HOW TO SURPASS CONVENTIONAL AND HIGH CAPACITY
STRUCTURED PACKINGS WITH RASCHIG SUPER-PAK

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Raschig Super-Pak is a novel development in structured packing product technology
that is fundamentally different to the well known corrugated perforated or non-
perforated, textured sheet metal structured packings. It comprises of a systematic
sequence of smooth sinusoidal waves above and below the plain of the metal sheet.

Total reflux distillation tests with Raschig Super-Pak 300 were conducted at the
Separations Research Program, University of Texas at Austin. Results in terms of
useful capacity, mass transfer efficiency, pressure drop and pressure drop per theor-
etical stage are presented. Comparisons with the standard and high capacity structured
packings tested under identical conditions [1] will be shown.

KEYWORDS: Raschig Super-Pak, structured packings, distillation, useful capacity,
pressure drop

TEST UNIT AND EXPERIMENTAL PROCEDURES
Raschig Super-Pak 300 (RSP-300) is a novel development from Raschig GmbH comprising
of a systematic sequence of smooth sinusoidal waves above and below the plain of the
metal sheet that are arranged in rows at a 45° angle as shown in Figure 1.

At the University of Texas at Austin Separations Research Program (SRP) con-
ducted total reflux distillation tests were conducted to characterize the new RSP-300
metal structured packing. Hydraulic and mass transfer performance was measured using
the cyclohexane/n-heptane (C₆/C₇) test system at operating pressures of 0.165, 0.33,
1.65 and 4.14 bar. Performance of the new RSP-300 structured packing is compared
against the B1-250 and B1-250M conventional and high capacity structured packings
from Montz tested under identical conditions. These data were taken from the Paper,
“Performance of a New High Capacity Structured Packing” by Olujic et al [1]. In addition
results are compared against F.R.I. tested Mellapak M250.Y and MellapakPlus M252.Y
structured packings from Sulzer for the C₆/C₇ at 0.34 and 1.65 bar test systems as reported
by Pilling and Spiegel [2].

Distillation tests were performed in the SRP 0.43m ID column with a bed height of
3.124m. The liquid distributor used was the SRP high capacity narrow trough drip tube
distributor, with 145 pour points/m² and liquid flow rate range of 5 to 50m³/m²/h. A
complete description of the experimental set up and operating procedures can be found
elsewhere [3].

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RESULTS AND DISCUSSION
LIQUID RATE AND OPERATING PRESSURE EFFECT ON EFFICIENCY
Figure 2 shows good and stable HETP values for RSP-300 at all four operating pressures over almost the entire liquid rate range of the high capacity liquid distributor. With each operating pressure, HETP reaches a constant value in the preloading regime. In the loading regime there is a pronounced decline in HETP values, indicative of improved mass transfer efficiency, prior to a sharp break in the HETP curve as the packing enters incipient flood. The exception was at 4.14 bar because the reboiler capacity had reached its upper limit prior to flooding. It can be seen the HETP is generally between 0.305 and 0.410 m regardless of pressure.

At 4.14 bar system pressure and liquid rate of 48.7 m$^3$/m$^2$/h, typical of high pressure distillation, there was no “efficiency hump,” a phenomenon observed with both conventional and high capacity structured packings [1,4]. The open structure helps alleviate any restrictions in vapour-liquid flows and possible vapour backmixing that otherwise may be found in the more closed channels of corrugated sheet structured packings.

Figure 2 has superimposed on it the 90% System Limit for each of the four operating pressures and will set a precedent for the remaining figures below. At higher pressures, the rise in RSP-300 HETP at flow rates close to hydraulic flood occurs long before the 90% System Limit is reached. This is clearly shown with 1.65 bar pressure. With 4.14 bar pressure, the rise in RSP-300 HETP at hydraulic flood would have occurred long before the 90% System Limit had the reboiler not reached its capacity limit. With decreasing

Figure 1. Photograph of a segment of raschig gmbh Raschig Super-Pak 300 structured packing
pressure, the rise in the RSP-300 HETP curve at flow rates close to hydraulic flood converge and rapidly approach the 90% System Limit until a critical point is reached where it crosses the 90% limit. This is illustrated with 0.165 bar pressure in Figure 2. Overall, it implies that as lower the operating pressure, the increased tendency of high performance structured packings such as Raschig Super-Pak to rapidly approach 90% System Limit before entering full hydraulic film flood.

EFFICIENCY AND USEFUL CAPACITY
Capacity-efficiency comparative plots of RSP-300 with B1-250 and B1-250M structured packings are presented in Figures 3 and 4 with the C6/C7 system, high capacity distributor with drip tubes.
Had B1-250 and B1-250M been tested at 1.65 bar the useful capacity advantages may have been greater. Similarly at 0.33 bar in Figure 4, the RSP-300 useful capacity advantage is 37% compared to B1-250 and 7% over B1-250M.

