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 theoretical 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) conducted total reflux distillation tests were contucted to characterize the new RSP-300 metal structured packing. Hydraulic and mass transfer performance was measured using the cyclohexane/n-heptane (C_6/C_7) 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 C_6/C_7 at 0.34 and 1.65 bar test systems as reported by Pilling and Spiegel [2].

Distillation tests were performed in the SRP 0.43 m ID column with a bed height of 3.124 m. The liquid distributor used was the SRP high capacity narrow trough drip tube distributor, with 145 pour points/m^2 and liquid flow rate range of 5 to 50 m^3/m^2/h. A complete description of the experimental set up and operating procedures can be found elsewhere [3].

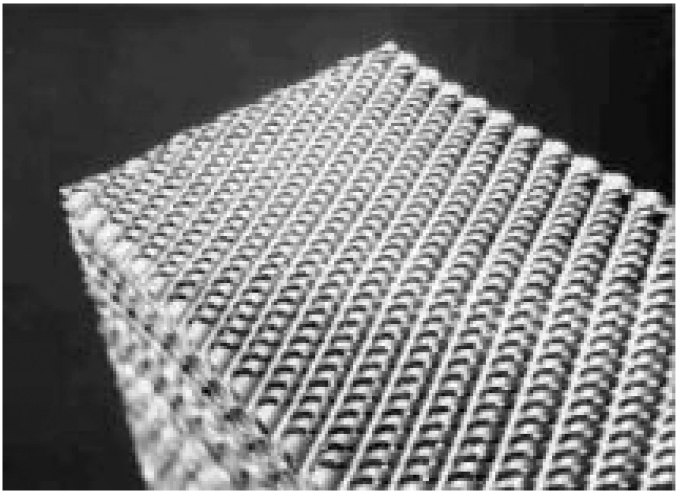

Figure 1. Photograph of a segment of raschig gmbh Raschig Super-Pak 300 structured packing

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

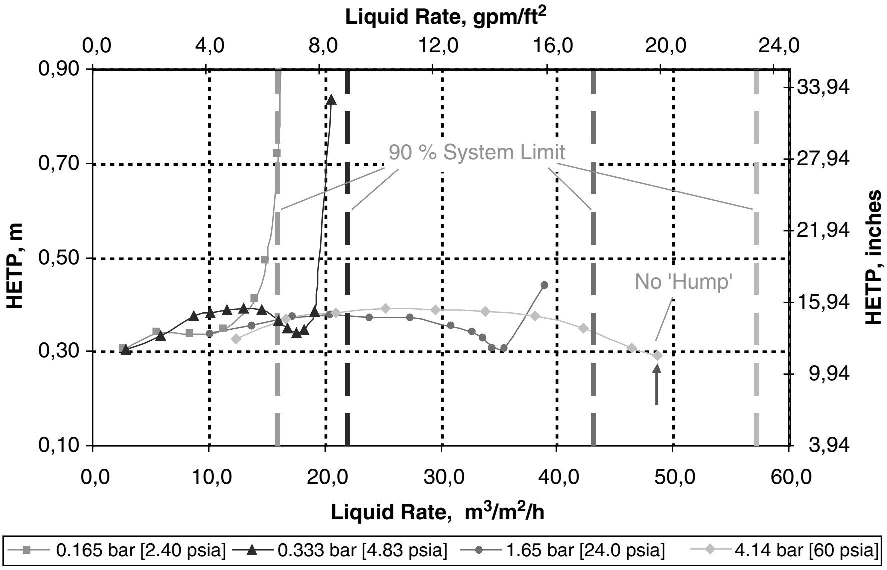

Figure 2. Effect of liquid rate and operating pressure on Raschig Super-Pak 300 HETP at total reflux. 0.43 m I.D. SRP column, 3.124 m bed, C6/C7 system, high capacity distributor with drip tubes

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 C_6/C_7 at 1.65 and 0.33 bar test systems. RSP-300 hydraulic and mass transfer data at 1.65 bar operating pressure are compared against B1-250 and B1-250M packing measurements at 1.03 bar since no runs were made at 1.65 bar. In Figure 3 the HETP in the mid capacity range at 1.65 bar pressure for RSP-300 is 0.375 m compared to 0.36 m and 0.39 m for the B1-250 and B1-250M respectively. At 0.33 bar, Figure 4 shows an HETP of 0.38 m for RSP-300 in the mid capacity range compared to 0.36 m for B1-250 and 0.41 m for B1-250M.

