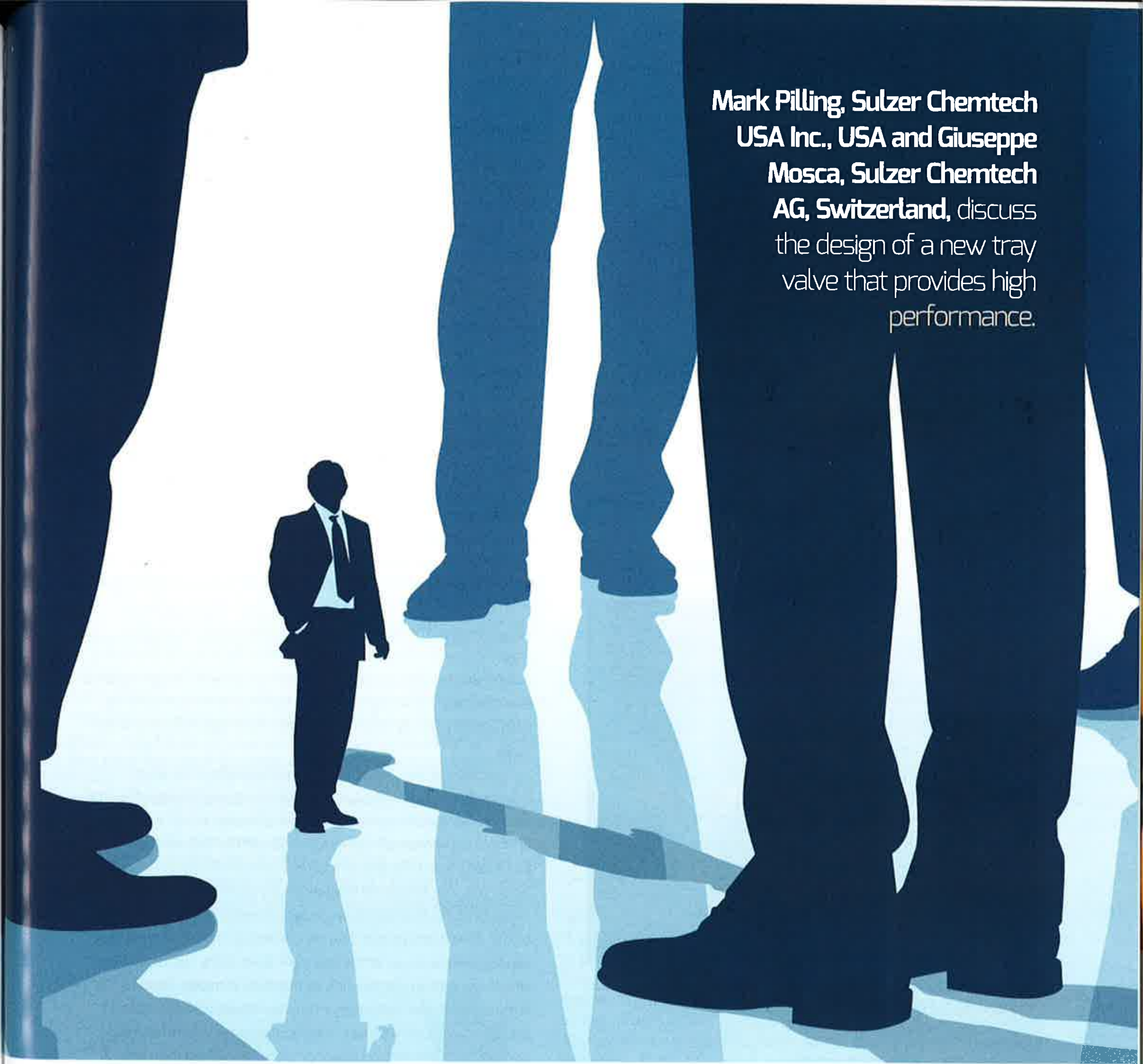

Mark Pilling, Sulzer Chemtech USA Inc., USA and Giuseppe Mosca, Sulzer Chemtech AG, Switzerland, discuss the design of a new tray valve that provides high performance.

MINI VALVE, BIG EFFICIENCY

Sulzer has developed a new valve for distillation trays that provides higher useful capacity than other valves available on the market. The valve, called an Umbrella Valve™, provides a downward vapour flow to encourage mixing within the entire liquid pool on the tray deck. When evaluating tray decks only, the data show 10% higher useful capacity than a Sulzer MVG™ tray. When incorporated with high performance VGPlus™ downcomers, the data shows a 38% higher capacity than a conventional moving valve tray at a leading independent commercial scale test facility.

