Application of the Self-Heat Recuperation Technology to Deisobutanizer Column

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***Abstract*—An innovative self-heat recuperation technology, in which not only latent heat but also sensible heat is circulated in the thermal process, was studied and applied to the deisobutanizer column. To determine the amount of energy required for this technology, ASPEN HYSYS was used. According to the simulation of the proposed sequence, the condenser duty and reboiler duty were saved up to 73.43 and 83.48%, respectively as compared to conventional column.**

***Index Terms*—Distillation process, self-heat recuperation, deisobutanizer.**

I. Introduction

Separations by distillation columns account for the largest fraction of energy used in industry, making them a major concern for sustainable development in industrially developed countries. Distillation is the most widely used separation process in industry, and its large-scale equipment makes it one of the most capital-intensive industrial processes. With global industrial growth, distillation is increasing in both variety and size of applications. Hence distillation systems are required that are sustainable and economically feasible, i.e. industrially viable [1]-[3].

In the distillation process, heat is supplied at a feed heater and a reboiler, and an overhead stream is cooled at a condenser. Almost all of the supplied heat at the reboiler in the conventional distillation process is discarded in the overhead condenser [4]. Heat pumps in distillation allow the heat of condensation released at the condenser to be used for evaporation in the reboiler [5]. This is an economic way to conserve energy when the temperature difference between the overhead and the bottom of the column is small and the heat load is high. Heat pumps can also be used in grass-roots or retrofitting design because they are easy to introduce and plant operation is usually simpler than heat integration [6]-[10]. However, the high capital expenditure required for compressors make them industrially viable only for high-capacity, end-of-train (practically binary) separations of substances with close boiling points, which require minimal compressor/compression costs. This is the case mainly in the separation of light hydrocarbons, such as C_2, C_3 and C_4 components, where the adiabatic exponents of the substances are large enough to enable significant temperature increases with relatively low compression effort [1], [4], [11]. Furthermore, in heat pump, only the heat recovery duty to the reboiler in the distillation column is considered, but the heat during preheating is not or is less recognized [4].

Self-heat recuperation technology facilitates recirculation of not only latent heat but also sensible heat in a process, and helps to reduce the energy consumption of the process by using compressors and self-heat exchangers based on exergy recuperation [13]-[14]. Fig. 1 shows the structure of a self-heat recuperative distillation process consisting of two standardized modules, namely, the heat circulation module and the distillation module. The cooling load is recuperated by compressors and exchanged with the heating load to recirculate the self heat in the process. As a result, the heat of the process stream is perfectly circulated without heat addition, and thus the energy consumption for the process can be greatly reduced.

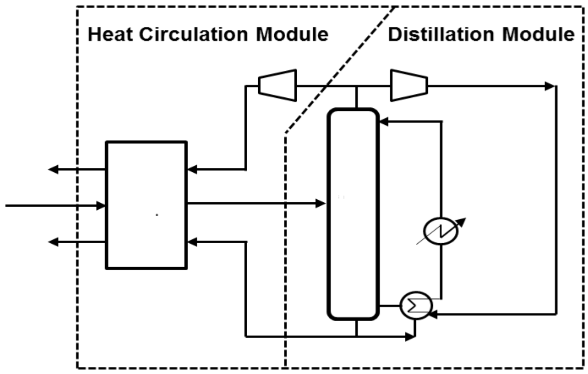

Fig. 1. Self-heat recuperative distillation process.

As industrial applications of this self-heat recuperative distillation processes, Kansha et al. examined the energy saving efficiency of an integrated bioethanol distillation process using an azeotropic distillation method as compared with the conventional azeotropic distillation processes [15]. They also applied it to the cryogenic air separation process and examined the energy required compared with the conventional cryogenic air separation for an industrial feasibility study [16]. There was potential for a 40% energy reduction by using self-heat recuperative distillation.

Liquid hydrocarbons recovered from NGL are typically separated into relatively pure ethane (C_2), propane (C_3), isobutane (iC_4), normal butane (nC_4), and gasoline products (C_{5+}). This is conventionally done by distilling C_2, C_3 and C_4 from gasoline in sequence and then distilling iC_4 from nC_4. The final distillation of iC4 from nC4 is energy and capital intensive because these compounds' small relative volatility [17]. This work aims to apply self-heat recuperation for improving the performance of the deisobutanizing fractionation step of NGL processing.

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II. Conventional Distillation Column - Deisobutanizer

A deisobutanizer, possessing 92 theoretical trays, was designed and operated for 6.5 bar (Fig. 2) as commercial isobutane can be condensed with cooling water at this pressure [18]-[20]. Modeled columns' maximum flooding was determined using a rating mode simulated using the columns' internal specifications such as type of trays, column diameter, tray spacing, and number of passes. Simulations were performed using the simulator ASPEN HYSYS V7.3. The Peng-Robinson equation of state was used to predict the vapor-liquid equilibria of these simulations [21]. The base case simulation model shows that the energy consumption of deisobutanizer was 7271 KW.

