RASCHIG SUPER-RING
A NEW FOURTH GENERATION PACKING OFFERS NEW ADVANTAGES

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ABSTRACT

Since its introduction to the market in 1995, numerous mass transfer columns have been packed with Raschig Super-Rings in the various chemical process industries, petrochemicals, refining and environmental applications. To support these highly successful applications, the Raschig Super-Ring No. 2 was tested at the Fractionation Research Inc. (F.R.I.) test facility at the end of 1998.

The purpose of this paper is to discuss the F.R.I. 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 will be taken on the comparison of test results with Raschig Super-Ring No. 2 to other modern and standard random packings as well as to structured packings.

The comparison will show that a modern random packing design have mass transfer efficiency advantages compared to structured packings, if the same specific surface area is taken as the comparison basis.

Further on industrial applications will be shown where Raschig Super-Ring's had been used successfully. New column design will be explained as well as revamp situations. Latest will show revamps of trayed towers, random packed towers as well as columns with structured packings.

INTRODUCTION

Owing to the development of modern dumped packings for mass transfer processes such as rectification, absorption and desorption in recent years especially the randomly dumped packing 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 display process properties which, firstly, approximate those of structured packings and, secondly, meets the advantages of mass transfer trays.

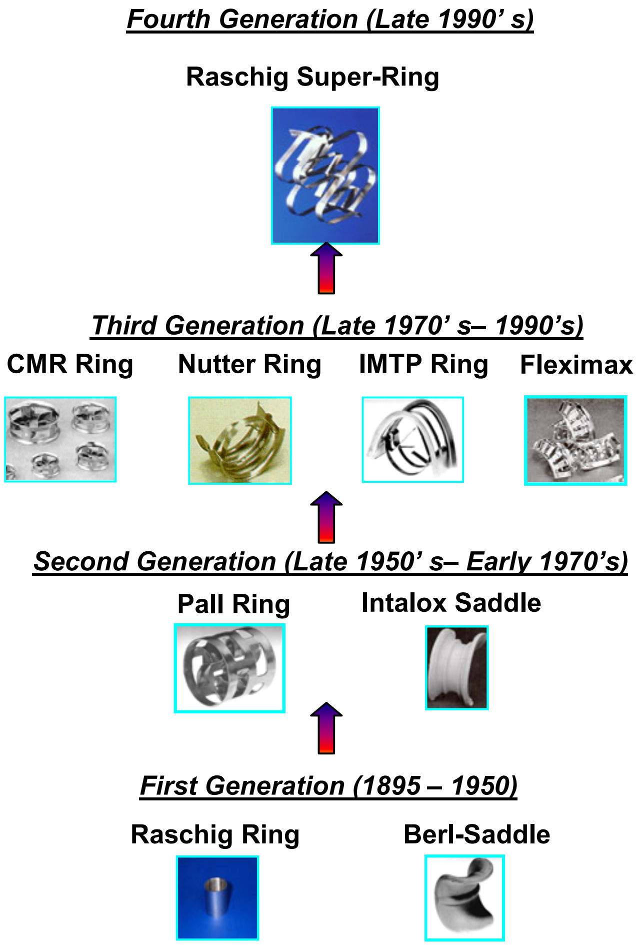

Fig. 1: History of development of characteristic random packings of different generations

This excellent 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 here 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, see Figure 1, and be measured in comparison with structured packings.

In the following chapter therefore first of all 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 /1,2/. Tab. 1 shows the various equivalent Raschig Super-Ring to Pall-Ring sizes if the surface area is taken as the comparison bases. These study and the early successes in industrial applications resulted in 1998 of specific tests under distillation conditions with Raschig Super-Ring No. 2 at one of the world's largest test institutes, the Fractionation Research Inc. (FRI) in Stillwater, Oklahoma /1/, Figure 2.

Fig. 2: FRI test facility in Stillwater Oklahoma/USA.

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

Pall-Ring		Raschig Super-Ring	
size	a[m²/m³]	size	a[m²/m³]
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

Figure 3 shows as an example the pressure drops of Raschig Super-Rings No. 0.7 and 2 in comparison with the 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.