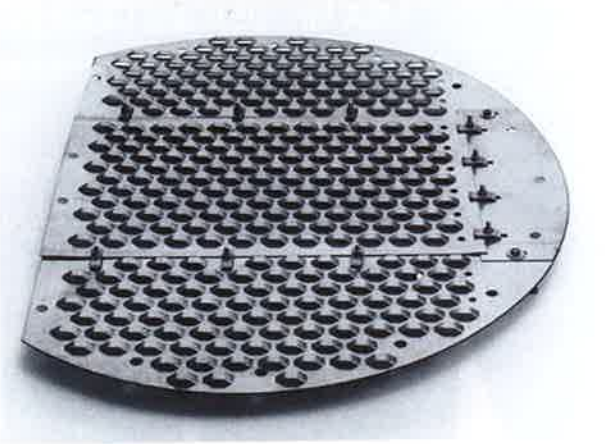

Figure 1. Sulzer MVG tray deck.

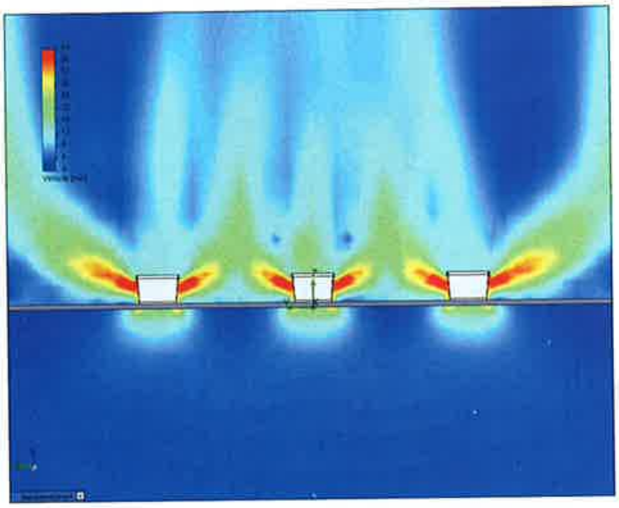

Figure 2. CFD simulation of Sulzer MVG valves.

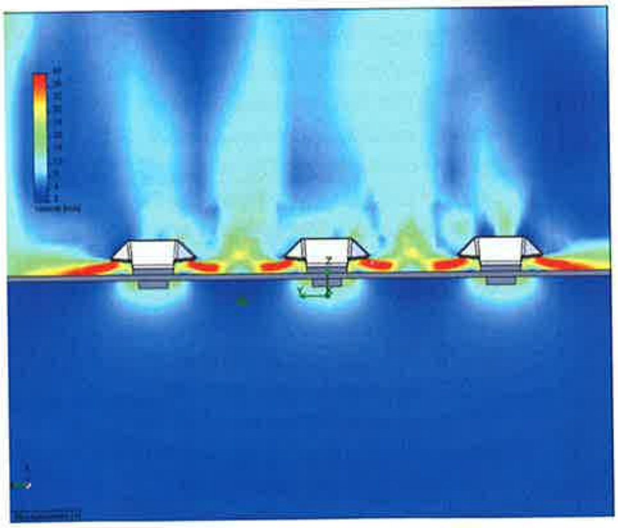

Figure 3. CFD simulation of Sulzer UFM valves.

Background

Throughout the years, a seemingly endless number of valve designs have been tested on distillation tray decks. Simple sieve holes, moving valves and bubble caps are just a few of them. One of the more popular types of high performance valve being used today is the Mini V-Grid (MVG) valve (Figure 1) from Sulzer's V-Grid™ family of valves.

V-Grid valves are constructed with an integral design where the valve top portion is formed from the tray deck itself. This design gives a lateral vapour release with a slight forward push due to its trapezoidal shape. MVG's are the benchmark high performance valve that Sulzer uses in its research.

One of the main differences between valve trays and sieve trays is the direction of the vapour flow. While a sieve tray directs vapour generally upward through a horizontal orifice, valve trays direct vapour generally in a horizontal direction through vertical orifices, after which the vapour turns upward to travel to the tray deck above. When studying the MVG tray performance closely, it was seen that the liquid in the immediate vicinity of the valve orifices was not flowing laterally away from the valves, but rather at an angle upward from the tray deck. This indicated that the vapour leaving the valves was flowing primarily at an upward angle. To confirm this, computational fluid dynamics (CFD) testing was conducted. Results showed a distinct upward flow of vapour from the near vertical side orifices of the valves (Figure 2) along with a relatively low flow region at the deck level adjacent to the valve.

