Reprint from Presentation at

ERTC PETROCHEMICAL Conference
20st-22nd February 2002, Amsterdam, The Netherlands

and

ARTC PETROCHEMICAL Conference
11th – 13th March 2002, Bangkok, Thailand

Sulzer Chemtech, March 2002

DESIGN AND REVAMP OF MODERN C2 SPLITTERS USING HIGH CAPACITY INTERNALS AND FAST INSTALLATION TECHNIQUES

Jose L. Bravo, Jan Sikkenk, Shell Global Solutions International, Amsterdam, NL

Mario Roza, Loris Tonon, Sulzer Chemtech, Winterthur, CH

For Presentation at the ERTC Petrochemical Meeting in Amsterdam (NL), 20 – 22 February 2002

ABSTRACT

Two factors are key in successfully implementing revamps of olefins distillation trains:

a) Effective increase in column productivity by increasing hydraulic capacity and separation efficiency.
b) Fast turnaround times during installation. The use of High Capacity trays in these cases can provide the first but to ensure the second one needs to apply specialized designs and installation techniques.

This paper describes first the technology available today to revamp ethane/ethylene splitters with high performance trays at various tray spacings. The discussion will cover items such as process simulation, plates vs. reflux effects, tray capacity and efficiency, and the importance of other internals such as distributors for flashing feeds. Consideration is given to a balance between number of trays in the column and the capacity needed. A discussion of specific design requirements for low pressure heat-pumped strippers vs. higher pressure ones will also be presented in the context of how high performance column internals can reduce or eliminate the need for heat pump revamp in many cases.

The second part of the paper will discuss mechanical design features that need to be incorporated into high performance trays that allow for fast installation in revamp conditions and the impact this could have on project economics.

An example of a successful revamp using these concepts will be presented as well to illustrate their application.

Typical C2 Splitter Designs

Two kinds of C2 splitters can be commonly found in olefins plants:

a) Low Pressure C2 Splitters with heat pump or refrigeration
b) High Pressure C2 Splitters

The low pressure configuration is a more energy efficient and often also capital efficient one but requires special equipment to be able to condense the overhead vapors. High pressure C2 splitters normally require more stages for separation and much higher reflux/feed ratios but can condense overheads in a more conventional manner.

Normally the ethylene produced overhead will have a purity of 99.9%, and a recovery in excess of 99% and occasionally close to 99.9% with respect to the ethylene in the feed. Higher recovery splitters are normally configured in the low pressure mode.

For example, a typical low pressure C2 splitter will produce specification ethylene, with 99.9% recovery with a feed as high as 85% ethylene and a bottoms propane stream with about 0.5% ethylene. Conversely, a high pressure stripper could yield specification ethylene with a feed, of say, 59% olefin. The ethane stream leaving the bottom in this case will have less than 1.5%.

Plates vs. Reflux for C2 Splitters

As is the case with all binary separations, a plates vs. reflux curve can be constructed for each specified separation and pressure. This curve clearly indicates the minimum number of stages and the minimum reflux required for separation and the design point will fall between these two extremes. Of note is that the feed location also has an important effect on these curves.

Figure 1 represents such a curve for a low pressure C2 splitter. It clearly indicates that lower pressures are conducive to lower reflux requirements and lower required number of stages. This is of prime importance in revamps since the ability to increase reflux is often limited by the heat pump or refrigeration limits as the case may be. There is great value in being able to increase C2 splitter capacity without increasing reflux/feed ratio and in some cases reducing it. The first variable to look at in this case will be column pressure. If the column has say 80 theoretical stages or more, then pressure is the only variable to manipulate to try to reduce reflux/feed ratio.

