THE MVG TRAY WITH TRUNCATED DOWNCOMERS: RECENT PROGRESS

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ABSTRACT

Efficiency data for MVG trays with truncated downcomers are presented for the first time. Various operating conditions including vacuum and high pressure are considered. While 7 bar and 11 bar data are very promising it has been possible to show that a uniform liquid flow pattern does indeed affect the efficiency at atmospheric pressure positively. A special downcomer outlet device has been developed to achieve an optimum initial velocity and mass distribution on the tray.

INTRODUCTION

Since their introduction in the year 1994 more than two thousand sets of Mini V-Grid MVG trays have been installed successfully worldwide. The well known geometrical features of the fixed valves bring about a substantial increase in capacity and turndown while maintaining high efficiencies.

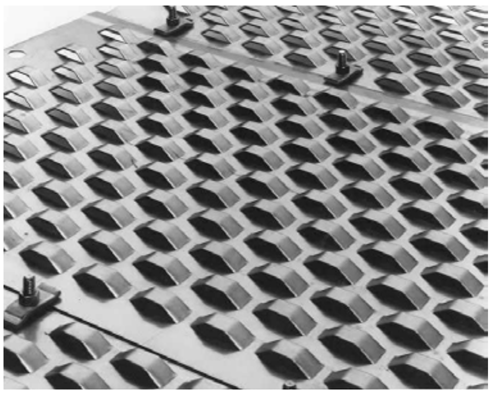


Fig. 1: MVG Tray deck

Following detailed simulator testing [1], FRI tests carried out in spring 1998 proved the capacity advantage of 10 to 20% over sieve trays [0] and their high efficiency. To take even more advantage of the V-Grid technology and to provide more bubbling area they have been first combined with truncated downcomers 1995 [0]. Since then various installations combining both technologies have been operating successfully. The increase in capacity which could be achieved in air/isopar simulator tests has been published recently [0]. Although the combination of fixed valve trays with truncated downcomer technology has already proven its superiority above the conventional set-up, it is still subject to further improvement. Efficiency data from experimental distillation tests have not been published yet.

This paper reports recent progress in the development of MVGT trays (MVGT stands for MVG with Truncated downcomers). Efficiency data for vacuum and high pressure services are presented. It is shown that efficiency can indeed be improved with a downcomer bottom plate carefully designed to achieve a good initial liquid and velocity distribution.

EQUIPMENT

The Tray Panel

The MVG trays consist of raised slots on triangular pitch. They are formed as a part of the tray deck (see Fig. 1) and offer unique advantages, including

- horizontal dispersion of the vapor into the liquid on the tray, thereby lessening entrainment,
- lower pressure drop,
- better turndown than sieve trays,
- more rigid tray deck, and
- a tray deck which is less prone to fouling than sieve trays or valve trays with movable elements.

The Downcomer

A special downcomer bottom plate (Fig. 2, patent pending) has been developed in order to achieve a uniform flow over the tray deck, similar to plug flow. A row of slots, arranged along the column wall, is designed with varying opening area to provide an optimum liquid distribution onto the tray deck. The direction of the discharge flow is imposed by means of special guide vanes. Fig. 3 shows a free surface simulation of the discharge flow out of one downcomer slot. It has been obtained using CFD (Computational Fluid Dynamics). Such investigations help a great deal in understanding and quantifying the effect of the guide vanes. They can also provide important information to establish design rules.

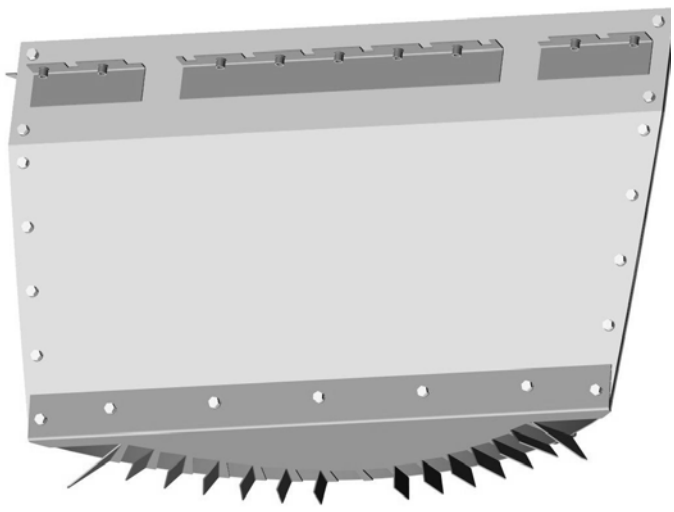


Fig. 2: Truncated downcomer with special bottom plate.