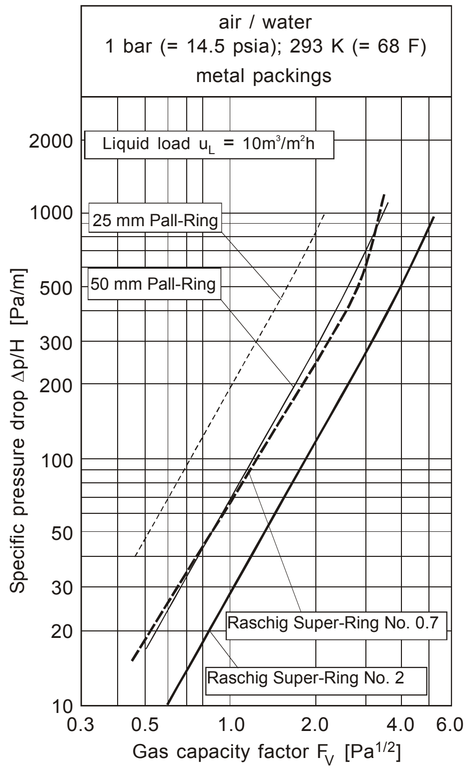

Fig. 3: Pressure drop comparison between Pall-Rings and Raschig Super-Rings in various sizes.Tests had been performed at Ruhr University Bochum/Germany.

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.

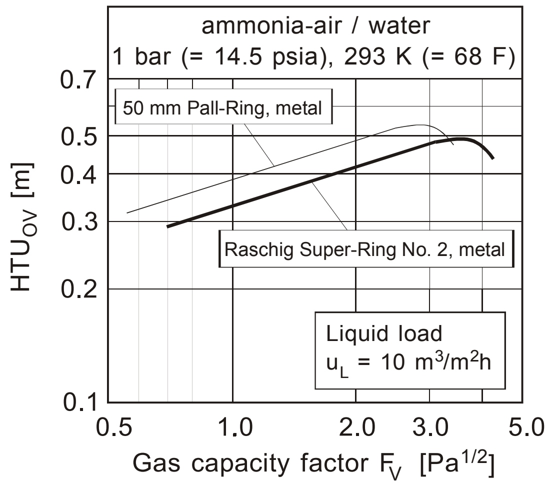

Fig. 4: Height of an overall gas side mass transfer unit for various gas capacity factors and constant liquid load for 50 mm Pall-Ring and Raschig Super-Ring No. 2 in metal. Tests had been performed at Ruhr University Bochum/Germany.

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 optimised geometry of Raschig Super-Rings. Owing to its sinusoidally undulating geometry not only the shape of this dumped packing is very open but mainly liquid films are formed which are otherwise only found with structured packings. These in particular ensure, an excellent loading capacity of this dumped packing.

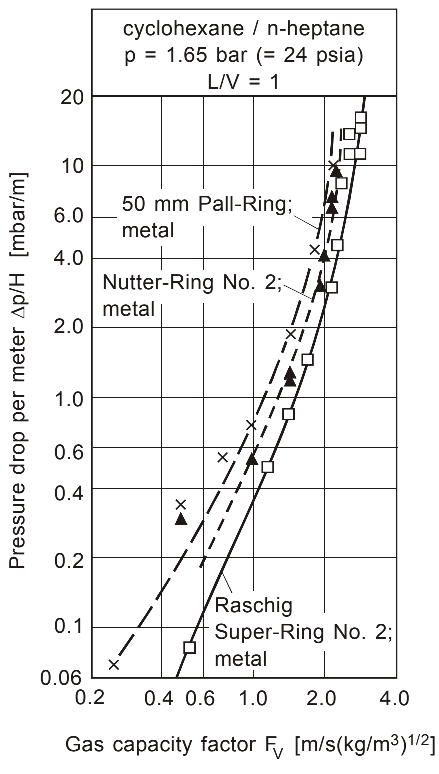

Fig. 5: Comparison of pressure drop for Raschig Super-Ring No. 2, 50 mm Pall-Ring and Nutter-Ring No. 2. Tests had been performed at FRI facility in StillwaterOklahoma/USA.

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 cyclohexane/n-heptane mixture. The diagram also includes measurements of Nutter-Ring No. 2 which is also called as a high performance random packing /3,4,5/. As in the air/water investigations the Raschig Super-Ring displays a pressure drop which is app. 60% smaller than that of the Pall-Ring and which is app. 40% smaller than that of the Nutter-Ring. The Figure also shows that the flooding capacity of the Raschig Super-Ring is app. 25-33% larger than that of the 50 mm Pall-Ring and app. 10-15% larger than that of the No. 2 Nutter-Ring.

