Manage risks with dividing-wall column installations

A simple auxiliary configuration and an extensive modeling study can mitigate the implementation risks of DWCs

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Dividing-wall columns (DWCs)—also called partitioned-wall columns—have been introduced as an attractive option to reduce energy consumption and capital costs in distillation processes. However, risks and worries associated with the implementation of DWCs hamper the expansion of this technology in conservative process industries. This article introduces a real implementation case in which a conventional column was upgraded to a DWC. It also discusses how the risks in DWC implementation can be mitigated by establishing contingencies and predicting the column performance via modeling.

BACKGROUND
Since Wright first introduced the concept of the DWC in 1949, over 90 commercial-scale applications have been reported. However, the industrial implementation of DWCs has been slow, despite the potential benefits and promising results of this technology. Most reported DWC applications have been attributed to a few leading companies, namely BASE, Dow and UOP. Recently, other companies have begun to consider this technology more seriously, although only large companies with sufficient research and development (R&D) capabilities can evaluate and benefit from such complex, energy-saving technologies.

The slow acceptance of DWCs is also due to industries' entrenched preference for proven methods over potentially risky new technologies. Hydrocarbon plant operators generally prioritize stable production over energy savings. Such caution is necessary, and it is important that any new system be able to demonstrate its suitability before it is implemented.

This article examines the implementation of a DWC in an LG Chem Ltd. plant, with emphasis on the practical risks of the installation. Extensive modeling studies were used to mitigate implementation risks, check for human error, and demonstrate the industrial suitability of DWCs.

Plant specifications prior to DWC installation. Fig. 1 outlines a 2-ethylhexanol (2-EH) production plant, in which butyraldehyde (BAL) is synthesized from propylene and synthesis gas by the oxo reaction. Normal butyraldehyde (NBAL) and isobutyraldehyde (IBAL) isomers are then separated through an isomer process, and the NBAL is converted to 2-EH by aldol condensation. Crude 2-EH is then generated from EPA and hydrogen by hydrogenation and purified to a final 2-EH product in an alcohol purification unit.

The alcohol purification unit consists of two sequential simple distillation columns: a heavy-cut column and a light-cut column. Column-targeting studies were performed to improve the energy efficiency of the alcohol purification unit. The studies showed that energy consumption could be reduced by 5% with a preheater that recovers heat from the second column's bottom stream. Modification of the column's interior with high-performance packing did not yield significant energy savings.

A preliminary feasibility study for installing the DWC was conducted. The DWC configuration shown in Fig. 2—a retrofit of the existing column—was proposed. Simulation of this DWC
configuration showed that considerable energy savings could be achieved at a reasonable installation cost. Field engineers and plant operators reviewed the feasibility study, but some were skeptical about the DWC's performance and reliability. Further technical evidence was needed to convince the field engineers of the DWC's merits and to ensure safe operation before the installation of the DWC.

**DWC with conventional operation.** DWCs involve simple concepts that should be familiar to chemical engineers. However, plant operators are more familiar with conventional, two-product column systems. A DWC column may also be required to switch between DWC operating mode and conventional operating mode, due to unforeseen circumstances or maintenance. Therefore, dual operation was incorporated into the DWC to allow for conventional operation as a contingency (Fig. 3).

The operating mode of this DWC can be switched by varying the valve positions (Table 1). Additional features required for the contingency mode are vapor-equalizing lines, feed nozzles and several block valves that are also useful for maintenance.

In DWC mode, the side product is withdrawn from the middle of the main section. Liquid flow from the overhead is directed to a liquid-splitting device (i.e., a reflux splitter), and the two liquid streams are then introduced into the prefractionator section and main section. Vapor- and liquid-splitting ratios in the dividing-wall section are the most important variables in DWC operation. Liquid splitting can be easily adjusted using the reflux splitter, making it suitable as a manipulated operating variable. Vapor splitting, however, is determined by the column's interior and the pressure drop of each dividing-wall section, making it a design variable that cannot be freely adjusted after column installation. Therefore, the column's internal design must be based on an accurate prediction of the hydraulics in the partition section to ensure that the vapor-splitting ratio follows the design. Ensuring the integrity of the column requires close collaboration with internal suppliers and other vendors at every stage of the DWC design.

