

More than just Thermodynamics, mechanical design of dividing wall columns – best practice experiences

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Abstract. Dividing wall columns, still apply a complicated mechanical design for many processes. Avoiding the challenging design, including positioning of the dividing wall, liquid and vapor split above and below the dividing wall, preference is often given to a conventional column sequence. Even though the sequence is more energy- and cost-intensive. While welded-in dividing walls are often used for new columns, the use of non-welded dividing walls is more suitable for revamp projects. Sealing is of great importance for all wall types and various solutions up to fully sealed screwable versions are available. In addition, special designs such as insulated dividing walls have been developed. The required liquid split above the dividing wall and the vapor split can be obtained by different solutions. These mechanical solutions are illustrated by four case studies.

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Introduction

In the field of distillation applications, the advancing global warming and the accompanying necessary reduction of carbon dioxide emissions is always connected with the reduction of energy demand. A simple reduction of the energy demand was already described in the first half of the 20th century in two American patents [1,2], addressing the application of a dividing wall column. The concept combines the heat-integrated connection of two columns in one apparatus. As shown in Fig. 1, this integration makes it possible, to save energy, where in a conventional two column system the energy used in the first column to concentrate component B, is lost again in the stripping section of the first column withdrawing a mixture of B and C and the energy intensive separation of B and C has to be performed again in the second column.

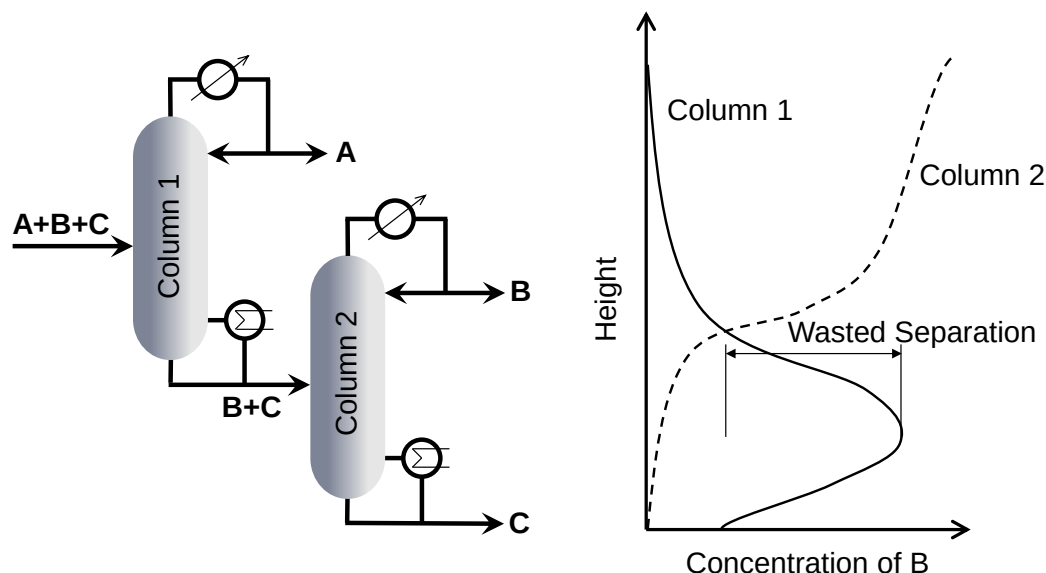


Fig. 1 Concentration profile of component B as function of the column height in a conventional column system.

In the first half of the 20th century, however, there were not yet sufficient possibilities to design a dividing wall column thermodynamically. This changed in the second half of the 20th century by increasing simulation capabilities and developing a short-cut method [3,4,5] for a simple and fast simulation of a dividing wall column. All developments of dividing wall columns showed energy savings up to 50%. The first commercially used dividing wall column was built and put into operation in the mid-1980s. The column was equipped with internals by Julius Montz GmbH. This combination of thermodynamical knowledge of the operating company and the hydraulic knowledge of column internals by Montz is a decisive contribution to the proper usability of a dividing wall column. Despite the possibility of simulating dividing wall columns, a critical factor is the distribution of the vapor flow below the dividing wall to both sides of the wall. Thus, the exact knowledge of the hydraulic behavior of the column is necessary. Otherwise, the vapor split will not adjust according to the simulation and the separation result will be different from the simulation results. The challenges of dividing wall column design and the myth of uncontrollability in the operation of dividing wall columns led to the fact that only single large chemical and petrochemical companies were able to design, build and operate dividing wall columns. Even today, the opinion persists that dividing wall columns are only a marginal phenomenon in distillation and that even the mechanical challenges are too great to bring dividing wall columns to a wider range of applications. In the following, this thesis will be refuted by four case studies to show that for almost every theoretical thermodynamical consideration in the design of a dividing wall column, a mechanical solution already exists which has also been tested and proven on an industrial scale.

