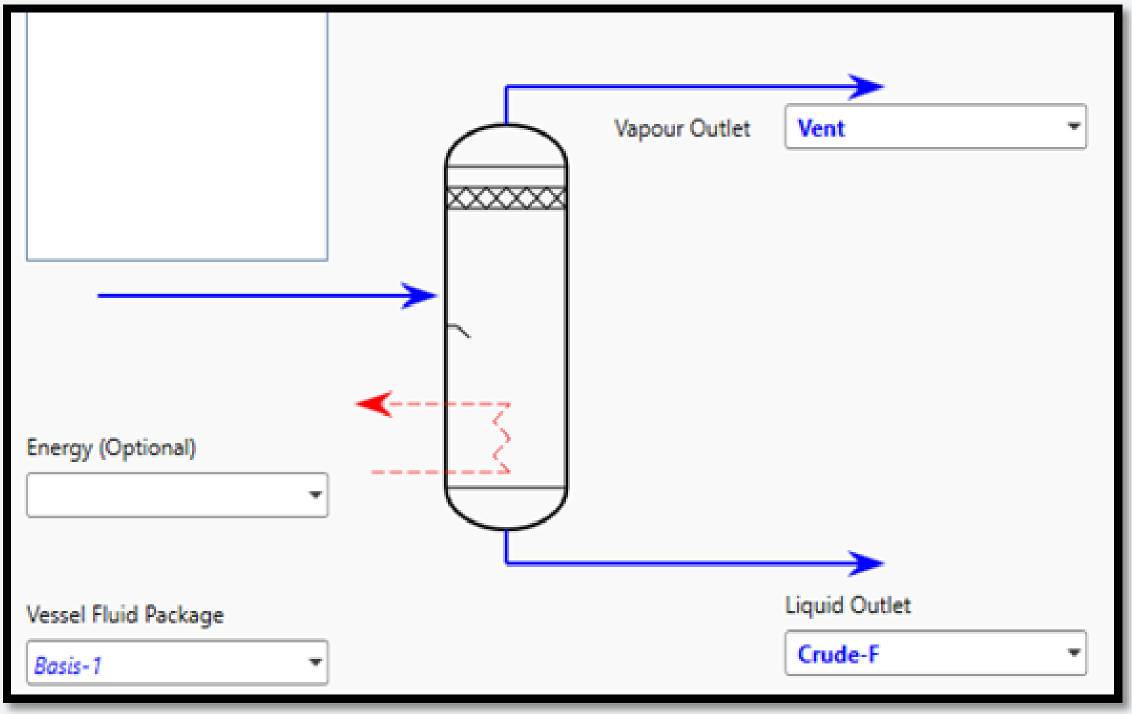

Figure 6b: Design of the crude separator.

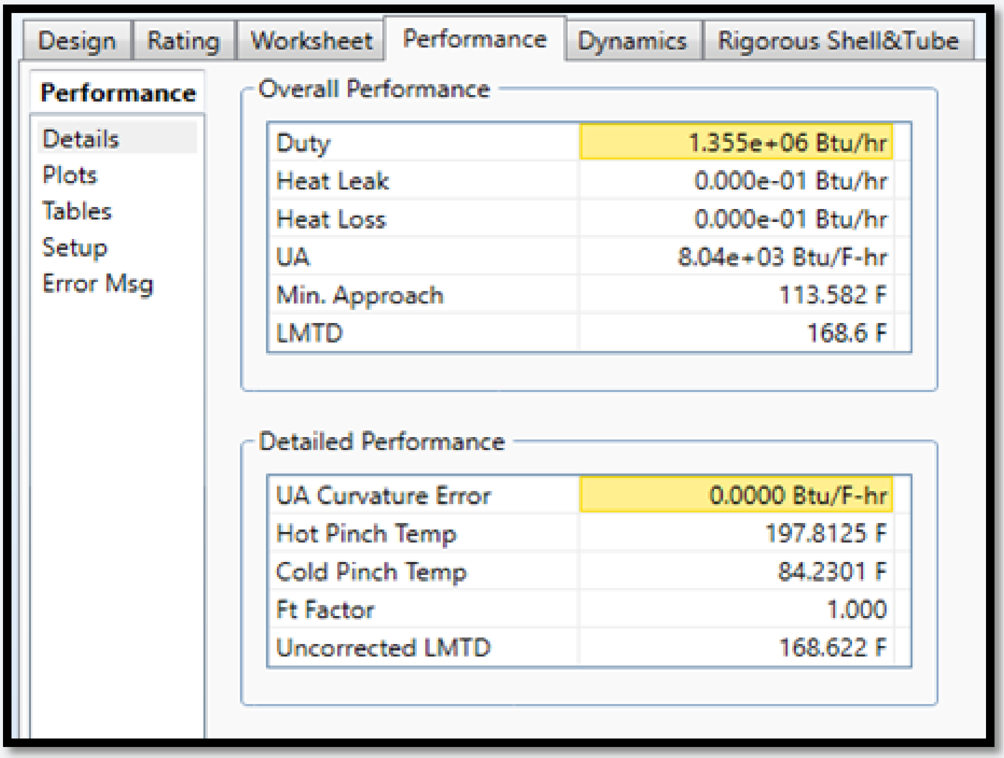

Figure 7a: Performance of the crude/diesel heat exchanger.

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Designing of crude/diesel and crude/residue heat exchanger: The heat exchanger (crude/diesel or crude/residue) is a shell and tube type. It consists of a large pressure vessel with a bundle of tubes inside. One fluid runs through the tubes (P-diesel or P-residue) and another fluid (crude-F1 or crude-Sx) flows over the tubes (through the shell) to transfer heat between the two fluids. The fluids are of different temperatures and heat is transferred from one fluid to the other fluid through the tube walls. In this study, the crude/diesel heat exchanger was designed by inputting the desired duty of 1.355e+06 Btu/hr while crude/residue heat exchanger was designed by inputting the desired duty (3.309e+05 Btu/hr) as represented in Figures 7a & 7b and Figures 8 a & 8b.