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

Tab. 2: Performance comparison between various sizes of Pall-Rings and Raschig Super-Ring's out of metal; system: ammonia-air/water, 1 bar

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

*) $\dot{L} / \dot{V} = \text{const.}$ for the revamped packing

Tab. 3 provides further on a comparison of specific pressure drop, capacity, height equivalent to a theoretical stage and pressure drop per theoretical stage between Raschig Super-Ring No. 2, IMTP 50, Nutter-Ring No. 2 and 50 mm Pall-Ring /4,9/. The shown third generation random packings like IMTP 50 and Nutter-Ring No. 2 offers already a noticeable advantage in comparison to Pall-Rings. But as it can be seen the Raschig Super-Ring's offer a further evident benefit in comparison to the third generation random packings which is why it is called a new 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 is presented in Figure 6 /3,6/.

Tab. 3: Comparison of different 50 mm random packings out of metal; system: cyclohexan / n-Heptan, 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 (s. text)

** IMTP: Iso-octane/Toluene (1 bar) and air/water

In Fig. 6 "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 Fig. 6 the HETP of the Raschig Super-Ring No. 2 suddenly rised at a gas capacity factor of $F_V = 2.3\sqrt{Pa}$ (1.89 ft/s(lb/ft^3)$^{0.5}$, which was not expected based on the air/water tests or industrial experience. Above the gas capacity factor of $F_V = 2.3\sqrt{Pa}$ (1.89 ft/s(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 sub-cooling the liquid distributor heavily which owing to its design, had a large liquid hold-up. As the column load continued to increase, the liquid distributor even flooded. Both these circumstances caused condensation of rising gas which shifted downwards into the packed bed randomly and periodically and created backmixing effects of the phases and a premature drop in mass transfer efficiency.

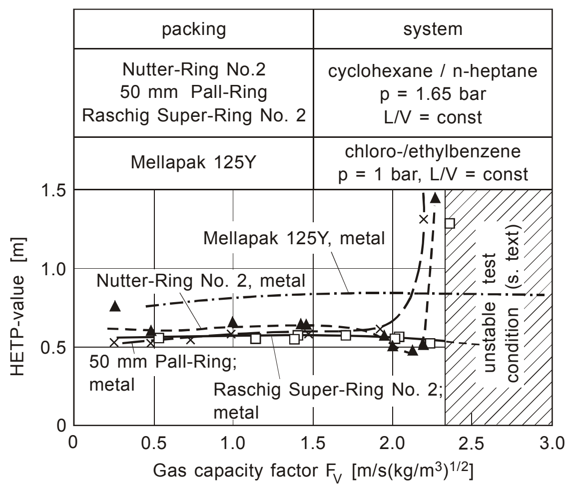

Fig. 6: Comparison of mass transfer efficiency for Raschig Super-Ring No. 2, 50 mm Pall-Ring, Nutter-Ring No. 2 and the structured packing Mellapak 125 Y. Tests had been performed at FRI facility in Stillwater Oklahoma/USA.

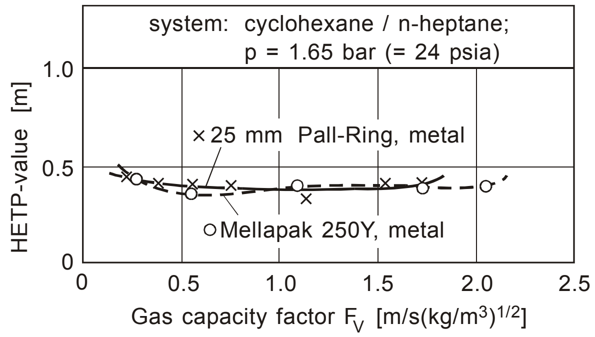

Fig. 7: HETP-value for 25 mm Pall-Ring and Mellapak 250Y for rectification system cyclohexane/n-heptane at 1.65 bar. Tests had been performed at FRI facility in Stillwater Oklahoma/USA.

It can be clearly seen from Figure 6 that the dumped packings shown with a specific surface area of app. 100 m²/m³ display a mass transfer efficiency which differs from the one to the other only by app. ± 10%. The mass transfer efficiency of the structured packing, however, is lower by app. 30 %, although its specific surface area is app. 25 % larger. Figure 7 confirms this comparison for a 25 mm Pall-Ring (surface area: 215 m^2/m^3) and the Mellapak 250 Y (surface area: 250 m^2/m^3).

