Simulation of the atmospheric distillation Tower at Azzawia refinery

Mohamed E. Said** * Mohamed A. Albasir**

ABSTRACT

The atmospheric distillation tower is the most important unit in any refinery. Its performance is crucial to the economics of operating the refinery. This unit also known as the fractionation column is used to fractionate about 410 m^3/hr of crude oil at Azzawia refinery. The crude oil is a blend of Sharara and Hamada oil fields at a composition of 90%, and 10%, respectively. This paper presents a simulation study of this column by using Aspen-Hysys simulation software package which is widely recognized as a reliable simulation tool in the process industries. The study investigates the effect of up to ±10% variations from the actual feed crude oil flow rate on the mass balance of the tower products and the effect of varying the main steam input heat load on the product distribution of the tower. The results obtained showed that, although the feed to the tower is mixed crude, variations of its flow rate between ±10% indicate small changes in the product mass flow rate distribution except for the residue which showed significant variations in its mass flow rate between (±50%). This is due to the nature of the mixed crude having more of the heavy components as indicated by its API gravity of 38.8. Varying steam heat duty on the other hand, either by increasing its quantity or quality, showed significant changes in the naphtha cut. This is explained by the fact that steam reduces the partial pressure of the hydrocarbons and thus lowers the temperature required for vaporization. This result provides for more naphtha that can be stripped off from the residue by just a small increase in the main steam input. The study concludes that the main steam at Azzawia refinery can be used to effectively control the product distribution of the atmospheric tower especially that of naphtha in accordance with market demand.

Keywords: refinery, distillation tower, simulation, main steam

*Staff member, Faculty of Engineering, University of Tripoli
**Engineer, Department of Chemical Engineering

1. Introduction

Azzawia refinery was put on stream in 1974 to process a designed capacity of 120,000 BPD of a mixed crude oil where 90% of this crude comes from Sharara and the rest comes from Hamada oil fields. The refinery consists of an atmospheric distillation (fractionation) also known as a crude distillation unit (CDU), hydro-treating unit, naphtha reforming unit, LPG unit, and asphalt unit. The crude oil is preheated through a series of heat exchangers and finally is further heated in a furnace to about 330°C (temperature should not exceed 360ºC to avoid undesirable thermal cracking of the crude) before fed to the atmospheric distillation Fig (1). This unit which is the subject of this paper consists of 34 trays. The tower bottom consists of heavier product (atmospheric residue) which is stripped by low pressure superheated steam and sent to storage after heat exchange with the feed crude. The tower overhead product is