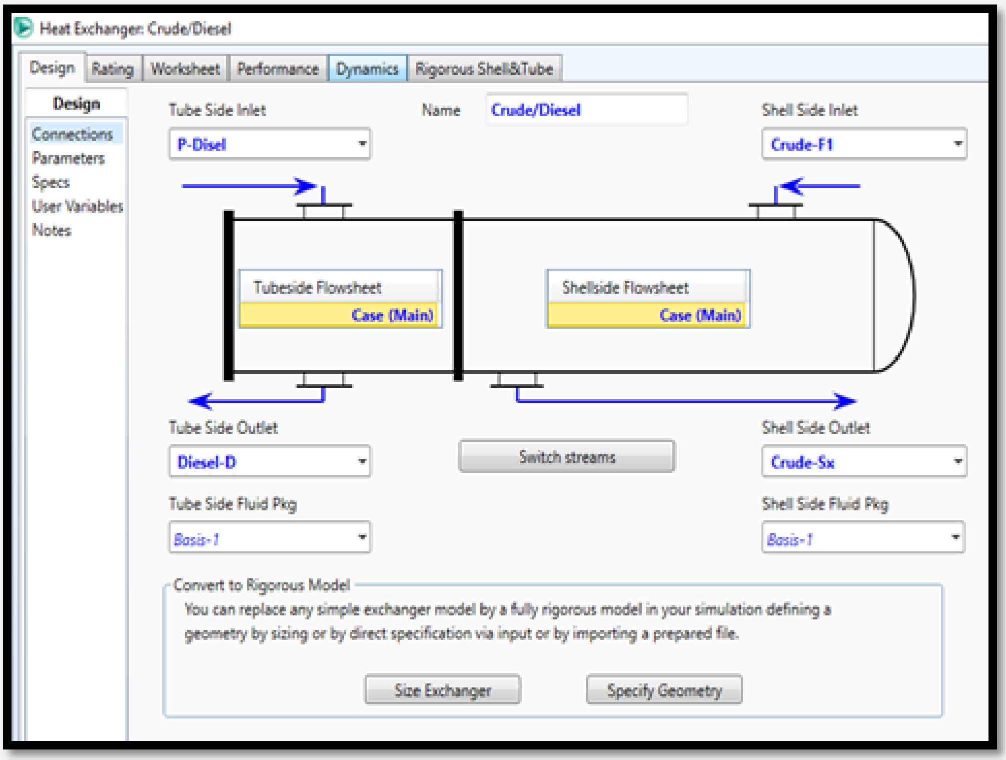

Figure 7b: Design of crude/diesel heat exchanger.

Design of crude heater: The crude heater (E-100) is equipment used to provide heat for crude oil. The fuel gas flows into the burner and is burnt with air provided by an air blower, the flames heat up the tubes which in turn heats the tube inside in the first part of the heater known as the radiant section. In this chamber where combustion takes place, the heat is transferred by radiation to tubes around the fire in the chamber. In this study, the design of crude heater was carried out by setting temperature at 550ºF/288°C and pressure 16.91psia/0.117MPa as shown in Figures 9a & 9b.

Design and installation of atmospheric distillation unit: The atmospheric distillation unit is equipment that allows the separation of crude oil into different fractions depending on the difference in volatility. In this study, the designed and installation of atmospheric distillation unit was carried out by setting up the basic pressure profile in the column, the condenser temperature, the distillate rate, the basic information for the side strippers, the basic information for the pump-around. The basic pressure profile in the column and the condenser temperature were set as presented in Figure 10. The condenser temperature for atmospheric crude tower was set at 276.6°**F**/138°C and 789°F/421°C for the top and bottom stages respectively. The basic information for the three side strippers and draw stages were input as shown in Figures 11a & 11b. Consequently, the basic information for each pump-around was added as presented in Figures 12a & 12b while the worksheet and ADU design were presented in Figures 13a & 13b.

Result and Discussion

Process flow description

Figure 1 presents the flow scheme of the crude oil processing simulated on Aspen HYSYS. The simulation results show that the crude feed entered the flash separator (V-100) at a temperature of 85ºF/29°C and a pressure of 14.6psia/0.101MPa, the flash separator flashed off the light ends and sent the crude out as Crude F, the light ends went out through the vent in the flash separator. Crude F was then pumped using pump (P-100), the pressure of the crude (Crude F1) increased to 150psia/1.034MPa then went into the crude/diesel heat exchanger to gain heat.

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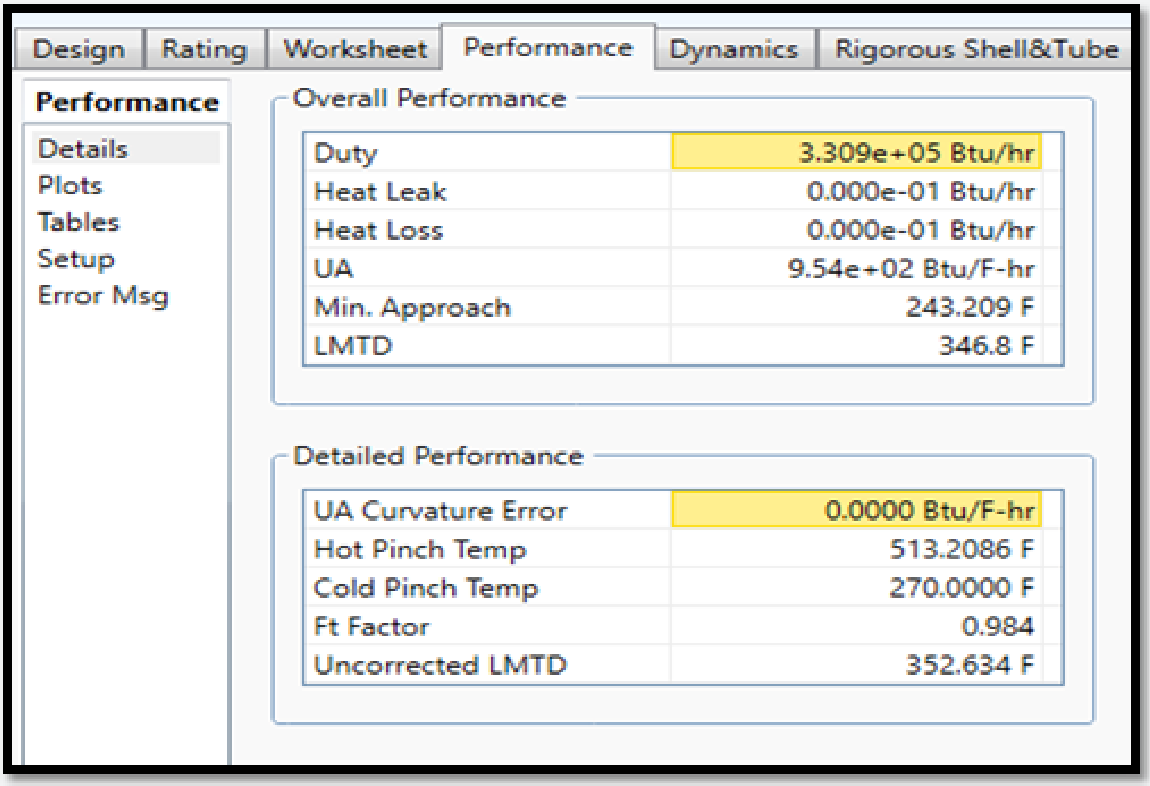

Figure 8a: Performance of the crude/residue heat exchanger.

