This article was downloaded by:
On: *25 January 2011*
Access details: *Access Details: Free Access*
Publisher *Taylor & Francis*
Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK

Separation Science and Technology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713708471

Experimental Studies on the Interaction Between the Initial Liquid Distribution and the Performance of Structured Packings

Ž. Olujić[a]; J. de Graauw[a]
[a] Delft University of Technology Laboratory for Process Equipment, CA Delft, The Netherlands

To cite this Article Olujić, Ž. and de Graauw, J.(1990) 'Experimental Studies on the Interaction Between the Initial Liquid Distribution and the Performance of Structured Packings', Separation Science and Technology, 25: 13, 1723 — 1735
To link to this Article: DOI: 10.1080/01496399008050419
URL: http://dx.doi.org/10.1080/01496399008050419

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.informaworld.com/terms-and-conditions-of-access.pdf

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

SEPARATION SCIENCE AND TECHNOLOGY, 25(13-15), pp. 1723-1735 (1990)

EXPERIMENTAL STUDIES ON THE INTERACTION BETWEEN THE INITIAL LIQUID DISTRIBUTION AND THE PERFORMANCE OF STRUCTURED PACKINGS

Ž. Olujić and J. de Graauw

Delft University of Technology
Laboratory for Process Equipment
Leeghwaterstraat 44, 2628 CA Delft
The Netherlands

Downloaded At: 12:47 25 January 2011

ABSTRACT

Distillation and hydraulic test data are reported which give insight into the effect of the quality of initial liquid distribution on the performance of two corrugated sheet metal structured packings, differing considerably in surface area and texture. As expected, the packing with the larger surface (Montz-Pak BS-450) is more sensitive to initial liquid maldistribution. From the packing with smaller surface (Ralu-Pak 250 YC) a good performance may be expected even with only 40 drip points/sq m.

INTRODUCTION

Distillation is one of the most extensively used as well as one of the most energy intensive separation processes. From an energy audit summarized in the article by Mix et al (1) it has become evident that distillation is a major consumer of energy in the U.S. petroleum, natural gas, and chemical industries. They also suggested rough criteria for choosing among many energy conservation options for distillation. In a recent study sponsored by the U.S. Department of Energy (2) the distillation in conjunction with high efficiency mass transfer devices is considered to have a considerable potential for energy savings.

Notwithstanding that the use of large diameter packed columns is a recent development industrial applications have proven that distillation columns equipped with structured packings may enable

Copyright © 1991 by Marcel Dekker, Inc.

energy savings resulting in some cases (large vacuum fractionators) in drastically reduced operating costs. However, some malperformances of large diameter columns contributed to the fact that production companies have not a firm trust in the use of structured packings. This mistrust was often even enlarged by the fact that all improvements made in liquid distribution and redistribution were not sufficient to ensure expected performance. Most probably, the "improvements" mentioned above were based on own industrial experience and the experimental work with random packings.

Though considerable progress has been made in industrial applications and performance evaluations of structured packings relatively little experimental effort has been devoted to the understanding of sources and extent of maldistribution of liquid and gas as they flow through the bed (3). A detailed review of the experimental work devoted in the past to solving maldistribution problems related to random and structured packings may be found elsewhere (4,5). It is a general belief that an uniform liquid distribution over structured packing is imperative for developing the full efficiency of the packing. This is even more so for structured than for random packings (6), since the inherent fixed geometry of structured packings should make it practically impossible to correct uneven liquid flow. Results of most recent investigations (4,7) have proven that liquid distribution stabilizes after approximately three layers of packing, and is not influenced strongly by the gas flow, unless the loading range is reached. As a measure of the deviation from the normal liquid distribution the so-called maldistribution factor (4,8) may indicate differences in liquid distribution properties of structured packings, which also became obvious. Taking into account diversities in structured packing designs there should exist for each packing type an initial distribution which will minimize the depth of packing required for the flow to reach (natural) uniformity. The level of flow uniformity should depend mostly on the quality of initial liquid distribution. The implication of this consideration for a designer is usually the question: what degree of initial liquid distribution uniformity is required for commercial columns with structured packings to perform satisfactorily? An answer suggested in the recent literature (3-9) that there seems to be little sense to apply more drip (pour) points then the nature of the packing requires is an academical one.