During contingencies, the side draw is not used and liquid flow from the column overhead directly enters each partitioned section. A specially designed distributor can allow dual operation by evenly distributing liquid into each partitioned section. The difference between the pressure drops of the prefractionator and main sections should be minimized, and the two sections should act as one in the contingency mode. An equalizing vapor line must be present to alleviate pressure differences. It is possible to predict pressure drops in the partitioned section with hydraulic correlations from the column internal suppliers and through rigorous computational fluid dynamics (CFD) analysis. Simple correlation is generally sufficient to calculate the pressure drop of each section to reasonable accuracy.

Also, as the arrangements of nozzles and pipes are complicated and potentially confusing, a 3D visual model was created to help reduce human error in construction (Fig. 4).

**Predicting column performance.** Installing a partitioning wall does not guarantee energy savings. The benefits are system specific and depend on the properties of the separation system and the required products. Potential benefits should, therefore, be rigorously estimated through an extensive case study. Simulation software can be used to design a DWC and to predict its performance using built-in, thermodynamic physical properties. For an existing column, plant operations data can be used to reassure the reliability of the physical and thermodynamic property methods selected. Design variables—such as total number of trays, feed and product locations, and liquid- and vapor-splitting ratios in the partitioned section—can be determined by simulation. Construction costs should be estimated with regard to site-specific concerns.

The concept of a DWC with dual operating modes can be realized without greatly increasing the installation cost. Before implementing the concept, the performance of each operational mode of the column was predicted through rigorous modeling. Fig. 5 shows column temperature profiles for the two operational modes. In DWC mode, the temperature profile of the prefractionator section differs from that of the main section, while they are identical in contingency mode.

The vapor-splitting ratio in the partitioned section is uncertain and cannot be adjusted freely once the column is installed, while the liquid-splitting ratio can be easily manipulated during opera-
tion. Therefore, to assess the effects of unexpected performance deteriorations, sensitivity studies are required that examine possible variations of the actual vapor-splitting ratio. Temperature profiles are shown for vapor-split ratios in DWC mode (Fig. 6) and contingency mode (Fig. 7). In the example column in Fig. 6, performance was not greatly affected by changing the vapor-splitting ratio. Product quality remained within the product specifications for the vapor-splitting ratios tested.

The effects of changes in feed composition, the liquid-splitting ratio and other operating variables were modeled to ensure that performance and product quality could be maintained within acceptable ranges. Nominal operating conditions were set and reviewed before startup. The column's temperature profile during operation was well-matched to the simulation results.

**Turndown ratio.** DWCs generally lack operational flexibility. If a plant is not operating with a normal load during startup or shutdown, the column should be operated with a considerably lower feedrate. DWCs use less energy, implying that vapor and liquid loadings are lower than in conventional columns. With lower loads, internal flows can be increased by raising the boil-up and reflux rates, at the cost of increased energy use. The example column was successfully operated at below half of the normal load without showing problems during startup.

**Foundation reinforcement, instrumentation.** In this installation, the bottom section of the existing column could be used. The only problem related to the implementation was ensuring sufficient structural strength for the increased height and

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CONCLUSION

A DWC with two operating modes was designed and studied to minimize operational risks and to ensure a safe retrofit to an existing column. The DWC was then installed in an LG Chem Ltd. plant, and it has been operating successfully since startup. Computer modeling was an important factor in establishing the DWC, as these columns require extensive analysis.

The existing conventional column was easily upgraded to a DWC through the addition of a partition wall. This upgrade was achieved in an acceptable period of time. The proposed DWC arrangement can be used in the revamp of other single conventional columns, allowing for significant reductions of energy expenses at a reasonably low capital cost.

The idea of a dual-mode DWC alleviates plant personnel’s concerns about the potential risks of DWC implementation and thus contributes to the greater application of DWCs in the hydrocarbon industry. HP

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LITERATURE CITED


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Operator training and troubleshooting. The concepts of the DWC, its operational modes, and the new equipment were explained to the plant operators, as were the startup and shutdown procedures. The operators understood the concept and benefits of DWCs, and their questions were clarified with 3D models and simulation results. The help of operators and plant engineers was essential to the project’s success at all stages, from the preliminary study to the actual implementation. Thorough and clear communication reduces unnecessary time losses and risks during implementation. In most cases, process engineers who design DWC columns are not aware of site-specific concerns.