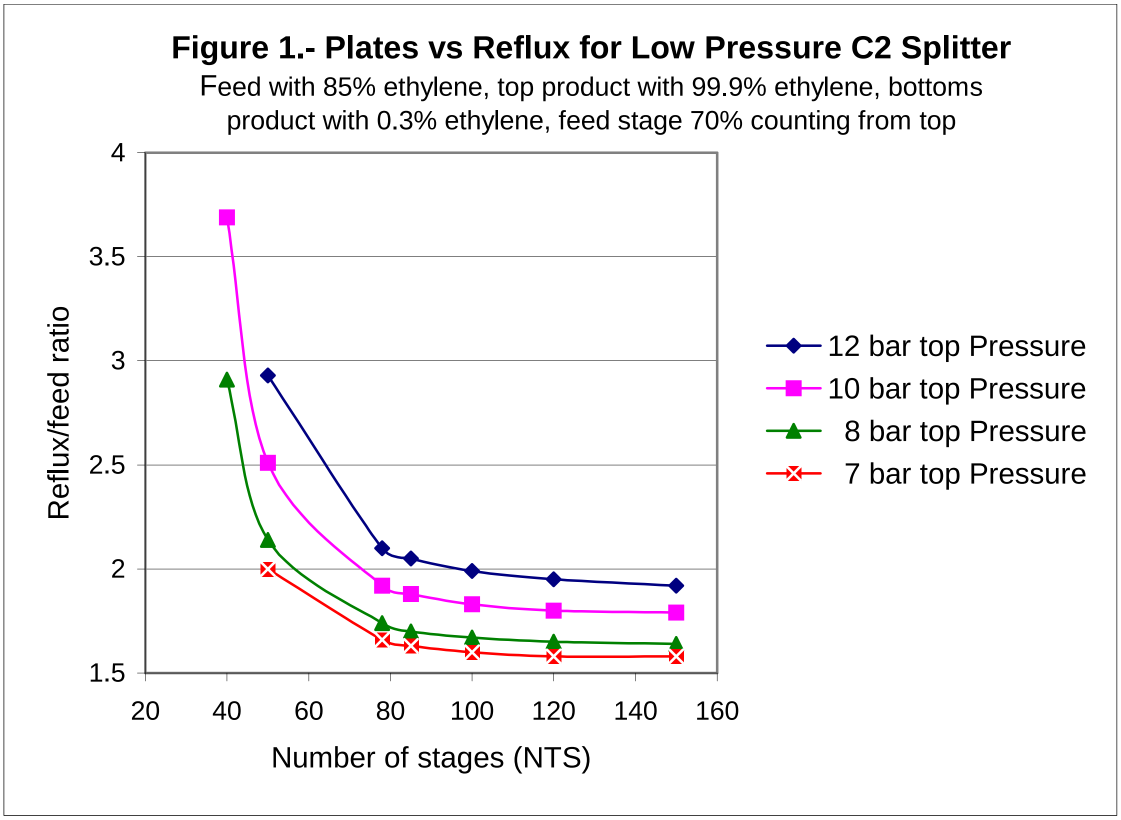
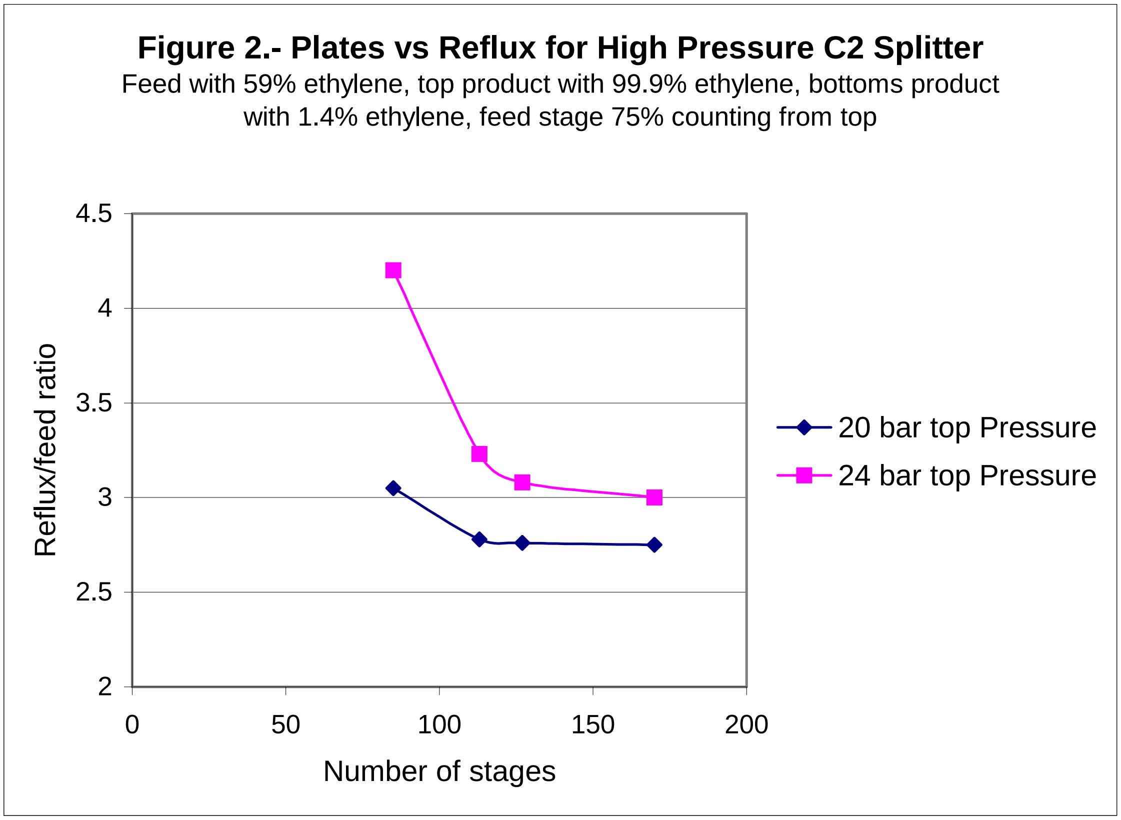