The choice of distributor type and design which will correlate with packing performance is commonly based on proprietary knowledge. Based on their own experience the manufacturers of packings, such as Northon Co. (10) for example, have developed proprietary liquid distributor rating systems. Consequently, the design of columns equipped with structured packing may still be

Downloaded At: 12:47 25 January 2011

considered as a privilege (mainly) of packing manufacturers, which also employ special facilities for full size testing of industrial distributors, using water as test liquid.

However, the matching of distributor design (number of drip points and location of drip points over the column cross section, distance from the packing, turndown, etc.) with the packing and the studies of structured packing redistribution properties are still carried out in small diameter columns. Our intention is to do this for a number of structured packings and to make publically available the results which could help to increase industrial confidence in the realibility of the design of columns equipped with structured packings. In this paper the results of such an experimental investigation are reported, introducing hydraulic and separation efficiency studies on the effect of initial liquid distribution quality on the performance of two less known types of structured packings.

Downloaded At: 12:47 25 January 2011

EXPERIMENTAL WORK

Experiments were performed on systems as described concisely in following paragraphs.

Packings Tested

Raschig's Ralu-pak 250 YC is a sheet metal structured packing which consists of crosswise folded specially perforated lamellae which lay countercourse in such a way that they create channels crossing each other at an angle of 45° with column axis. The height of an element (packing layer) is 0.21 m, the surface area is 250 m^2/m^3 and the porosity above 96%. The main feature of Ralu-pak, described in some details elsewhere (11,12), when compared to similar structured packings such as Sulzer Mellapak 250 Y and Montz Montz-pak B1-250, is a slightly higher capacity limit.

Montz-pak BS is a new J. Montz development which also uses the already well known and proven geometry consisting of countercourse corrugated sheets. However, its distinctive quality should be a specially designed surface with perforations and a texture which extends its surface area up to 500 m^2/m^3.

These two packings were evaluated in a 0.45 m diameter distillation column under total reflux conditions and in a 0.5 m diameter column designed specially for gas and liquid distribution measurements.

Test Columns and Distributors

Distillation column shown schematically in figure 1, made of stainless steel, may handle packing heights up to 2.6 m. Auxiliary

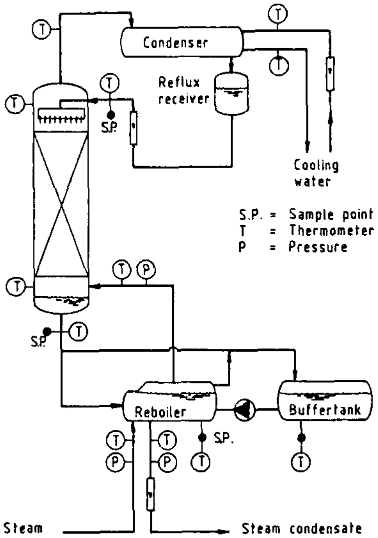

Fig. 1 Simplified schematic of the set-up for total reflux distillation test.