Air/water simulation tests in a 1 m column with transparent walls were carried out to observe the flow on tray which can be achieved with various downcomer outlet devices. To this purpose a small amount of dye was instantly injected on a line within the downcomer. The evolution of the color fronts was filmed by video and processed on the computer. Two typical snapshots with color distributions are given in Fig. 4. It is expected that the uniformity of initial liquid distribution has a positive effect on the performance of the tray.

Test Columns and Tray Layout

The efficiency has been measured in a 1 m distillation column using monochlorobenzene and ethylbenzene (CB/EB) at total reflux. The column was equipped with 6 trays (spacing 450 mm) and a false downcomer on top. The open area of the tray (13.5% with respect to the active area) and the single downcomer size were designed for optimum operation at atmospheric pressure. The downcomer covered 5% of the column cross section. Vacuum tests have also been carried out with the same layout.

The 7 and 11 bar data have been obtained in the 450 mm general purpose column of Shell Global Solutions in Amsterdam [0]. The isobutane and n-butane system (iC4/nC4) has been applied in total reflux operation. Six trays were mounted with a spacing of 600 mm. Other geometrical features, including the open area of 14.3% and the downcomer area of 11%, were optimally designed for 7 bar.

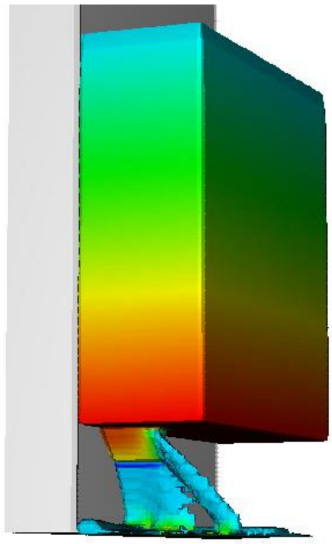
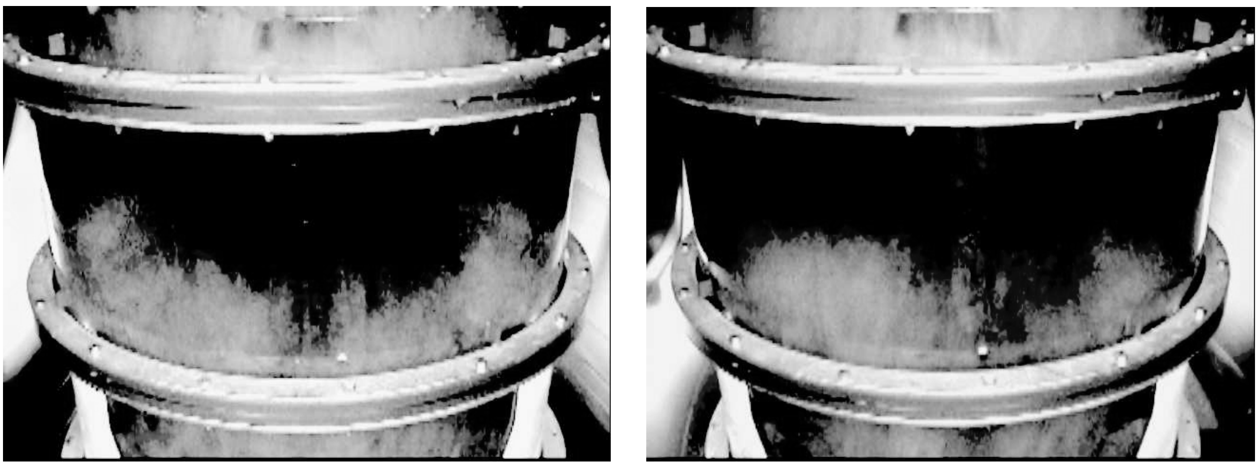