Figure 8 shows equivalent results by comparing the mass transfer efficiency for the ammonia-air/water system of various Raschig Super-Rings with the Ralu-Pak 250 YC. With a surface area of 250 m²/m³ 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-Rings No. 1 with 150 m^2/m^3 surface area.

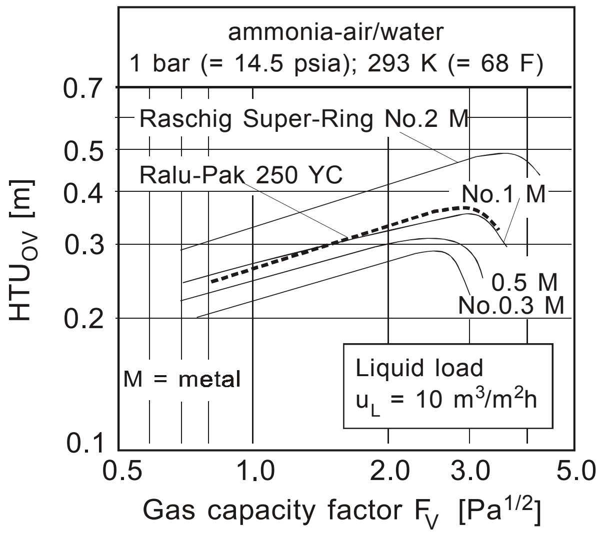

Fig. 8: Comparison of the height of overall gasside mass transfer unit between various sizes of Raschig Super-Rings and the structured packing Ralu-Pak 250 YC for the absorption system ammonia-air/water. Tests had been performed at Ruhr University Bochum/Germany.

An analysis of Figs. 9 and 10 can help to explain the phenomena described. It shows the mass transfer curve and the pressure drop curve of a Mellapak 250 Y and of a Mellapak 250 X measured by Sulzer in Switzerland /7/. 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.

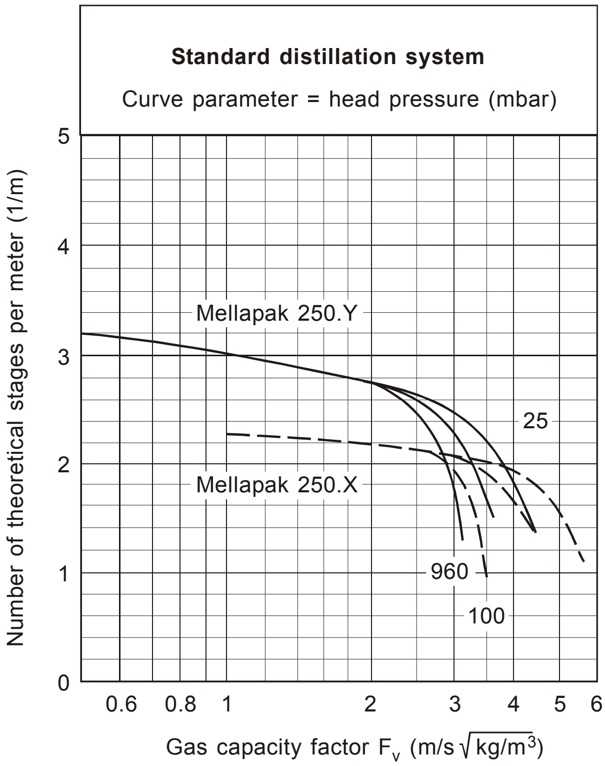

Fig. 9: Number of theoretical stages of Mellapak 250 Y and Mellapak 250 X for standard distillation system from vacuum to normal pressure /7/

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 despite 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 instance, 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 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 geometry's the liquid film remains thin and turbulent at the intersection zones so that, despite the smaller pressure drop in these areas, the mass transfer efficiency remains /8/.

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 meter of packed height. This fact is meanwhile made use of in many column revamps from structured packings to Raschig Super-Rings, as the following chapters will show.