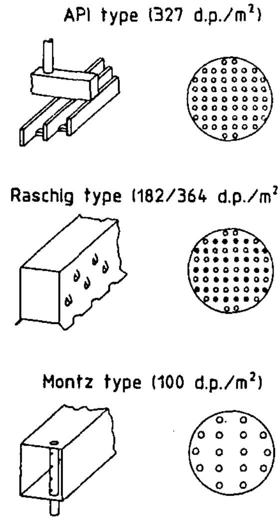

Fig.2 Principal design characteristics of the liquid distributors used in this study

Downloaded At: 12:47 25 January 2011

equipment includes a steam heated reboiler, a water cooled condenser, and a buffer vessel which is used to regulate the liquid level of the test mixture in the reboiler. The tests were carried out with a methanol/ethanol mixture at atmospheric pressure. During each run column pressure and a number of temperatures and flows were recorded. The liquid samples were taken after stabilization of process conditions and then analyzed by means of a refractive index meter (ABBE 60). The reliability of this very simple method has been proved via gas/liquid chromatography. The methanol concentrations in reflux and bottom have been transformed into HETP values by means of Fenske equation. HETP (Height Equivalent to a Theoretical Plate) values calculated via HTU (Heigt of a Transfer Unit) have been practically equal to those estimated by Fenske equation.

The column was originally a tray column, designed for an atmospheric operation and F-factors up to 2 m/s $(kg/m^3)^{0.5}$. This is a limitation with respect to flooding limits of structured packings, so that only the separating efficiency within standard operating range may be evaluated. However, this fact was not considered as a deficiency, because the loading range behaviour of structured packings was not the subject of this study, which is concerned with the effect of initial liquid distribution quality. For this purpose three different liquid distributors were employed. As can be seen from figure 2 the employed distributors differ in the designs and the number of distribution (drip, pour) points. Out-of-column tests indicated that the distribution was within acceptable limits of uniformity. The Montz-type distributor proved to be the most suitable for the purpose of diverse maldistribution tests, and was, therefore, used also in conjunction with the hydraulic tests. Types of initial liquid maldistribution applied in this study are illustrated in figure 3.

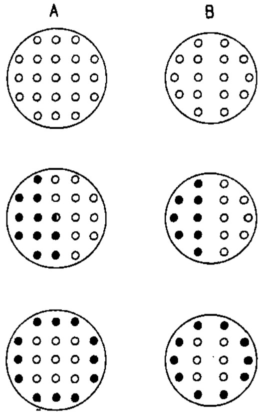

Fig. 3 Configurations of initial liquid distribution as applied in hydraulic (A) and separating efficiency studies (B) : • denotes blanked holes.

Downloaded At: 12:47 25 January 2011

The experimental set up for liquid distribution tests is shown schematically in figure 4. This installation was designed

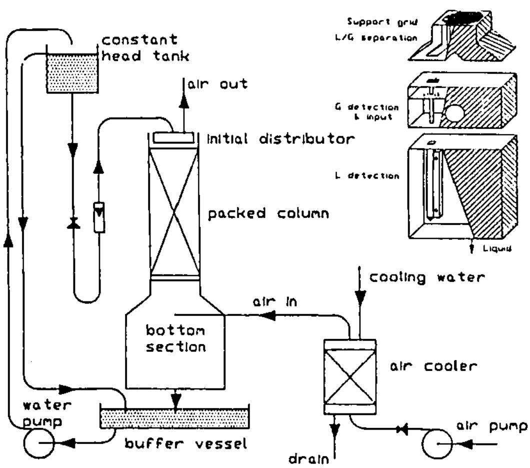

Fig. 4 Schematic of equipment for hydraulic tests with enlarged representation of bottom section

specially for the purpose of a packing maldistribution investigation described in detail in the most recently published PhD Thesis by R. Stikkelman (4), which also contains a comprehensive description of employed equipment. The general features are as follows. The column is built from perspex flanged units with a height of one metre. The liquid flow ranges up to superficial velocities of 0.015 m/s, and the conditioned (once through) air flow may be regulated between 0 and 3.4 m/s. The most interesting part of this installation is the support grid which utilizes gas and liquid separation and flow measurement. This grid divides the cross section of the column into 332 modules of 25x25 mm^2, allowing the collection of the liquid and the insertion of gas at the reasonable small scale without interference of the countercurrent flows.