Fig. 3: CFD simulation of the discharge flow from a part of the downcomer over one guide vane. The color indicates static pressure (red: high, blue, low).



a) b)

Fig. 4: Dye experiments in a transparent 1 m column. The flanges indicate the position of two MVGT trays. View onto the froth flow on the lower tray. The flow is directed towards the camera position. The exit weir is on the facing side. a) Flow without special bottom plate. Channeling in the center, stagnant regions appear on both sides. b) More uniform flow pattern obtained with the bottom plate.

EFFICIENCY RESULTS

Comparison with other Truncated Downcomer Trays

Fig. 5 shows efficiency measured for the MVG tray with truncated downcomer at atmospheric pressure (960 mbar). For comparison purposes, results obtained with sieve trays and trays using Snap-in valves are also included. Each tray has its own optimum operation range. As expected, the Snap-in and the MVG tray display a wider range of operation. The MVGT achieves a 95% efficiency, showing clearly its superiority above the other two tray types.

Comparison between Conventional and Truncated Downcomers

Experiments to quantify directly the effect of the truncated downcomer compared to the conventional design have not yet been performed. The other MVG tray data available for this test setup is for 150 mbar top pressure, with an open area of 11.1% and a downcomer area of less than 4%. Nevertheless, the qualitative information provided in Fig. 6 should be sufficient to show that the efficiency is at least not affected negatively by the truncated downcomer. Two MVGT curves are presented, for 960 mbar and 100 mbar pressure. They suggest that the efficiency has even improved. This may be due to the increased active area but is more likely due to the uniform liquid flow achieved by means of the special downcomer bottom plate. Note that the MVGT tray has not been designed for vacuum operation, otherwise more capacity could have been achieved.

Influence of the Downcomer Bottom Plate

A goal of the current investigations was also to quantify the effect of a uniform liquid flow pattern. The same, exact MVGT tray for optimum operation at atmospheric pressure has been used in both cases, but in the second case the downcomer bottom plates have been replaced by a conventional two slot arrangement without guide vanes. Fig. 7 shows a clear improvement by up to 10% when the special bottom plate is used.

High Pressure Data

Large scale experimental data for high pressure operation are still missing. It is expected that FRI measurements scheduled for summer 2002 will provide more insight. Small diameter data from the Shell general purpose column suggest that MVGT also meets the expectations at 7 and 11 bar. Due to the high ratio of froth height to flow path length the efficiency increases with increasing load factor. This explains the unusual form of the efficiency curves in Fig. 8. The efficiency is not significantly dependent on pressure, and values above 90% can realistically be expected also at these operating conditions.

CONCLUSIONS

The combination of Mini V-Grid tray decks with truncated downcomers (an MVGT tray) is a well established mass transfer device. However, based on the results presented above, it may be concluded that even greater technical potential is possible with the combination of MVG trays and optimized truncated downcomers.

Distillation tests at vacuum, atmospheric and high pressure display an efficiency between 90% and 95%. Hydraulic and distillation tests clearly demonstrate the positive effect of a downcomer bottom plate which induces a uniform liquid flow pattern over the tray deck.

LITERATURE

1. D. Perry and D. E. Nutter (1994), 'Debottleneck entrainment limited columns using the MVG Tray', IChemE Fluid Separation Process Group – Debottlenecking Conf, London, UK.

2. D. E. Nutter (1999), Trans IChemE, Vol 77, Part A, 493-497.

3. D. E. Nutter (1995), U.S. Pat., 5,454,989 (Oct. 3).

4. M. Pilling (1998), 'Effect of Downcomer Geometry on High Capacity Trays', 1998 Distillation Technology Conference Orlando, Florida.