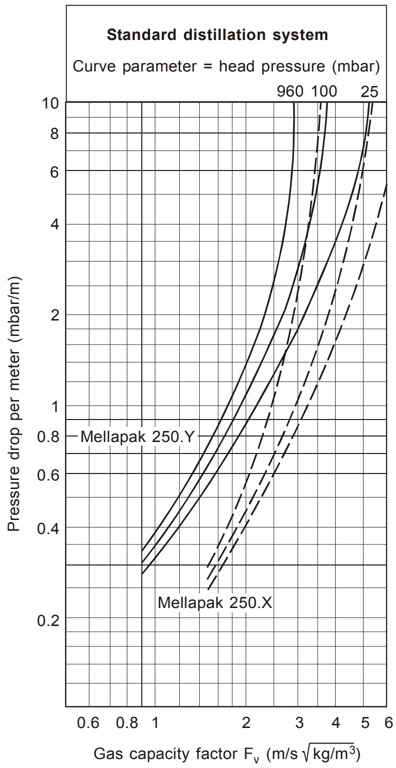

Fig. 10: Pressure drop of Mellapak 250 Y and Mellapak 250 X for standard distillation system from vacuum to normal pressure /7/

THE RASCHIG SUPER-RING IN INDUSTRIAL PRACTICE

The previously described good properties of the Raschig Super-Ring are also confirmed in industrial plants. But the large dimensions of industrial mass transfer columns require further advantages from modern packings which exceeds 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 /10/. The same occurs according to earlier studies if packed beds assume great heights /11,12/. 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 /13/. If ones 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 application. 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 1960's initially using trayed columns.

The great successes with the use of dumped packings in the various mass transfer processes at BASF led in the 1990's to the increased use of dumped packings in the main distillation columns of the NMP process as well. The Figs. 11 and 12 /14/ 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, mainly the butanes and butenes are 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.

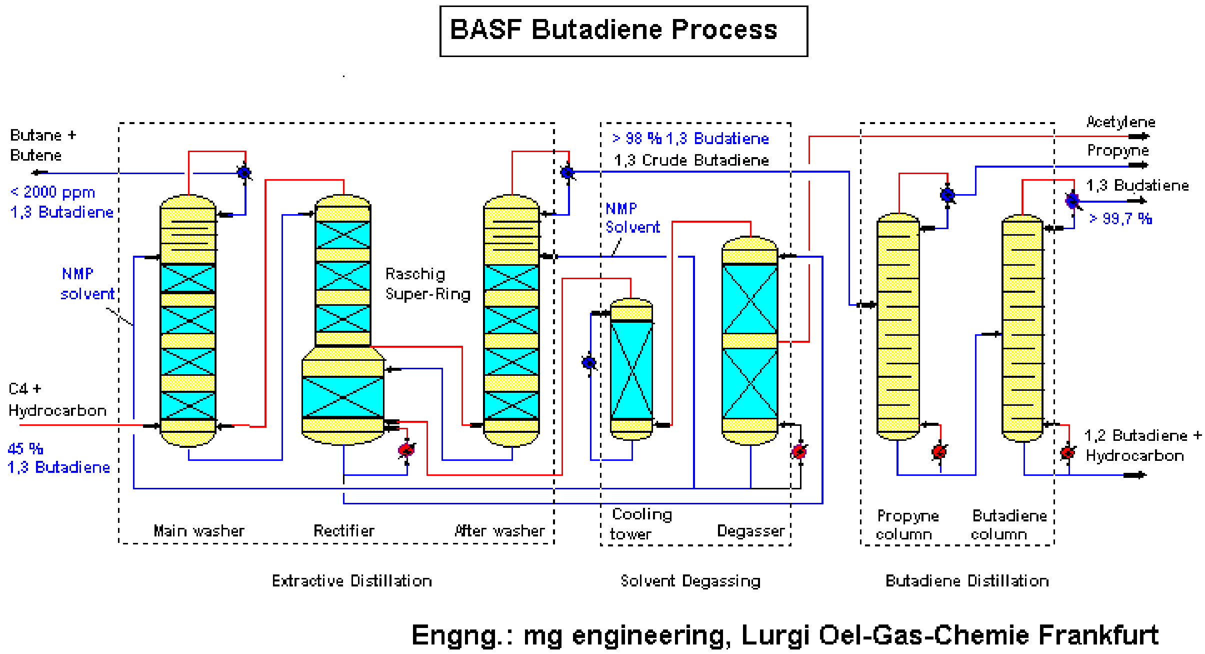

Fig. 11: BASF NMP butadiene process for production of 1,3 butadiene

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 more and more 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%. Until today 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 meter of height.

Fig. 12: Main packed columns for BASF NMP butadiene process /8/

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 mg engineering, Lurgi Oel-Gas-Chemie in Frankfurt and was designed for a capacity to produce 100000 t/year (220,000 Klb/year) 1,3-butadiene. For instance 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 supposed.