Figure 2 indicates that high pressure splitters exhibit the same characteristics as described above but that the required reflux/feed ratios are generally much higher as are the number of theoretical stages required to perform the separation. In this case though, making more reflux in case of a revamp is less complicated since it may not involve changes to refrigeration compressors or heat pumps. The incentive thus to go to lower pressures in revamps might seem less pronounced.



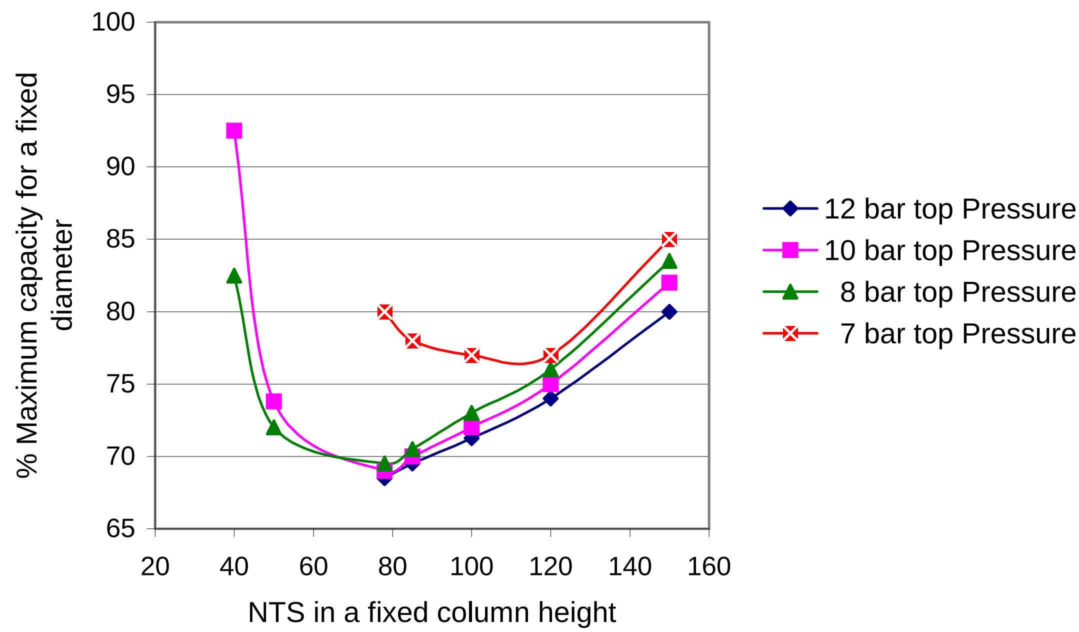
Capacity of Trayed C2 Splitters

The discussion above indicates that lower pressure in C2 splitters yields lower reflux requirements for a fixed number of stages. On the other hand, lower pressure frequently leads to a hydraulic limitation for tray operation, especially in the case of C2 splitters that are commonly limited by jet or entrainment flood and not by liquid handling capacity. In these cases, the low pressure results in higher vapor velocities in the column that leads to flooding.

The analysis of a revamp then becomes a comparison between the beneficial effects of pressure reduction with respect to reflux reduction versus, the negative effects of lower pressure on tray capacity. In the cases where lowering the pressure is mandated by the limitations of the heat pump or refrigeration system, then the use of high capacity trays is of great benefit. Figure 3 is an illustration as to how the splitter characterized in Figure 1 previously is affected by changes in pressure when looking at a revamp situation (column diameter and total length are fixed meaning the fewer stages have more tray spacing and more stages require less tray spacing). Note that the vertical axis shows the fraction of the maximum capacity of the existing column and as such, a lower number means that the column has that much more room.

