

UNFIXED DIVIDING WALL TECHNOLOGY FOR PACKED AND TRAY DISTILLATION COLUMNS

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Dividing wall columns are state of the art single shell distillation columns which allow separation of three or more component feed streams into pure products. Dividing wall is in the simplest case a flat metal sheet which is welded on both sides to the column shell. An advanced mechanical construction concept provides stacked wall elements which are not fixed to the column shell. This offers the possibility of easy retrofit of existing columns. Poor tolerances of the column shell can easily be compensated. In combination with self-centring packing elements very high purities of the products can be obtained. At present the unfixed dividing wall technique has become the standard solution for packed columns.

KEYWORDS: Distillation column, dividing wall column, unfixed dividing wall, energy saving

INTRODUCTION

Although the origins of dividing wall columns (DWC) can be traced back to American patents issued to Monroe in 1933, with the partition wall located in the bottom part of the column, and that issued to Wright in 1946, with the partition wall placed in the middle part of the column, it took nearly 40 years until first implementation in industrial practice. The first application has been reported by BASF in 1985, and the whole concept elaborated thoroughly in a paper by G. Kaibel of BASF in 1987. Presently, at the chemicals company BASF, the pioneer in this field, there are some 50 dividing wall columns in operation. Majority of these columns are packed columns built by MONTZ, a process equipment manufacturer that was instrumental in practical realization of BASF designs and presently is manufacturing dividing columns, both packed and tray ones for third parties. First of a number of patents was issued to MONTZ in 1993 (Jansen et al.) for packed columns and the last ones (Zich et al.) in 2002 for tray columns.

Figure 1 shows the number of packed dividing wall columns built by MONTZ. The trend shows two different slopes of the applications line indicating a stronger increase in the number of delivered columns maintained over the last ten years. It should be noted that the point of the departure from initial slow grow coincides with the moment that BASF adopted the idea, and consequently commenced installing unfixed walls, which provided for much more flexibility regarding both process and mechanical design side. This important decision, which enabled real breakthrough of this technology, was made upon execution of a series of devoted proprietary tests carried out by the Laboratory for Process Equipment of the Delft University of Technology in cooperation with

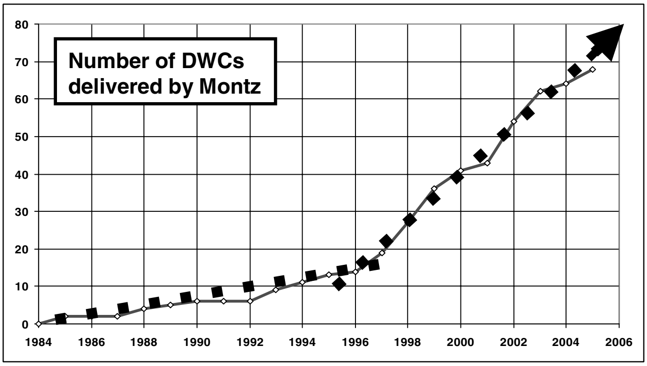

Figure 1. Number of dividing wall columns delivered by MONTZ over the years

MONTZ, using hydraulic column simulator facilities available in Delft and at MONTZ in Hilden. The diameter of the experimental column was 1 m. The tightness of the assembly of stacked wall elements was tested with colored water as liquid phase tracer and carbon dioxide as gas phase tracer. This proved to work and BASF extended the number of potential applications significantly. Unfixed dividing walls have been applied in different types of dividing wall columns.

Strikingly, it took about fifteen years before other companies joined. Anyhow, initial reluctance towards the new system, which is more demanding with respect to the lay-out, construction and control, has been broken finally after repeated demonstration of the considerable advantages of this type of distillation column, and during last few years other companies started with installing and running dividing wall columns. Another breaking development, i.e. milestone occurred in 1999 when first tray column with welded dividing wall was taken into operation at Sasol in RSA (Becker et al., 2000). Linde Germany did the engineering, supported by the know-how from BASF, and in the meantime a 100 m tall tray column came into operation at Sasol. Present status of this now established and widely accepted technology is documented in a series of lectures given by G. Kaibel and other people exposed in this field on the occasion of IChemE Dividing Wall Column Symposium held in September 2004 at the University College in London (UCL, 2004).