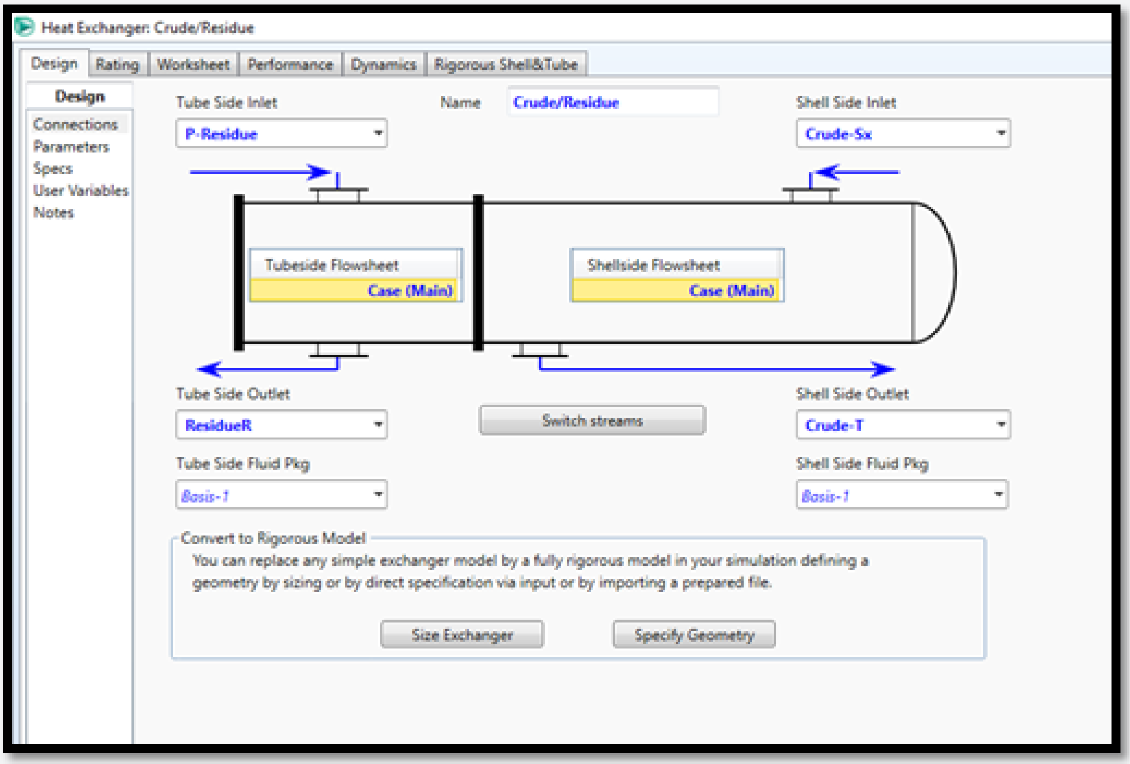

Figure 8b: Design of crude/residue heat exchanger.

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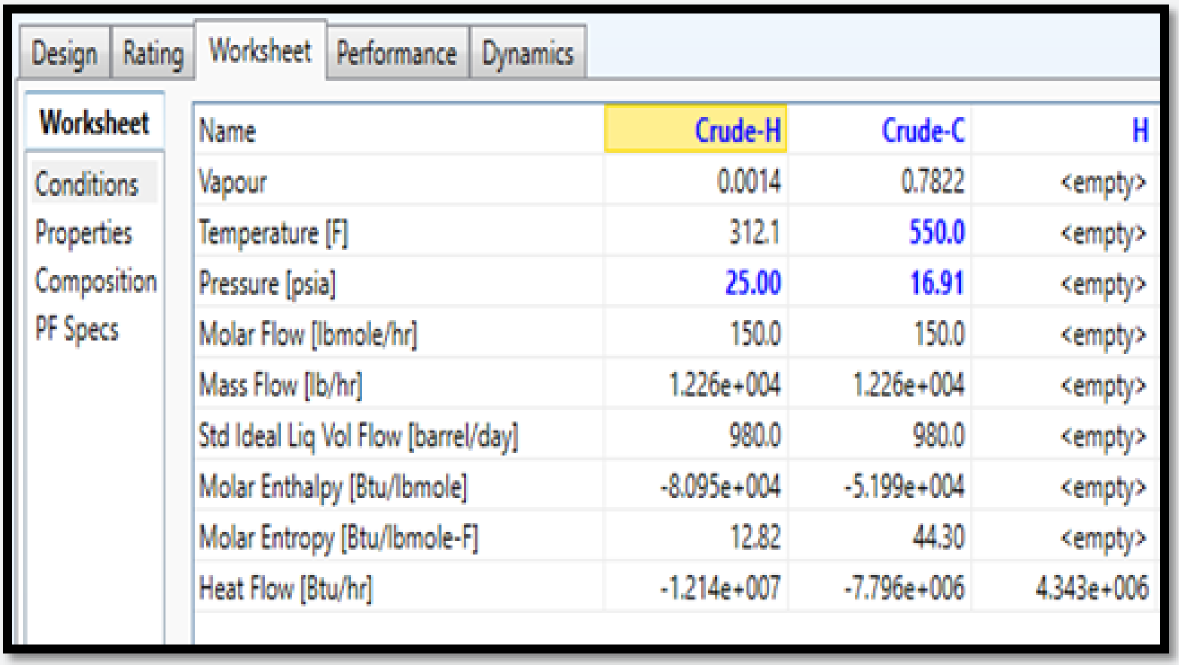

Figure 9a: Worksheet and design of crude heater.

