IChemE
www.ingentaselect.com/titles/02638762.htm

0263–8762/03/$23.50+0.00
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Trans IChemE, Vol 81, Part A, January 2003

RASCHIG SUPER-RING
A New Fourth Generation Packing Offers New Advantages

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Since its introduction to the market in 1995, numerous mass transfer columns have been packed with Raschig Super-Rings in various chemical process, petrochemical, refining, and environmental applications. To support these applications, the Raschig Super-Ring No. 2 was tested at the Fractionation Research Inc. (FRI) test facility at the end of 1998. The purpose of this paper is to discuss the FRI experimental results. The tests verified that the Raschig Super-Ring No. 2 provides exceptional low pressure drop, high capacities, and excellent mass transfer efficiency. Special attention is given to a comparison of the test results with other modern and standard random packings as well as to structured packings. The comparison shows that a modern random packing design has mass transfer efficiency advantages compared to structured packings, if the same specific surface area is taken as the comparison basis. Industrial applications are shown where Raschig Super-Ring's have been used successfully. New column design is explained as well as revamp situations.

Keywords: packing; Raschig Super-Ring; absorption; distillation; rectification.

INTRODUCTION

Owing to the development, in recent years, of modern dumped packings for mass transfer processes such as rectification, absorption, and desorption, randomly dumped packing, in particular, has continued to play an established role in these applications. This is particularly due to the fact that the new open geometry's of the dumped packings displays process properties that, firstlly, approximate those of structured packings and, secondly, meet the advantages of mass transfer trays.

This strong position of modern dumped packings on the market has, in recent years, given this product in particular a continuously growing market share once again. The Raschig Super-Ring plays a particularly important role since it is known as the first dumped packing of the fourth generation and therefore has to prove itself as the newest development both against the high performance random packings of the third generation (Figure 1) and also be measured in comparison with structured packings. Accordingly, in the following chapter the pressure drops, mass transfer efficiencies, and capacities of the Raschig Super-Ring determined in test columns under standard conditions are to be compared with those of other high-performance random packings and structured packings.

COMPARISON OF RASCHIG SUPER-RINGS WITH OTHER RANDOM AND STRUCTURED PACKINGS

At the Ruhr University of Bochum, all Raschig Super-Ring sizes were tested fluid-dynamically in air/water simulators and examined with respect to mass transfer with ammonia–air/water and carbon dioxide–water/air systems (Schultes, 2001a,b) Table 1 shows the equivalent Raschig Super-Ring and Pall-Ring sizes if the surface area is taken as the comparison basis. These studies and early successes in industrial applications resulted in the conductance, in 1998, of specific tests under distillation conditions with Raschig Super-Ring No. 2 at one of the world's largest test institutes, Fractionation Research Inc. (FRI) in Stillwater, Oklahoma (Figure 2) (Schultes, 2001a).

Figure 3 shows as an example the pressure drops of Raschig Super-Rings No. 0.7 and 2 in comparison with 25-mm and 50-mm Pall-Rings. It can be clearly seen that, with comparable geometric surface area, the pressure drop of both Raschig Super-Rings is approximately 60% smaller. However, the Raschig Super-Rings display no disadvantages as regards to mass transfer efficiency in comparison with the Pall-Rings, as Figure 4 shows for the ammonia–air/water testing system.

The improved mass transfer efficiency and the greater loading capacity are clearly recognizable despite the smaller pressure drop. The reason for this lies in the fluid-dynamically optimized geometry of Raschig Super-Rings. Owing to its sinusoidally undulating geometry, the shape of this dumped packing is not only very open, but liquid films are mainly formed that are otherwise only found with structured packings. These, in particular, ensure an excellent loading capacity for this dumped packing. The very even wetting with liquid with the recurrent turbulence-promoting connection points of the sinus strips is the other reason behind the excellent mass transfer efficiency of the Raschig Super-Ring.

Figure 5 confirms these advantages in pressure drop and capacity as measured by FRI in the rectification of the

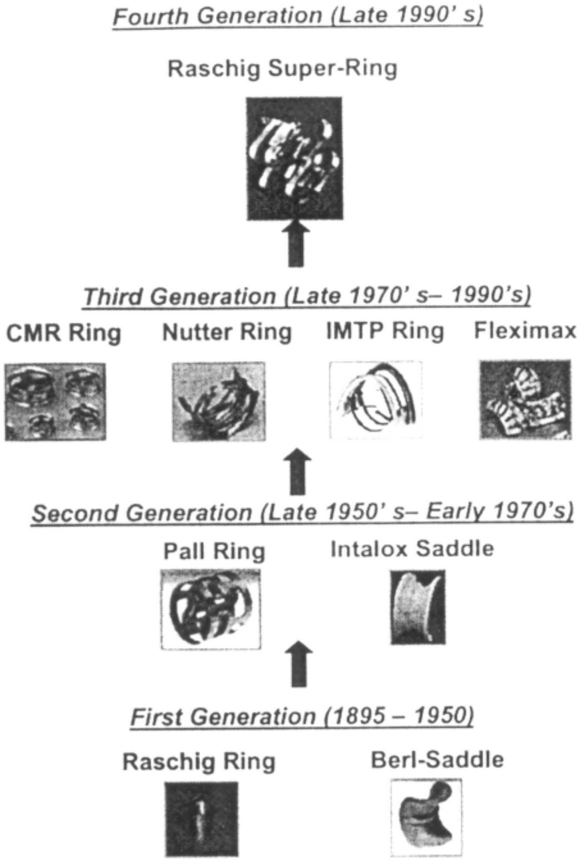


Figure 1. History of the development of characteristic random packings of different generations.

cyclohexane/*n*-heptane mixture. The diagram also includes measurements of Nutter-Ring No. 2 which is also a high-performance random packing (Shariat and Kunesh, 1995; Nutter, 1987; Spiegel and Meier, 1987). As in the air/water investigations, the Raschig Super-Ring displays a pressure drop which is approximately 60% smaller than that of the Pall-Ring and which is approximately 40% smaller than that of the Nutter-Ring. The figure also shows that the flooding capacity of the Raschig Super-Ring is approximately 25–33% larger than that of the 50-mm Pall-Ring and approximately 10–15% larger than that of the No.2 Nutter-Ring.

Table 2 shows the comparison of various metal Raschig Super-Ring sizes to corresponding metal Pall-Rings based on the ammonia–air/water test system. The gain of

Table 1. Equivalence of metal Raschig Super-Ring to metal Pall-Rings for various sizes.