Academic work has been concentrated mainly around performance simulation (decomposition into sections connected in parallel and in series proved to work) and evaluation of energy saving potential as well as control aspects. Main sources in this respect are numerous papers from R. Smith group of the University of Manchester. A fresh view on these aspects of DWC can be found in a recent paper by G. Kaibel et al. (2004), indicating that simultaneous equation solving algorithm approach overcomes convergence difficulties experienced with sequential algorithms. However, the software side of DWC is another subject and this paper concentrates on hardware aspects, which are scarcely (Becker, 2001), if at all, described in open literature.

DWC FEATURES AND PROSPECTS

Dividing wall columns offer substantial advantages: they provide considerable energy savings in the range of 10 to 45%; savings of investment costs are in the same range of about 30%; less construction volume is required; degradation of thermally sensitive substances is reduced as residence times in critical regions with high temperatures, e.g. reboilers, remains short, etc. There is a broad field of applications. Initially dividing wall columns were applied in final distillations, where the medium boiling component represented the main component and had to be separated at high purity specifications from small amounts of low boiling and high boiling by-products. In this field of application dividing wall columns exhibit their full spectrum of advantages. In some cases dividing wall columns are used for the production of chemicals at highest electronic grade purities, where impurities are specified in the ppb range. The range of products is wide. It covers hydrocarbons, alcohols, aldehydes, ketones, acetals, amines and others. Obviously there are no restrictions with respect to the type of chemicals.

At present there are additional fields of application, e.g. azeotropic and extractive distillation. Reactive distillation in dividing wall columns might become a new promising process, as it offers considerable advantages. At present industrial applications of reactive distillation in dividing wall columns have not yet been reported, but research and development is making a steady progress in this direction.

TYPES OF DIVIDING WALL COLUMNS

THREE-COMPONENTS MIXTURES

There are two main types of conventional dividing wall columns for separation of three component feeds. Both configurations can be equipped with unfixed dividing walls. The more common type of dividing wall column is shown in Fig. 2 on the left hand side. The dividing wall is placed in the middle section of the column above and below the feed and the side draw. The first description of this type of column was published in 1946 patent by R. Wright. This type of DWC columns represents a good approximation of a thermodynamically optimal (direct heat coupling) distillation arrangement. In the case of the separation of a 3-component mixture the thermodynamically ideal separation sequence is achieved and the formation of additional entropy of mixing on the feed plate due to differences between the feed concentration and the concentration on the feed plate can be avoided. This configuration of DWC was first implemented in practice.

An even simpler configuration is a DWC which has the dividing wall placed either at the upper or the lower end of the column (Fig. 2, second and third column), as suggested in the 1933 patent by Munro. The first applications of this rather simple configuration in industrial practice occurred in 2004. This type of dividing wall column is a practical one-shell solution for a common situation, with a main column associated with a side, rectifying or stripping only column. This configuration enables investment savings, as the costs of a second column shell are avoided.

