

# Studying Effect of Feed Vapor Fraction on Consumption Energy in Distillation Process

Shymma Kadhem Rahem

School of Chemical engineering, Babylon University, Hilla, Iraq.

\* E-mail of the corresponding author: shymmakadhem@gmail.com

## Abstract

An acetone- benzene was selected to analyze the effect of feed vapor fraction on the total heat consumption in conventional distillation process. Heat consumption by distillation column ( $\Sigma Q$ ) were evaluated by using the Aspen plus software, in order to determine the best economically state of feed.

The work results are based on the lower consumption of energy at boiling point feed state. The operation cost of feed at saturated liquid ( $V.F=0$ ) is reduction by (32.3%) than the cost of feed at saturated vapor ( $V.F=1$ ).

**Keywords:** Vapor fraction ,distillation , consumption energy.

## 1. Introduction

Synthesis of separation is a problem repeatedly discussed in chemical engineering literature. 40-50% is capital investment in separation equipment is of the total for a conventional fluid processing unit. About 70% of the total energy consumption of an average unit is for the separation steps. But about 95% of the separation consumption, the distillation method accounts. The chemical productive operating costs of processes are highly influence by the downstream separation units. Distillation is a nonlinear process and the product valuation patterns add non linearity to the economic function. Thus, calculating the correct operational targets can be complicated. (Fidkowski Z. and Krokowki.1986) (Fair, J. 1987) (Kister H. 1997) (White D. 2012)

The phase separation is operated by the differences in vapor pressures, with the lighter vapor rising to the top and the heavier liquid flowing to the bottom of the column. The portion of the column above the feed is called the rectifying section and below the feed, the stripping section. The fractions that rise highest in the column before condensing are called light fractions, and those that condense on the lowest trays are called heavy fractions. (Liptak B. 2009) (Paul S. and Donald P 1997 ) (Tonnang Z. 2003)

Column control includes both overhead and bottoms product purities, minimizing energy, and maximizing throughput while maintaining operations within equipment limits. Distillation columns need to use a large amount of energy because of the evaporation steps involved like the re boilers of distillation columns. (Smart Process® Distillation2012) (Kunesh J. et al 1991)

However, the decreasing of number of trays can produce by increasing the reflux ratio but with higher energy costs. Particularly, reflux ratio optimization is important for distillation columns that operate with: 1. high reflux ratio; 2. High differential product values between overhead and bottom; 3. high utility costs; 4. low relative volatility, and 5. feed light key far from 50%. [12] 25-40% of the energy usage which consumed in distillation. One disadvantage of distillation process is the large energy requirement. Distillation consumes a large energy to change liquid to vapour and condense the vapour to liquid at the condenser. Distillation is carried out in distillation columns which are used for about 95% of liquid separations and the energy use from this process accounts for an estimated 3% of the world energy consumption. (Hewitt, G. 1999) Most distillation columns operate above ambient temperature, and heat consumed along the column are a finite thermal conductivity. Heat consumed along the distillation column increase condensation and reduces evaporation. (Sloley, A. 2001)

Reducing the energy consumption is not straightforward in distillation column, because of the many configurations of columns and these differences due to distinct dynamic behaviors and different operational degrees of freedom making it more difficult to optimize control.

However, distillation is nonlinear process, and the product-valuation patterns add more nonlinearity to the economic function. therefore, the correct operational targets calculation is complicated. (Douglas C. 2012 )

The study case:

Many papers and books have been studied the advanced control and design of distillation columns. (Douglas C. 2012) (Blevins, T. et al 2003) (Luben, W. 1992) (Shinsky E. 1984)

Acetone –benzene used at (100 Kmole /hr) with mole fraction (0.5) and pressure (1atm) ,the separation have been achieve distillation product(98%) and benzene at bottom(2%).