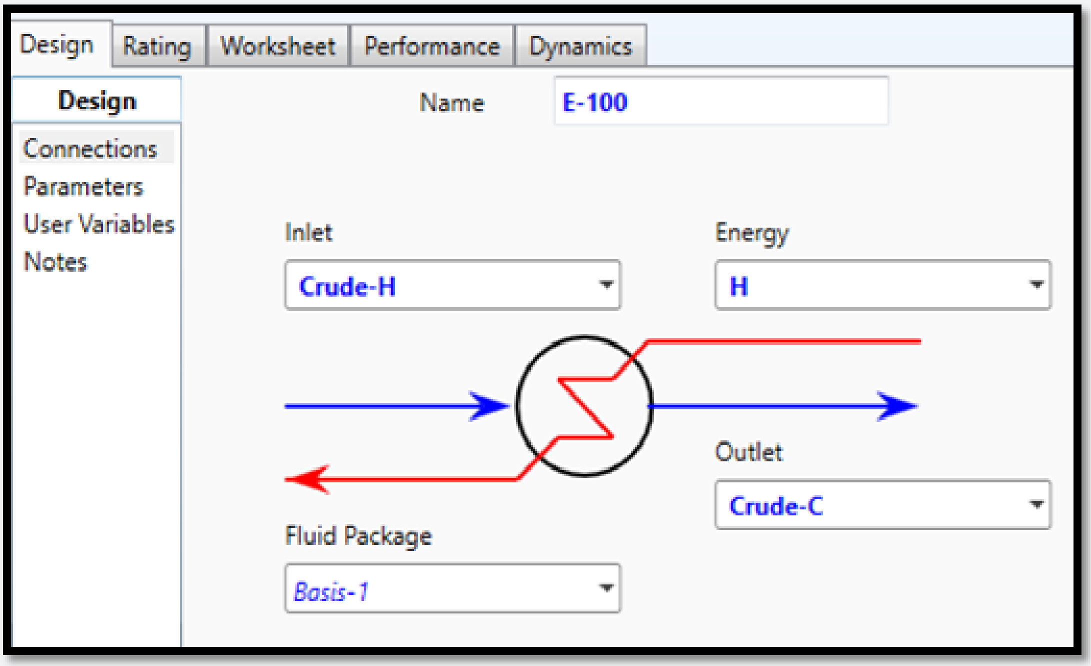

Figure 9b: Worksheet and design of crude heater.

The temperature increased to 270ºF/132°C and left the crude/diesel heat exchanger as Crude Sx, it entered the crude/residue exchanger to further gain heat. The temperature rose from 270ºF/132°C to 311ºF/155°C and left the heat exchanger as Crude T, crude T passed through a pressure valve (VLV 100) where its pressure was reduced to 25psia/0.172MPa, to ensure that the crude oil enters the crude heater at a pressure close to the atmospheric pressure. Crude H entered the crude heater (E-100) and was heated to a temperature of 550ºF/288°C.

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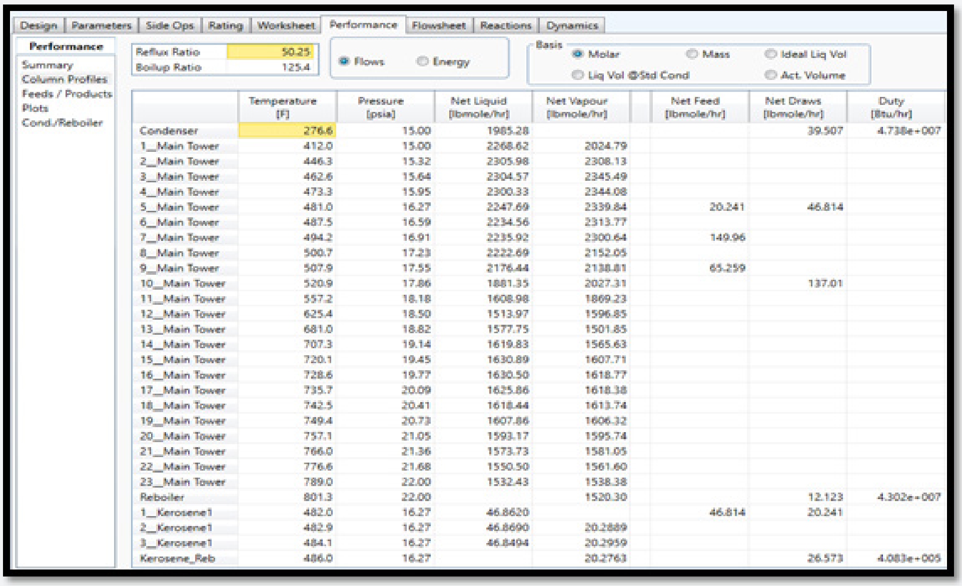
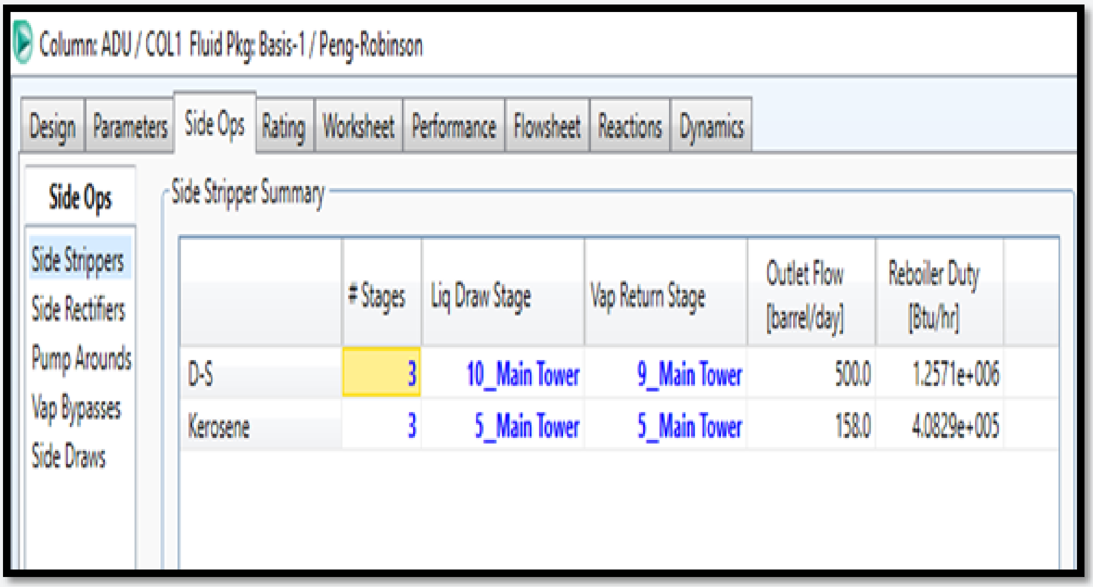