Pall-Ring		Raschig Super-Ring	
Size	a [m^2/m^3]	Size	a [m^2/m^3]
15	360	0.3	315
–	–	0.5	250
25	215	0.7	180
–	–	1.0	150
38	135	1.5	120
50	105	2	100
80	78	3	80

a = total surface area of packing.

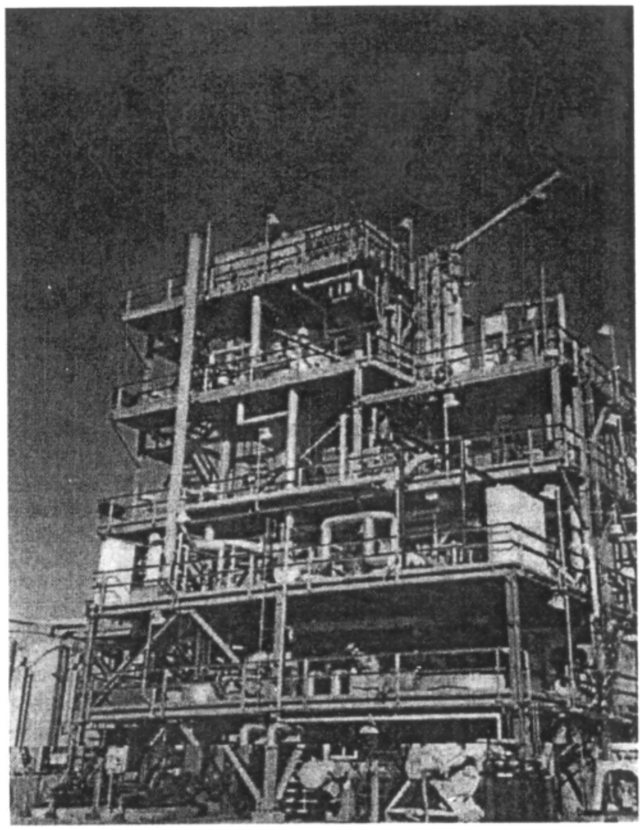


Figure 2. FRI test facility in Stillwater, Oklahoma, USA.

the fourth-generation random packing is obvious in comparison to the second-generation packing. In all cases higher capacities, lower pressure drops, and better mass transfer efficiencies are given using Raschig Super-Rings.

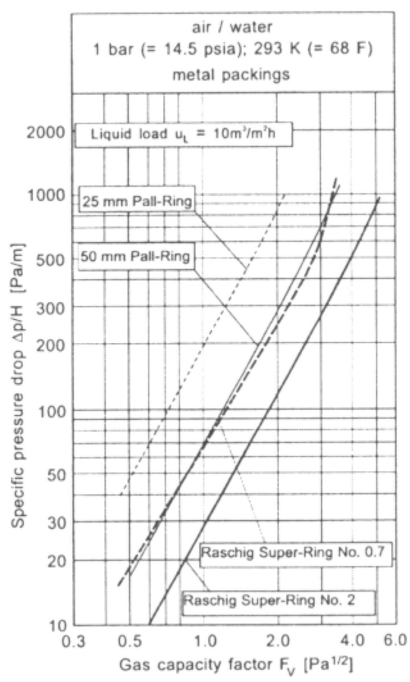


Figure 3. Pressure drop comparison between Pall-Rings and Raschig Super-Rings in various sizes. Tests performed at Ruhr University, Bochum, Germany.

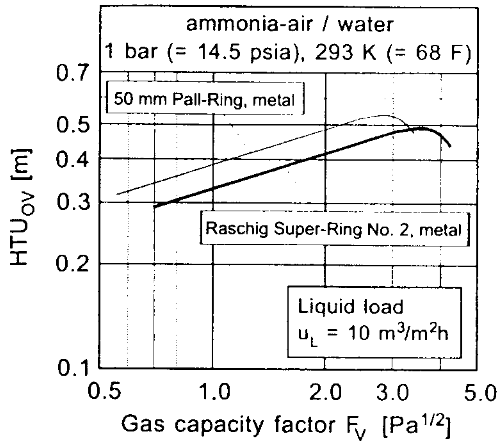


Figure 4. Height of an overall gas side mass transfer unit for various gas capacity factors and constant liquid load for 50-mm Pall-Ring and Raschig Supr-Ring No. 2 in metal. Tests performed at Ruhr University, Bochum, Germany.

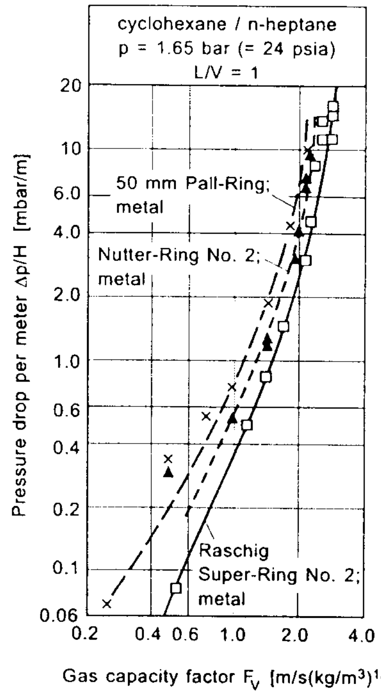


Figure 5. Comparison of pressure drop for Raschig Super-Ring No.2, 50-mm Pall-Ring, and Nutter-Ring No. 2. Tests performed at FRI facility in Stillwater, Oklahoma, USA.

Table 3 provides further comparison of specific pressure drop, capacity, height equivalent to a theoretical stage, and pressure drop per theoretical stage between the Raschig Super-Ring No. 2, IMTP 50, Nutter-Ring No. 2, and 50-mm Pall-Ring (Nutter, 1987; NORTON). The third-generation random packings such as IMTP 50 and Nutter-Ring No. 2 already offer a noticeable advantage in comparison to Pall-Rings. However, as can be seen, the Raschig Super-Rings offer a further evident benefit in comparison to the third-generation random packings—this is why it is called 'fourth generation'.

Measurement results for the mass transfer efficiency of the various dumped packings and of Mellapak 125 Y structured packing, which has a somewhat larger specific surface area are presented in Figure 6 (Shariat and Kunesh, 1995; 1999).