The liquid distributor is also a special design and contains 149 drip points (760 d.p./m^2). Gas flows at the bottom and top of the column are measured by means of small NTC (Negative Temperature Coefficient) resistors, and the fluid flows at the bottom are measured via level sensors inserted in liquid collecting U-pipes. All these sensors are connected with a data acquisition system which enables a three-dimensional graphic representation of results. Preliminary tests have proved that both gas and liquid initial maldistributions can be neglected, so that there is no negative influence on the measurements of maldistribution factor (Mf) of packings. To quantify the liquid maldistribution in the bulk of packing the following definition of maldistribution factor is used (4):

$$Mf = \frac{1}{n} \sum_{i=1}^{i=n} \frac{[u(1) - \langle u \rangle]^2}{\langle u \rangle^2}$$

Here n denotes the number of samples, u (m/s) is superficial velocity, and the maldistribution factor Mf is accordingly equal to the relative standard variation of the flows in the bulk of the packing. For an ideal distribution it has a value of zero. In order to quantify the wall portion of the flow a wall flow factor (Wf) is used, which is defined as the ratio between the flow rate in an annulus near the wall and the average flow rate. In the case of an uniform distribution it has a value of one.

RESULTS AND DISCUSSION

Figures 5 and 6 show the HETP values obtained with different types of distributors. In all cases the efficiency is practically constant over the range investigated, which expressed in form of F-factor reaches values up to 1.9. This covers about 90% of the operating range of Montz-pak BS-450 and about 50-60% of the Ralu-pak 250 YC operating range. This means that the performance of both packings was practically not affected by the fact that completely different liquid distributors were used. This also means that both packings perform well with 100 drip points per

Downloaded At: 12:47 25 January 2011

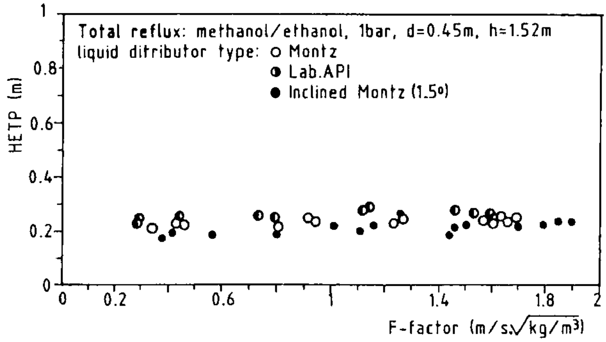

Fig.5 Influence of liquid distributor type on separation efficiency of Montz-pak BS 450, with illustration of the effect of inclined distributor.

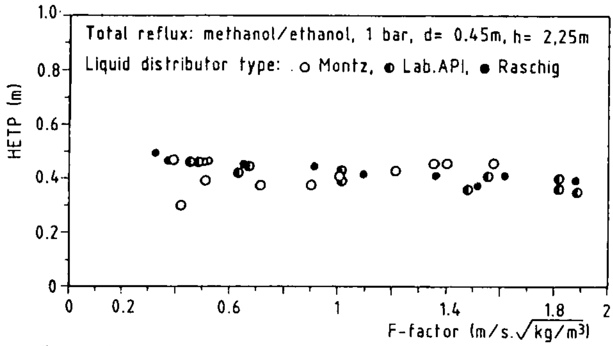

Fig.6 Influence of liquid distributor type on separation efficiency of Ralu-pak YC.

Downloaded At: 12:47 25 January 2011

meter square and that an unleveled Montz-type distributor must not adversely affect the performance of the packing.

Figures 7 and 8 illustrate the varying effect of different types of maldistribution. As expected, the more severe initial maldistribution (one half of the distributor inactive) has a much stronger adverse effect on efficiency than blanking the periphery holes. The deviations from the standard situation are for Montz-pak BS factors 2.5 and 1.5 respectively. The deterioration of the separation efficiency of the packing with smaller surface (Ralu-pak 250 YC) is much less. It amounts to a factor of around 1.5 for more severe initial maldistribution and is practically negligible when the liquid is introduced only through the area in the center of the packing. This means that Ralu-pak may perform well with only 40 drip points/sq.m.