Particularly the small tendency of plugging and the low foaming tendency of the Raschig Super-Rings have a positive effect. The continuous liquid film provides an uninterrupted cleaning of the surface of the dumped packings and the small static liquid holdup in comparison with other dumped packing geometry's ensures that no stagnant dead space liquids can occur. In particular the latter impairs polymerization phenomena in the NMP process. Furthermore, the reduced droplet formation in the Raschig Super-Ring geometry suppresses foaming.

USING RASCHIG SUPER-RING IN BENFIELD ABSORPTION COLUMNS

Figure 13 a and b show a typical revamp application with Raschig Super-Rings performed at EC-Dormagen/Germany. An existing column was built with 33 4-pass trays to absorb CO2 in a caustic solution.

Benfield Absorber

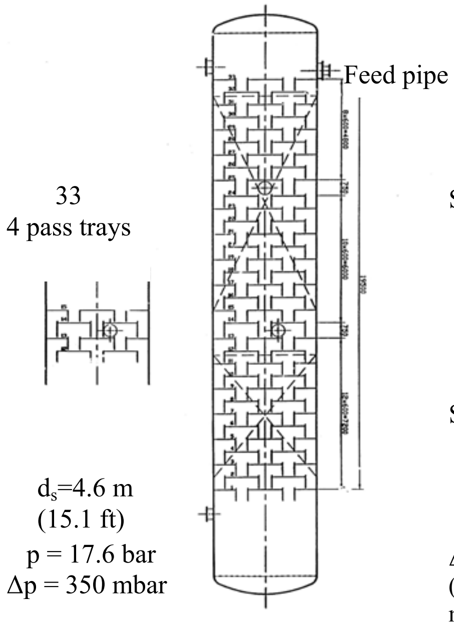

Fig. 13a: Benfield absorber with 4-path trays before revamp

Benfield Absorber

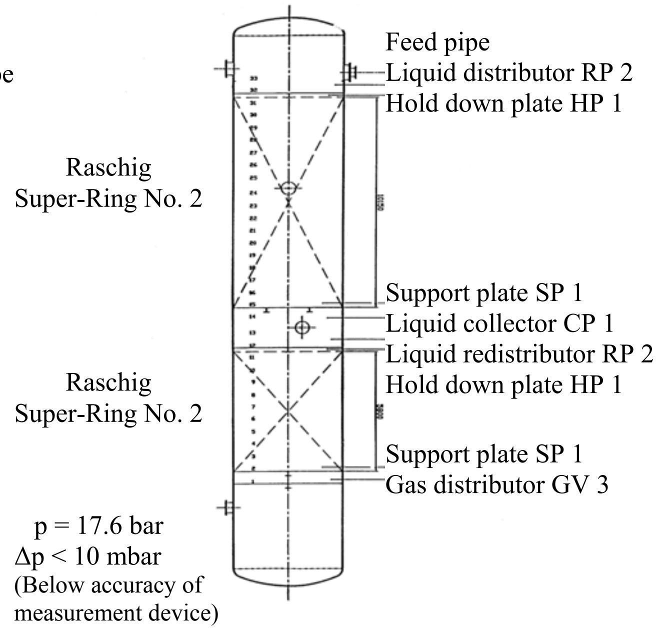

Fig. 13b: Benfield absorber with Raschig Super-Ring No. 2 after revamp

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 minimise the pressure drop and to provide extra capacity available for future operation conditions. The revamp study verified that Raschig Super-Ring No. 2 fit the future operation condition as well as the maximum pressure drop criteria. Furthermore it was decided to install a packed bed of more than 10 m (33 feet) height in top of the column and a second bed of approx. 6 m (19.7 foot) height in the bottom. A further advantage of Raschig Super-Ring was the fact that all support rings and downcomer bars of the existing 4-pass tray column were left inside so that the shutdown time was minimised. 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 top and liquid redistributor between the beds to realise 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 dropped down tremendously in comparison to the tray solution. 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 also operates one of the largest formaldehyde (FA) plants for the production of 440000 t/year (960,000 Klb/year) of formaldehyde solution. As one can see in Figure 14, first of all a methanol/water mixture is evaporated in a vaporisation 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 app. 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 characterised 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 for now over one year in the first plant the second plant of the same design will also to be equipped with Raschig Super-Rings at BASF Ludwigshafen.