5. H. Nooijen, K. Kusters, J. Pek (1997), IChemE Symp., Vol 142, 885-897.

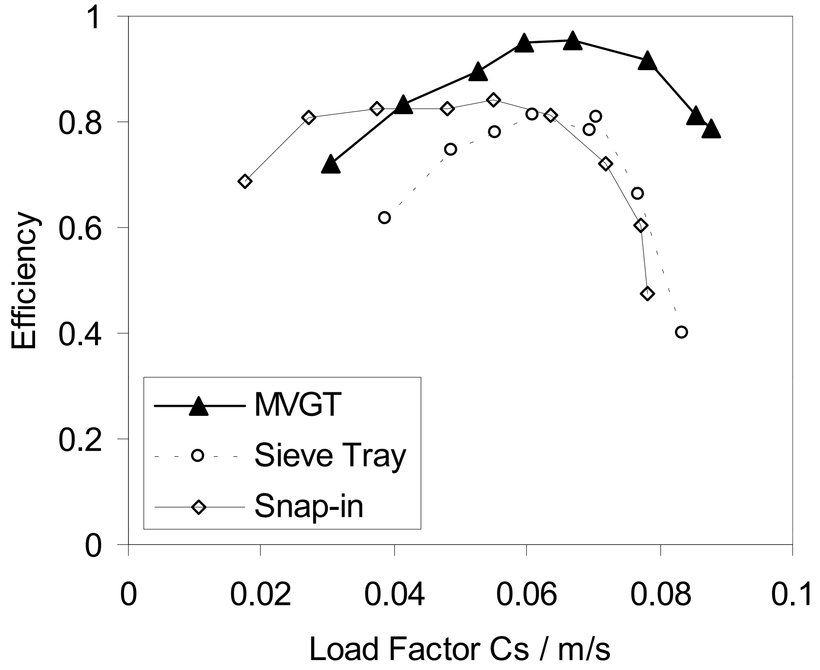


Fig. 5: Efficiency for various tray types. Pressure 960 mbar (atmospheric pressure), CB/EB at total reflux in the 1 m column.

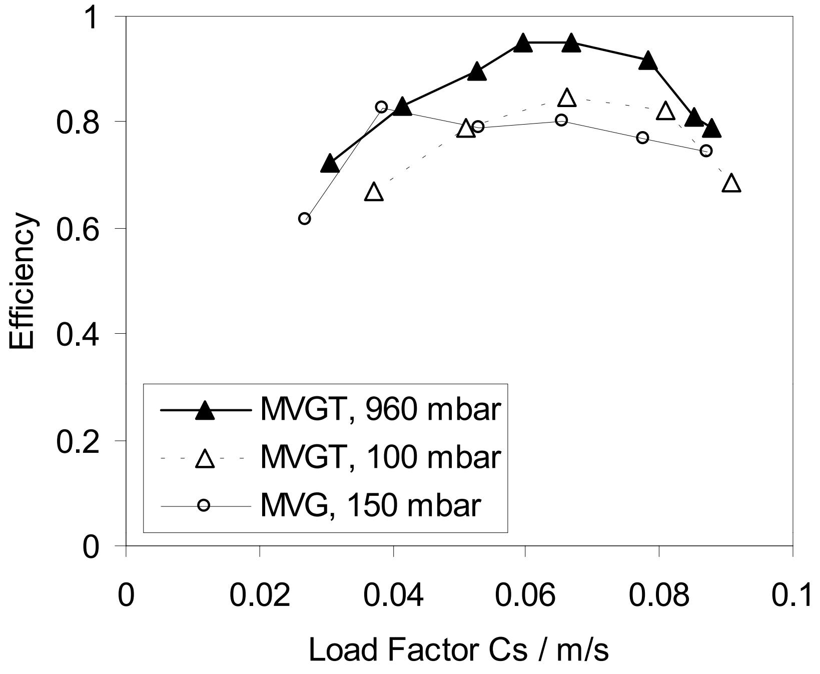


Fig. 6: Effect of truncated downcomer design measured in the 1 m column using CB/EB. MVG is a tray with conventional downcomer designed for operation at low pressure. MVGT with truncated downcomer has been designed for atmospheric pressure.