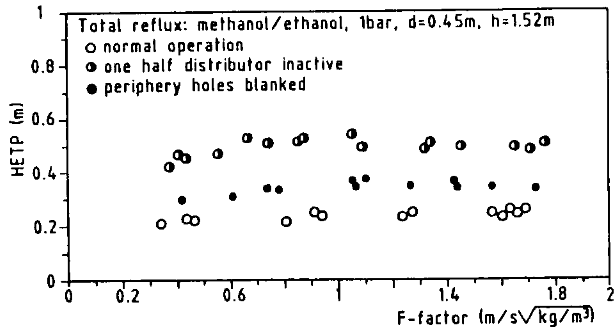

Fig.7 Influence of initial liquid maldistribution on separation efficience of Montz-pak BS 450.

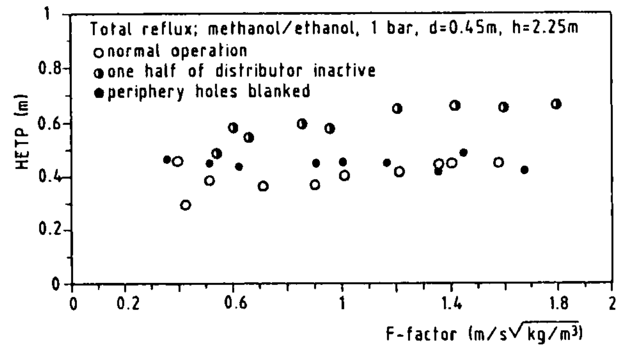

Fig.8 Influence of initial liquid maldistribution on separation efficiency of Ralu-pak 250 YC.

Downloaded At: 12:47 25 January 2011

A firm confirmation of this observation may be found in the results of a hydraulic test performed at flow conditions corresponding to that of total reflux tests. As may be seen in figure 9, the maldistribution factor of Ralu-pak 250 YC undergoes approximately equal changes with respect to quality of initial liquid distribution. Figure 10 shows that the gas flow does not exhibit a strong influence on liquid distribution of Ralu-pak 250 YC, which is in agreement with the observations from some earlier investigations (4,8). Extreme values of maldistribution factors belong to minimum values of liquid load, where the liquid distribution measurement is less reliable. Figure 11 illustrates the effect of liquid load on the maldistribution factor of Ralu-pak 250 YC. Obviously, the liquid distribution improves with the increase in the liquid load, and slightly with increasing gas-load. For an equal liquid load the distribution seems to be considerably better with much low number of drip points than that (760 dp/sq.m.) which is closer to an "ideal" liquid distribution. Figure 11 also illustrates a good reproducibility of hydraulic tests.

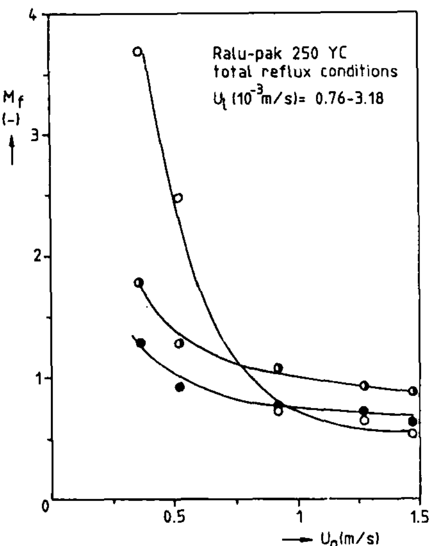

Fig. 9 Influence of the initial liquid maldistribution on the maldistribution factor:
o normal operation
◑ one half of distributor inactive
● periphery holes blanked