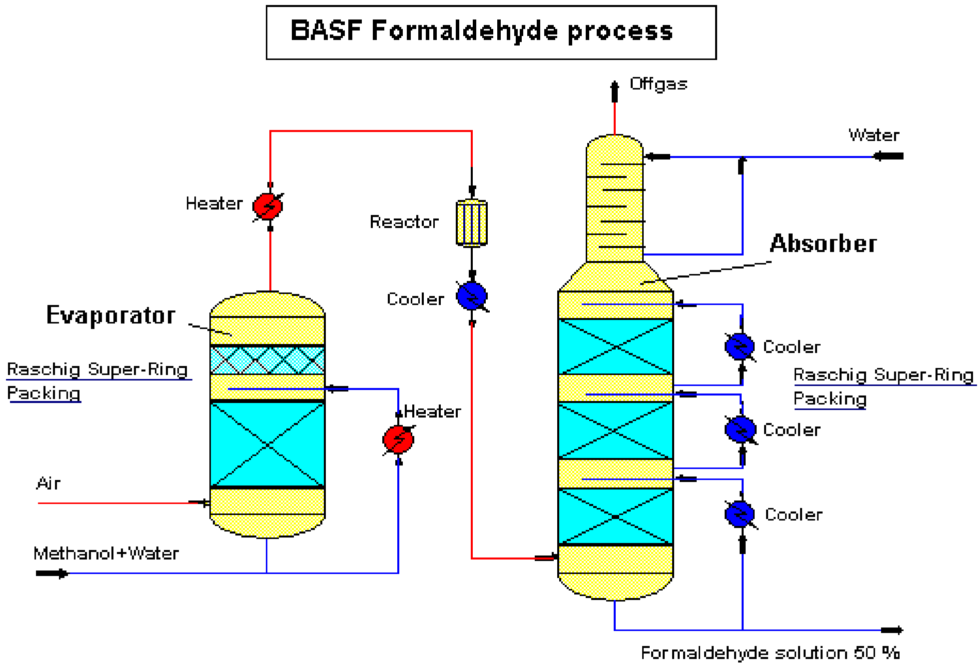

Fig. 14: BASF formaldehyde process with Raschig Super-Rings for production of 50% formaldehyde solution

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 meter 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 3-5 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 3- to 5-month intervals.

The most urgent requirement when converting the vacuum distillation was to minimise 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 whereby 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 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.

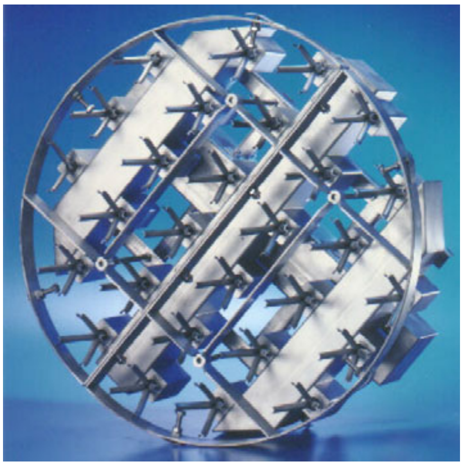

Fig. 15a: Raschig Multiflow distributor type DT-MF for low liquid load (view from bottom)

In order to ensure the mass transfer efficiency also 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 influencing the total pressure drop in the column substantially.

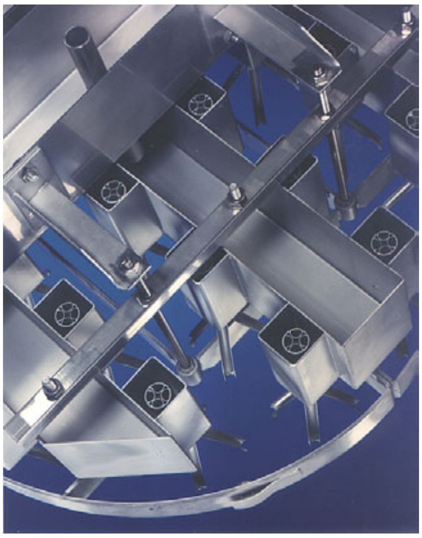

Fig. 15b: Raschig Multiflow distributor type DT-MF for low liquid load (view from top)

Owing to the good experiences with the Raschig Super-Ring No. 0.3 in the enrichment part it was later on decided that the stripping section should also be converted to size Raschig Super-Rings No. 0.5. Here too the type DT-MF liquid distributor was used as a redistributor. Presently the column operates at much longer periods and due to cleaning of Raschig Super-Rings during shutdown time the cost could be noticeably reduced.