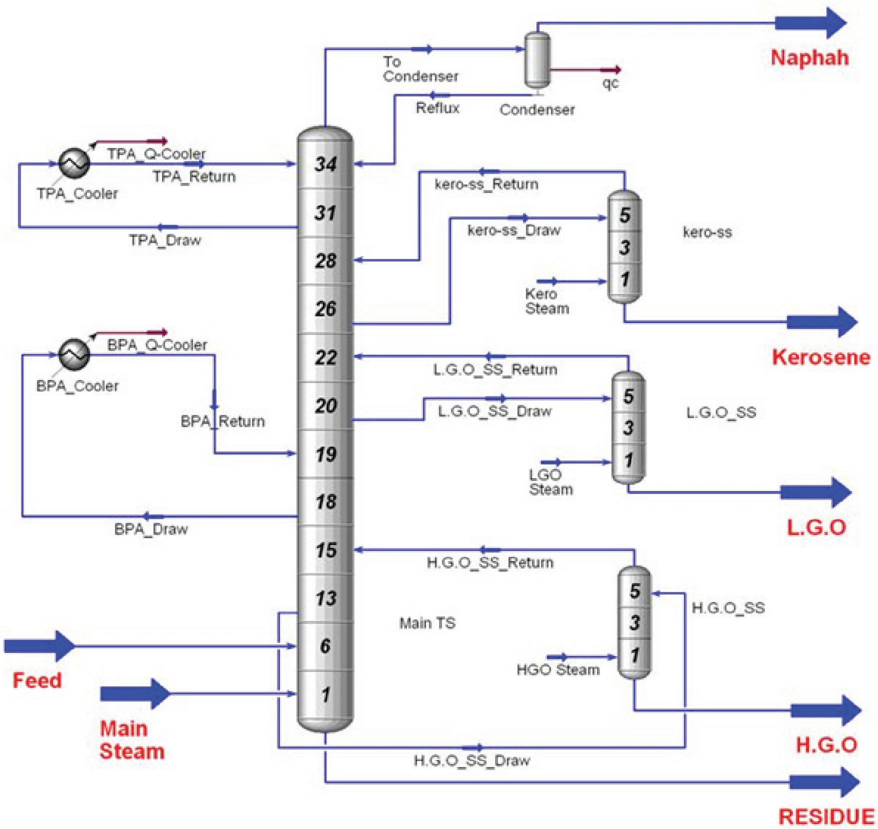

Figure 1. Azzawia Atmospheric Distillation Tower

sent after cooling to a three-phase separator where the liquid naphtha is sent to a stabilizer, the gas effluent is sent to fuel gas stream, and water is sent to the desalter unit. The first cut (side product) is kerosene which is drawn off between trays 26 and 28. Light gas oil (LGO) is drawn off between trays 20 and 22. Heavy gas oil (HGO) cut is drawn off between trays 13 and 15. A comprehensive literature on the subject of petroleum refining can be reviewed in references (Gary,2001; Henry, 1992; Speight, 2006; Hobson, 1975).Process simulation has been widely used in the chemical and petrochemical industries. It provides a powerful tool for design, analysis, and optimization. In refineries process simulation has many benefits such as optimizing process operating conditions to enhance performance of refinery units and identifying process bottlenecks, in addition to understanding the impact of small alterations (disturbances) in the operating conditions on the overall performance of the refinery (Rhodes,1996; Forrest, 2003). A process simulator is a large computer program which accommodates a large library of physical and chemical properties of many pure compounds and mixtures and mathematical models and relations. Several simulators are commercially available. One most widely used and accepted is Aspen-Hysys. It provides a user friendly interface to conveniently construct a flow diagram of the process and simulate its operation both at steady and unsteady states (Aspen Technology, Inc.).

The objective of this simulation study using Hysys is to investigate the effect of small changes of some operating parameters, namely, the feed flow rate, and the main steam flow rate on the product distribution of the CDU at Azzawia refinery (known as sensitivity analysis). The results may assist the operators of this unit to further improve its performance and the performance of the other downstream units.

2. Simulation Data

Table 1, lists the mixed crude feed physical properties, while Table 2, gives the true boiling point (TBP) of the crude which shows the relationship between percent distillate liquid volumes and boiling temperature ranges.

Table 1. Crude Mix General Characteristics ASTM Distillation (personal communication)

TBP Distillation Assay	
Liquid Volume Percent Distilled	(Temperature (°C
5.0	98.0
10.0	110.0
20.0	147.0
30.0	195.0
40.0	250.0
50.0	318.0
60.0	377.0
70.0	438.0
80.0	519.0
84.0	568.0

Table 2. Crude Mix General Properties (personal communication)

Properties of crude oil	
Specific Gravity 60/60 °F	0.8309
API Gravity	38.8
Acid Number , mg KOH/g	0.064
Flash Point , °C	2.2
Kinematic Viscosity at 10 °C , cst	13.64
Kinematic Viscosity at 37.8 °C , cst	4.454
Pour point , °C	-7
Reid Vapor Pressure , Kpa	31.7
Reid Vapor Pressure , Psig	4.6
B.S. & W. , vol. %	< 0.05
Sediment , wt. %	< 0.001
Water , vol . %	0.1
Ash , wt. %	< 0.001
Carbon Residue	2.09
Salt as NaCl , lbs/Mbbls	1.6
Sulfur, wt. %	0.07
Mercaptan Sulfur , ppm	6
Nitrogen , wt , %	0.082
Carbon , wt . %	86.1
Hydrogen , wt . %	12.8

Characterization Factor , Uop k	12.15
Gross Heating Value , kcal/kg	10,870
Net Heating Value , kcal/kg	10,220

3. Results and Discussion

The first step in the simulation study was carried out to assess the reliability of Aspen-Hysys software by using current operating conditions at the refinery. Table 3. gives a comparison between actual side products flow rates and calculated rates by Hysys.