In Figure 6 an 'unstable test condition' for Raschig Super-Ring No. 2 is indicated, which relates to the following situation during the test procedure. As can be seen from Figure 6 the HETP of the Raschig Super-Ring No. 2 suddenly increased at a gas capacity factor of $F_v = 2.3\sqrt{\text{Pa}}$ (1.89 ft/s $(\text{lb/ft}^3)^{0.5}$), which was not expected based on the air/water tests or industrial experience. Above the gas capacity factor of $F_v = 2.3\sqrt{\text{Pa}}$ (1.89 ft/s $(\text{lb/ft}^3)^{0.5}$) a marked condensation of the vapor phase was suddenly observed in the gas passing the liquid distributor. This was a result of the cold reflux used in subcooling the liquid distributor heavily, which, owing to its design, had a large liquid hold-up. As the column load continue to increase, the liquid distributor even flooded. Both these circumstances caused condensation of rising gas, which shifted randomly downwards into the packed bed and periodically created backmixing effects of the phases and a premature drop in mass transfer efficiency.

It can be clearly seen from Figure 6 that the dumped packings shown with a specific surface area of approximately $100\,\text{m}^2/\text{m}^3$ display a mass transfer efficiency that differs from the one to the other only by approximately ±10%. The mass transfer efficiency of the structured packing, however, is lower by approximately 30%, although its specific surface area is approximately 25% larger. Figure 7 confirms this comparison for a 25-mm Pall-Ring (surface area: $215\,\text{m}^2/\text{m}^3$) and the Mellapak 250 Y (surface area: $250\,\text{m}^2/\text{m}^3$).

Figure 8 shows equivalent results by comparing the mass transfer efficiency for the ammonia–air/water system of

Table 2. Performance comparison between various sizes of Pall-Rings and Raschig Super-Rings (metal) system: ammonia–air/water, 1 bar.

		At same throughput		At same pressure drop*	
Existing packing	Revamped packing	Press. drop	HETP	Throughput	HETP
Pall-Ring 5/8 in.	Raschig Super-Ring No. 0.3	−40%	−18%	+30%	−21%
Pall-Ring 1 in.	Raschig Super-Ring No. 0.5	−21%	−23%	+13%	−23%
Pall-Ring 1 in.	Raschig Super-Ring No. 0.7	−53%	−14%	+40%	−17%
Pall-Ring 1.5 in.	Raschig Super-Ring No. 1	−33%	−24%	+20%	−25%
Pall-Ring 1.5 in.	Raschig Super-Ring No. 1.5	−57%	−11%	+40%	−15%
Pall-Ring 2 in.	Raschig Super-Ring No. 2	−58%	−11%	+30%	−14%
Pall-Ring 3 in.	Raschig Super-Ring No. 3	−60%	−7%	+48%	−10%

*L/V = constant for the revamped packing.

Table 3. Comparison of different 50-mm metal random packings; system: cyclohexane/n-heptane, 1.65 bar, total reflux; bases of comparison: 50-mm Pall-Ring indicated as 100%.

Standard/High performance packing	Spec. pressure drop $\Delta p/H$ (%)	Capacity L/V = constant (%)	Height equivalent to a theoretical stage HETP (%)	Pressure drop per theoretical stage $\Delta p/h_{th}$ (%)
50-mm Pall-Ring	100	100	100	100
50-mm IMTP-Ring**	58	110	105–109	63
Nutter-Ring No. 2	61	110	105–109	67
Raschig Super-Ring No. 2	38	125–133*	100–96	37

*Unstable test condition due to performance of FRI distributor (see text).
**IMTP: Iso-octane/Toluene (1 bar) and air/water.

various Raschig Super-Rings with the Ralu-Pak 250 YC. With a surface area of 250 m^2/m^3 the latter has a comparable specific surface area to that of the Raschig Super-Ring No. 0.5, but its mass transfer efficiency is in the order of magnitude of that of the Raschig Super-Ring No. 1 with 150 m^2/m^3 surface area.

An analysis of Figures 9 and 10 can help to explain the phenomena described. They show the mass transfer curve and the pressure drop curve of a Mellapak 250 Y and a Mellapak 250 X measured by Sulzer in Switzerland (Sulzer, 1997). Both these structured packings have an identical specific surface area, but the mass transfer efficiency of the Mellapak 250 Y is approximately 2.8–3 theoretical stages per meter of height while the mass transfer efficiency of the Mellapak 250 X, with 2.2 theoretical stages, is equivalent to that of a 50-mm Pall-Ring. This can be explained by comparing the pressure drop of the two Mellapak types (Figure 10). Owing to the steeper attitude of its structural waves, the Mellapak 250 X has a considerably smaller pressure drop, which leads to a smaller turbulence in the gas phase. The latter reduces the mass transfer coefficient in the gas phase and explains the lower mass transfer efficiency, as shown in Figure 9.

In addition to this, however, even further circumstances play a role in the comparative evaluation of packings. For instance, the Raschig Super-Ring No. 2 in Figure 6 displays a comparable and, in certain load ranges, even a slightly better mass transfer efficiency than the 50-mm Pall-Ring in spite of a considerably reduced pressure drop. Here the interfacial area offered for the mass transfer plays a further role. In the case of the Raschig Super-Ring, numerous thin liquid films are formed in comparison with the thick trickles and flows of droplets of a dumped bed of Pall-Rings. This larger interfacial area, together with the high turbulence in the thin film and a considerably better contact between the gas and the liquid owing to the open geometry of the Raschig Super-Ring, ensure these advantages.

A comparable effect can also be seen, for example, in modern structured packing designs like MellapakPlus. In the case of this new high-capacity structured packing the transfer flow of liquid between the packing layers is

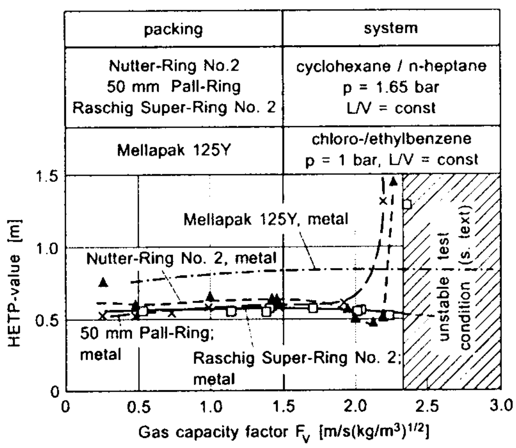


Figure 6. Comparison of mass transfer efficiency for Raschig Super-Ring No. 2, 50-mm Pall-Ring, Nutter-Ring No. 2, and the structured packing Mellapak 125 Y. Tests performed at FRI facility in Stillwater, Oklahoma, USA and at Sulzer Chemtech Ltd, Winterthur, Switzerland.