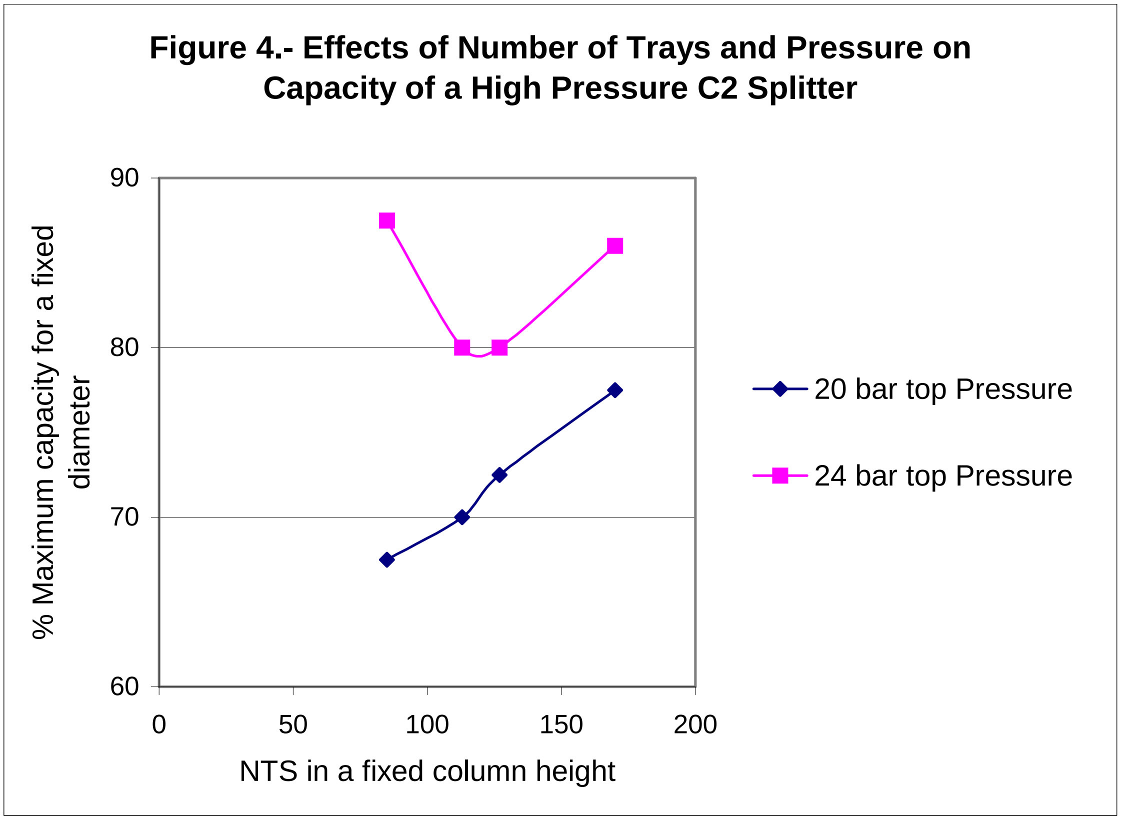
In this case one can clearly see that a revamp at 7 bar is impossible in the existing column since jet flood will limit the capacity severely. The top curve shows how even as the reflux rate is reduced, the increased vapor velocity caused by the low pressure overcomes this benefit. The ideal combination for this case is probably 8 bar since it produces the maximum available extra capacity (lowest % maximum capacity) and the lowest reflux/feed ratio requirements. Figure 3 also indicates that having more than 80 stages in the column is fruitless.

Figure 3.- Effects of Pressure and Number of Trays on Capacity of Low Pressure C2 Splitter



To maximize the column ability one needs to look at high capacity trays that maximize jet flood capacity by the use of trays with maximum bubbling area and effective bubblers. The Shell Calming Section™ (CS) and HiFi Plus™ trays combine such features by using truncated downcomers with perforations underneath that maximize bubbling area and by applying Sulzer MVG™ valves as bubblers that produce markedly less entrainment.