Table 3. Comparison between Simulated and Actual Side Products Distribution

Side product	Actual flow rate (m^3/hr)	Calculated flow rate (m^3/hr)
Naphtha	120	120
Kerosene	84	83.99
L.G.O	56.80	56.78
H.G.O	45.65	45.65
RESIDUE	100	107

Clearly, an overall good agreement is obtained. Then the effect of varying the crude feed flow rate on the product distribution is shown in table 4, and figure 2. Variations up to about ± 10% from the current crude feed flow rate of 410 m^3/h (341ton/h) show changes between ± 2% change in mass flow rate of naphtha, about ±8% change in mass flow rate of kerosene, about ±12% change in mass flow rate of LGO, about ±12% change in mass flow rate of HGO, and about ±50% change in residue. This result clearly shows that the residue product capacity is very sensitive to even small changes in the crude feed capacity for this particular crude mix which is rich of heavy components. Table 5 and figure 3

demonstrate the effect of varying the main steam heat duty rate on the mass flow rates of tower products. The results illustrate that all side products quantities show a steady decrease as the main steam duty increases except for naphtha which has significantly increased through the range of variation of the main steam duty. This is explained by the fact that the stripping process of light components, in this case naphtha, is enhanced by injecting more steam into the bottom of the tower. This emulates the role of the reboiler duty in traditional distillation columns.

Table 4. Simulation Results with Varying Crude Flow Rates

Flow Rate of Crude Feed (410 m³\hr)					
Flow rate (m³\hr)	NAPHTHA (Kgmole\hr)	KEROSENE (Kgmole\hr)	L.G.O (Kgmole\hr)	H.G.O (Kgmole\hr)	RESIDUE (Kgmole\hr)
450	785.8	372.9	174.2	112.6	229.4
440	782.3	366.3	169.8	109.7	209.6
430	778.4	359.7	165.5	106.4	190.5
420	774.3	352.8	161.2	103.4	171.6
*410	770	345.7	157.1	100.6	152.7
400	765.5	338.3	153.0	96.98	135.1
390	761.0	330.5	148.9	93.71	117.6
380	756.3	322.4	144.8	90.20	100.8
370	751.1	314.3	140.3	86.91	84.62
360	745.6	306.0	136.0	83.14	69.27

*Note: * highlights the actual operating conditions*

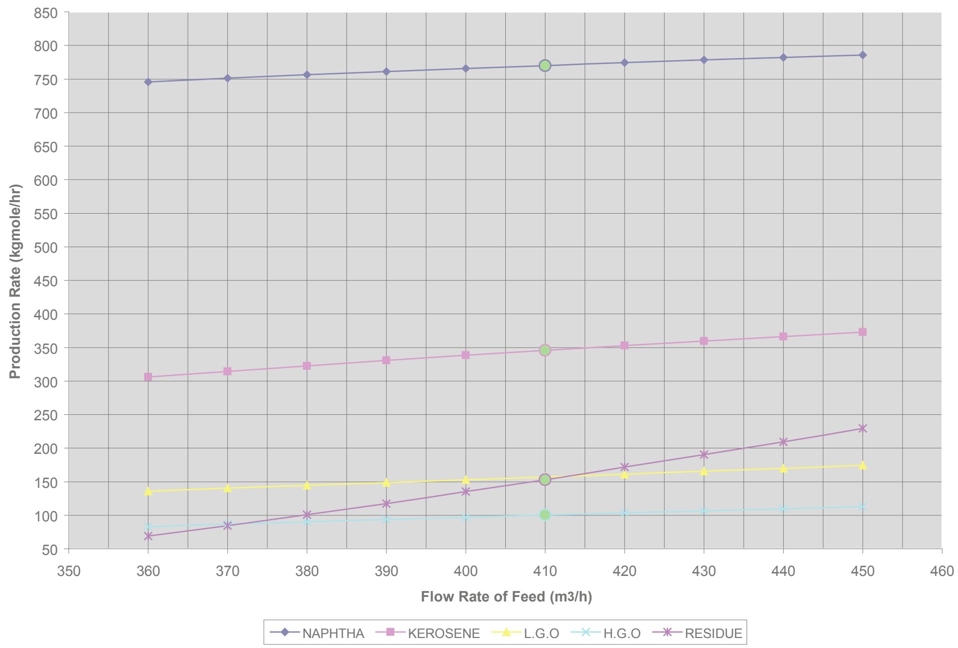

Figure 2. Effect of Varying Crude Flow Rate on Product Distribution_

Note the actual operating data is highlighted by a small green circle

Table 5. Simulation Results with Varying Main Steam Duty

Actual Heat duty of Main Steam (68.6 MW)					
Main Steam Duty, MW	NAPHTHA (Kgmole \ hr)	KEROSENE (Kgmole \ hr)	L.G.O (Kgmole \ hr)	H.G.O (Kgmole \ hr)	RESIDUE (Kgmole \ hr)
120	1027	248.9	120.6	74.11	55.10
110	994	260.9	125.5	77.99	67.50
100	955.7	275	131	82.45	81.75
90	905.1	294.1	138.1	87.66	101
80	847.1	316.4	146.3	93.11	123.2
70	781.5	341.4	155.4	99.39	148.4
68.60	770	345.7	157.1	100.6	152.7
60	705.2	369.7	167.1	106	178.1
50	601.4	406.5	185.4	115.4	217.4
40	469.6	449.8	211.1	127	269