Figures 5 and 6 compare HETP of RSP-300 with F.R.I. tested Mellapak M250.Y[4,2] and high capacity MellapakPlus M252.Y[2]. Both plots utilize Cs-Factors based on column bottom conditions and mid-bed C6 composition range except for M250.Y since no data were available in the original tests to calculate Cs from bottom column conditions. With this in mind, the HETP in the mid capacity range for M250.Y and M252.Y at 1.65 bar (Figure 5) are 0.39m and 0.35m respectively compared to the RSP-300 HETP of 0.375m. At 0.33 bar, the HETP in the mid capacity range for M250.Y and M252.Y are 0.48m and 0.37m respectively compared with the RSP-300 HETP of 0.38m as shown in Figure 6. As with the B1–250 packing, RSP-300 displays a substantial maximum useful capacity advantage compared with M250.Y. This is illustrated in Figures 5 and 6 with maximum useful capacity advantages of 28% and 41% for RSP-300 compared with M250.Y at the respective operating pressures of 1.65 and 0.33 bar. When compared against the high capacity M252.Y, the useful capacity gains of RSP-300 at 1.65 and 0.33 bar are 9% and 5% respectively; a significant result. All HETPs and useful capacities are summarised in Table 1 where B1-250 is taken as a
Pressure drop comparative plots of RSP-300 with B1-250 and B1-250M packings are presented in Figure 7 for 1.65 and 0.33 bar operating pressures. For both system pressures RSP-300 pressure drop is considerably lower than both the B1-250 and B1-250M structured packing over the entire operating range. To quantify the useful capacity and pressure drop advantages of Raschig Super-Pak 300 over B1-250, we will use 3 mbar/m as a reference point since it is typically the design value for standard structured packings. With high capacity structured packings, there is a shift in useful capacity to higher pressure drop values (3 up to 5 or 6 mbar/m). As a result we will compare useful capacity change of RSP-300 with the B1-250M at 5.0 mbar/m reference point. Figure 7 indicates 43% and 13% useful capacity advantages for RSP-300 over B1-250 and B1-250M at 1.65 bar. At 0.33 bar pressure, RSP-300 displays useful capacity gains of 43% and 11% compared with B1-250 and B1-250M. Had B1-250 and B1-250M been tested at 1.65 bar the useful capacity advantages may have been greater.

**Figure 4.** Mass transfer efficiency (HETP) comparison at total reflux. Raschig Super-Pak300 vs B1-250 and B1-250M at 0.33 bar, 0.43 m I.D. SRP column, 3.124 m bed, C6/C7 system, high capacity distributor with drip tubes

reference point set at 100% for a given liquid and vapour rate, against which all the other packings are compared.

**PRESSURE DROP COMPARISON**

Pressure drop comparative plots of RSP-300 with B1-250 and B1-250M packings are presented in Figure 7 for 1.65 and 0.33 bar operating pressures. For both system pressures RSP-300 pressure drop is considerably lower than both the B1-250 and B1-250M structured packing over the entire operating range. To quantify the useful capacity and pressure drop advantages of Raschig Super-Pak 300 over B1-250, we will use 3 mbar/m as a reference point since it is typically the design value for standard structured packings. With high capacity structured packings, there is a shift in useful capacity to higher pressure drop values (3 up to 5 or 6 mbar/m). As a result we will compare useful capacity change of RSP-300 with the B1-250M at 5.0 mbar/m reference point. Figure 7 indicates 43% and 13% useful capacity advantages for RSP-300 over B1-250 and B1-250M at 1.65 bar. At 0.33 bar pressure, RSP-300 displays useful capacity gains of 43% and 11% compared with B1-250 and B1-250M. Had B1-250 and B1-250M been tested at 1.65 bar the useful capacity advantages may have been greater.

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Figure 5. Mass transfer efficiency (HETP) comparison at total reflux. Raschig Super-Pak300 vs. F.R.I. tested M250Y and M252Y at 1.65 bar, 0.43 m I.D. SRP column, 1.22 m F.R.I. column, C₆/C₇ system, high capacity liquid distributors.

Figure 6. Mass transfer efficiency (HETP) comparison at total reflux. Raschig Super-Pak300 vs. F.R.I. tested M250Y and M252Y at 0.33 bar, 0.43 m I.D. SRP column, 1.22 m F.R.I. column, C₆/C₇ system, high capacity liquid distributors.
Table 1. Performance comparison Raschig Super-Pak 300 versus B1-250, M250.Y, standard and B1-250M and M252.Y high capacity structured packings at total reflux conditions with C₆/C₇ system