Figure 4 shows the same analysis but for the high pressure splitter described above in Figure 2. In this case the choice is clear, the lower pressure gives the advantage of maximum capacity for the overall system. It is interesting to note that in this case, the 24 bar case has such a detrimental effect on volatility that the reflux requirements become extremely high making this an unworkable pressure.



High Capacity Trays for C2 Splitters

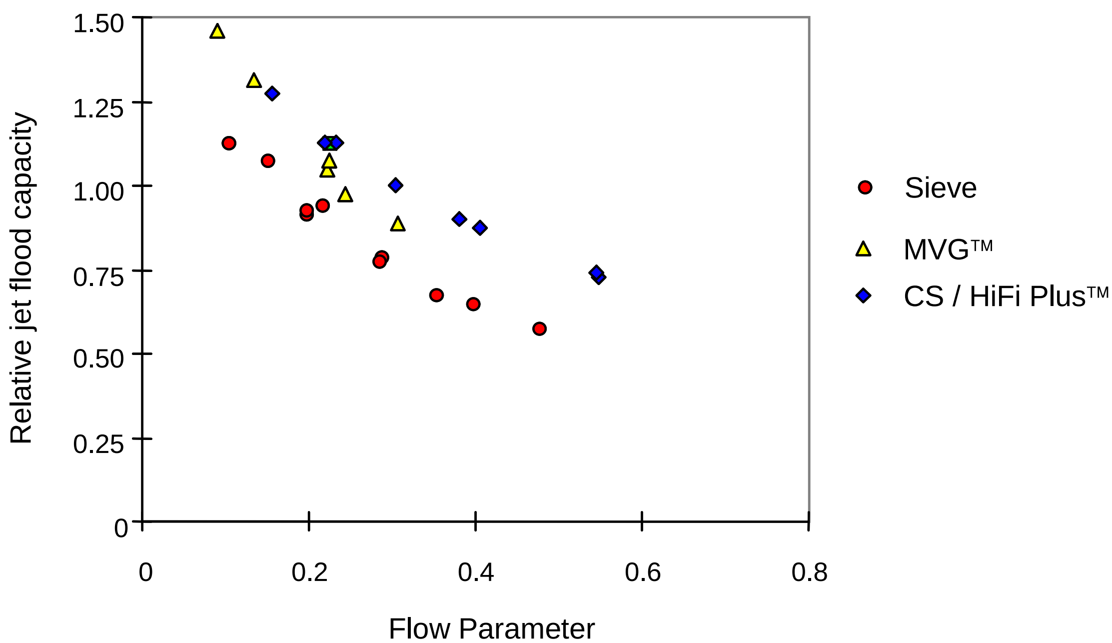
As mentioned above, revamps of C2 splitters for higher capacity can effectively take advantage of high capacity tray technology. In particular, the use of trays that increase jet flood capacity at high pressure can be very interesting. Tray features that increase jet flow capacity are, among others:

a) Truncated downcomers that allow for perforation underneath leading to larger bubbling areas.
b) Bubblers such as small fixed valves that reduce entrainment.
c) Devices at the inlet and outlet of downcomers that produce a lower and more uniform froth height.

Figure 5 demonstrates the effectiveness of these features in enhancing the capacity of trays. The vertical axis represents the relative jet flood capacity whereas the horizontal axis, the Flow

Parameter, is an indication of liquid load and pressure. C2 Splitters are typically found in the Flow Parameter range of 0.1 to 0.3.

Figure 5. - Relative Jet Flood Capacity of Various Tray Devices



The graph compares the capacity of a sieve tray with that of the same tray with MVG valves. The upper set of points represents the performance of the HiFi or CS Plus trays that include the MVG valves as well as other features to stabilize the froth on the tray. Clearly the MVG adds 10-20% capacity and the other feature adds an additional 10-20% as well depending on the tray regime.

Construction and Installation Considerations for fast Revamps of Tray Columns

The critical path for a shutdown involving extensive modifications to C2 and other splitter columns as described above is often determined by the installation time of the new internals. The number of days involved in a shutdown can have a very large impact on the profitability of a revamp. It is therefore of extreme interest to look carefully to the installation techniques applied for new trays and how they can reduce the required time.

Once a modification to the column is established, there is little one can do to achieve any major time savings in the dismounting and removal phase of the old internals. Careful planning of such work on several levels in the column with manhole access and coordination of removal of old trays and associated internals and supports is necessary to optimize the dismounting time.