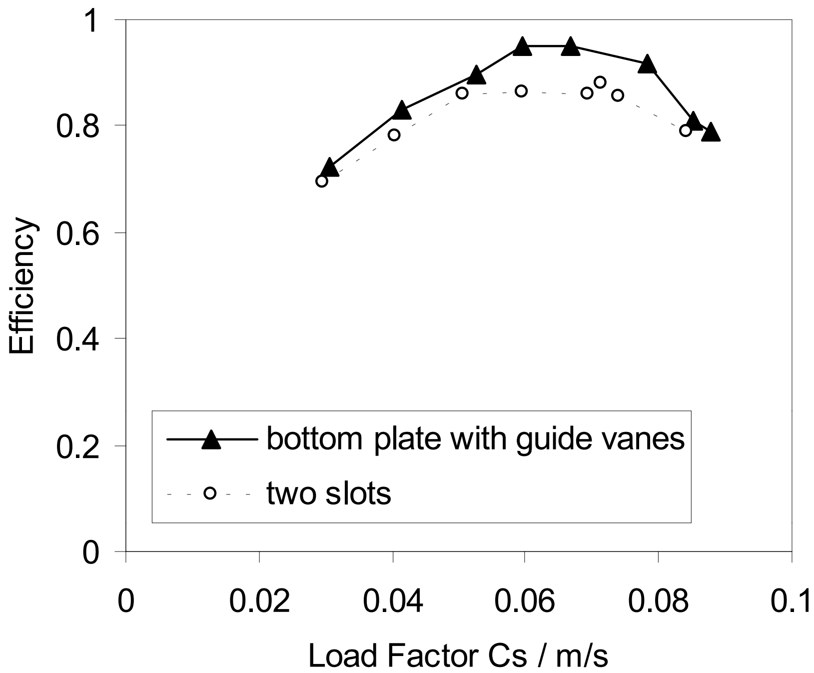


Fig. 7: Efficiency data for MVGT, atmospheric pressure and CB/EB in the 1 m column. Effect of the special bottom plate compared with a two slot design.

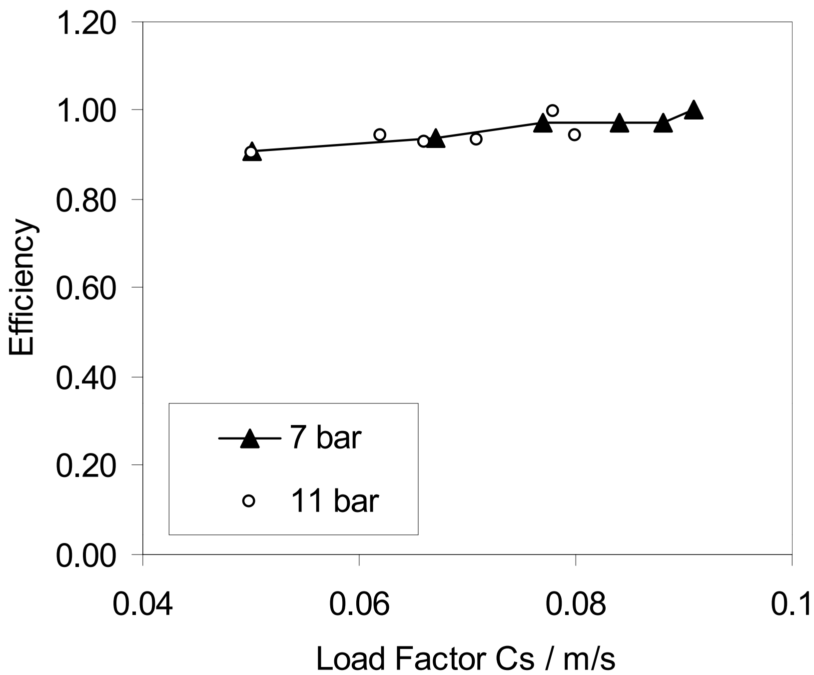


Fig. 8: High pressure data for MVGT using iC4/nC4, total reflux.