<table>
<thead>
<tr>
<th>Pressure p [bar]</th>
<th>Valuation</th>
<th>Montz B1-250</th>
<th>Sulzer M250 Y</th>
<th>Montz B1-250M</th>
<th>Sulzer M252 Y</th>
<th>Raschig RSP 300</th>
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<tr>
<td>1.65 (1.03)*</td>
<td>FS,Flood [Pa¹/²]</td>
<td>100%</td>
<td>106%</td>
<td>115%</td>
<td>113%</td>
<td>123%</td>
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<td>FS,max [Pa¹/²]</td>
<td>100%</td>
<td>101%</td>
<td>121%</td>
<td>128%</td>
<td>136%</td>
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<tr>
<td></td>
<td>Δp = 5 mbar/m</td>
<td>100%</td>
<td>104%</td>
<td>118%</td>
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<td>139%</td>
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<tr>
<td></td>
<td>Δp = 3 mbar/m</td>
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<td>0.38</td>
<td>0.39</td>
<td>0.35</td>
<td>0.375</td>
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<td>Mid Capacity</td>
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<tr>
<td></td>
<td>Range HETP [m]</td>
<td>0.36</td>
<td>0.38</td>
<td>0.39</td>
<td>0.35</td>
<td>0.375</td>
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<th>Pressure p [bar]</th>
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<th>Montz B1-250</th>
<th>Sulzer M250 Y</th>
<th>Montz B1-250M</th>
<th>Sulzer M252 Y</th>
<th>Raschig RSP 300</th>
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<tr>
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<td>FS,Flood [Pa¹/²]</td>
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<td>102%</td>
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<td>FS,max [Pa¹/²]</td>
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<td>Δp = 5 mbar/m</td>
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<td>142%</td>
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<td>0.48</td>
<td>0.41</td>
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Notes: **Extracted from data reported by Pilling and Spiegel [2] *Montz B1-250 and B1-250M tested at 1.03 bar [1] not 1.65 bar. With conventional structured packings Useful Capacity corresponds to standard design ΔP of 3 mbar/m. With high capacity structured packings, the shift in Useful Capacity towards higher pressure drop corresponds to arbitrary design ΔP of 5 mbar/m.
Figure 7. Pressure drop comparison at total reflux. Raschig Super-Pak300 vs. B1-250 and B1-250M at 1.65 and 0.33 bar, 0.43 m I.D. SRP column, 3.124 m bed, C6/C7 system, high capacity distributor with drip tubes.

Figure 8. Pressure drop (ΔP/H) comparison at total reflux. Raschig Super-Pak300 vs. F.R.I. tested M250Y and M252Y at 1.65 and 0.33 bar, 0.43 m I.D. SRP column, 1.22 m F.R.I. column, C6/C7 system, high capacity liquid distributors.
Figure 8 compares the pressure drop of RSP-300 with M250Y and M252Y at 1.65 to 0.33 bar operating pressures. No pressure drop data were taken at 1.65 bar for M250.Y test in 1987. On comparing useful capacity at the design reference point of 3 mbar/m for the standard M250.Y and 5 mbar/m for the high capacity M252.Y, RSP-300 at 0.33 bar has 41% more useful capacity than M250Y and 5% more than M252.Y. At 1.65 bar RSP-300 has a more pronounced useful capacity advantage of 9% over the high capacity M252Y; a remarkable result. Like the B1 packings, all HETPs and useful capacities for M250.Y and M252.Y are summarised in Table 1.

Figure 9 shows the pressure drop per theoretical stage comparisons of RSP-300 with B1-250 and B1-250M at 1.65 and 0.33 bar, 0.43 m I.D. SRP column, C6/C7 system. For both pressures, the pressure drops per theoretical stage of RSP-300 is consistently and distinctly lower than the B1-250 and B1-250M in Figure 9. In Figure 10, RSP-300 shows a noticeably lower pressure drop per theoretical stage over M250Y and M252Y in the high capacity operating range for both operating pressures. These results are very favourable in low pressure and vacuum columns processing thermally sensitive fluids.

CONCLUSIONS
The open structure results in excellent hydraulic and mass transfer efficiency characteristics as verified in the total reflux distillation tests at the Separations Research Program (SRP), University of Texas at Austin. Significant useful capacity and low pressure drop...
advantages were obtained not only over the standard B1-250 and M250.Y structured packings but over the B1-250M and M252Y high capacity structured packings as well. Equally important is that mass transfer efficiency was at least as good as if not better than the 250 m²/m³ surface area structured packings.

Figure 10. Pressure drop per theoretical stage comparison at total reflux. Raschig Super-Pak300 vs F.R.I. tested M250Y and M252Y at 1.65 and 0.33 bar, 0.43 m I.D. SRP column, 1.22 m F.R.I. column, C₆/C₇ system

NOMENCLATURE

C₆ Cyclohexane
C₇ n-Heptane
Cₛ m/s Gas or vapour capacity factor = \( F_s / \sqrt{\rho_L - \rho_V} \)
Fₛ \( \sqrt{\text{Pa or m/s(kg/m}^3)\text{)}^{1/2} \) Gas or vapour capacity factor = \( u_s \sqrt{\rho_V} \)
H m Packing height
HETP m Height equivalent to a theoretical stage
p bar Operating/system pressure

GREEK LETTERS

ΔP Pa, mbar Pressure drop
\( \rho_L \) kg/m³ Liquid density
\( \rho_V \) kg/m³ Gas or vapour density
ACKNOWLEDGEMENTS
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REFERENCES