The impact of tower internals on column performance

Full scale testing and analysis of operation demonstrate the importance of tower internals on the performance of mass transfer packings

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Fractionation Research Inc. (FRI) is the most modern independent test institute in the world for performing tray, random packing, and structured packing tests under rectification conditions on an industrial scale test column (see **Figure 1**). In 1998, Raschig Super-Ring No. 2 was tested at FRI for the first time, and FRI high performance tower internals were selected for this test. However, in 2012, Raschig elected to retest Super-Ring No. 2. In this retest, the company used state of the art tower internals. This article shows the impact of tower internals on packing performance, comparing both FRI test results.

In addition to the FRI test results, the article provides information about Raschig's large scale liquid distributor test facility. The test facility was built to improve large and small scale distributor designs as a development project and to demonstrate their performance after fabrication for industrial columns. Finally, the article describes an industrial design example for which modern tower internals were applied.

Figure 1 FRI facility for testing random packings, structured packings and trays under industrial scale conditions; left: low pressure column D = 1200 mm; right: high pressure column D = 1200 mm

Tests with two sets of tower internals

The development over the past few decades of the most modern packing generations and tower internals, such as distributors, hold-down plates and support plates, have seen pronounced and noticeable design improvements.

High performance tower internals used 10 to 20 years ago in mass transfer columns are currently often considered to be low or standard performance devices, especially when they are used with high performance packings. When Raschig Super-Ring No. 2 was tested at FRI in 1998 for the first time, the FRI high performance tubed drip pan (TDP) distributor and the FRI support plate and hold-down plate were selected for the test (see **Figure 2**).

However, in 2012, Raschig elected to retest Super-Ring No. 2. In this retest, the company used a more modern, narrow trough type distributor that is very open to the gas phase compared to FRI's TDP distributor. In addition to the high performance DT-S distributor which Raschig used in 2012, FRI employed a modern Raschig SP-1 support system and HP-1 hold-down device.