At 1.65 bar, Figure 3 shows a maximum useful capacity advantage of 22% for RSP-300 compared with B1-250 and more significantly 7% over the high capacity B1-250M.

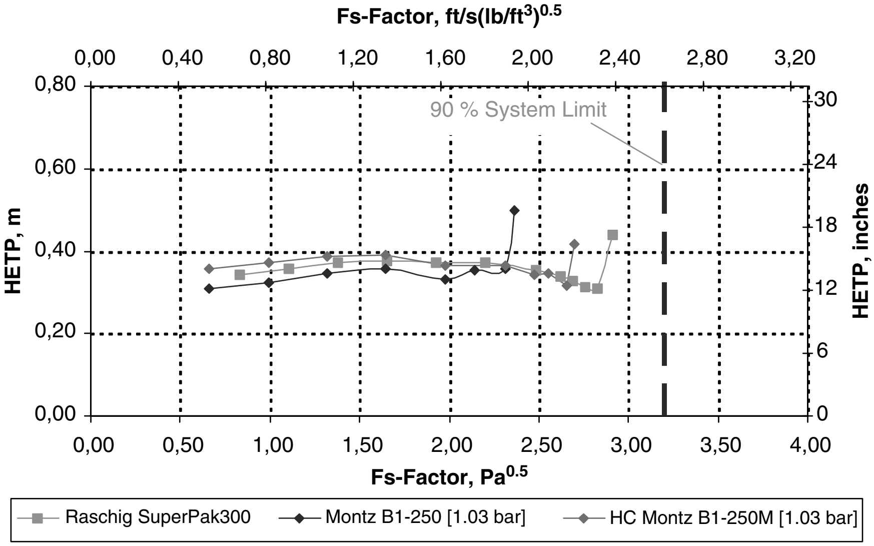

Figure 3. Mass transfer efficiency (HETP) comparison at total reflux. Raschig Super-Pak300 vs B1-250 and B1-250M at 1.65 bar, 0.43 m I.D. SRP column, 3.124 m bed, C_6/C_7 system, high capacity distributor with drip tubes

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 0.39 m and 0.35 m respectively compared to the RSP-300 HETP of 0.375 m. At 0.33 bar, the HETP in the mid capacity range for M250.Y and M252.Y are 0.48 m and 0.37 m respectively compared with the RSP-300 HETP of 0.38 m 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

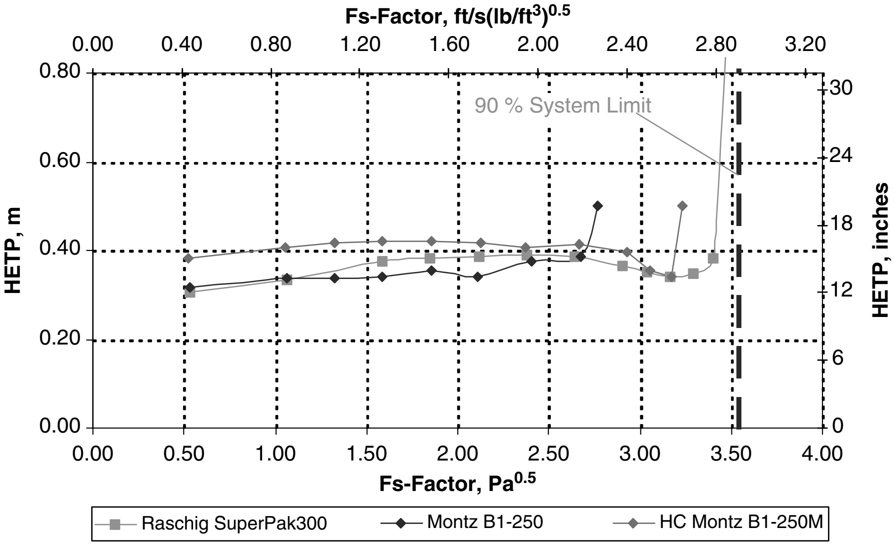

Figure 4. Mass transfer efficiency (HETP) comparison at total reflux. Raschig Super-Pak300 vs B1-250 and B1-250M at 0.33 bar, 0.43 m I.D. SRP column, 3.124 m bed, C_6/C_7 system, high capacity distributor with drip tubes

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.