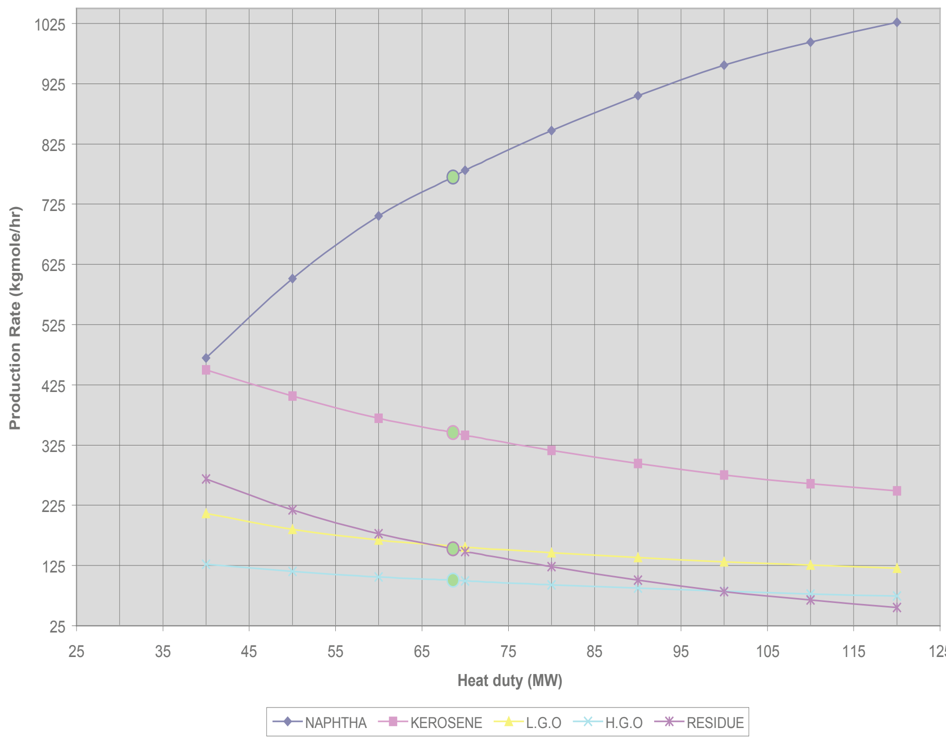

Figure 3. Effect of Varying Main Steam Duty on Product Distribution

4. Conclusion and recommendation

Reviewing the results of this study leads to the following concluding and recommendation remarks

1- Simulation studies are useful tools to explore different operating scenarios, trouble-shooting, and assess process performance.

2- Since the main steam flow rate seems to have significant effect on the tower side products capacities, it should be used as a manipulated variable for cost-effective control scheme.

3- Further simulations studies with respect to the impact of varying crude blending ratio on the CDU performance should be carried out.

4- A comprehensive simulation study of Azzawia refinery including all downstream units will be beneficial to the economics of the refinery.

5- Finally, because the refinery is aging, a revamp study using pinch analysis to the crude preheat train may be useful to minimize energy consumption and therefore reduce the overall operating cost.

References

1. Gary, J. H. and Handwerk, G. E., 2001, “Petroleum Refining”, New York, pp31-40.

2. Henry, Z. K.,1992, “Distillation Design”, New York pp201-220

3. Speight, J. G., 2006,”The Chemistry and Technology of Petroleum”, CRC Press. pp 126-140

4. Hobson,G.D. and Pohl, W.,1975,”Modern Petroleum Technology”, Applied Science Publisher pp241-255.

5. Rhodes, C.L., 1996, “The Process Simulation Revolution”, J. chem. Eng. Data, 41 pp68-87.

6. Forrest, J., *et. al.,* 2003, “Refinery-Wide Rigorous Simulation Drives New Values for Refiners”, NPRA Plant Automation and Decision Support, San Antonio, Texas 111-120.

7. Aspen-HYSYS 1.0, Aspen Technology, Inc.

8. Private Communication with Azzawia Refinery Co., Operation, Department.