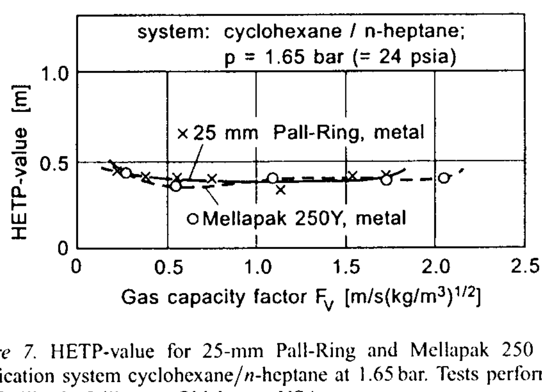


Figure 7. HETP-value for 25-mm Pall-Ring and Mellapak 250 Y for rectification system cyclohexane/n-heptane at 1.65 bar. Tests performed at FRI facility in Stillwater, Oklahoma, USA.

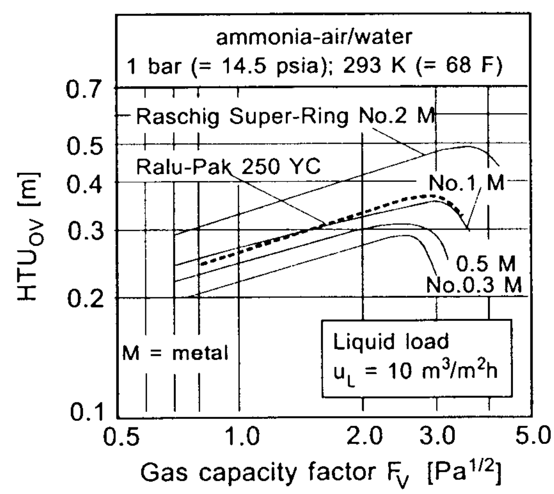


Figure 8. Comparison of the height of overall gas side mass transfer unit between various sizes of Raschig Super-Rings and the structured packing Ralu-Pak 250 YC for the absorption system ammonia–air/water. Tests performed at Ruhr University, Bochum, Germany.

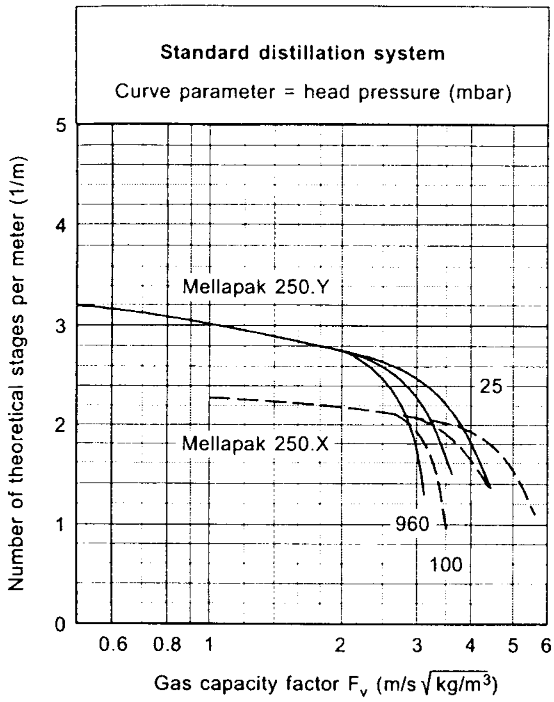


Figure 9. Number of theoretical stages of Mellapak 250 Y and Mellapak 250 X for standard distillation system from vacuum to normal pressure (Sulzer, 1997).

considerably better and the pressure drop is smaller owing to the vertical course of the structural waves at the intersection points of the packing layers. With the new packing geometrys the liquid film remains thin and turbulent at the intersection zones so that, inspite of the smaller pressure drop in these areas, the mass transfer efficiency remains (Moser and Kessler, 1999).

Of course the structured packing, with a comparable surface area, has a greater capacity than a dumped packing owing to its smaller pressure drops. Structured packings therefore continue to be excellent for use in vacuum columns, where the smallest possible pressure drops per theoretical stage are particularly important. However, this unsurpassedly small pressure drop per stage in the case of structured packings does not come from an excellent mass transfer efficiency but from the small pressure drop per metre of packed height. This fact is made use of in many column revamps from structured packings to Raschig Super-Rings, as the following sections will show.

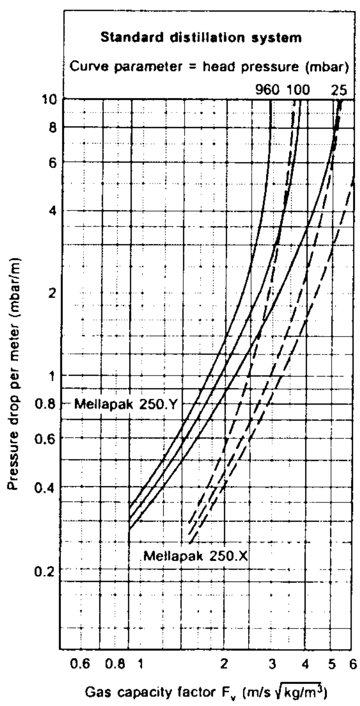


Figure 10. Pressure drop of Mellapak 250 Y and Mellapak 250 X for standard distillation system from vacuum to normal pressure (Sulzer, 1997).

THE RASCHIG SUPER-RING IN INDUSTRIAL PRACTICE

The previously described good properties of the Raschig Super-Ring are also confirmed in industrial plants. However, the large dimensions of industrial mass transfer columns require scale-up from the properties that can be measured in small test facilities. The ratio of column diameter to nominal packing diameter is often very much larger than in experimental plants and brings up the question of the influence on mass transfer efficiency. In the past it was reported on repeated occasions that with a diameter ratio of column shell to nominal packing size larger than 20 a drop in mass transfer efficiency is to be expected (Billet, 1973). The same occurs, according to earlier studies, if packed beds assume great heights (Huber and Hiltbrunner, 1966; Kister, 1992). One sees the causes for this in a maldistribution of the liquid or gas phase, which may be caused by an uneven distribution of the phases over the column cross-section or by the effect that the liquid tends to flow towards the column wall as the column length increases (Kister, 1990). If once the liquid reaches the wall, it remains there and trickles faster downwards in an accelerated manner, with the result that the mass transfer efficiency deteriorates.