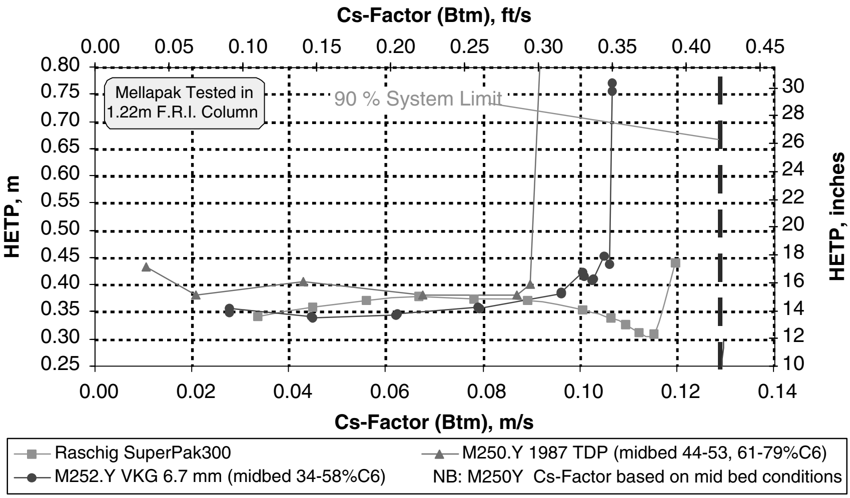

Figure 5. Mass transfer efficiency (HETP) comparison at total reflux. Raschig Super-Pak300 vs. F.R.I. tested M250Y and M252Y at 1.65 bar, 0.43 m I.D. SRP column, 1.22 m F.R.I. column, C_6/C_7 system, high capacity liquid distributors

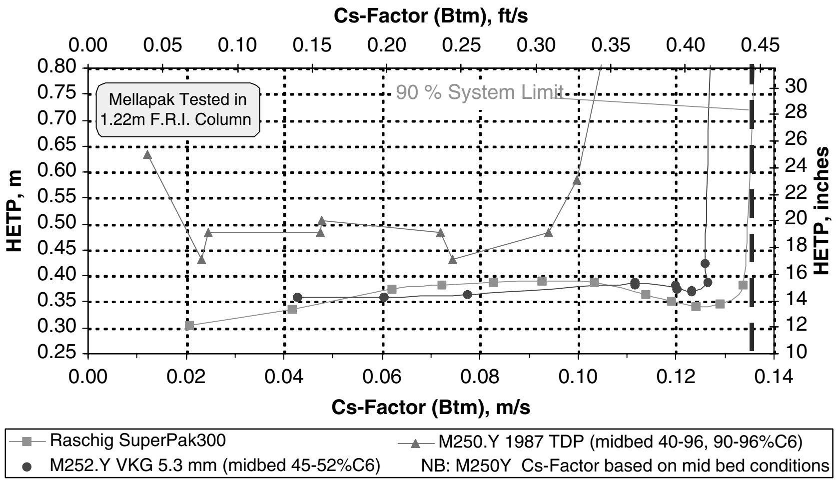

Figure 6. Mass transfer efficiency (HETP) comparison at total reflux. Raschig Super-Pak300 vs. F.R.I. tested M250Y and M252Y at 0.33 bar, 0.43 m I.D. SRP column, 1.22 m F.R.I. column, C_6/C_7 system, high capacity liquid distributors

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 C_6/C_7 system

Pressure p [bar]	Valuation	Montz B1-250	Sulzer M250 Y	Montz B1-250M	Sulzer M252 Y	Raschig RSP 300
1.65 (1.03)*	$F_{S,Flood}$ [$Pa^{1/2}$]	100%	106%	115%	113%	123%
	$F_{S,max}$ [$Pa^{1/2}$] $\Delta p = 5$ mbar/m	100%	101%	121%	128%	136%
	$F_{S,max}$ [$Pa^{1/2}$] $\Delta p = 3$ mbar/m	100%	104%	118%	129%	139%
	Mid Capacity Range HETP [m]	0.36	0.38	0.39	0.35	0.375
0.33	$F_{S,Flood}$ [$Pa^{1/2}$]	100%	102%	113%	121%	124%
	$F_{S,max}$ [$Pa^{1/2}$] $\Delta p = 5$ mbar/m	100%	119%	128%	138%	145%
	$F_{S,max}$ [$Pa^{1/2}$] $\Delta p = 3$ mbar/m	100%	121%	129%	146%	142%
	Mid Capacity Range HETP [m]	0.36	0.48	0.41	0.37	0.375

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.