Figs. 15a and b show a typical liquid distributor type DT-MF. It has proved successful for very small liquid loads of 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 used for years which was equipped with structured packings owing to the number of theoretical stages required. Periodically the column was shutdown 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 this distillation column.

The result was impressive. 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-RING 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 the 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 top of the column and 5 further beds each of 6 m (19.7 foot) height below the feed whereby the column diameter was 1.85 m (6 ft). The purpose of the revamp was a capacity increase by 150% but without any loss in the separation efficiency so that the top and bottom specification of the product quality could be maintained.

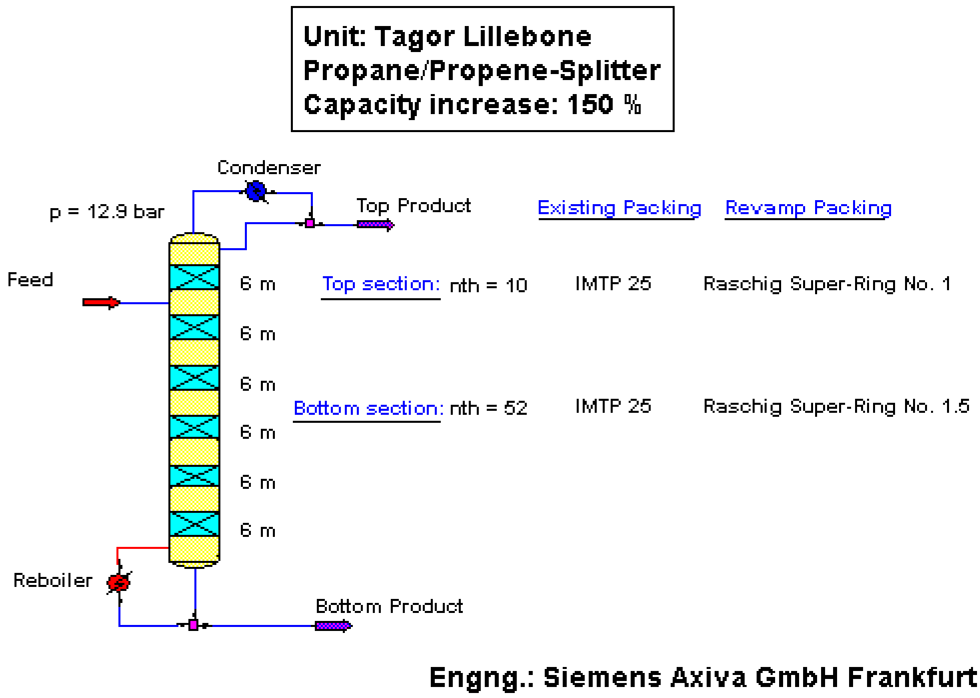

Fig. 16: Revamp of a C_3-Splitter from IMTP 25 to Raschig Super-Ring No. 1 and No. 1.5

The process study verified that the Raschig Super-Ring equivalent to IMTP 25 was not able to handle a capacity increase of 150 % because the IMTP 25 packing was already operated at their capacity limits. The first larger size of Raschig Super-Ring that could handle the capacity increase was Raschig Super-Ring No. 1 in top and Raschig Super-Ring No. 1.5 in the bottom. The efficiency study furthermore verified that the HETP of the existing packing IMTP 25 was higher than expected and could be also guaranteed by the selected Raschig Super-Rings in top and bottom of the column. The study of the column internals shows that the liquid redistributors used in the existing column were not able to equalise 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 C3-splitter the new capacity and product specification were reached in only a few hours.

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

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

SUMMARY

The test results shown here 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 geometry's and requires large interfacial areas. Based on the same surface area, dumped packings have advantages over structured packings therefore, 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	m^2/m^3	spec. total surface area of packing
F_V	$\sqrt{Pa}$, m/s $(kg/m^3)^{1/2}$	gas or vapor capacity factor = $u_V \cdot \sqrt{\rho_V}$
H	m	height
HETP	m	height equivalent to a theoretical stage
HTU_{OV}	m	overall height of a mass transfer unit
L	kmol/h	molar liquid flow rate
n_{th}		number of theoretical stage
p	bar	total pressure
u_L	m^3/m^2h	superficial liquid velocity
u_V	m/s	superficial vapor velocity
V	kmol/h	molar vapor flow rate
Δp	Pa, mbar	pressure drop

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