Assume the feed mole fraction (50%-60%) ,and calculate the a mount of energy in distillation Column. The vapor fraction which fed to distillation column was changed from (0-1) and the total consumption in processes was calculated for different  $R/R_{min}$  ratio. The results were simulated using Aspen pulse soft ware in order to determine the total energy.

## 2. Total consumption energy

A distillation process flow diagram is shown in fig.1. The heat to the distillation tower is supplied by a reboiler ( $Q_r$ ) using the utility steam or hot oil. The overhead vapor is sub cooled by an overhead condenser ( $Q_c$ ) and the condensed liquid is routed into the overhead drum. One of the liquid streams from the overhead drum is the reflux stream, which is sent back to the top tray of the distillation tower, and the other is the overhead low boiling point component.

The lost of energy in reboiler  $Q_r$  depend on released heat in condenser  $Q_c$ :

$$Q_r = Q_c + D.C_{pD}.T_D + B.C_{pB}T_B - F.C_{pF}T_F \quad (4)$$

$$\text{Where } Q_c = D(R+1). \lambda_D \quad (5)$$

Heat absorbed and released in liquid streams is nearly equal, so

$$F.C_{pF}T_F \approx D.C_{pD}.T_D + B.C_{pB}T_B \quad (6)$$

$$\text{So from equation (5) we have } Q_r \approx Q_c \approx D(R+1). \lambda_D \quad (7)$$

$$R = \sigma R_{\min} \quad (8)$$

Where:

$\sigma$ : excess factor.

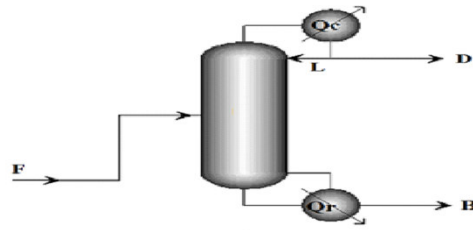
## 3. Conclusion

From our results for different excess factor values, reflux ratio was increase with the increasing the amount of heat consumption by reboiler in distillation tower as show in figures (2-4) and as shown from equation (7), for the constant amount and purity of product.