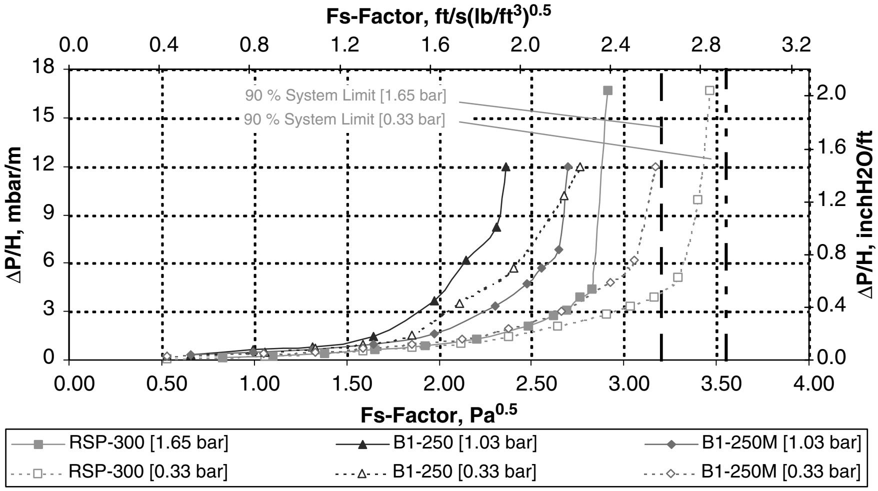

Figure 7. Pressure drop comparison at total reflux. Raschig Super-Pak300 vs. B1-250 and B1-250M at 1.65 and 0.33 bar, 0.43 m I.D. SRP column, 3.124 m bed, C_6/C_7 system, high capacity distributor with drip tubes

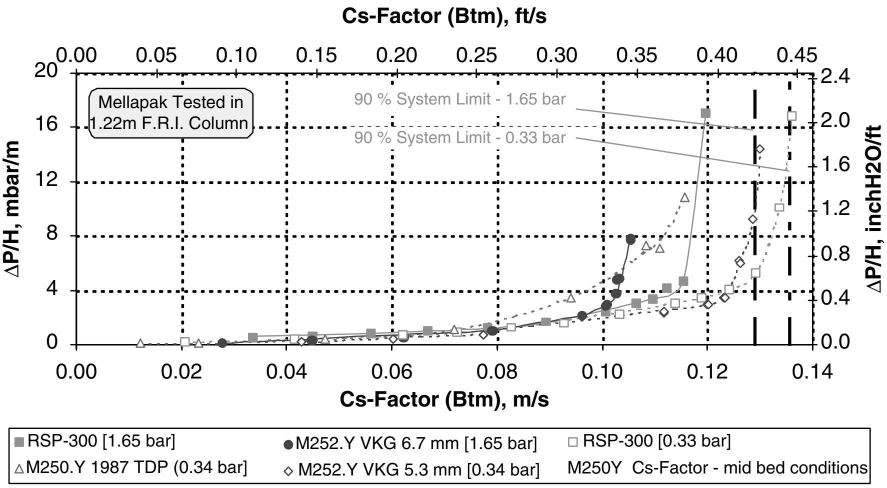

Figure 8. Pressure drop ($\Delta P/H$) comparison at total reflux. Raschig Super-Pak300 vs. F.R.I. tested M250Y and M252Y at 1.65 and 0.33 bar, 0.43 m I.D. SRP column, 1.22 m F.R.I. column, C_6/C_7 system, high capacity liquid distributors