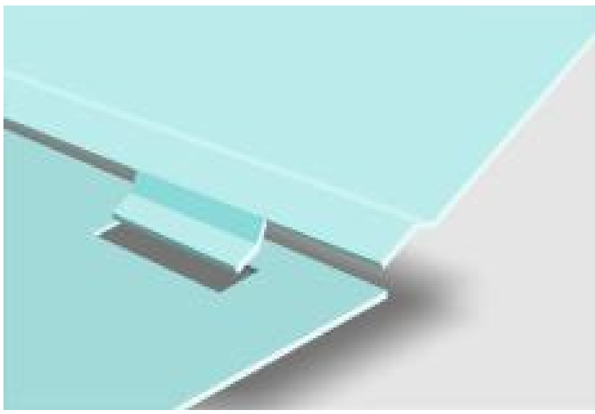
When a different number of trays than originally installed in the column have to be applied, new support structures have to be foreseen for these additional trays. New tray rings and bolting bars that have to be welded normally lead to time consuming hot work and associated risks. Furthermore, stress relief for columns operating at high pressure has to be performed if welds to the column wall are necessary. In all cases, pressure tests of the column shell and nozzles need be done if new penetrations are specified

Finally it is important that the new trays can be installed very quickly and where possible in parallel on as many levels as possible. This means that the number of parts and requirement for bolted connections should be reduced to a minimum.

Sulzer Chemtech has developed a number of techniques that avoid welding to the column wall and bolting of tray panels when installing trays ad different trays spacings than prior to a revamp. They are described below

Reducing Installation Time with Special Tray Design Features

The unique Lip-Slot™ panel connection as seen in Figure 6 eliminates the need for bolting along the trusses of adjacent tray panels. The time required to fasten panels to each other when using this type of connection once inside and at the tray location is reduced to practically zero. Only the last panel or the manway in most cases at or around the center of the column is bolted or connected with the wedge type connections described hereafter.



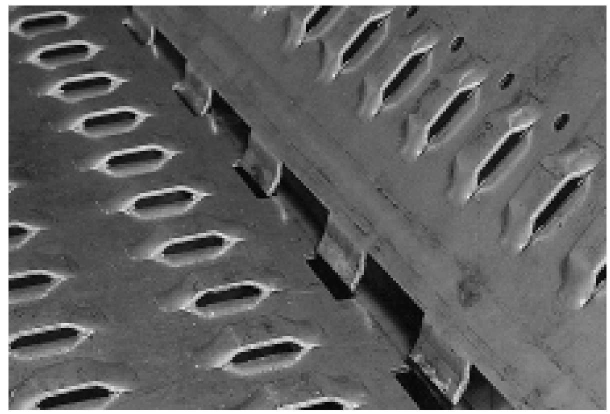


Figure 6. – Lip-Slot™ connection, 3D sketch and photo

Lip-Slot connections have been successfully used in the most diverse applications in the HPI field. Special comparative third party studies have been made showing superior mechanical strength of Lip-Slot panel connections compared to bolted panels. Only in those rare cases, where strong vibrations are expected due to wildly varying vapor loads bolted connections are preferred.

Split-wedge™ type tray support ring and downcomer connections (Figure 7a) also eliminate the need for bolting. After installation the wedges are secured by bending them out. They have also been subject to extensive comparative testing with the usual bolted tray clamp (Figure 7b). They are standard for all Shell fractionation trays for both the downcomer and for the tray support ring connection. They can also be used for conventional trays.