Case study 1: Working with a small column diameter

The first case study is a dividing wall column with a diameter of 500 mm. The difficulty was the insertion of the dividing wall. Due to the small diameter of the column, the column must be designed with apparatus flanges and the dividing wall must be welded in as assembly of multiple bolted wall pieces was not possible due to limited installation space. The challenges were the flange connections in the area of the dividing wall. Not only must the column shell be flanged, but also the dividing wall at the same time. A loose dividing wall, that is loosely sealed to the column shell with wall wipers in the area of packing beds and has no fixed connection to the column shell, cannot be installed due to the impossible assembly. Fig. 2 shows an exemplary welded-in dividing wall in a larger column that can be accessed through manholes. Requiring a diameter of at least 1200 mm, the installation of the internals can be easily realized through the manhole.



Fig. 2 Welded-in dividing wall.

This dividing wall can also be insulated if necessary [6] to minimize heat transfer from one side of the dividing wall to the other side of the dividing wall as the energy transfer leads to condensation and evaporation at the dividing wall and can have a negative effect on the separation efficiency. For smaller column diameters, only an apparatus flange connection is possible, since there is no space left for the installation inside the column. For the 500 mm diameter column described, there were also very high tightness requirements resulting from the polymerization of the medium in the presence of air humidity. The weak point in the column was the connection of the dividing wall to the column

shell on the sealing side of the flange. This required both turning off the flange, but at the same time milling off the dividing wall so that the gasket could also meet its sealing requirements. An offset or, in particular, a difference in height between the dividing wall and the flange would have immediately led to enormous leakage to the atmosphere as well as internally between the two sides of the dividing wall. Where the latter one would lead to a decreased purity of the product stream, which was not acceptable for this process. The use of tightened tolerances for turning and milling resulted in an excellent solution from a first visual point of view. To verify this visual result, a helium leakage test was performed with a maximum leakage rate of $1 \cdot 10^{-6}$ mbar $\cdot$ l $\cdot$ s $^{-1}$. The helium leak test was accepted with a maximum leak rate of $7 \cdot 10^{-7}$ mbar $\cdot$ l $\cdot$ s $^{-1}$.

In addition to the leakage at the flange connection, there were two other challenges. The first challenge was to avoid heat distortion when the dividing wall was welded in. With heat distortion, out-of-roundness of the column would have formed, which would lead to a gap between the structured packing and the column shell. This gap would result in bypass flows for liquid and vapor and thus reduced separation efficiency. To prevent this heat distortion, the welding of the dividing wall to the column shell was explicitly monitored and the roundness of the column, also on the two dividing wall areas, was subsequently checked with templates of the structured packing. The second challenge was the split of the liquid above the dividing wall to both sides of the dividing wall. There were various alternative solutions for the liquid split. Starting with purely static piping with different orifices, which, however, deviated greatly from the prescribed operating point in the case of a larger operating range and could not be changed after installation, to a total liquid draw-off into a buffer tank and a pumped return to the column. This leads to additional equipment costs and, due to the additional pump, also to increased maintenance costs. However, the pump can always be readjusted so that the entire operating range can be covered and future changes in the process can also be accommodated. The third alternative was a reflux splitter, which was also finally used. This reflux splitter is flanged to the outside of the column and contains a funnel that takes over the liquid split in a time-controlled manner via a magnetic coupling that is pneumatically driven. Even with this reflux splitter, the liquid split can still be optimized after installation and during commissioning by changing the timing.

Case study 2: Revamping a conventional trayed column to a dividing wall column with structured packing

The second case study involves a revamp of an existing 2200 mm diameter trayed column to a dividing wall column equipped with structured packing. The revamping work was extensive, as all the support rings of the trays had to be cut out. A loose dividing wall was chosen to minimize the work in the column. In this case, the dividing wall is only sealed to the column shell with wall wipers and the position of the dividing wall is dictated by the design of the packing beds. Thus, the dividing wall does not need any weld-in parts in the area of the packing beds. This avoidance of weld-in parts led to a drastic reduction in the amount of work required during the revamp in the column. The challenge with the loose dividing wall is a possible leakage across the dividing wall from one side of the dividing wall to the other side of the dividing wall. However, this leakage flow is a function of the driving force, i.e. temperature, pressure and concentration differences between the two sides of the dividing wall. In this case study described, the driving force was very small and thus negligible, and the loose dividing wall was used. A trial assembly of the packing in conjunction with the loose dividing wall is shown in Fig 3.



Fig. 3 Loose dividing wall column for a revamp project of a conventional column to a dividing wall column.

A further development of the loose dividing wall is the bolted dividing wall, which minimizes leakage rates [7]. To use a bolted dividing wall, support bars are welded to the column shell in the area of the packing beds, to which the single pieces of the dividing wall are finally bolted, also sealed with PTFE gaskets for example. Particularly in the case of smaller columns, both solutions, the loose dividing wall, and the bolted dividing wall, provide a considerable advantage during installation. Due to the simultaneous assembly of the packing and the dividing wall, the assembly team has the entire column cross-section area at its disposal and thus does not have to contend with such cramped conditions as when using a welded in dividing wall.