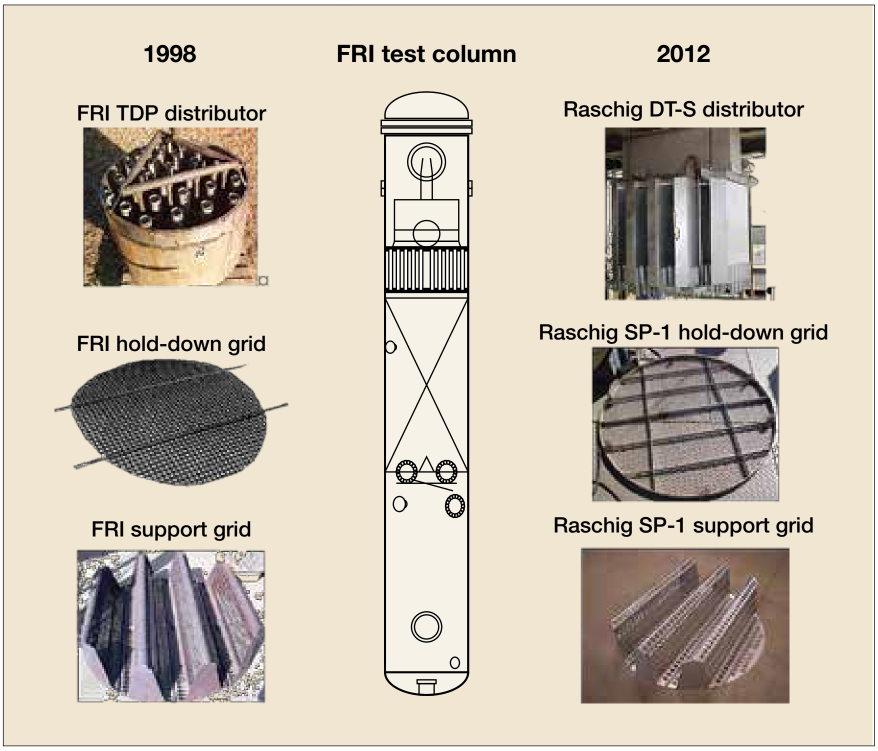

Figure 2 FRI column set-up in 1998 and 2012

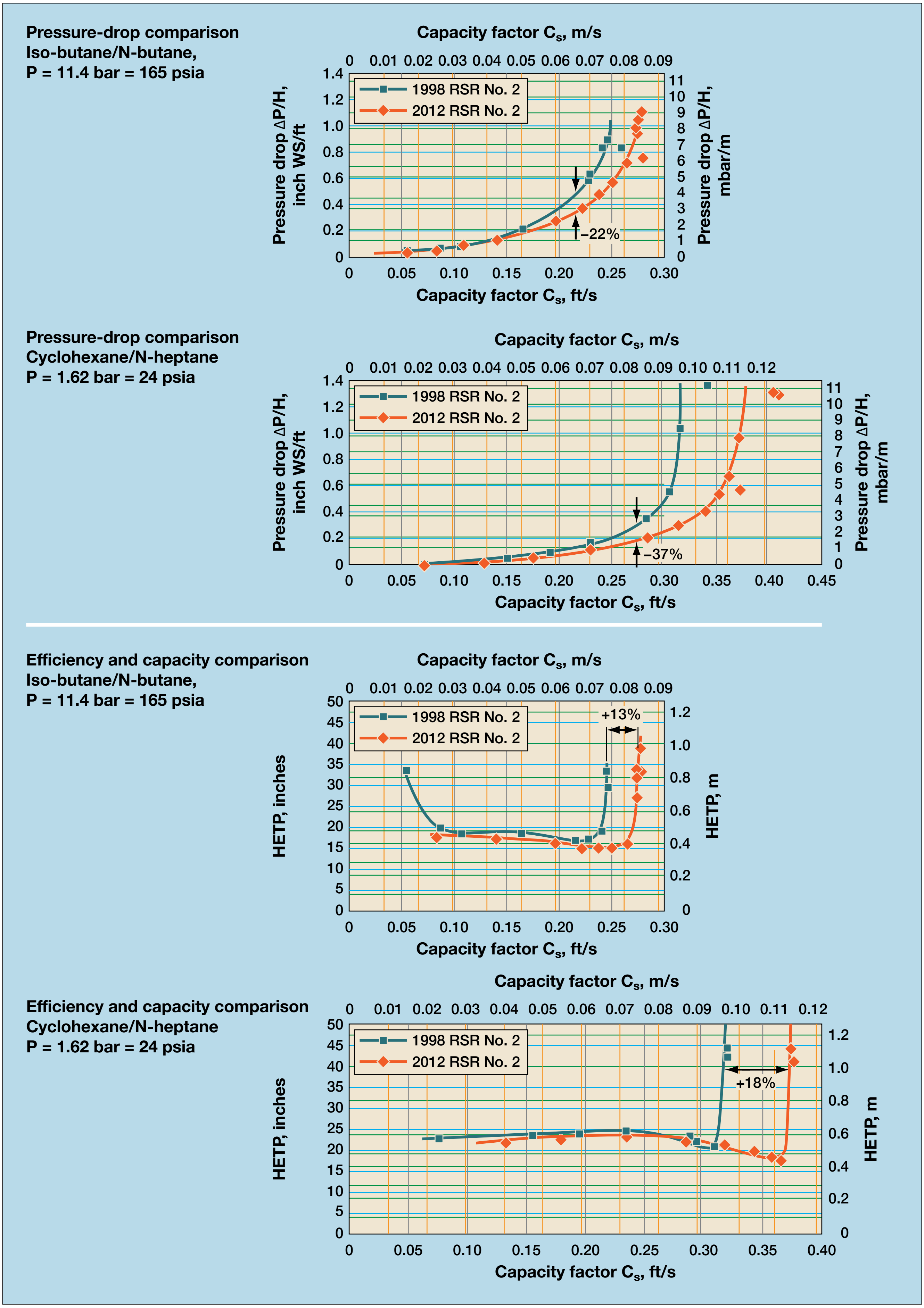

Figure 3 Raschig Super-Ring pressure drop, capacity and efficiency comparison for the iso-butane/n-butane distillation system at 165 psia (11.4 bar) and the cyclohexane/n-heptane distillation system at 24 psia (1.62 bar)

The impact of the TDP distributor on the performance of Super-Ring No. 2 from 1998 has been discussed in detail in previously published papers.[1,2,3] In short, the narrow gas space of the TDP distributor and the large volume of sub-cooled reflux filling up in the pan type construction initiated heavy condensation of the vapour in the gas risers and caused pre-flooding of the distributor and finally of the whole test column.