	Temperature [F]	Pressure [psia]	Net Liquid [lbmole/hr]	Net Vapour [lbmole/hr]	Net Feed [lbmole/hr]	Net Draws [lbmole/hr]	Duty [Btu/hr]
Condenser	276.6	15.00	1985.28			39.507	4.738e+007
1__Main Tower	412.0	15.00	2268.62	2024.79			
2__Main Tower	446.3	15.32	2305.98	2308.13			
3__Main Tower	462.6	15.64	2304.57	2345.49			
4__Main Tower	473.3	15.95	2300.33	2344.08			
5__Main Tower	481.0	16.27	2247.69	2339.84	20.241	46.814	
6__Main Tower	487.5	16.59	2234.56	2313.77			
7__Main Tower	494.2	16.91	2235.92	2300.64	149.96		
8__Main Tower	500.7	17.23	2222.69	2152.05			
9__Main Tower	507.9	17.55	2176.44	2138.81	65.259		
10__Main Tower	520.9	17.86	1881.35	2027.31		137.01	
11__Main Tower	557.2	18.18	1608.98	1869.23			
12__Main Tower	625.4	18.50	1513.97	1596.85			
13__Main Tower	681.0	18.82	1577.75	1501.85			
14__Main Tower	707.3	19.14	1619.83	1565.63			
15__Main Tower	720.1	19.45	1630.89	1607.71			
16__Main Tower	728.6	19.77	1630.50	1618.77			
17__Main Tower	735.7	20.09	1625.86	1618.38			
18__Main Tower	742.5	20.41	1618.44	1613.74			
19__Main Tower	749.4	20.73	1607.86	1606.32			
20__Main Tower	757.1	21.05	1593.17	1595.74			
21__Main Tower	766.0	21.36	1573.73	1581.05			
22__Main Tower	776.6	21.68	1550.50	1561.60			
23__Main Tower	789.0	22.00	1532.43	1538.38			
Reboiler	801.3	22.00		1520.30		12.123	4.302e+007
1__Kerosene1	482.0	16.27	46.8620		46.814	20.241	
2__Kerosene1	482.9	16.27	46.8690	20.2889			
3__Kerosene1	484.1	16.27	46.8494	20.2959			
Kerosene_Reb	486.0	16.27		20.2763		26.573	4.083e+005

Figure 10: Basic pressure profile in the column.



	# Stages	Liq Draw Stage	Vap Return Stage	Outlet Flow [barrel/day]	Reboiler Duty [Btu/hr]
D-S	3	10_Main Tower	9_Main Tower	500.0	1.2571e+006
Kerosene	3	5_Main Tower	5_Main Tower	158.0	4.0829e+005

Figure 11a: Side strippers.

The crude oil (Crude C) was sent out of the crude heater (E-100) and sent into the atmospheric distillation column (ADU) where separation by fractional distillation took place. Different streams were obtained from the atmospheric distillation unit (ADU) which includes the gas-out, naphtha, diesel, kerosene, and residue. The gas-out and naphtha were left at a temperature of 276.6ºF/135.9°C, the diesel at a temperature of 508.9ºF/264.9°C, the kerosene at a temperature of 486ºF/252°C and the residue at a temperature of 801.3ºF/427.4°C.

The naphtha, gas-out and water were passed through pressure valves (VLV-Naphtha, VLV-Gas-Out and VLV-Water) for pressure reduction. The diesel was collected at tray 10 and sent into the crude/diesel exchanger to reduce the temperature from 508.9ºF/264.9°C to 197.8ºF/92.1°C while the kerosene was collected at tray 5 and passed through a pressure valve (VLV-Kerosene) to reduce pressure to 11.27psia/0.078MPa before sent into the cooler (E-101) for the temperature to reduce from 486ºF/252°C to 150ºF/66°C as shown in Figure 14.

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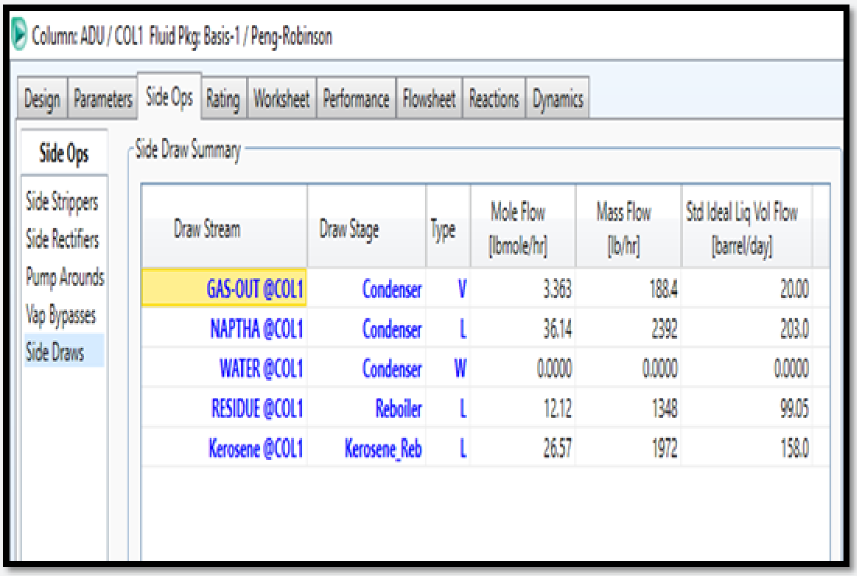