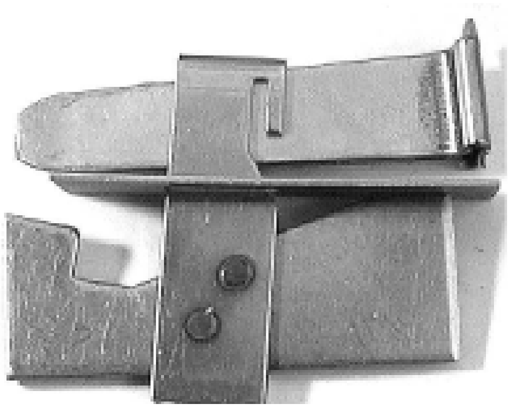


Figure 7a. – Wedge type connection

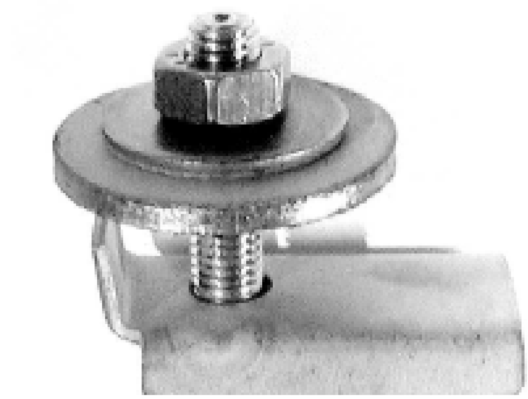


Figure 7b. – Bolted clamp

The Sulzer MVG™ fixed valves (Figure 8) are a good alternative for moving valves. They offer a significantly higher capacity while having nearly the good turndown characteristics. They also offer a large advantage from a handling point of view during and installation. Whereas panels with moving valves are easily damaged and have to be handled with more care, panels with MVG fixed valves are more robust. Furthermore, installation of missing valves is avoided.

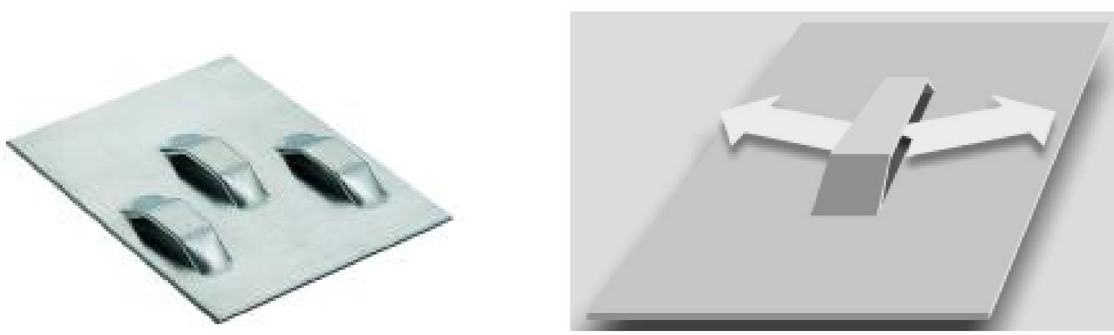


Figure 8. - MVG™ valves

Case story to Illustrate the Benefits of Lip-Slot Construction

In 1997 a US gas plant in Louisiana needed to revamp a de-ethanizer, de-propanizer, de-butanizer and a de-isobutanizer from conventional trays to Shell HiFi™ trays. Downtime was critical for the operator as is often the case in tight markets. The critical path was determined by the installation of more than 100 sieve trays in the de-isobutanizer.

Comparative bids were collected for the hardware and installation for the above-mentioned towers. The solution with Lip-Slots and Wedge connection required only 65% of the installation time quoted by the vendors using conventional bolted panel connection and tray clamps. In all cases the tray design was identical except for the fastening mechanism.

Based on this difference the contract was awarded and executed successfully and the columns have not suffered any mechanical set-backs in close to 5 years of operation. Not only was money saved by the operator in installation costs but also in down time. The savings in downtime were close to the value of the new trays!

Reducing Hot Work to Minimize Installation Time

First step in each revamp is to determine the maximum number of existing attachments to be reused. If tray spacing is reduced from 600 mm to 400 mm in principle every second tray ring and associated beam brackets if applicable can be reused for Shell HiFi trays.

Next step is to check which of the other attachments available might be reused or modified without welding to the column wall. Especially the bolting bars of the conventional trays are of interest. A typical example showing the existing tray attachments in relation with the attachments for the additional trays is shown in Figure 9.

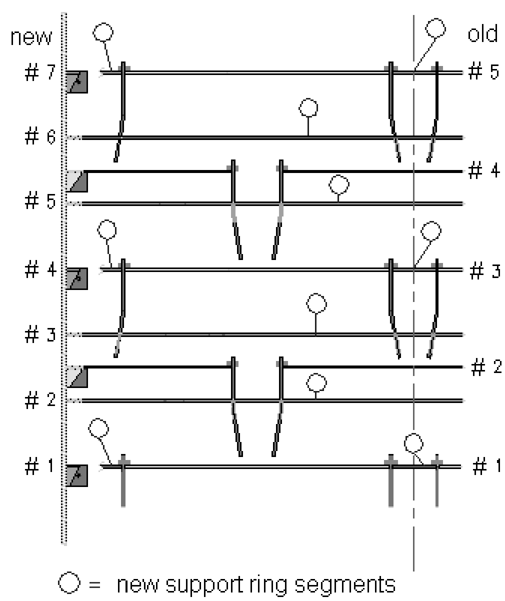


Figure 9. – New and existing tray attachments (4 for 3 retray)

Case story to Illustrate the Use of Non-Welded Attachments

Figure 10 shows the solution chosen for a C2-Splitter. The additional trays have been mounted on specially designed expansion rings.