From various applications it was seen that the Raschig Super-Ring can be dumped very much higher than other random packings without a noticeable loss of mass transfer efficiency occurring. For instance, dumping heights of 10–11 m (33–36 feet) have already been achieved independent of absorption, desorption, or rectification applications. The very even distribution of material and liquid also makes it possible for very large ratios of column diameter to nominal packing diameter to be achieved. Even with a ratio of over 200, no loss of mass transfer efficiency is observed with Raschig Super-Rings in industrial plants. Of course, care has to be taken in the distributor design to ensure a uniform liquid distribution over the column cross-section.

USING RASCHIG SUPER-RINGS IN BUTADIENE PLANTS

The BASF butadiene extraction process using the solvent N-methylpyrrolidone (NMP) is one of the world's leading methods for obtaining high-purity 1,3-butadiene from a mixture of C4 feed. The technology was developed by BASF in the 1960s, initially using trayed columns.

The great successes with the use of dumped packings in the various mass transfer processes at BASF led in the 1990s to the increased use of dumped packings in the main distillation columns of the NMP process. Figures 11 and 12

(BASF) show the currently typical applications of dumped packings in the BASF NMP process.

A mixture of 45 mass% 1,3-butadiene components is concentrated using the solvent NMP in three consecutive extractive distillation columns to 1,3 crude butadiene with a purity of over 98 mass%. While the concentrated crude butadiene is removed from the after washer as a top product and then flows to the high purity butadiene distillation, the butanes and butenes are mainly removed by the main washer as the top product. This top product flow should contain the smallest possible lost quantities of 1,3-butadiene, for which reason a 1,3-butadiene content of <2000 ppm is defined in the top product specification for the main washer.

The loaded solvent NMP leaving the rectifier as the bottom product is recovered for the process in the degaser at increased temperature and lowered pressure and in the cooling tower (solvent regeneration step). The three extractive distillation columns as well as the two NMP regeneration columns are presently equipped increasingly with dumped packings.

Afterwards the 1,3-crude butadiene, purified to over 98 mass%, is treated in two high-purity butadiene distillation columns from its residual components propyne and 1,2-butadiene + C5 hydrocarbons. At the top of the butadiene distillation column the process meets the 1,3-butadiene product specification of >99.7 mass%. To date these two distillation columns are typical applications of mass transfer trays, which achieve, with a small tray spacing, a large number of theoretical stages per metre of height.

In a new butadiene plant in operation since 1999 the use of Raschig Super-Rings in all extractive distillation columns and the NMP regeneration columns has proved particularly successful. The process was engineered by , Lurgi Oel-Gas-Chemie in Frankfurt, and was designed for a capacity to produce 100,000 tons/year 1,3-butadiene. For example, the mass transfer efficiency of the extractive distillation and the regeneration columns was better than expected in comparison with other dumped packings as a result of the use of the Raschig Super-Ring. Both the low pressure drops and the gain in terms of mass transfer efficiency ultimately led to lower operating costs than were expected.

The characteristics of small tendency to plugging and low foaming of the Raschig Super-Rings have a positive effect.

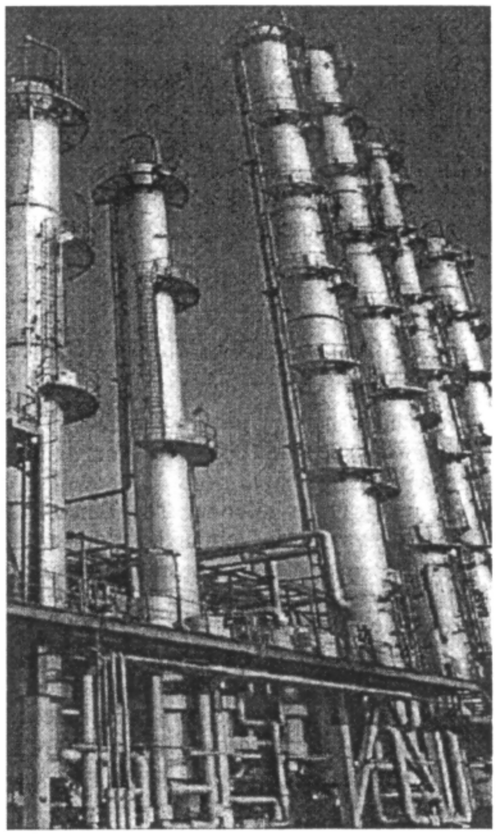


Figure 12. Main packed columns for BASF NMP butadiene process (Moser and Kessler, 1999).

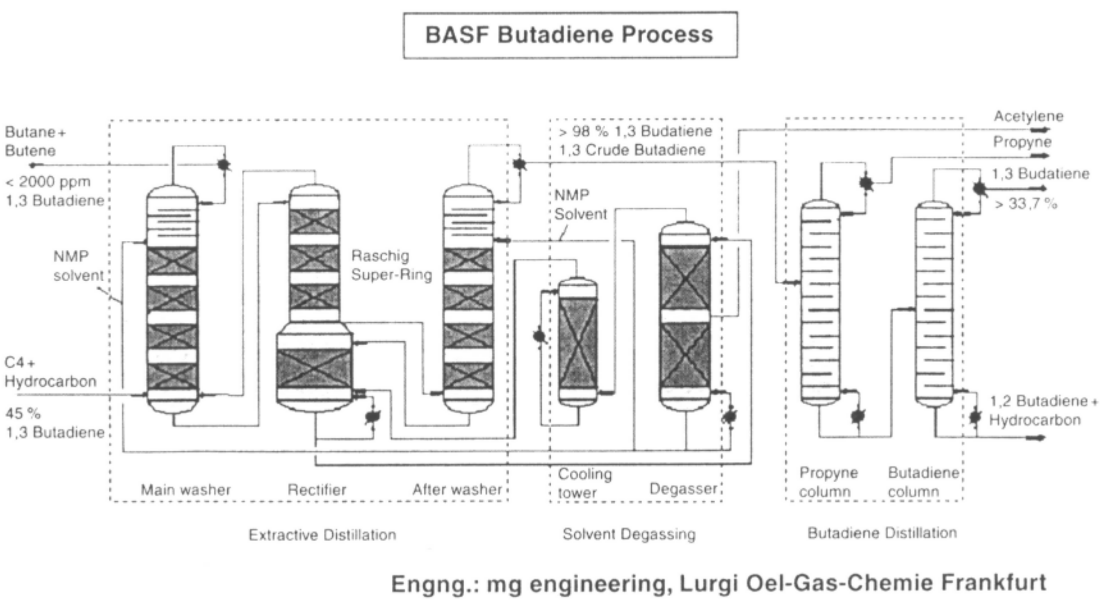


Figure 11. BASF NMP butadiene process for production of 1,3-butadiene.