Column: ADU / COL1 Fluid Pkg: Basis-1 / Peng-Robinson

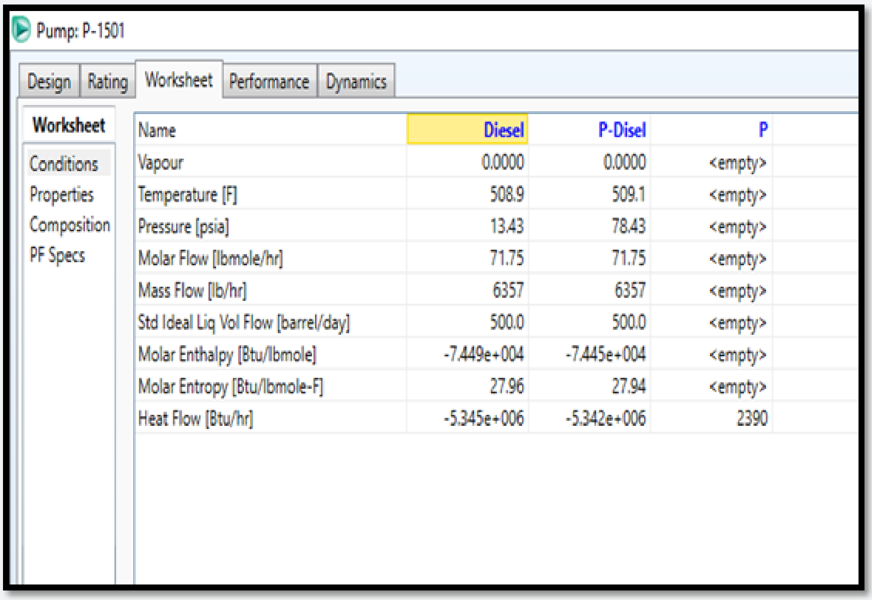
Design | Parameters | Side Ops | Rating | Worksheet | Performance | Flowsheet | Reactions | Dynamics

Side Ops: Side Strippers, Side Rectifiers, Pump Arounds, Vap Bypasses, Side Draws

Side Draw Summary

Draw Stream	Draw Stage	Type	Mole Flow [lbmole/hr]	Mass Flow [lb/hr]	Std Ideal Liq Vol Flow [barrel/day]
GAS-OUT @COL1	Condenser	V	3.363	188.4	20.00
NAPTHA @COL1	Condenser	L	36.14	2392	203.0
WATER @COL1	Condenser	W	0.0000	0.0000	0.0000
RESIDUE @COL1	Reboiler	L	12.12	1348	99.05
Kerosene @COL1	Kerosene_Reb	L	26.57	1972	158.0

Figure 11b: Side draw stages.



Pump: P-1501

Design | Rating | Worksheet | Performance | Dynamics

Worksheet: Conditions, Properties, Composition, PF Specs

Name	Diesel	P-Disel	P
Vapour	0.0000	0.0000	<empty>
Temperature [F]	508.9	509.1	<empty>
Pressure [psia]	13.43	78.43	<empty>
Molar Flow [lbmole/hr]	71.75	71.75	<empty>
Mass Flow [lb/hr]	6357	6357	<empty>
Std Ideal Liq Vol Flow [barrel/day]	500.0	500.0	<empty>
Molar Enthalpy [Btu/lbmole]	-7.449e+004	-7.445e+004	<empty>
Molar Entropy [Btu/lbmole-F]	27.96	27.94	<empty>
Heat Flow [Btu/hr]	-5.345e+006	-5.342e+006	2390

Figure 12a: Worksheet of the pump.

Material balance

The process simulation was able to achieve material balance in the entire system as presented in Table 3. At the inlet stage, the total mass (crude feed) entering the system was 1.235e+004 lb/hr (1.145e+003 bbl/d). Meanwhile, after processing of the crude, the total mass coming out of the system from the vent outlet was 94.06 lb/hr (8.71 bbl/d), from the diesel outlet was 6357 lb/hr (588.75 bbl/d), from the residue outlet was 1348 lb/hr (124.84 bbl/d), from the gas-out outlet was 188.4 lb/hr (17.5 bbl/d), from the water outlet was 0.00 lb/hr (0.00 bbl/d), from the naphtha outlet was 2391 lb/hr (221.53 bl/d), from the kerosene outlet was 1972 lb/hr (182.63 bbl/d).

Energy balance

The process simulation was able to achieve energy balance in the entire system as shown in Table 4. At the inlet, there were various energy inputs such as crude feed, P-F, H, RB, D-S energy, Kerosene energy, P, and P2 that summed up to 3.503e+007 Btu/hr (3.693e+007 kJ/h). At the outlet, the various energy outlets such as: vent; diesel-D; residue-R; CD; gas-out-1; water-1; naptha-1; kerosene-2 and D also summed up to 3.503e+007 Btu/hr (3.693e+007 kJ/h).

