Enhance operation and reliability of dividing-wall columns

Dividing wall columns (DWCs) are an attractive option when the goals are to reduce energy consumption and capital investment for distillation processes. A major component in a DWC system is the reflux splitter, which separates the liquid products from the column overhead into two liquid streams: one to the prefractionation section and the other to the main column section of the DWC. A more reliable reflux-splitting system stabilizes the entire column, thus minimizing unit/process downtime. Several novel developments for a reflux-splitting system can improve the operation and reliability of DWCs.

Background. DWC technology has been successfully applied in various petrochemical processes.\(^1\)\(^2\) A DWC can reduce energy consumption by removing the remixing phenomenon within a conventional two-column system for a ternary mixture. DWC systems can minimize capital investment by intensifying a conventional two-column system into a single column with a simple dividing wall.

The concept of DWC was proposed in 1949; however, it took a long time to adopt this principle.\(^3\) Availability of proper design tools is a major obstacle in developing more complex separation-column systems as compared to a conventional column. Since the 1980s, powerful CAD software enables the design and commercialization of DWCs for a range of petrochemical processes.

Once the structure of a DWC is fixed for a given product specification, the most important optimizing variables remaining are the liquid and vapor split in the dividing wall section, as shown in FIG. 1. These variables have a significant effect on the total separation performance in the DWC.\(^2\) FIG. 2 shows the effect of internal flow distribution on the energy consumption in a typical DWC. This figure illustrates the existence of an optimal internal flow distribution that generates the lowest energy consumption. Generally, the internal liquid and vapor flows into the prefractionator and main dividing wall section are the most crucial design factors. Both impact the total energy consumption and separation efficiency. The energy efficiency of DWC can drastically deteriorate by a small deviation in the net flows from the optimal conditions. Conversely, only the liquid split can be adjusted during operation. The vapor split cannot be manipulated arbitrarily once the column is

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FIG. 1. Schematic diagram of a typical DWC.

FIG. 2. Typical effects of liquid and vapor split on energy efficiency in DWCs.
constructed. For this reason, in most commercial DWCs, there should be a device to split the liquid coming from the column overhead into sections divided by a wall, i.e., a prefractionation section and main column section.

Several reflux splitters have been adopted in commercial DWC installations. A simpler and more reliable reflux-splitting system is the optimum choice for better operability and reliability of the total column system. A novel reflux-splitting system can provide better operation and a more energy-efficient DWC.

**Internal reflux splitters for DWC.** Conceptually, the splitting of a liquid stream can be achieved by a simple arrangement of a pump, valves, pipes and vessel, as shown in FIG. 3. Nevertheless, it still requires additional plot area, equipment and instruments. The increased equipment inventory within the system should be minimized. For this reason, this concept is rarely used in practical applications of DWCs.

The ideal reflux-splitting device for DWC applications should have these technical features and requirements, considering its purpose and mounting location:
- Design does not include a pump and a moving/rotating unit.
- Height and volume of the column should be minimized.
- System can accurately manipulate and control the split ratio.
- Unit is simple, durable and reliable.

**Moving bucket reflux splitter.** First-generation reflux-splitting systems are shown in FIG. 4.\(^5\) These early systems consist of a casing that is subdivided into three chambers. The feed chamber is located above where the liquid is directed onto either the prefractionation or main column chamber depending on the positioning of the dividing body. The split ratio is controlled by adjusting the timing of the hollow inner bucket into the prefractionation or the main column chamber. The dividing body is actuated by magnetic coupling, which allows a pressure- and vacuum-tight design. The exterior drive is a pneumatically driven rotary motor.

**Manual reflux splitter.** The moving elements in the first-generation reflux splitter can be damaged by the constant movement of the mechanical parts. In a petrochemical plant, the splitter should operate at least 8,400 hr/yr without mechanical problems. For example, the naphtha cracking center (NCC) has more severe requirements to address possible equipment malfunction because it needs to have run length of at least three to four years without regular scheduled plant maintenance. A more reliable liquid-splitting device should be used in such cases. For this purpose, a manual-type reflux splitter that requires no moving element was devised, as shown in FIG. 5, and it was successfully installed on several commercial DWCs in LG Chem plant sites.\(^7\)

The internal structure of the manual reflux splitter appears complex, but the basic principle is quite simple. As shown in FIG. 5, the splitter is divided into several sections that receive the liquid drawoff from the column overhead. **Note:** Each section has a liquid distributor with a different number of holes to adjust the liquid flowrate.