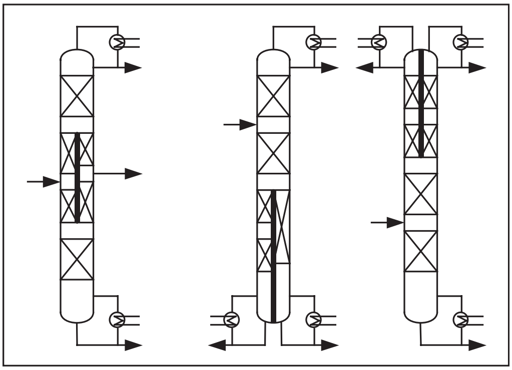

Figure 2. Basic types of dividing wall columns

However, in contrast to columns with the dividing wall in the middle section of the column, energy savings can not be obtained. Also, temperature differences at both sides of the dividing wall can be higher compared to columns with the dividing wall in the middle section. In cases with high temperature differences the mechanical stresses exhibited on the construction should be checked, e.g. by finite element calculations. In critical situations replacing the welded dividing wall by an unfixed wall is advisable. This way the peak values of the mechanical stress are drastically reduced. In general, if the temperature difference between two sides of dividing wall is such that it could affect the separation process, insulation of the dividing wall should be considered.

MULTICOMPONENT MIXTURES

Dividing wall columns can also be used for the separation of feed streams containing more than three components. Obviously, this provides for much larger investment savings. The separation of a 4-component mixture, which can be performed in a single dividing wall column (Fig. 3, left side), replaces 3 separate columns which would be necessary when applying conventional column arrangements. There are already some industrial applications of a DWC for separation of four-component mixtures.

In principle, comparable, thermodynamically more efficient column arrangements with a larger number of dividing walls might be applied for multi-component feed streams. A feasible configuration is illustrated on the right hand side of Fig. 3. So far, no industrial applications are known. Potential applications may be limited, as the number of theoretical stages increases with additional components and the temperature difference between the reboiler and the condenser may reach impractically high values.

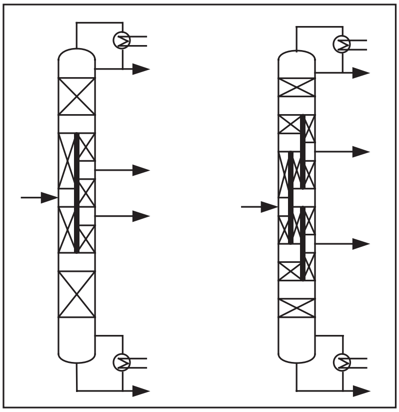

Figure 3. Dividing wall column with (left) and without (right) formation of entropy of mixing on the feed plate for the separation of a 4-component mixture

CONSTRUCTION ASPECTS

Dividing wall columns can be equipped with trays as well as with random or structured packings including all auxiliary equipment. Technically, there is no difference to conventional columns, provided the internals designed for a DWC comply with increased process and mechanical design requirements. Regarding the column dimensions, the diameters of industrial dividing wall columns cover a wide range from 0.3 m to more than 5 m. The before mentioned tray DWC at Sasol has a height of more than 100 m.

Tray columns are easier to deal with, due to their robust construction. The dividing wall can be used to increase the mechanical strength of the construction. Importantly, by shortening (halving) the distances between opposite walls the dimensions of support beams of the trays can be kept smaller. Stacked wall elements are an interesting alternative to large dividing walls which are welded to the column shell; however this promising option has still not been proven in practice.

Construction details strongly depend on the desired product specifications. Leakages of liquid and/or vapour should absolutely be avoided, which is less certain if unfixed wall design is considered. The related know-how belongs to proprietary mechanical engineering knowledge produced jointly or shared by BASF and MONTZ.

Columns with structured packing impose stronger demands with respect to constructional details, particularly if high product purity is required. The direct contact of packing elements with the column walls should be avoided to prevent excessive wall flow of liquid, which would adversely (bypassing) affect separation. For columns with welded dividing walls, the welding procedure represents the most critical fabrication step when structured packings are considered. The dividing wall must remain absolutely flat and the packing elements must not touch the dividing wall or column shell. In cases