The continuous liquid film provides an uninterrupted cleaning of the surface of the dumped packings and the small static liquid hold-up, in comparison with other dumped packing geometries, ensures that no stagnant dead-space liquids can occur. In particular the latter impairs polymerization phenomena in the NMP process. Furthermore, reduced droplet formation in the Raschig Super-Ring geometry suppresses foaming.

USING RASCHIG SUPER-RINGS IN BENFIELD ABSORPTION COLUMNS

Figures 13a and b show a typical revamp application with Raschig Super-Rings performed at EC-Dormagen, Germany. An existing column was built with 33 four-pass trays to absorb CO_2 in a caustic solution. The Benfield process operated in an ethylenoxide unit under a top pressure of 17.6 bar (255 psia) with a total pressure drop of 350 mbar (5.1 psia). The purpose of the revamp was to minimize the pressure drop and to provide extra capacity available for future operation conditions. The revamp study verified that Raschig Super-Ring No. 2 fitted the future operation condition as well as the maximum pressure drop criteria. It was decided to install a packed bed of more than 10 m (33 feet) height in the top of the column and a second bed of approximately 6 m (19.7 feet) height in the bottom. A further advantage of Raschig Super-Rings was the fact that all support rings and downcomer bars of the existing four-pass tray column were left inside so that the shut-down time was minimized. Between the beds a liquid collector was installed to mix the liquid from the top bed before it was redistributed into the second bed. Special care was taken in the design of the liquid distributor in the top and the liquid redistributor between the beds to realize a homogenous liquid distribution over the packing. Below the bed a gas distributor was installed to ensure also a homogenous gas distribution over the column cross-section. After starting up the column the pressure drop decreased tremendously in comparison to the tray solution, as might be expected. Presently the column operates with a pressure drop below the accuracy of the measurement device, which starts to show the pressure drop at 10 mbar (0.15 psia) total pressure drop.

USING RASCHIG SUPER-RINGS IN FORMALDEHYDE ABSORPTION PLANTS

BASF in Ludwigshafen, Germany, also operates one of the largest formaldehyde (FA) plants for the production of 440,000 t/year of formaldehyde solution. As one can see in Figure 14, a methanol/water mixture is first evaporated in a vaporization column with the addition of process air. Then the hot gas mixture flows into a fixed-bed reactor where the gas mixture is converted into formaldehyde and subsequently quenched by indirect water cooling. In a four-stage absorption column the formaldehyde gas is then concentrated to an approximately 50% formaldehyde solution. Raschig Super-Rings were used both in the evaporator and in the first three stages of the absorption column. Owing to the small liquid loads, the last stage of the absorption column is traditionally a tunnel tray section.

The FA process is characterized by the fact that fouling in the columns due to the formation of paraformaldehyde cannot be ruled out and therefore the use of random packings is preferred in comparison to structured packings.

Since Raschig Super-Rings have been successfully used now for over one year in the first plant, the second plant of the same design will also be equipped with Raschig Super-Rings at BASF Ludwigshafen.

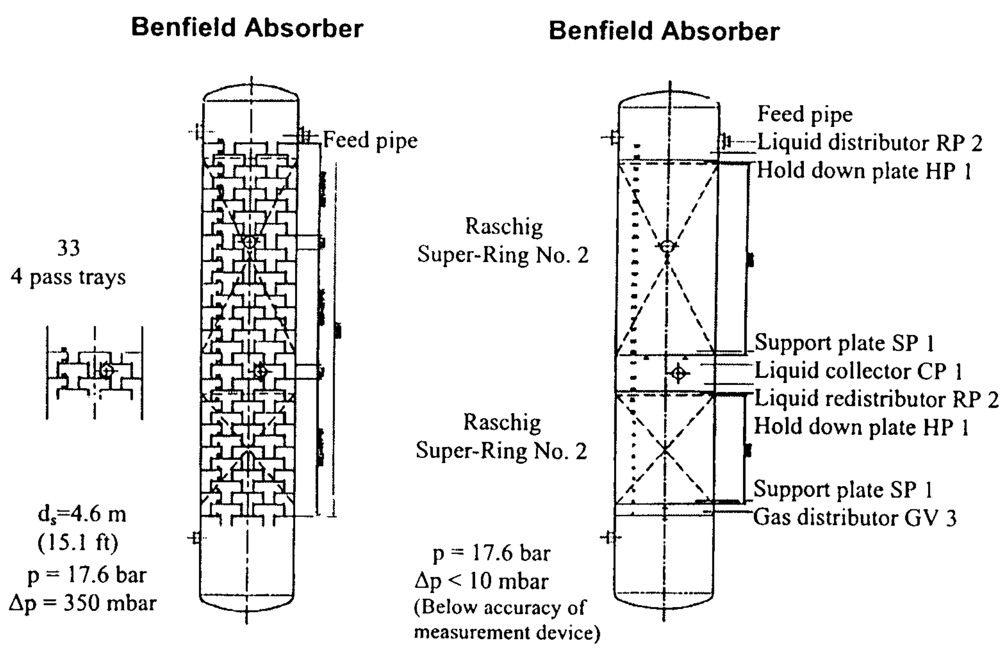


Figure 13. (a) Benfield absorber with four-path trays before revamp; (b) Benfield absorber with Raschig Super-Ring No. 2 after revamp.