Because of this, Sulzer began experimenting with valve designs directing the vapour at angles downward towards the tray deck. It was speculated that this type of design would reduce the upward momentum of the vapour and thereby decrease the amount of liquid entrainment carried upward at higher operating rates. This, in turn, should then result in higher operating capabilities for the new valve designs. Another perceived benefit of the downward vapour flow was increased mixing between the vapour and the liquid at the tray deck level. Since the liquid flows across the tray on the top side of the deck, it makes sense to ensure that all the liquid gets intimately mixed with the vapour (and vice versa) to maximise interfacial area necessary for mass transfer. A design that could accomplish this would then have a chance to increase capacity and efficiency simultaneously.

After evaluating various possibilities and a few subsequent prototypes, one valve design emerged as having the best operating characteristics, the Sulzer UFM™ valve. UFM stands for umbrella floating mini. Umbrella denotes the top shape of the valve. Floating designates a moveable valve for better turndown capabilities. Mini denotes that the size is comparable to a Mini V-Grid (MVG).

For many years, it has been known that smaller sized orifices and valves achieve higher capacities than larger, standard size valves, especially in moderate pressure distillation applications where entrainment is a limiting factor. So, in most high performance applications, a smaller size valve like an MVG will be used rather than a larger valve like a standard rectangular or round valve. Since the MVG valve is a well proven high performance valve, it was decided to use it as a starting platform for the new valve design and then modify that to get the performance characteristics required. The umbrella shape was selected to provide a uniform downward flow of the vapour to the tray deck. It allows a smooth transition for the vapour flowing vertically

SULZER

Sulzer Chemtech

Tower Technical Bulletin

Using the Correct Simulator Results to Rate Tower Internals

Background

Process simulations of fractionation columns can generate a wide variety of information. Because of this, it can sometimes be a bit tricky to decide what information to use for rating the internals. In order to size distillation column internals, we generally need the stage by stage output with the physical and transport properties as well and the feed and draw information. Within the column simulation, the liquid and vapor rates will vary across each stage. In other words, the vapor and liquid rates to an individual stage will differ from the vapor and liquid rates from that same stage. Unless you design columns on a frequent basis, selecting the proper flow rates can be challenging. Understanding the fundamentals can make things easier.

Tray Ratings

Since column internal ratings mainly deal with hydraulics, it is important to understand how flows affect the tray performance. Most importantly, the equipment needs to be designed for the flow rates that it will process. During operation in a conventional trayed column, liquid flows across the tray deck and then downward into the downcomer to the tray below. Vapor flows upward through the liquid on the deck generating a froth or spray. The tray deck open area is designed based on the vapor flow before it contacts the liquid on the tray. Therefore, the correct vapor stream to use for rating is "Vapor To" the stage. The downcomer top area is typically the critical design point for liquid so the proper liquid stream is "Liquid From" the stage.

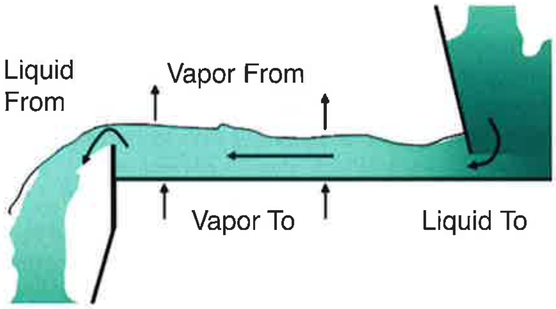

Figure 1: Flows to an Individual Tray

Packing Ratings

While each tray represents a discrete mechanical mass transfer point, a packed bed is one continual contacting device representing multiple contact stages. So packed beds take a little more consideration when deciding what streams to use for rating. Streams associated with a packed section are shown in Figure 2. Since rates change throughout the bed elevation, it's important to rate the packing from top to bottom with the proper rates. For the bottom of the bed, the loads the packing processes are the "Vapor To" and the "Liquid From". For the top of the bed, the packing processes "Vapor From" and the "Liquid To".

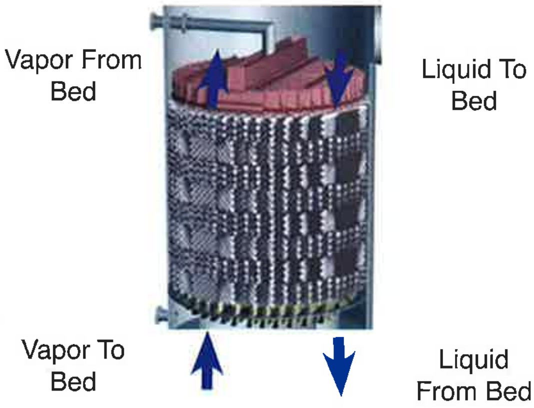

Figure 2: Flows to Packed Bed

General Comments

Whether rating trays or packings, you need to pay special attention to feeds, draws, and any other flow variances within a section of a column. When in doubt, make a mass balance around a section to be sure all flows are accounted for. In columns with subcooled liquid feeds or superheated vapor feeds, the highest flow rates within the column may likely be in the middle of the section. Be sure to look for the maximum and minimum volumetric flows within each section to rate your internals. Even though it is simpler to put in one single tray design or packing type for an entire column section, the optimal design may require some variation. This is especially true in stripping applications where the vapor rate varies substantially from top to bottom.