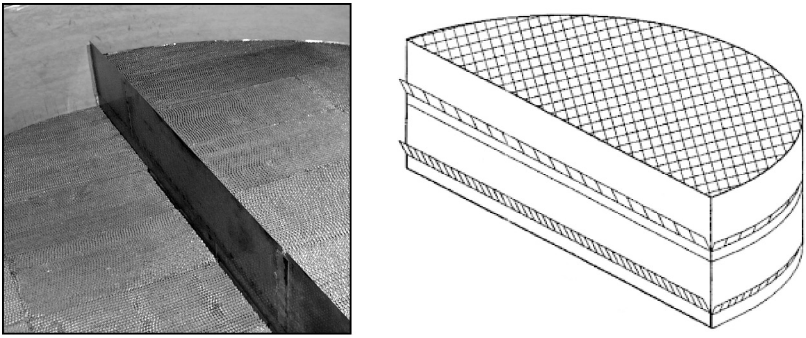

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Figure 4. Stacked dividing wall elements and packings with proprietary self-fitting wall wipers

with poor tolerances of the column shell this can lead to difficulties during inspection or, more worse, during installation. It is essential to have a good working system of wall wipers and to adjust them properly during installation.

When dealing with the development of unfixed wall concept, MONTZ and BASF arrived at some very effective practical solutions. First of all the dividing wall is assembled in the column from unit size elements which can be stacked in parallel and upon each other. These basic elements consist of metal sheets with a thickness of only about 1.5 mm (Fig. 3) with dimensions allowing easy access through manholes. The assembled dividing wall is fixed by structured packing manhole size segments which can easily be formed to fit precisely in the space available, if needed to compensate for pronounced unevenness in column diameter, which occurs frequently in practice. Provided with proprietary self-fitting wall scrappers the packing segments help to fix non-welded wall appropriately. In addition, first experiences indicated that DWCs with unfixed walls can be installed faster and with more precision. Fewer manholes are required. Most importantly, revamping conventional columns became simpler, faster, and cheaper.

Flexibility provided by unfixed wall enabled tailor made approach to assembling dividing wall columns, to meet special process requirements. Some unusual configurations illustrated schematically in Fig. 5 have already been realized in industrial practice. These include positioning the feed stage and the side draw at different heights (Fig. 5a), which accounts for larger differences in relative volatilities of the feed components as well as off-centre positions of the dividing wall (Fig. 5b), to handle different loads of DWC sections. In cases with vapour feeds and vapour or liquid side draws a diagonal off-centre position is to be preferred (Fig. 5c and 5d).

Even more, the non-welded wall technique makes easier building dividing wall columns for the separation of four and more component mixtures under difficult process conditions as e.g. high vacuum. Figure 6 shows a detail of the liquid distribution

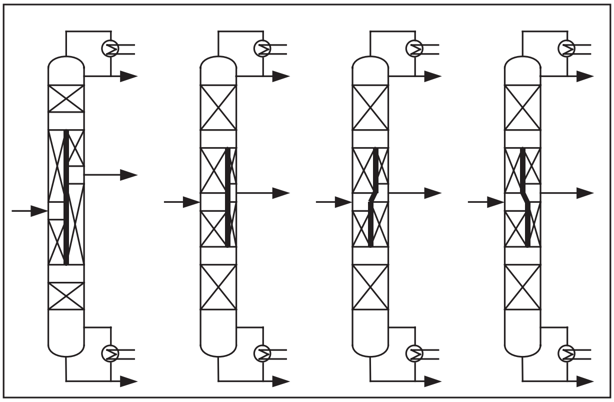

Figure 5. Different positions of the dividing wall

system for very low liquid loads. The pre-distribution unit comprises narrow troughs with drip tubes, with orifices in the side walls, and final distribution devices, i.e. narrow troughs are equipped with provisions for capillary action. Top left photograph shows a reflux splitter.