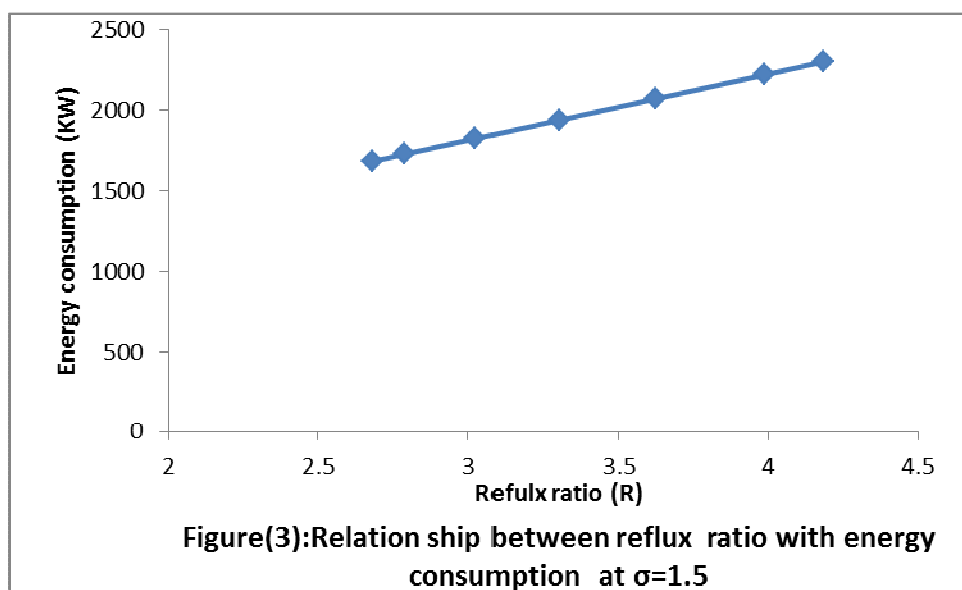
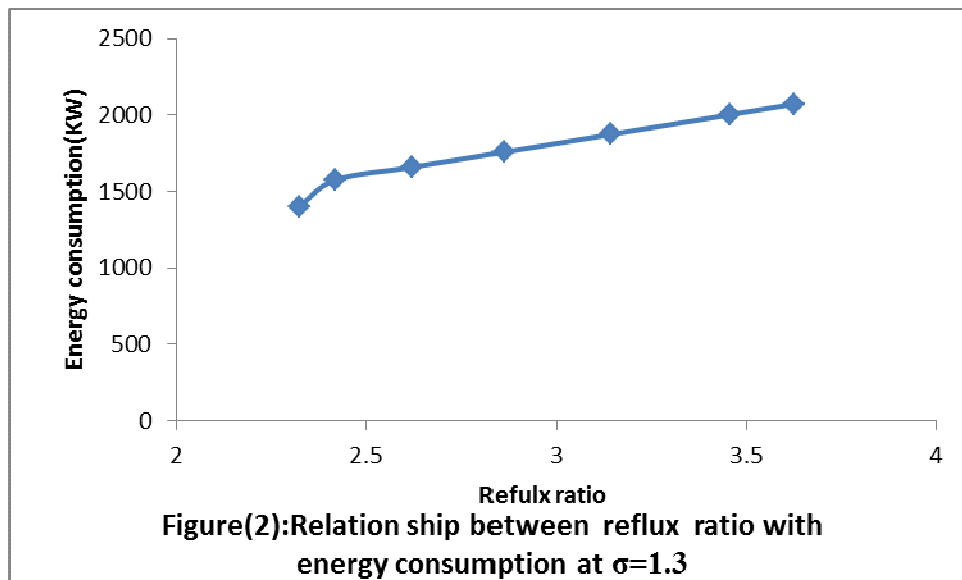
In this work made comparison with different state of feed and found the best economic choice in the state of vapor fraction equal to zero (at boiling point of feed) mixture as shown in figure (5). The feed state changed from state of boiling point to vapor state that will reduce 32.3% from the cost of heat required for separated mixture in distillation column.