An on/off type of automatic valve is mounted to each section. If the valve is closed, the received liquid will overflow into the main section, which is connected directly to the main column without a valve. By combining the opening of each valve, the split ratio can be controlled by predetermined values. The control range of the split ratio can be determined.
from a sensitivity study of the DWC column for possible operation scenarios, such as variations in feed compositions and product quality. The performance of the reflux splitter can be verified before mounting it into the DWC column using a water-run test.

**In-the-column reflux splitter.** The latest development in the reflux-splitter system increases unit reliability with a simple modification of the conventional distributor and collector tray, as shown in FIG. 6. The in-the-column reflux splitter consists of a modified collector tray, collector box and two transfer lines. The collector tray gathers the liquid from the top section and transfers it to the collector box located below.

Holes in the middle of the collector tray (see FIG. 6B) divide the liquid into four sections in the collector box with predefined fractions. As shown in FIG. 6C, the splitting ratio can be adjusted by the on/off operation of two valves, which are located on the transfer lines (see FIGS. 6A and 6C) at the outside of the column. If the two valves are open, then the liquid stream from the middle sections goes to the pre-section via liquid transfer lines, which are connected to the distributor for the presection. Thus, it will increase the liquid flow to the pre-section. If the two valves are closed, the liquid flow to the main section will be increased by the liquid overflow to the main section. Four combinations in the on/off valve are possible, and, thus, the four split ratios are available. In the design phase, the required split ratios can be predefined considering possible operational scenarios.

The developed reflux splitter satisfies all the technical requirements or specifications described earlier; it can reduce fabrication and installation costs. This splitter type is simpler and cheaper than the manual reflux splitter, as well as the bucket splitters. In addition, it can reduce the column height, thus providing the opportunity to install more trays or packing sections with a longer length.

The operating range of this splitter can be predetermined and the performance can be verified before installation in the column. As shown in FIG. 7, the reflux-split ratio can be controlled accurately by closing and/or opening the valves. LG Chem's experience from several petrochemical applications suggests that, in most cases, only four combinations are sufficient to control the split ratio for expected operational variations.

**Evaluation.** Several types of internal reflux splitters were analyzed in terms of reliability, structural simplicity and ease of maintenance. TABLE 1 summarizes the results of the study comparing three different reflux splitters.

Recent developments in the internal reflux-splitting system make the DWC application more reliable with a simpler structure. The reflux splitter without a moving element may not cover a wider range of split ratios, but it can provide more robust and reliable operation with less maintenance. Overall,

**TABLE 1. Comparisons of several reflux-splitter systems**

<table>
<thead>
<tr>
<th>Splitter type</th>
<th>Operating window/control</th>
<th>Reliability/maintenance</th>
<th>Cost/structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moving bucket</td>
<td>Wide/continuous</td>
<td>Fair/overhaul needed</td>
<td>High/complex</td>
</tr>
<tr>
<td>Manual</td>
<td>Narrow/discrete</td>
<td>Excellent/regular valve inspection</td>
<td>Moderate/simple</td>
</tr>
<tr>
<td>In-the-column</td>
<td>Narrow/discrete</td>
<td>Excellent/regular valve inspection</td>
<td>Low/simple</td>
</tr>
</tbody>
</table>

**FIG. 6.** In-the-column reflux splitter: A) overall, B) collector tray and C) collector box and transfer lines.

**FIG. 7.** Results of the water-run test for the in-the-column reflux splitter.
system specific design with a modeling study for possible operational scenarios is recommended to overcome the flexibility issues of the newly developed splitter.

ACKNOWLEDGMENT

This study was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2012R1A1A1001437).

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