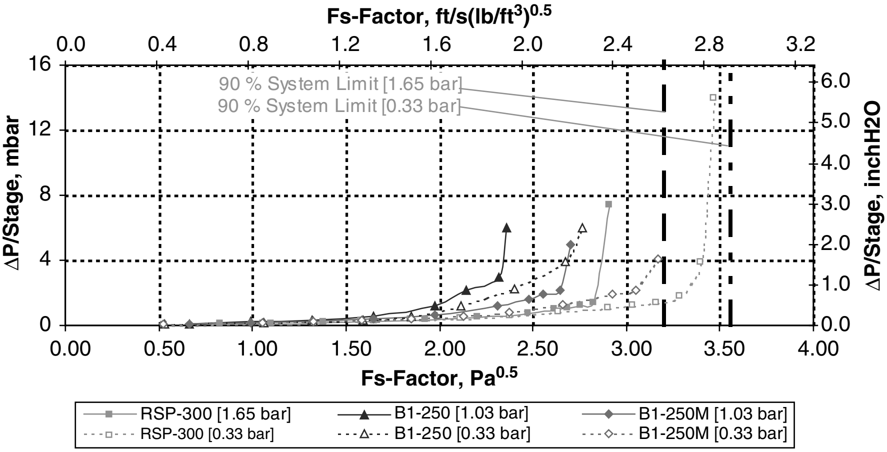

Figure 9. Pressure drop per theoretical stage comparison at total reflux. Raschig Super-Pak300 vs. B1-250 and B1-250M at 1.65 and 0.33 bar, 0.43 m I.D. SRP column, 3.124 m bed, C_6/C_7 system

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.

Also, pressure drop per theoretical stage is an important parameter in evaluating different structured packing designs. Figure 9 shows the pressure drop per theoretical stage comparisons of RSP-300 with B1-250 and 250 standard and high capacity structured packings at 1.65 and 0.33 bar operating pressures. Likewise Figure 10 shows the pressure drop per theoretical stage comparisons of RSP-300 with M250.Y and M252.Y. 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

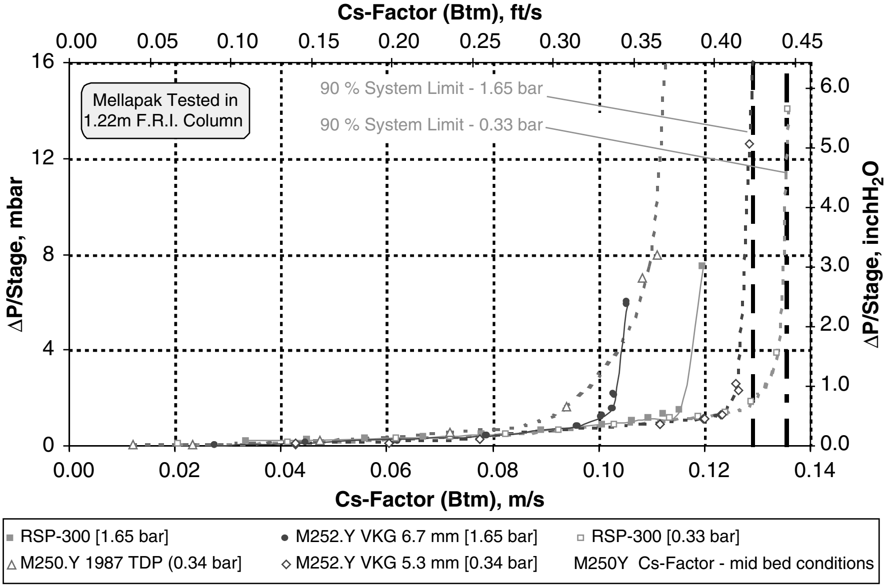

Figure 10. Pressure drop per theoretical stage comparison at total reflux. Raschig Super-Pak300 vs.F.R.I. tested M250Y and M252Y at 1.65 and 0.33 bar, 0.43 m I.D. SRP column, 1.22 m F.R.I. column, C_6/C_7 system

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 $250\,m^2/m^3$ surface area structured packings.

NOMENCLATURE

C_6		Cyclohexane
C_7		n-Heptane
C_S	m/s	Gas or vapour capacity factor $= F_s/\sqrt{\rho_L - \rho_V}$
F_S	$\sqrt{Pa}$ or $m/s(kg/m^3)^{1/2}$	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
ρ_L	kg/m^3	Liquid density
ρ_V	kg/m^3	Gas or vapour density

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