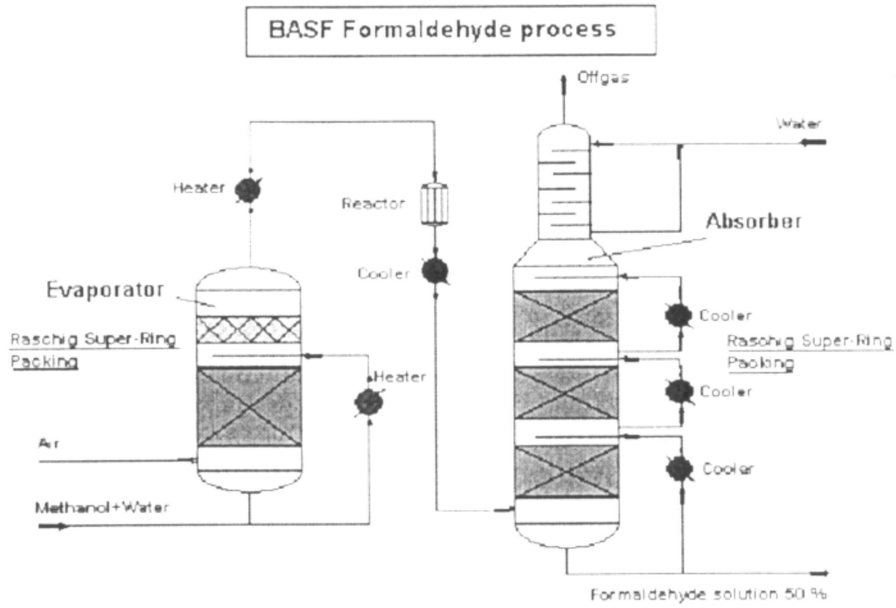


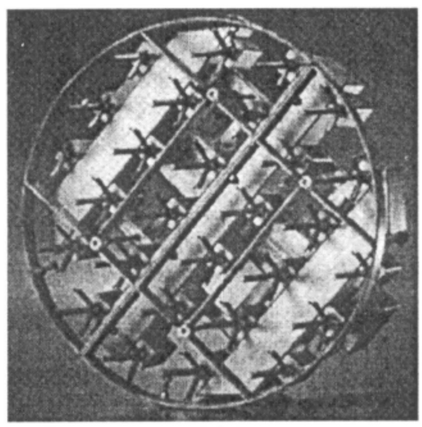
Figure 14. BASF formaldehyde process with Raschig Super-Rings for production of 50% formaldehyde solution.

USING RASCHIG SUPER-RINGS IN VACUUM DISTILLATION COLUMNS

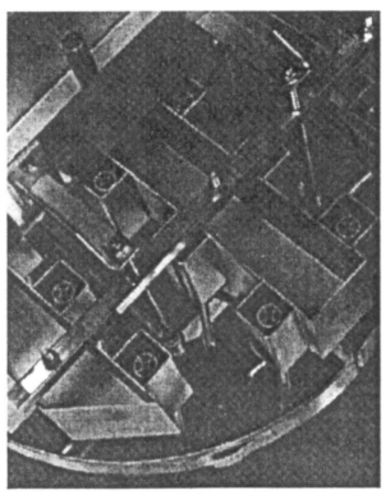
As a rule, the use of dumped packings is limited to processes in mild vacuum, normal pressure, and in overpressure systems. The relatively large pressure drop per metre of height and per theoretical stage limits their use under deep vacuum. With the Raschig Super-Ring, Degussa AG in Germany has now switched from gauze wire structured packing to Raschig Super-Rings in a vacuum distillation unit with a top pressure of 30 mbar (0.44 psia) and a column diameter of 0.8 m (2.6 ft). The decision to revamp the column was made because, after operating the plant for only three to five months, the gauze wire structured packing was so markedly blocked—particularly in the enrichment part—that the column had to be switched off and the packing removed. Since it was not possible to clean the gauze wire sufficiently it had to be replaced with a new packing at three- to five-month intervals.

The most urgent requirement when converting the vacuum distillation unit was to minimize the interruption of the operation of the column. Owing to the very small liquid load and the required mass transfer efficiency, the gauze wire packing used had a surface area of 500 m^2/m^3. The smallest Raschig Super-Ring, the No. 0.3, has a specific surface area of 315 m^2/m^3 and was chosen as an alternative in the enrichment part. The conversion of the enrichment part took place in the summer of 2000, and the Raschig liquid distributor type DT-MF, which is particularly suitable for and patented for small liquid loads, was used. Owing to its design, this liquid distributor has a very even distribution pattern even in the case of small liquid loads and can be designed particularly for fouling systems. Furthermore, it is easy to clean owing to its highly robust design.

In order also to ensure the mass transfer efficiency with the Raschig Super-Ring No. 0.3 in analogy to the gauze wire packing, the process is run with a slightly increased reflux ratio, but without substantially influencing the total pressure drop in the column. Owing to the good results using the Raschig Super-Ring No. 0.3 in the enrichment part it was



(a)



(b)

Figure 15. (a) Raschig multiflow distributor type DT-MF for low liquid load (view from bottom); (b) Raschig multiflow distributor type DT-MF for low liquid load (view from top).

later decided that the stripping section should also be converted to Raschig Super-Rings No. 0.5. Here, too, the type DT-MF liquid distributor was used as a redistributor. The column now operates over a much longer period and, because cleaning of Raschig Super-Rings is carried out during shutdown time, the cost could be noticeably reduced.

Figures 15a and b show a typical liquid distributor type DT-MF. It has proved successful for very small liquid loads down to 0.4 m^3/m^2h (0.164 gpm/ft^2). The side boxes house the MF elements, which distribute the liquid evenly over the column cross-section. Furthermore, the MF element can be adjusted very well to fouling systems by choosing holes or slits or a combination thereof.

USING RASCHIG SUPER-RINGS IN PROCESSES WITH HEAVY FOULING

In BASF's Toluene-di-isocyane (TDI) process a distillation column has been in use over many years that was equipped with structured packings owing to the number of theoretical stages required. Periodically the column was shut-down because the heavy contamination of the structured packing led to capacity bottlenecks in the plant. In 1999 a decision was made to use the Raschig Super-Ring, which, owing to its shape, promised comparable performance data but was judged to be considerably less prone to contamination in the distillation column. While the structured packing had to be exchanged every 12–16 months, the column has now been in continuous operation for over 24 months without any fouling effect.

USING RASCHIG SUPER-RINGS IN A C_3-SPLITTER

Figure 16 shows a further revamp application of Raschig Super-Rings. The column operates as a propane/propene splitter with a top pressure of 12.9 bar (187 psia) and was equipped with 25-mm IMTP-Rings at Targor Lillebonne, France. The design was given with a 6-m (19.7-foot) bed height in the top of the column and five further beds each of 6 m (19.7 foot) height below the feed so that the column diameter was 1.85 m (6 ft). The purpose of the revamp was a capacity increase of 50%, but without any loss in the separation efficiency so that the top and bottom specification of the product quality could be maintained.

