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Comparative Analysis of Manual and Aspen Plus Design for Crude Distillation Unit (CDU)

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Abstract- Nigeria is faced with high import of petroleum products, incessant shortage of the product and poor petroleum refining states. There is therefore the need to develop local technology in petroleum refining as a sustainable solution to these problems (Oche 2014). This paper focus on effective designing of crude distillation unit which is one of the basis for local petroleum refining development.

The CDU was designed to process 1bbl/day of Escravos crude. The unit consist of the following components; atmospheric distillation column, crude heater, condenser, reflux drum, heat exchanger and strippers. Both manual and Aspen plus was used to carry out the design separately and the results were compared to ascertain most acceptable technique for the design of CDU.

Although Aspen plus gave better design results, the design results of the manual calculation had narrow variation to Aspen plus design results. The manual design technique used was therefore effective. Therefore for CDU design, Aspen plus gives better results than manual calculation but in absence of the software a good manual technique such as that used can serve.

Index Terms- Crude oil, Aspen plus, Crude distillation Unit, Escravos crude

I. Introduction

Crude oil is a complex mixture. There exit about 1000 distinguishable components with boiling temperatures varying from room temperature to over 550^{0}C. Crude distillation yields mixtures called naphtha, kerosene, diesel and gas oil. These products are specified by ASTM D86 distillation temperatures (Bagajewicz 2001). Yield of refinery products from a refinery depends on the effectiveness of the processes and the petroleum feedstock. Light crude such as Escravos yields high amount of light product such as petrol. Approximately 65% of the crude oil produced in Nigeria is light (35^0 API or higher) and sweet (low Sulphur content).

Distillation is probably the most widely used separation process in the chemical and allied industries; its applications ranging from the rectification of alcohol, which has been practiced since antiquity, to the fractionation of crude oil. The separation of liquid mixtures by distillation depends on differences in volatility between the components (Sinnott 2006).

The basis of refinery distillation design rest completely on True Boiling Point (TBP) tests. Distillation of crude mainly takes place in two stages. First stage distillation is carried out at atmospheric pressure hence the name 'Atmospheric Distillation Unit (ADU)' also commonly called Crude Distillation Unit (CDU). The undistillated portion of crude, called reduced crude is further distilled under reduced pressure in a second unit known as 'Vacuum Distillation Unit (VDU)' (Rao 1990).

CDU comprising of an atmospheric distillation column, side strippers, heat exchanger network, feed desalter and furnace as main process technologies enables the separation of the crude into its various products. Usually, five products are generated from the unit namely gas + naphtha, kerosene, light gas oil, heavy gas oil and atmospheric residue. In some refinery configurations, terminologies such as gasoline, jet fuel and diesel are used to represent the CDU products which are usually fractions emanating as portions of naphtha, kerosene and gas oil (Uppaluri 2010).

II. Procedure

A. PROCEDURE FOR MANUAL DESIGN

The procedure used for the manual design is a trial and error method whereby design architecture is taken, conditions (flow rate, temperature and pressure) at selected points are solved by mass and energy balances. Then design conditions were tested for fractionation efficiency by the following standard ASTM gaps;

Naphtha – Kerosene: 25^{0}F
Kerosene – LGO: **-** 10^{0}F
LGO – HGO: **-** 35^{0}F (Uppaluri 2010)

Subsequently, further changes in the design architecture were carried out using trial and error approach to yield the best design architecture.

This procedure was carried out by the following series of calculations:

I. Mass balance across the ADU as well as its flash zone.
II. Determination of flash zone temperature.
III. Estimation of draw off temperatures.
IV. Estimation of tower top temperature.
V. Estimation of residue product stream temperature.
VI. Estimation of side stream stripper product temperatures.
VII. Overall tower energy balance and estimate condenser + Bottom Pump Around + Top Pump Around duties.
VIII. Estimation of condenser duties.
IX. Column hydraulics (I e estimation of overflow from top tray, verification of fractionation criteria and estimation of flash zone liquid reflux rate).
X. Determination of column diameter.

B. PROCEDURE FOR ASPEN PLUS DESIGN

Procedure for Aspen Plus design involves drawing flowsheet for process, entering input parameters for the units and running simulation. Output of simulation run is then compared with desired output. The input parameters are re-specified where simulation outputs do not met desired outputs. Input parameters that give desired simulation outputs are accepted for process design and operation.

For our CDU design, input parameters are Crude Assay, crude input conditions (temperature, flow rate and pressure), steam input conditions, column, stripper and heat exchanger specifications. Output parameters are product yields and conditions which are results of simulation run. The product yields and conditions from simulation were compared with Crude Assay yield. With unacceptable variation, input parameters were adjusted until an acceptable variance was gotten.

III. RESULTS

Table 1: Results of Manual Calculation and Aspen Plus Simulation Design for ADU

	Manual Calculation Result	Aspen Simulation Result	Difference
Condenser duty, Btu/hr	3237.76	3426.82	189.06
Reflux ratio	4	4.19	0.19
No of trays	20	20	0
Tray spacing, cm	25.4	15.2	-10.2
Column diameter, cm	6.1	7.5	1.4
Feed stage	19	18	-1
AGO drawoff stage	16	17	1
Kerosene drawoff stage	11	13	2
Heavy Naphtha drawoff stage	5	6	1

IV. DISCUSSION OF RESULTS

Aspen Plus gave a more optimal sizing of column than manual design with tray spacing reduction of 40%. Column size from manual design will therefore cost more to fabricate than that from Aspen plus.

The differences in feed and product draw-off stages for the two techniques of design are ±1, except for kerosene drawoff stage which is 2. Product draw-off stage has direct impact on product quality. Since most products of CDU are intermediary products, the deference from these narrow ranges can be augmented in other units of a refinery.

The differences in condenser duty and reflux ratio are 5.8% and 4.75% respectively. The higher the condenser duty and reflux ratio, the higher the cost of operating condenser. Therefore manual design results indicate slightly lower cost of operating condenser.

V. CONCLUSION

Although Aspen Plus gave better design results, the design results of the manual calculation had narrow variation to Aspen plus design results. The manual design technique used was therefore effective.

In conclusion, for CDU design, Aspen plus gives better results than manual calculation but in absence of the software a good manual technique such as that used can serve.

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