Case study 3: Trayed dividing wall column

Compared to the packed dividing wall columns shown so far, dividing wall columns equipped with trays are also in use. This third case study shows a trayed column with a diameter of more than 4 m, which was to be revamped into a dividing wall column equipped with trays. The existing support rings were to be reused, if possible, to minimize the work in the column and thus minimize the shutdown of the column. The hydraulic design showed that the tray spacing of the existing column was sufficient and therefore the existing rings only had to be cut out in the area of the dividing wall and the future downcomers. Then the dividing wall had to be welded in and finally the support rings on the dividing wall had to be connected to the support rings on the column shell. Due to the multi-flow design of the trays, the flow direction was in the same orientation as the dividing wall. In columns with low liquid loads, the downcomers can also be integrated into the tray deck as a complete downcomer. This saves additional effort since the existing support rings on the column wall do not have to be cut out for the new downcomers. A 3D model of a dividing wall section is shown in Fig. 4.

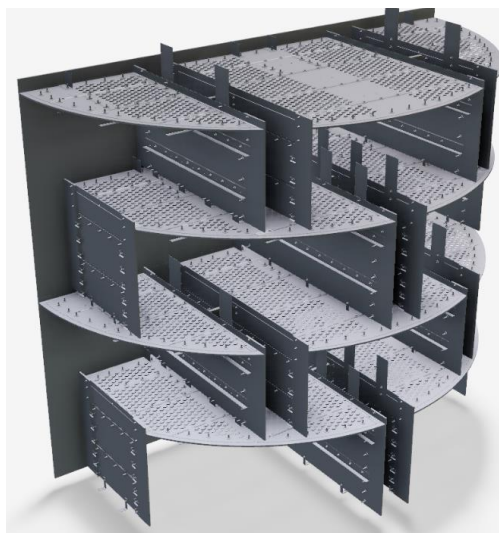


Fig. 4 3D Modell of a trayed dividing wall column section on one side of the dividing wall.

The dividing wall was welded in the center of the column despite a vapor split of above one. Central welding is a major advantage of trayed columns over packed columns. The design and manufacturing effort for internals for a centrally placed dividing wall is naturally lower since all internals are mirror images of each other. In packed dividing wall columns, center placement is usually not possible because of the pressure drop characteristics of the dividing wall column. There are possibilities to influence the pressure drop artificially, such as additional catcher trays, but this is only possible in a very small range of the pressure drop. Trayed dividing wall columns offer the possibility of strongly manipulating the pressure drop simply by changing the weir height of the trays and thus simply placing the dividing wall in the center of the column.

Case study 4: Changing wall position along the column

The fourth and final case study is a column with very different vapor loads above and below both the feed inlet and the side draw-off. This different vapor loads resulted in the need to change the position of the dividing wall above and below the feed inlet and the side draw-off. Fig. 5 shows the area of the position change during the installation work in the column photographed from top to bottom.

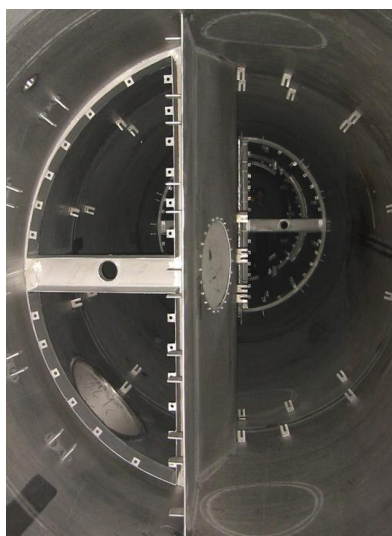


Fig. 5 Welded-in dividing wall with different wall positions in one dividing wall column.

The dividing wall was a loose dividing wall, which was only bolted to a welded-in dividing wall in the area of the redistribution sections. Especially when the feed or side draw-off is vapor, such unequal vapor loads occur on both sides of the dividing wall. However, this example also shows that an off-center position of the dividing wall is not a challenge but common practice. All other column internals, such as flash boxes, and additional feed streams and side draw-offs are just as possible as with conventional columns.

Conclusion

The four case studies presented show that nowadays there is a corresponding mechanical solution for almost every theoretical consideration for dividing wall columns. Thus, the still prevailing opinion that dividing wall columns are only a marginal solution for distillation in a small application range is simply wrong. All solutions shown in the various case studies are real partition wall columns, which are currently in operation and have the designed performance characteristics. In conclusion, the recommendation to all operators of distillation plants is to realize the potential energy savings of up to 50% compared to a conventional column system and to consider the use of dividing wall columns also for existing processes.

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