In order to avoid welding to the column wall the beams have also been attached to these rings. Using these techniques the installation time could not only be reduced to a minimum but it was also possible to avoid the need for heat treatment and pressure test of the vessel after the revamp.

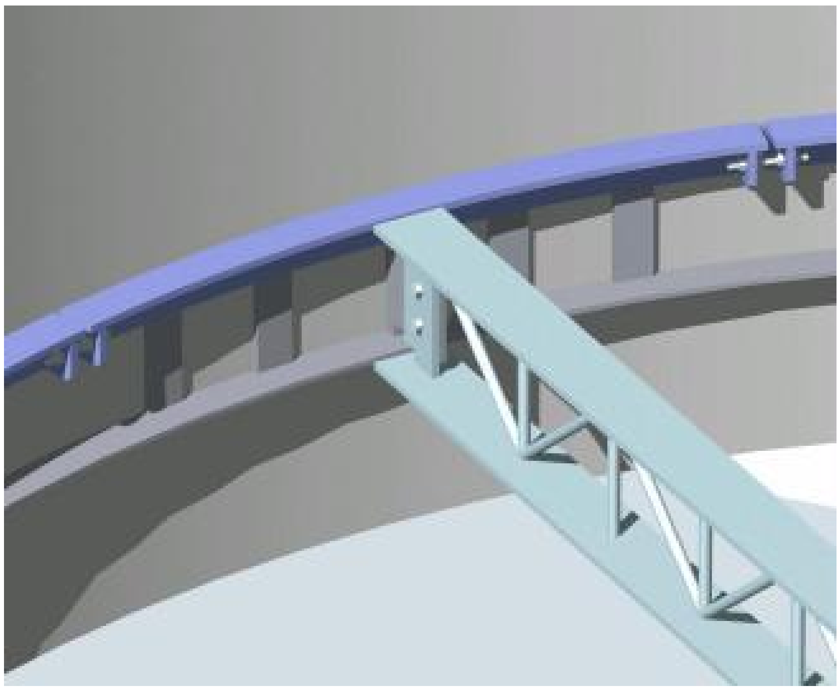


Figure 10. – Drawing of expansion ring construction including beam attachments

For large splitters, using 1 lattice beam to support two adjacent trays can further reduce installation time. In many cases it is possible to fix these beams to the existing bolting bars. An example of this configuration is shown in Figure 11.

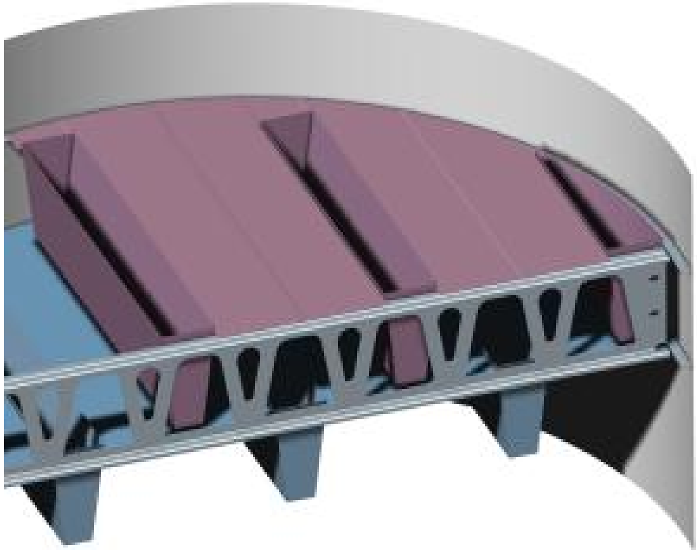


Figure 11. – Lattice beam construction supporting two HiFi™ trays

Conclusion

The use of high capacity trays in combination with sensible mechanical design and installation features can offer very interesting advantages in their application to C2 splitter revamps. Tray technology that includes truncated downcomers like the HiFi and CS trays combined with the extra fast Lip-Slot construction can provide 10-20% more capacity to existing splitters and be installed in a fraction of the time that other trays can for a savings of up to 35% on installation time with no welding to the column wall.

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