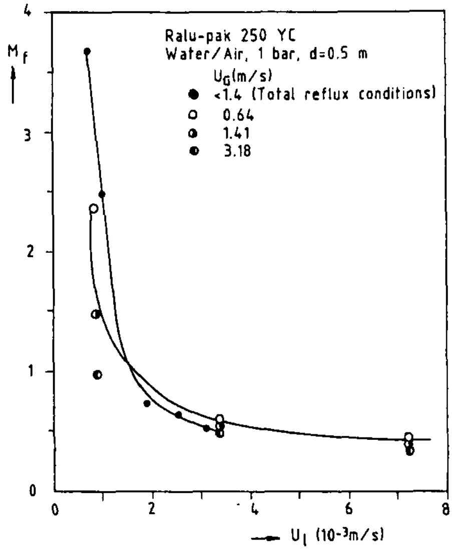

Fig.10 Maldistribution factor as a function of superficial liquid velocity, with the superficial gas velocity as a parameter.

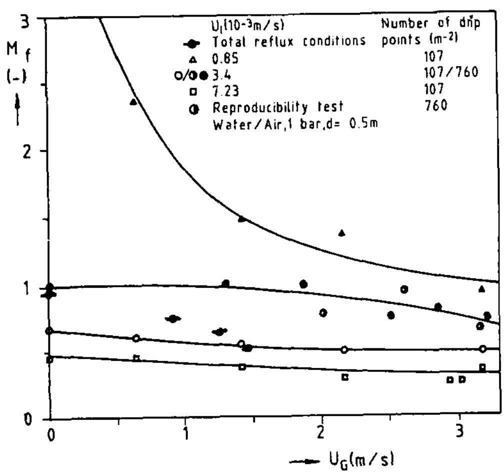

Fig.11 The maldistribution faxtor of the liquid phase for 4 elements of Ralu-pak 250 YC as a function of the superficial gas velocity, with superficial liquid velocity and the number of drip points as parameters.

Downloaded At: 12:47 25 January 2011

From earlier experiments it become evident that maldistribution factor follows somehow the tendency of efficiency behaviour with respect to increasing F-factor. Figure 12 illustrates this for the packings tested and two well known packings with the performance comparable to that of Ralu-pak 250 YC. Observed natural maldistribution remains constant within the operating range of packings. The quality of liquid distribution begins to deteriorate in the so-called loading range. Above a critical value of gas velocity the quality of liquid distribution deteriorates rapidly. The flooding limits for Mellapak 250 and Montz-pak 250 correspond roughly to that observed in proprietary efficiency tests (5). The capacity of our equipment was unable to flood the Ralu-pak 250, for which the flooding limits are obviously beyond that of similar packings, and it seems that the quality of liquid distribution of Ralu-pak improves slightly with increasing F-factor. An intriguing feature of this figure is that maldistribution factor values of Ralu-pak are approximately 3 to 4 times higher than that of Montz-pak 250 and Mellapak 250, although they all exhibit approximately equal HETP values (5).

Downloaded At: 12:47 25 January 2011

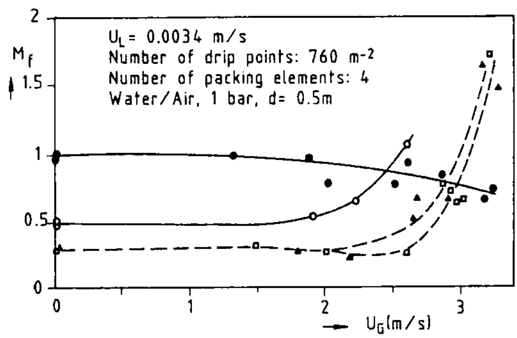

Fig.12 Effect of superficial gas velocity on the liquid distribution within Montz-pak BS-450 (o); Montz-pak B1-250 (▲);Mella-pak 250Y (□) and Ralu-pak 250 YC(●) [Stikkelman (1989)]