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Figure 4. Commercially available UFM valves.

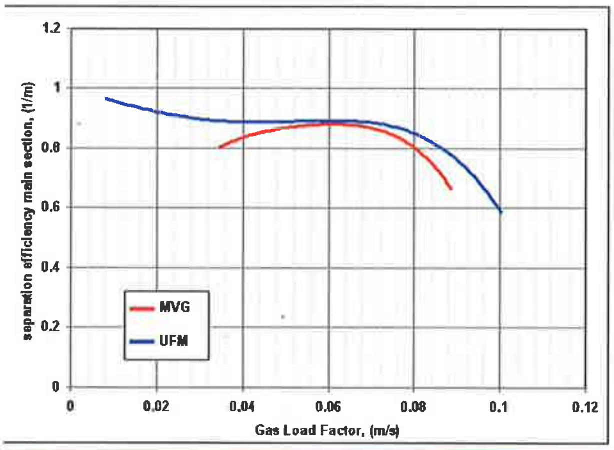

Figure 5. UFM and MVG test results, CB/EB at atmospheric pressure.

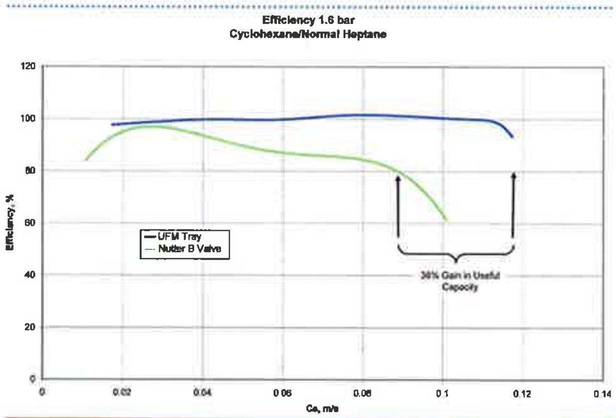

Figure 6. Total reflux resultrs, C6/C7 test system, 1.6 bara.

upward through the deck orifice back downward to the top of the tray deck where the liquid is flowing. The UFM prototype was developed and optimised using process simulator testing alongside CFD. As shown in Figure 3, CFD results show the vapour from the valves is directed smoothly to the tray deck. The high velocity flows at the deck level provide energy for mixing and generation of interfacial area necessary for mass transfer. The optimised UFM valve design produced from this test program is shown in Figure 4, resting on the tray deck in the closed position.

Test results

The UFM valves were first tested in Sulzer's Winterthur test facility using its 1 m diameter test column with a chlorobenzene/ethylbenzene test system operating at atmospheric pressure under total reflux conditions. The results are shown in Figure 5. Tests were conducted using UFM and MVG trays with identical downcomers (i.e. all tray design parameters were constant except for the valves on the tray decks). Results show that UFM trays maintained a higher baseline capacity and achieved up to a 10% increase in capacity over the MVG test tray. The pressure drop for both valve types was very similar.

The UFM tray was then tested at an independent US distillation research facility using its 1.2 m diameter column in a cyclohexane/normal heptane test system at an operating pressure of 1.6 bar, under total reflux conditions. The results are shown in Figure 6. The UFM trays show a 38% increase in Useful Capacity over a well designed conventional valve tray (Nutter B Valve as tested at Fractionation Research, Inc.)

The UFM trays also show an efficiency improvement of 15% over most of the operating range with a turndown of better than 6:1. The UFM baseline efficiency of nearly 100% is outstanding for this low pressure distillation service.

Conclusion

In summary, the UFM tray has been tested in two separate test systems showing superior performance over well known high performance tray designs. In independent testing, the unique design characteristics of the UFM valve yielded a 38% increase in useful capacity while also achieving a 15% increase in baseline efficiency over a conventional moving valve tray. UFM trays have subsequently been installed in a variety of commercial applications demonstrating performance as predicted. This compilation of data gives strong credence to the theory that proper control of the vapour flow is necessary for optimal tray performance.