Figure 3 shows the pressure drop and efficiency comparison of the Super-Ring No. 2 when tested in 1998 using FRI's 'high capacity' TDP pan type distributor and when tested in 2012 utilising Raschig's high performance DT-S distributor. The packing performance comparison presented is for the iso-butane/n-butane distillation system at 165 psia (11.4 bar) and the cyclohexane/n-heptane system at 24 psia (1.62 bar).

For the test systems shown, the pressure drop decreased by 22-37% and the capacity improved by 13-18%, especially with the DT-S distributor. **Figure 3** also demonstrates an efficiency improvement of 6-14%.

The DT-S distributor offers a much greater open space to the gas phase that facilitates the gas phase passing by, which consequently impacts the pressure drop and capacity measurement. It is important to note that open distributor designs are important for processes with high gas rates, as is the case under FRI test conditions. One has to consider that under conditions with limited gas rates and high liquid rates (absorbers and desorbers for example), deck type distributors with reduced open gas area are state of the art designs, allowing an easy passage of liquid over the entire distributor deck.

Raschig's large scale liquid distributor test centre

Raschig has developed expertise in designing high performance liquid distributors/tower internals. To test these liquid distributors, the company built one of world's largest liquid distributor test centres in Germany. Thus, it can test liquid distributors up to 12 m in diameter at full scale. For larger column diameters, Raschig tests these distributors in sections. Further smaller scale test facilities are available in Germany.

Figure 4 Large scale DT-S distributor in Raschig's test facility in Germany

Figure 5 Large scale flash gallery and distributor at Raschig's test facility in Germany

Modern computational fluid dynamics analysis can help to understand the fluid dynamics of modern internals if they cannot be tested on a test rack

Figure 4 shows a performance test Raschig implemented for a large scale DT-S trough type distributor. The liquid was fed into the distributor via a liquid feed pipe header and a multiple parting box system. This test facility enables the measurement of the 'drip point related coefficient of flow variation' as well as the 'drip area related coefficient of flow variations'. These measurements are supported by an automated collecting system.

The company is also equipped to test combined tower internal systems. For example, **Figure 5** shows a dummy shell erected to simulate a column section for a two phase flashing feed. The tested column section consists of two 24in tangential feed lines directing the feed into a flashing gallery. Below the flashing gallery, a trough type distributor is positioned to be tested for its 'drip point related coefficient of flow variation'.

High capacity CO_2 absorption column with modern tower internals

In 2014, a new CO_2 absorber was delivered to Australia, where a liquefied natural gas plant in Northern Territory went into operation in 2006. The CO_2 absorber was a replacement unit due to capacity limitations of the existing column. The facility is known to employ state of the art engineering and environmental technology and, wherever possible, local and regional resources.

The plant uses the ConocoPhillips Optimised Cascade Process, an LNG liquefaction technology that