The hydraulic tests performed with Montz-pak BS-450 confirmed that usually three packing elements are enough to smooth out the liquid distribution (see figure 13). This agrees well with results obtained with packings with smaller surface (4,5,7), which proved that for an "ideal" initial liquid distribution the natural flow of the liquid within the packing will be established after the third element of packing. Figure 13 indicates that the same occurs even with an extremely severe initial maldistribution, and that the level of stabilization, expressed here via maldistribution factor values, depends on the quality of initial maldistribution. However, if compared with the HETP behaviour shown in figure 5, maldistribution test gave no pronounced difference in the response of the packing to different types of initial maldistribution. This observation may rise some doubts with respect to appropriateness of maldistribution factor as a measure of the deviation of a

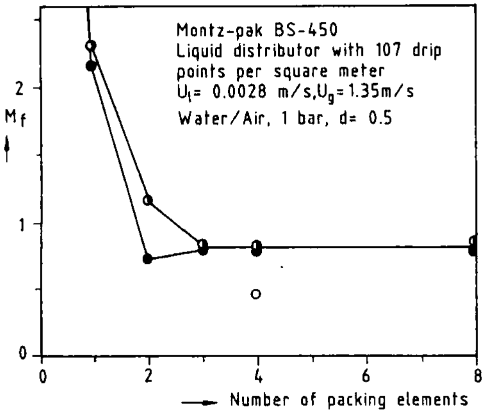

Fig.13 Liquid distribution as a function of packing height for different types of initial liquid maldistribution:
◑ - one half of distributor inactive,
● - periphery holes blanked
o - normal operation

Downloaded At: 12:47 25 January 2011

packing from normal operation. As a statistical value, i.e. the square of relative standard deviation of the flows within the bulk of a packing, the maldistribution factor is not capable to describe the flow pattern. Figure 14, which represents a visualisation of the diagram shown in figure 13, illustrates differences in flow patterns observed at approximately equal values of maldistribution factors for Montz-pak BS-450.

CONCLUSIONS

The main conclusion of this paper is that the efficiency of the packing with larger surface (Montz-pak BS-450) is more sensitive to initial maldistribution of the liquid. Even severe initial maldistribution is smoothed out within three elements of structured packings, however, it remains constant at a maldistribution factor value which is considerably higher than that for normal operation.
Blanking peryphery holes has not influenced negatively the performance of Ralu-pak 250 YC. This may mean that such packings can perform well even with a very low number of symmetrically arranged drip points (around 40 per sq.m.).

Further work is needed to improve the understanding of the relationship between the maldistribution (factor) and the separating efficiency.