All columns were designed with loads of ca. 85% of the flooding point load to prevent flooding. Furthermore, the pressure of the outlet compressor was adjusted to obtain a minimum approach in the heat exchanger of 10 ℃.

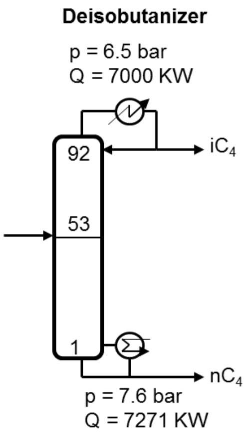

Fig. 2. Simplified flow sheet illustrating the conventional column – deisobutanizer.

III. Self-Heat Recuperation

In the vapor recompression technology, a well known heat recovery technology, the vapor is compressed to a higher pressure and then the pressurized vapor provides a heating effect when condensing. However, such technology utilizes only the latent heat but not the sensible heat [4]. In contrast, self-heat recuperation technology utilizes not only latent heat but also the sensible heat in the process by using a compressor. In self-heat recuperation technology, the heat of the streams is recuperated by using compressors and the recuperated heat of the pressurized stream is supplied to the cold stream by heat exchange.

In the distillation process for the heavy chemical industrial field, it can be said that the two types of self-heat recuperative processes were integrated [4]. One is the self-heat recuperation distillation in which the partial heat of the overhead vapor (the reflux stream) is recuperated and the recuperated heat is supplied to the reboiler. The other is the heat circulation system for feed heating, which leads to the remaining partial heat of the overhead vapor (the overhead product stream) being recuperated and being supplied to the feed heater.

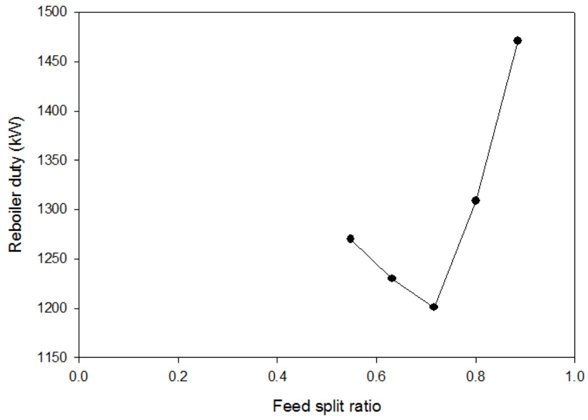

Fig. 3. Effect of feed split ratio on the reboiler duty.

The compressor treated all overhead vapor and the compressed vapor was divided into the reboiler and the feed heater. The feed stream was divided into two parallel streams, which were exchanged with the overhead and the bottom product streams to maximize the heat recovery duty. Adjustment of the feed split ratio in important in the maximization the heat recovery duty and minimization the compressor power (Fig. 3). A simplified flow sheet outlining the self-heat recuperative distillation process is shown in Fig. 4. Note that the split is defined as the ratio between the flow, which is heat exchanged with the bottom product stream, to the total flow (m2/m). A feed split ratio of 0.72 is optimal, reducing condenser duty, reboiler duty, and operating costs by 73.43, 83.48, and 53.49%, respectively as compared to conventional sequence. The simulation results show that when the feed is supplied the heat, the top vapor stream is increased, i.e. more heat can be recuperated.

Besides, the boil-up stream is decreased, which cause the column diameter decreases from 2.4 to 2.3 m. Thus, this sequence can be utilized not only in grass-root case but also in retrofit case, which is considered significantly nowadays by processing industry. This is a promising technology when problem is associated to binary mixture separation or that column should not integrate with other columns in sequence. From the existing column, new heat exchangers and compressor are installed while the number of trays and diameter of column are fixed. More pipe work is also needed for the equipment link. From a technique point of view, those works can be accomplished in easy manner and short modification time.

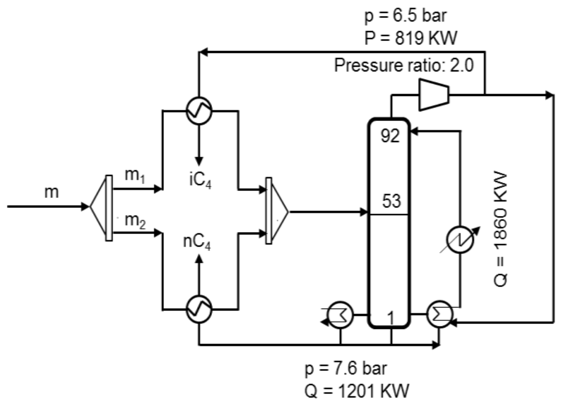

Fig. 4. Simplified flow sheet illustrating the self-heat recuperative distillation process.

IV. Conclusions

In this paper, the self-heat recuperative distillation process for industrial application was proposed. The results show that the advanced process with self-heat recuperation technology was able to reduce the energy consumption significantly by using the recuperated heat of the overhead vapor. This work also pointed out that those sequences are promising technology in retrofit project, which can be accomplished in an easy manner and short modification time.

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