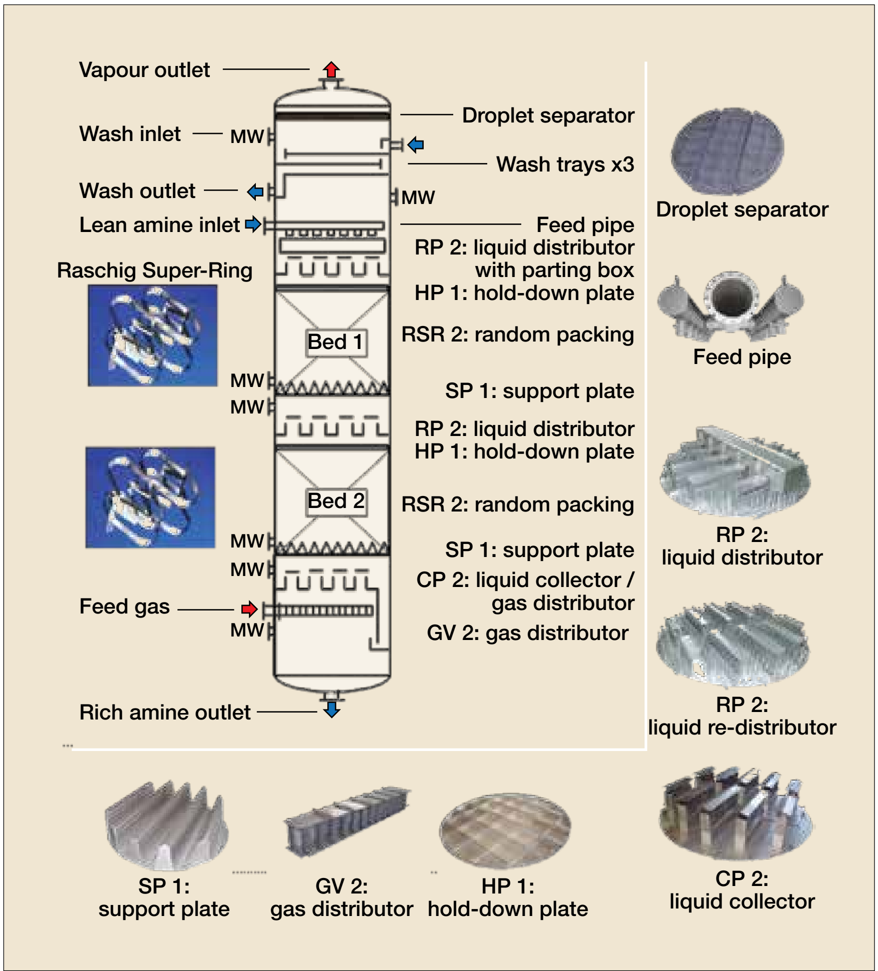

Figure 6 Typical arrangement for a high performance CO_2 absorber

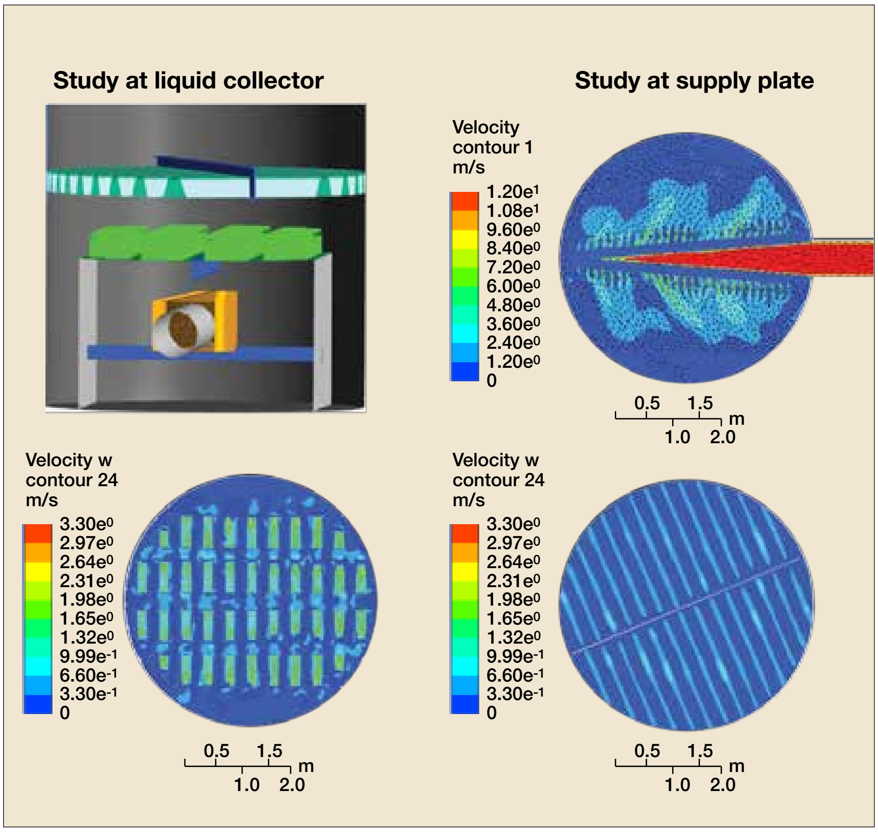

Figure 7 CFD study of the gas entrance to a high capacity CO_2 absorber

employs two trains in one design to increase reliability. Through a dual lift operation, the 38 m long and 530 t piece was successfully loaded onto a heavy duty trailer. It was pulled by four primary movers. Together, the absorber and the prime movers stretched 85 m and weighed more than 750 t, making it the largest road haul in the state's history.

The CO_2 absorber was designed with state of the art tower internals. Such a typical absorber design with Raschig's high performance tower internals is shown in **Figure 6**. To minimise the overall cost of a mass transfer tower, the column shell, the packing, and the internal components of the tower must be considered. Due to the use of the high performance Raschig Super-Ring, the diameter of the high pressure column shell could be reduced, which resulted in a reduced overall capital cost.

At the top of the amine absorber, a high performance droplet separator and three wash trays were used to avoid loss of amine and piperazine contained within the off-gas.

Raschig provided a high capacity feed pipe design that directs the high liquid flow rate into a special parting box to de-aerate the liquid and to reduce/eliminate any foam build-up. From the parting box, the liquid is directed to a high quality deck type RP 2 liquid distributor that allows the liquid to be very uniformly distributed across the deck. An equal liquid head above the distribution holes ensures a homogeneous liquid flow to the bed below.

Wide open hold-down plates type HP 1 and support plates type SP 1 were applied to keep the packing in place even if unusual column set-up or flooding were to occur. Between the packed beds, a high quality liquid redistributor was designed to ensure proper remixing of the liquid and gas phases. By design, the redistributor ensures both a homogeneous liquid flow to the bed below and a homogeneous gas distribution to the bed above.

