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DISTILLATION COLUMN

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Abstract *- In this study, a general overview on the latest developments on distillation columns and the networks consisted from distillation columns were investigated. During this study, various distillation techniques were reviewed from various sources in the literature and these methods were examined first and then the most effective one was determined regardingenergy efficiency and lowest cost. Consequently, Turkish industry's place in distillation column applications were considered and most feasible method is offered to Turkish industry among studied ones such as, dividedwall distillation column (DWC) technique, reverse calculation of Thomas algorithm technique, pinch analysis method, internal heat integration method and distillation cascade techniques.*

Keywords *- Distillation columns, distillation column structure.*

I. INTRODUCTION

Distillation is a process used to separate a mixture of two (or more) components into its virgin state by heating the mixture to a temperature between their respective boiling points.

A distillation column is a tube that provides surfaces on which condensations and vaporizations can occur before the gas enters the condenser in order to concentrate the more volatile liquid in the first fractions and the less volatile components in the later fractions. Energy is a fundamental parameter for all countries to sustain the needs of industry, agriculture, transportation and households. Increasing industrial facilities and rapid technological developments cause large energy requirements as opposed to decreasing energy sources. In addition, increased energy dependence leads to environmental pollution, global warming, increased energy costs, and inability to use energy. For this reason, many developing countries have difficulties balancing the energy gap between energy demand and energy supply [1].

Fossil fuels, one the most important energy sources in the world, cover 80% of world's energy need[2]. To keep the economy of transportation and industry alive, fossil fuel production is inevitable [3]. In the early 20th century, distillation columns became widely used in multicomponent liquid-liquid mixture separation processes.

Nowadays, approximately 90-95% of the separation operations are done by distillation columns. It became popular because, quality loss is in minimum levels in distillation columns when they produce mass[4]. Its working principle is based on separating components of the mixture by their volatilities via adding heat to the system or removing heat from the system. When it happens, more volatile components vaporize, while less volatile components remaining liquid [5]. This process happens in a column with determined number of trays, where gas and liquid phases in interaction, feed location and reflux ratio are also vital in distillation column design [4,6]. When the components' volatilities are close or even azeotropic, commonly used distillation techniques such as binary-mixture distillation, multi-component distillation, extractive & azeotropic distillation, batch distillation, become insufficient [7].

Recently, due to high energy consumption of distillation columns, which led to release of CO2 and environmental issues such as global warming, improvements in separation techniques have been considered [4]. Therefore, various methods have been arisen. Heat integration by pinch analysis, heat integration in packed columns considering effects of relative volatility, column height and product characteristics on the energy reducibility, distillation without theutilities (DWHU) as a new approach to distillation with vapor recompression (VRC), driving force design method, combining preconcentration and extractive distillation column, divided w all distillation column technique, distillation cascade and geometrical methods such as, examining separation space are the ones that are focused on this paper[4–10]. When these methods are considered, it is clearly seen that there are some effective approaches to the issue of energy saving in distillation columns by considering different aspects of the system.

Therefore, these various points of views can be gathered for a determination of a most energy efficient system existing. At that point, considering Turkey's high energy demand, hydrocarbon products become vital[3]. In Turkish distillation column design industry, there are some major Turkish companies in this field and they have their own methods mainly based on vapor liquid equilibrium (VLE) chart readings and restricted themselves with this design method. In this study, various enhanced distillation column operating techniques have been reviewed and a recommendation for Turkish industry has been made to catch up the latest industrial advancements in this area to be a demanding country among the others.

II. RESEARCH METHOD

Driving force of this study is the importance of energy in today's world. Considering importance of energy, fossil fuels was focused on and when it comes to processing of HCs, distillation columns was selected. After that point, it is clearly seen that there are various studies on improving the energy efficiency and decreasing environmental effects of distillation columns.