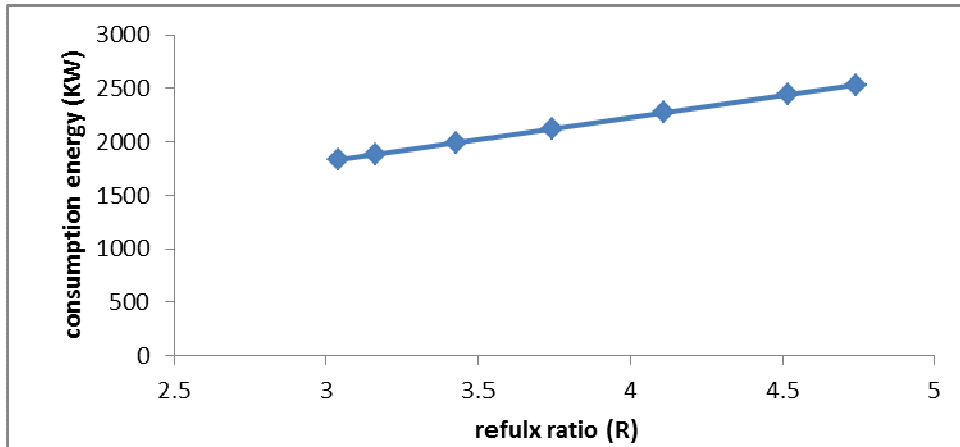
## References

- Blevins T.L, etal (2003), "Advance control unleashed," International Social for Automation (ISA), Research Triangle park, NC.
- Douglas C. (March 2012), "Optimize energy use in distillation", American International Chemical Engineering (AIChE).
- Fair, J.R., (1987), "Energy-Efficient Separation Process Design", Recent Developments in Chemical Process and Plant Design, Y.A. Liu, McGee, Jr., H.A. and Epperly, W.R. (eds.), John Wiley & Sons, New York.
- Fidkowski Z. & Krokowki L. (Ap. 1986), "Thermally coupled system of distillation columns: optimization procedure.", AIChE Journal, vol. 32, No. 4.
- GAMS Development Corporation (1998), GAMS A USER'S GUIDE, Washington, DC, GAMS Development Corporation.
- Hewitt, G. etal (1999). More Efficient Distillation. The Chemical Engineer, 21st
- Kennedy, M. & Warwick, J. (2000), "The Development of the Holon Planning and Costing Framework for Higher Education Management", Technical Report, SBU-CISM-11-00, South Bank University, 103 Borough Road, London, SE1 0AA.
- Kister H., (1997) "Distillation and absorption", 97, vol. one of IChemE Symposium Series No. 142, IChemE, Rugby, UK.
- Kunesh J. etal, " Distillation: still towering over other options", Chem. Eng. Progr. 91 (10)
- Liptak B. (2009), "Distillation Control and Optimization ", An Ebook by , MYNAH Technologies, www.controlglobal.com.
- Luben, W. (1992), "Practical distillation control" Van nostrand reinhold, New York, NY.
- Paul S. & Donald P. (1997), "Distillation column control design using steady state models.
- Smart Process® Distillation (September 2012), www.DeltaV.com, Delta V product data sheet , Page 3.
- Sloley, A. (2001). Energy Conservation Seminars for Industry: Texas Energy Conservation Distillation Column Operations Manual. 16.11.2005, Available from <http://www.distillationgroup.com>.
- Shinsky E. (1984), "Distillation control", McGraw-Hill, New York, NY.
- White D., (March 2012), "Optimize energy use in distillation", American Institute of Chemical

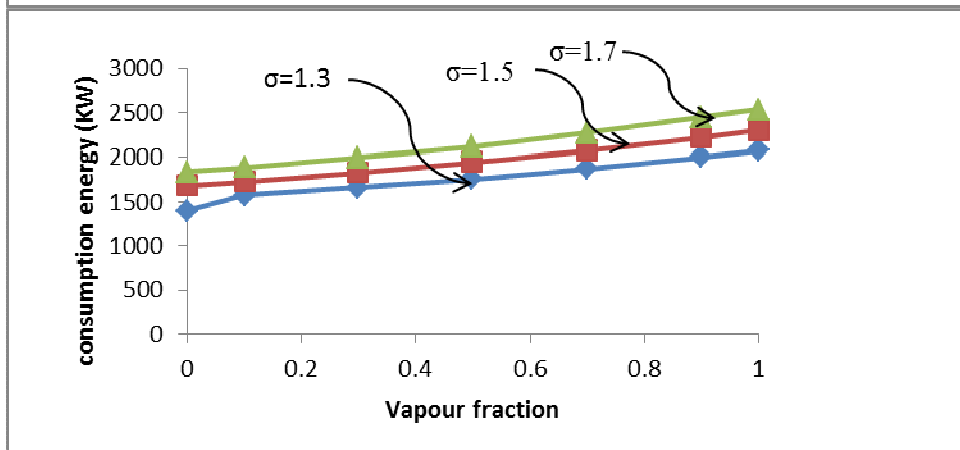


Figure(1):Distillation process





Figure(4):Relation ship between reflux ratio with consumption energy at  $\sigma=1.7$



Figure(5):Relation ship between the vapour fraction with consumption energy

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:  
<http://www.iiste.org>

## CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

**Prospective authors of journals can find the submission instruction on the following page:** <http://www.iiste.org/journals/> All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

## MORE RESOURCES

Book publication information: <http://www.iiste.org/book/>

## IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digital Library, NewJour, Google Scholar