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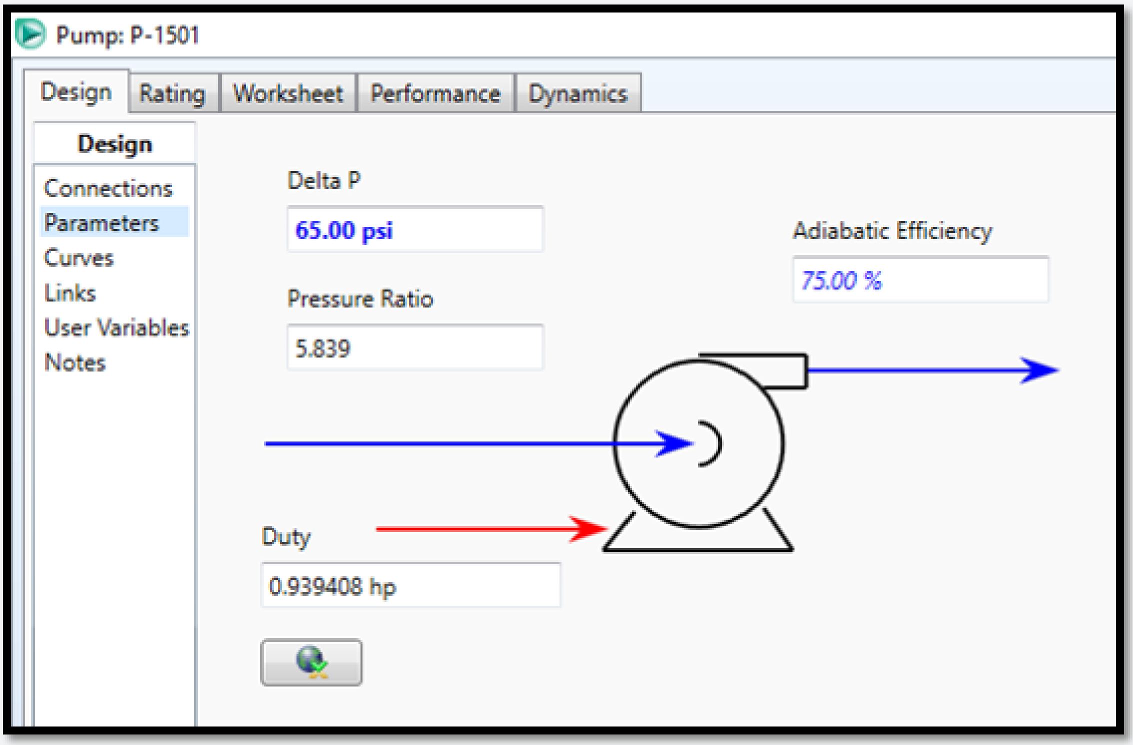
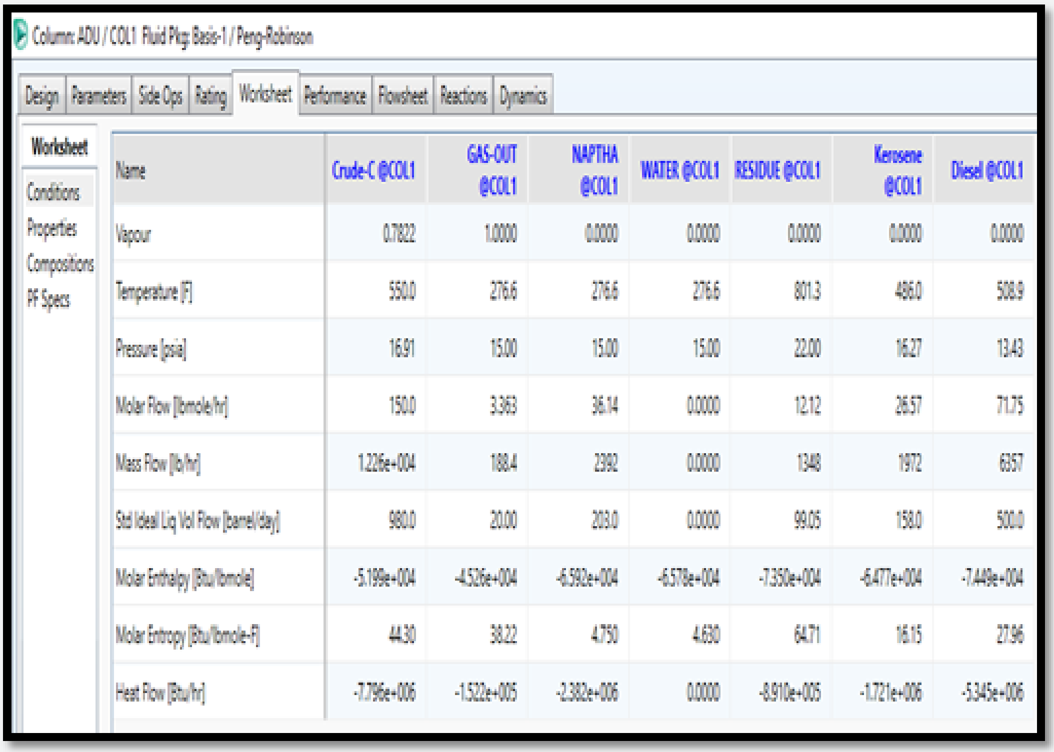


Figure 12b: Design of the pump.



Name	Crude-C @COL1	GAS-OUT @COL1	NAPTHA @COL1	WATER @COL1	RESIDUE @COL1	Kerosene @COL1	Diesel @COL1
Vapour	0.7822	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Temperature [F]	550.0	276.6	276.6	276.6	801.3	486.0	508.9
Pressure [psia]	16.91	15.00	15.00	15.00	22.00	16.27	13.43
Molar Flow [lbmole/hr]	150.0	3.363	36.14	0.0000	12.12	26.57	71.75
Mass Flow [lb/hr]	1.226e+004	188.4	2392	0.0000	1348	1972	6357
Std Ideal Liq Vol Flow [barrel/day]	980.0	20.00	203.0	0.0000	99.05	158.0	500.0
Molar Enthalpy [Btu/lbmole]	-5.199e+004	-4.526e+004	-6.592e+004	-6.578e+004	-7.350e+004	-6.477e+004	-7.449e+004
Molar Entropy [Btu/lbmole-F]	44.30	38.22	4.750	4.630	64.71	16.15	27.96
Heat Flow [Btu/hr]	-7.796e+006	-1.522e+005	-2.382e+006	0.0000	-8.910e+005	-1.721e+006	-5.345e+006

Figure 13a: Worksheet of the ADU.

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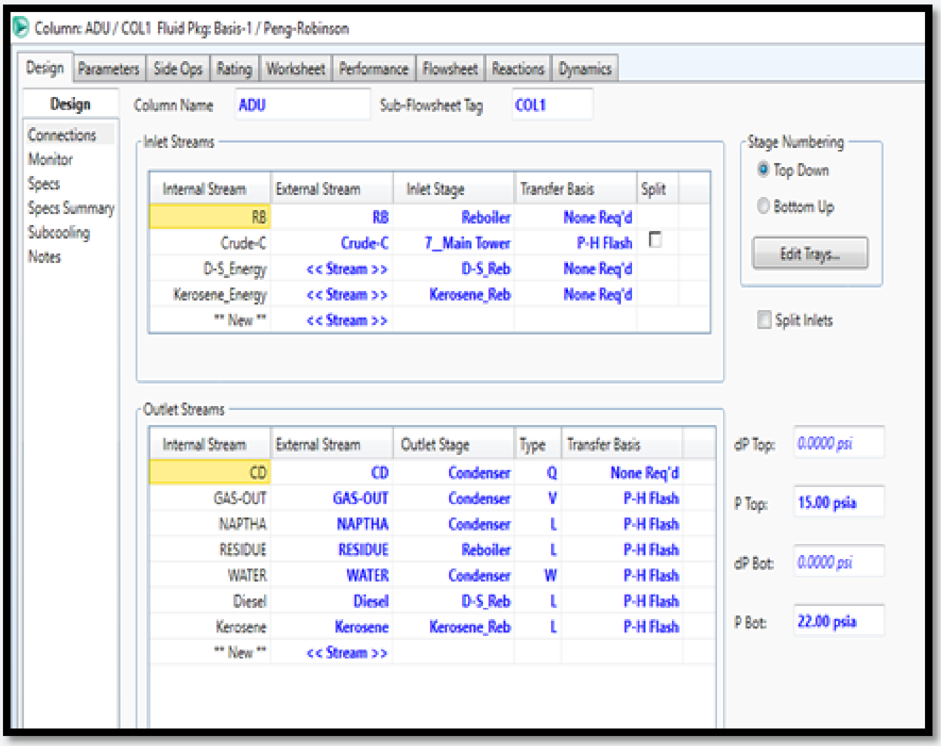

Figure 13b: Design of the ADU.