In this study, other parameters rather than improving energy efficiency and decreasing environmental effects were neglected in distillation column design. During these improvement processes, Aspen Plus and Aspen

Dynamics, which are very useful and advanced software with the capacity of plugging in large number of parameters, including complex stages of simulations, large number of trials to be precise and capable of running "what if" comments for precision and optimization, were generally used in different methods [11]. In addition to this software, there are also manual calculation methods that are used for designing more energy efficient and environmentally friendly distillation columns. Some of them are, driving force design method, reverse calculation of Thomas algorithm, potential environmental impacts calculations and Euler's Method (with MATLAB) [4,6].

During this study, most of the researches that are examined showed that, efficiency of distillation columns can be improved by either increasing precision of the system with the condition that, finding optimum values regarding cost or adding a new component to the system. In the light of these two factors, determination of optimal number of plates, optimal location for feed, optimal reflux ratio, optimal driving force in minimum energy need and number of flash tanks in purification are vital parameters in the improvement process.

III. EXPERIMENTAL OPERATIONS OF DISTILLATION COLUMNS

In this part of the study, all methods that are examined was explained in detail with results and the most advantageous one became one step ahead. First, shortcut method was shown to put a reference point to our research and continued with the comprehensive optimization applications. To begin with, as a shortcut method Fenske Underwood Gilliland (FUG) method is the most common one. Fenske Underwood Gilliland method considers mass overflow and relative volatility parameters as constant for entire column. This method based on specifying two boundaries with maximum reflux (no feed is entering or exiting from the column) and minimum reflux (an infinite number of trays) and by using Fenske equation, claims that the optimal value is in between these two boundaries [12]. Moving on to advanced methods, fully thermally coupled distillation column technique is studied by Uwitonze et al [13].

In their study, they provided a design method to determine the structures of conventional two-product and Petlyuk columns, using HYSY software and when steady state model is studied under closed-loop using PI controllers with respect to controllability results, good dynamic replies for load rejection were received. When the results compared to common simple methods, such as FUG, different than FUG method applying Gilliland correlation for determining main parameters are no longer needed. Another method, studied by Lueprasitsakul [10], is analyzing the effects of main parameters, such as column height, relative volatility and product characteristics, on energy efficiency by using internal heat integration on binary packed distillation columns. After applying simulation of integrated column, the effect of internal heat integration multiplies with the increase of relative volatility of the system. In addition to that, when the height of the column restricted effectiveness of it increases. In 2007, Gutierrez-Antonio and Jimenez-Gutierrez [14] studied design of side stream distillation columns.

In their design, different than conventional distillation columns, third stream is added to the column as side-stream, as seen in the figure 1 and figure 2, allowing to produce intermediate substances as third extraction from a single column. This additional stream requires less heat transfer units but more reflux ratio, so its annual cost is more than conventional ones. However, determining optimal location for feed point by trying different cases, economically feasible design can be concluded. As mentioned in their study, this method must be improved by further studies.

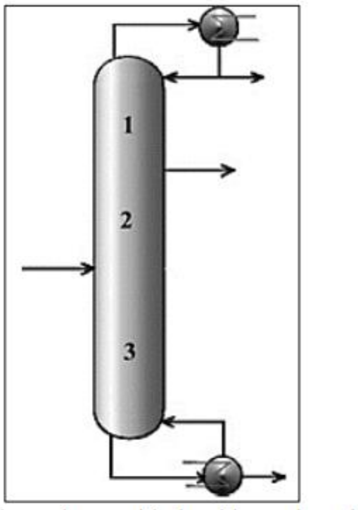

Figure 1. Distillation column with the side product above the feed point.

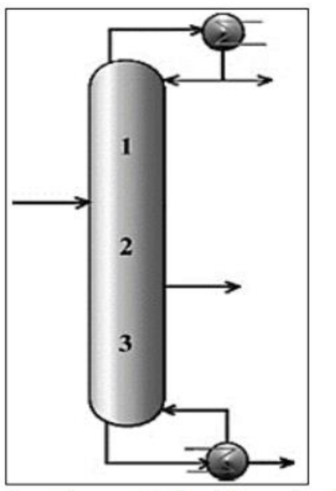

Figure 2. Distillation column with the side product below the feed point.