The process study verified that the Raschig Super-Ring equivalent to IMTP 25 was not able to handle a capacity increase of 50% because the IMTP 25 packing was already operated at its capacity limits. The first larger size of Raschig Super-Ring that could handle the capacity increase was Raschig Super-Ring No. 1 in the top and Raschig Super-Ring No. 1.5 in the bottom. The efficiency study further verified that the HETP of the existing packing IMTP 25 was higher than expected and could also be guaranteed by the selected Raschig Super-Rings in the top and bottom of the column. A study of the column internals showed that the liquid redistributors used in the existing column were not able to equalize any liquid maldistribution in the packed beds. With the new liquid redistributors special care were taken in the design to have the liquid homogeneously distributed over the column cross-section at each intersection of the packed beds. After start up of the C_3-splitter the new capacity and product specification were reached in only a few hours.

Table 4. Selection of applications for Raschig Super-Rings.

Natural gas plant	Methanol plant
Methionine plant	Butadiene plant
Caprolactam plant	*N*-Methylpyrrolidone plant
Refinery plant	Synthesis gas plant
Fatty acid plant	Effluent water treatment
Effluent gas plant	Ethylene plant
Ammonia plant	Sulfur plant
Ethanol plant	TDI plant
Formaldehyde plant	Ethylenoxid plant

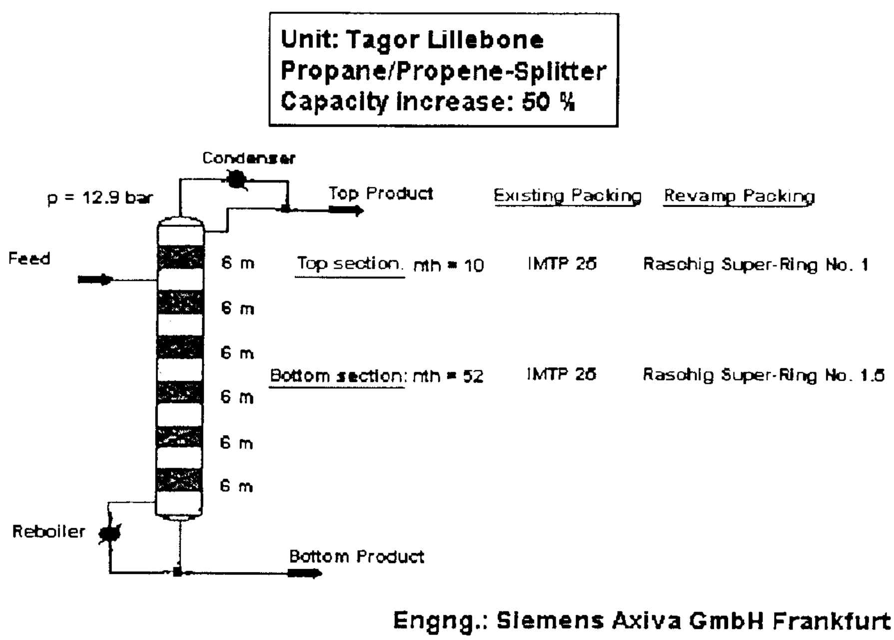


Figure 16. Revamp of a C_3-splitter from IMTP 25 to Raschig Super-Ring No. 1 and No. 1.5.

Table 4 shows a selection of applications in which a Raschig Super-Ring had been used.

SUMMARY

The test given in this paper display the performance data of randomly dumped packings and those of structured packings. It is shown that the mass transfer efficiency of packings is promoted by turbulence-generating geometries and requires large interfacial areas. Based on the same surface area, dumped packings therefore have advantages over structured packings, but also have higher pressure drops.

The plants with Raschig Super-Rings described thereafter also show that these advantages can successfully be applied both in new plants and in column revamp situations from trays or structured packings to the Raschig Super-Ring.

NOMENCLATURE

a	spec. total surface area of packing, m^2/m^3
F_V	gas or vapor capacity factor $= u_V \cdot \sqrt{\rho_V}$, $\sqrt{Pa}, m\,s^{-1}(kg\,m^{-3})^{1/2}$
H	height, m
HETP	height equivalent to a theoretical stages, m
HTU_{OV}	overall height of a mass transfer unit, m
L	molar liquid flow rate, $kmol\,h^{-1}$
n_{th}	number of theoretical stage
p	total pressures, bar
u_L	superficial liquid velocity, $m^3\,m^{-2}\,h$
u_V	superficial vapor velocity, $m\,s^{-1}$
V	molar vapor flow rate, $kmol\,h^{-1}$
Δp	pressure drop, Pa, mbar

REFERENCES

Schultes, M., 2001, Raschig super-ring—a new fourth generation random packing, *Spring AIChE Meeting & Petrochemical & Refining Exposition*, Houston, Texas.

Schultes, M., 2001, Raschig super-ring—a new fourth generation packing offers new advantages (part 2), *AIChE's 2001 Annual Meeting*, Reno, NV.

Shariat, A. and Kunesh, J.G., 1995, *Ind Eng Chem Res*, 34: 1273–1279.

Nutter, D.E., 1987, *IChemE Symp Ser*, 104: A129–A142.

Spiegel, L. and Meier, W., 1987, *IChemE Symp Ser*, 104: A203–A215.

Shariat, A., Kunesh, J.G. and Fitz, C.W., 1999, *Ind Eng Chem Res*, 38: 512–518.

Sulzer, 1997, *Structured Packings for Distillation and Absorption* (Sulzer Chemtech Ltd., Winterthur, Switzerland).

Moser, F. and Kessler, A., 1999, *Increased Capacity Thanks to Improved Geometry* (Sulzer Technical Review, Sulzer Chemtech Ltd., Winterthur, Switzerland).

NORTON, Intalox Metal Tower Packing, Bulletin IM-82, 2M-150010302-5/84.

Billet, R., 1973, *Industrielle Destillation* (Verlag Chemie GmbH, Weinheim, Bergstrasse, Germany).

Huber, M. and Hiltbrunner, R., 1966, *Chem Eng Science*, 21: 829.

Kister, H.Z., 1992, *Distillation Design* (McGraw-Hill Inc., New York, USA).

Kister, H.Z., 1990, *Distillation Operation* (McGraw-Hill Inc., New York, USA).

BASF, *BASF's NMP-Process—The Customized Process for Butadiene Extraction* (BASF Aktiengesellschaft, Ludwigshafen, Germany).

ADDRESS

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The paper was presented at the International Conference on Distillation and Absorption held in Baden-Baden, Germany, 30 September–2 October 2002. The manuscript was received 8 July 2002 and accepted for publication 22 October 2002.