Figure 7 shows the top view of an empty cross section indicating transition between two sections of different cross sectional area as well as provisions for fixing liquid distributors. The manhole in the short inclined fixed wall section allows access from one side to the other side of the non-welded dividing wall. Only short parts of the wall are welded to provide sufficient mechanical strength to fix and carry liquid collectors,

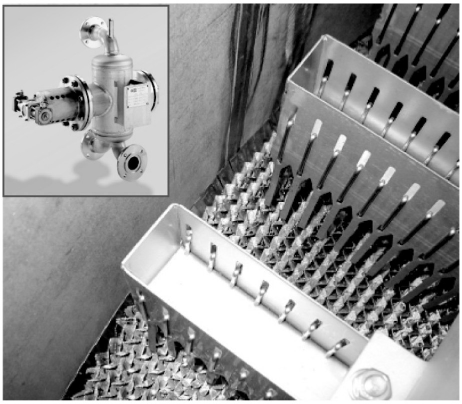

Figure 6. Photographs of the details of the liquid distribution system for very low loads

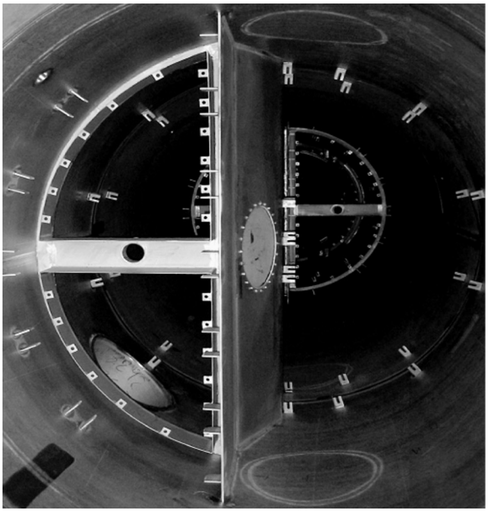

Figure 7. Top view of a cross section of the column indicating construction and installation details

redistributors and packing supports. In the packed part, non-welded stacked wall elements are installed, and the fixing is achieved by specially designed wall wipers.

Although still not applied in industrial environment, proprietary technology and know-how for utilization of unfixed partition walls in tray columns is available

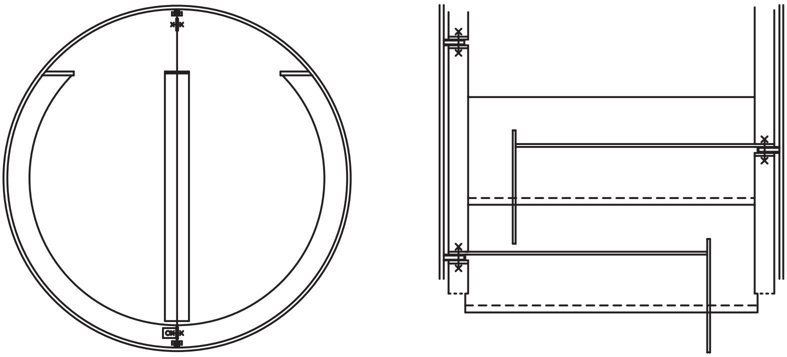

Figure 8. Stacked dividing wall elements for tray columns

(Zich et al., 2001, 2002). Drawings shown in Fig. 8 illustrate basic arrangements for conventional cross flow trays. As mentioned before, adoption of non-welded walls proved to be useful on both sides, mechanical as well as process design. The tray rings are welded, however, the problems associated with welding the partition wall and mechanical stresses are eliminated. On the process side, similar to packed columns, unfixed walls introduces a great degree of flexibility with respect to composition and thermodynamic condition of the feed as well as internal flows and the relative volatilities of components involved.

CONCLUDING REMARKS

Dividing wall columns which accomplish separation of three or more components into pure products within one shell gained the status of a proven technology and after a period of initial reluctance it is gaining increasing acceptance in industry. The introduction of unfixed dividing or partition wall proved to be the key to a technology breakthrough, because it provided a great degree of process and installation flexibility, which enabled a strong expansion of the application window. After numerous successes experienced over the past ten years with structured packing columns a similar strong growth is expected also in typical tray column applications. In any case, DWC can already be considered as a distillation process intensification success story, and will certainly develop into a standard type of distillation column in the near future.

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