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An et al. [7] studied a new energy saving extractive distillation method. It is shown in the figure 3. In their new proposed method, they came up with a new approach to three-column extractive distillation design. New proposed method combines preconcentration and extractive distillation columns and by adding less volatile entrainer, relative volatility of less volatile substances was reversed and removed as distillate from the extractive column. In this study, decreasing both energy and annual cost are achieved mainly by supplying vapor flow needed for preconcentration by extractive column. This application reduces the need of vapor flow supplied by intermediate reboiler. To support the study, global economic optimization method was applied, and findings were compared with conventional distillation process. Results showed that, both energy consumption and total annual cost were reduced 22.76% and 17.25 respectively in two different cases.

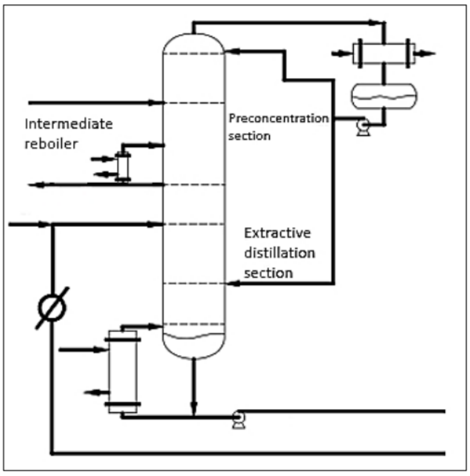

Figure 3.New proposed design with an extra reboiler in preconcentration section

Another research is done by Kazemi et al. [8] on distillation without hot utilities. Recently, vapor recompression (VRC) technique is commonly preferred in improving energy efficiency of distillation processes. Because there is no additional heat source as steam in this type of distillation columns, they are called distillation without hot utilities (DWHU). In this study, it is claimed that cooling water can be used as both cold and hot utilities.

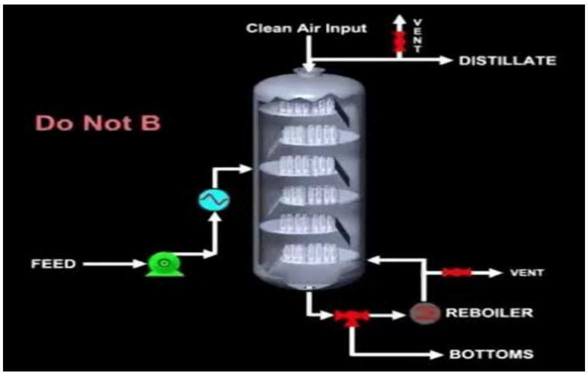

Figure 4. Operating schematic of DWHU system.

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Ling and Luyben proposed a new structure for divided-wall columns [17]. In their paper, by controlling ratio of the heaviest substance in the prefractionator, purities of components were controlled, and energy consumption was minimized simultaneously. During this process, alterations in feed flow rate and feed composition were used to determine effectiveness. In their design, impurity of the heavy component controlled at the top of the prefractionator by extracting only liquid from the side stream. This method applied on various mixtures and proved its effectiveness in all cases. Various articles have been reviewed and distillation columns handled from economic and environmental aspects. After a general consideration it is revealed that, some enhanced method studies have reached some concrete solutions, some of them have given an idea about a new proposed method and some of them needs further improvements.

IV. CONCLUSION

In this work, an overview of recent developments in distillation columns and nets composed of distillation columns has been investigated.

In this study, various distillation techniques were examined from various sources and these methods were reviewed first, and then the most useful ones were determined considering the energy efficiency, lowest cost and the environmental effects. In Turkish industry, distillation columns are used in many areas such as, refineries, chemical substance producing facilities, etc. and mostly conventional techniques are preferred.

It is seen that; Turkish industry needs some enhanced design recommendations in this area. In conclusion, the location of the distillation column in Turkish industry practices led us to this study and after considering entire aspects of the all examined design methods, due to its certainty and promising results study, distillation without hot utilities (DWHU), is the best choice with reduction in annual operating and total costs by 35.9 and 17.6%, respectively.

In addition to that, because there is no additional heat source needed in this type of distillation columns, the environmental effects of this facility is also reduced [8].

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Photo Gallery

Model