To minimise interference between the gas phase entering at the column bottom and the liquid trickling from the bed above, a liquid collector type CP 2 was installed. Via a long downcomer, the amine passes by the entering gas stream. To ensure proper gas distribution, a high quality vane type gas distributor type GV 2 was used. This set-up also eliminates erosion of the column shell at the elevation of the gas feed, and the phase separation eliminates the risk of foaming due to extensive interactions between the gas feed and the liquid falling from the bed above.

To optimise the lower section of the column, a detailed computational fluid dynamics (CFD) study was performed (see **Figure 7**). The CFD study incorporated the vane type gas distributor, the liquid collector above with two side downcomers, the support grid of the packing and all beam constructions involved. The gas velocity profiles were simulated at the gas entrance elevation but also especially at the top end of the liquid collector and at the top end of the support plate for detecting critical zones where flooding may appear. The CFD study approved the design of Raschig's tower internals.

Conclusion

This article discussed the importance of tower internals on the performance of mass transfer packings. The repeated FRI tests on Raschig Super-Rings in 2012 demonstrated the advantages one can achieve by using, in particular, modern liquid distributors.

To design modern distributors and to prove their performance Raschig has built one of the world's largest test facilities. The company not only tests liquid distributors but also huge flash devices.

A modern column design will use modern fourth generation random packings like Raschig Super-Rings. This ensures the minimum column diameter, which is especially important for high pressure vessels like CO_2 absorbers. Besides modern packings, high performance tower internals have to be selected to optimise the column performance. Modern CFD analysis can help to understand the fluid dynamics of modern internals if they cannot be tested on a test rack.

References

1 Schultes M, Researching rings, *Hydrocarbon Engineering*, 2001, 57-62.

2 Schultes M, Raschig Super-Ring – a new fourth generation packing offers new advantages, *IChemE*, Vol 81, Part A, 2003, 48-57.

3 Schultes M, The impact of tower internals on packing performance, *Chem. Ing. Tech*., Vol 86, No 5, 2014, 1-9.

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