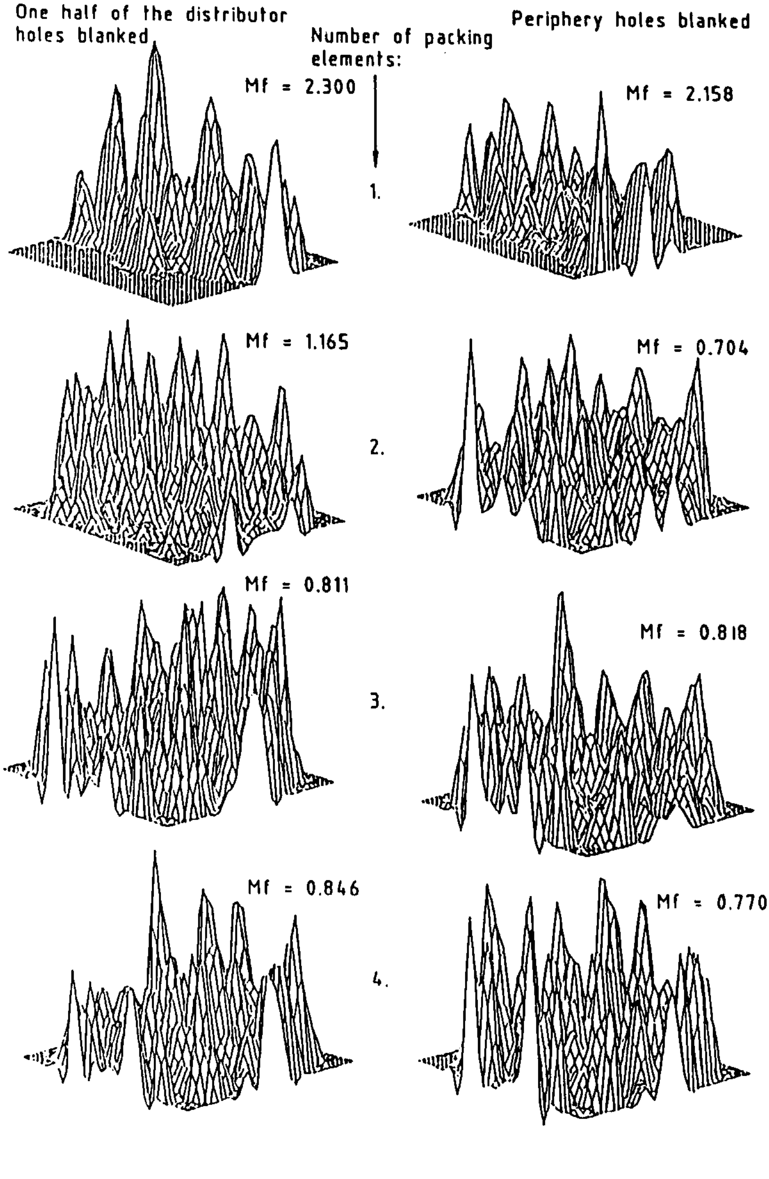

Fig.14 Three dimensional presentation of liquid velocity profiles leaving the bottom of the Montz-BS 450 packing bed consisting of one to four packing elements, for two different types of initial liquid maldistribution.

Downloaded At: 12:47 25 January 2011

Acknowledgements

We are grateful to J. Montz GmbH and Raschig AG for providing us with packings and distributors as well as to our graduate students: P. de Konink, E. Simon, P. Coremans, and D. Havenaar for their enthusiastic and careful performing of experimental work. We are also indebted to our sponsors SHELL and DSM for financial support of our research project.

REFERENCES

1. T.J. Mix, J.S. Dweck, M. Weinberg, R.C. Armstrong. Chem. Eng. Progr. 74 (4), 49 (1978).

2. J.L. Bravo, J.R. Fair, J.L. Humphrey, C.L. Martin, A.F. Seibert, S. Joshi. Fluid mixture separation technologies for cost reduction and process improvement. Noyes Publications, Park Ridge, N.J., 1986.

3. Distillation and Absorption 1987, I. Chem. E. Symposium Series No. 104, 1987.

4. R.M. Stikkelman, Gas and liquid maldistributions in packed columns. Ph.D. Thesis, Technical University of Delft, 1989.

5. Ž. Olujić, J. de Graauw. Chem. Biochem. Eng. Quarterly 3, 181 (1989).

6. G.K. Chen, K.T. Chuang. Hydrocarbon Processing 85 (2), 37 (1989).

7. R.K. Stikkelman, J. de Graauw, Ž. Olujić, H. Teeuw, J.A. Wesselingh. Chem. Eng. Technol. 12, 445 (1989).

8. P.J. Hoek, J.A. Wesselingh, F.J. Zuiderweg. Chem. Eng. Res. Des. 64, 431 (1986).

9. M.A. Albright. Hydrocarbon Process. 63 (9), 173 (1984).

10. R. Strigle. Random packings and packed towers. Gulf Publ. Co., Houston, 1987.

11. R. Billet, J. Mackowiak, Chem. Ing. Techn. 57, 1 (1975).

12. R. Billet, J. Mackowiak, Chem. Eng. Technol. 11, 213 (1989).

Downloaded At: 12:47 25 January 2011