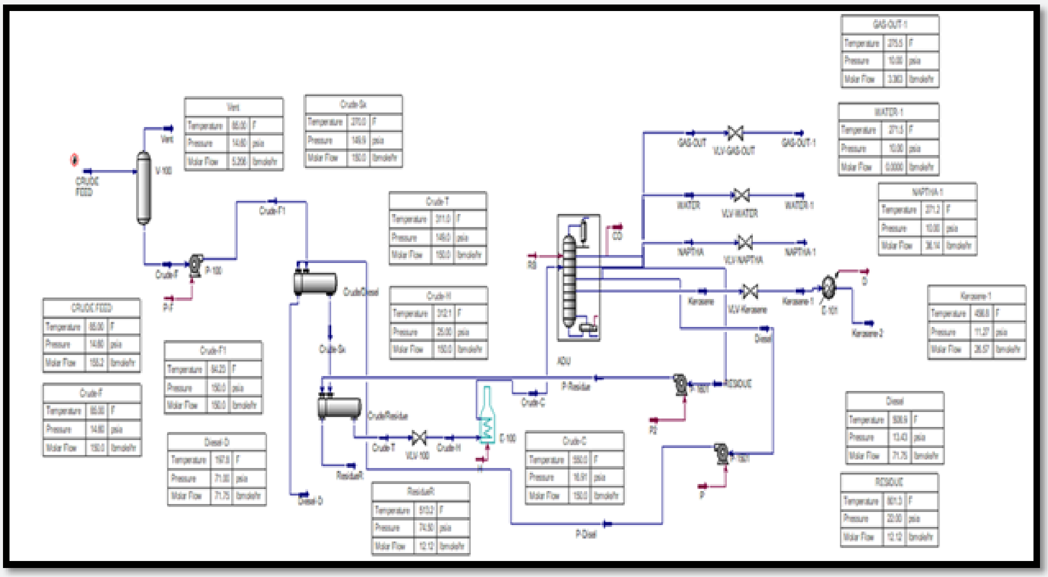

Figure 14: Process flow diagram showing temperature, pressure, and molar flow.

Process Co_2 emissons

The total carbon feed from inlets and outlets (lb/hr) is 0.0e-1 as shown in Tables 5 & 6 respectively. As a result of this, it is established that the effect of CO_2 on the environment is infinitesimal.

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Table 3: Overall mass balance.

In Stream	Mass Flow (lb/hr)	Out Stream	Mass Flow (lb/hr)
Crude feed	1.24E+07	Vent	94.06
		Diesel-D	6357
		Residue-R	1348
		GAS-OUT-1	188.4
		WATER-1	0
		NAPTHA-1	2391
		Kerosene-2	1972
Total In Mass Flow (lb/hr) 1.235e+004		Total Out Mass Flow (lb/hr) 1.235e+004	
Mass Imbalance (lb/hr) 7.402e-11		Relative Mass Imbalance Pct. (%) 0.00	

Table 4: Overall energy balance.

In Stream	Energy Flow (Btu/hr)	Out Stream	Energy Flow (Btu/hr)
CRUDE FEED	-1.40E+10	Vent	-1.72E+05
P-F	7.78E+03	Diesel-D	-6.70E+06
H	4.34E+06	Residue-R	-1.22E+06
RB	4.30E+07	CD	4.74E+07
D-S Energy	1.26E+06	GAS-OUT-1	-1.52E+05
Kerosene Energy	4.08E+05	WATER-1	0.00E+00
P	2.39E+03	NAPTHA-1	-2.38E+06
P2	4.90E+02	Kerosene-2	-2.18E+06
		D	4.55E+05
Total In Energy Flow (Btu/hr) 3.503e+007		Total Out Energy Flow (Btu/hr) 3.503e+007	
Energy Imbalance (Btu/hr) 628.7		Relative Energy Imbalance Pct (%) 0.00	

Table 5: Process CO_2 emissions inlet stream.

Inlet Stream	IFPP (1995) (lb/hr)	IFPP (2007) (lb/hr)	EPA (2009) (lb/hr)
Crude Feed	1.80E+03	2.18E+03	1.80E+03
Total from inlets	1.80E+03	2.18E+03	1.80E+03
Total carbon fees from inlets (cost/hr)	0.00E+00	0.00E+00	0.00E+00

Table 6: Process CO_2 emissions outlet stream.

Outlet Stream	IFPP (1995) (lb/hr)	IFPP (2007) (lb/hr)	EPA (2009) (lb/hr)
Vent	1.64E+03	1.95E+03	1.64E+03
Diesel-D	2.01E-18	2.39E-18	2.01E-18
Residue-R	4.08E-27	4.86E-27	4.08E-27
Gas-out-1	1.83E+02	2.18E+02	1.83E+02
Water-1	0.00E+00	0.00E+00	0.00E+00
Naphtha-1	6.25E+00	7.44E+00	6.25E+00
Kerosene-2	2.80E-11	3.34E-11	2.80E-11
Total from outlets	1.83E+03	2.18E+03	1.83E+03
Total carbon fees from outlets (cost/hr)	0.00E+00	0.00E+00	0.00E+00

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Conclusion

The design of crude oil modular refinery using ASPEN HYSYS process simulator has been carried out where material balance and energy balance throughout the system were achieved. The McCabe Thiele method was used for the determination of theoretical stages and the Peng Robinson was used for the determination of the equation of state. The study considered the development of crude oil feed which includes the selection of light components, selection of equation of state, selection of assay data type, selection of cut option and inputting of the crude properties.

Also, the fundamental design of components of the modular refinery was carried out which include a separator, two heat exchangers, a crude heater, and an atmospheric distillation unit to extract kerosene and diesel. From the design, diesel was obtained at tray 10 of the distillation column at a temperature of 508.9ºF/264.9°C and sent to the crude/diesel exchanger to reduce heat to 197.8ºF/92.1°C while the kerosene was drawn from tray 5 of the distillation column at a temperature of 486ºF/252°C and sent to the cooler where temperature is reduced to 150ºF/66°C. The total emission of CO_2 from both inlet and outlet stream flow process was equal to 1.803e+3 which is infinitesimal when compared with standard.

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