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CHEMICAL ENGINEERING

Performance of Staggered Disc Packing

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Abstract. A new kind of packing is proposed for use in vacuum distillation. The packing consists of circular disks with holes at the center, which are placed at equal distances on vertical rods. The liquid descending the packing is slowed down, mixed and spread on each layer of discs, while the gas flows up in a zig-zag way. Preliminary experiemental results have been obtained in a pilot size distillation column though not yet under vacuum. These show that, at atmospheric pressure, pressure drop and mass transfer efficiency of the packing are better than for conventional packings and comparable to those for other modern packing types at low vapor rates.

Nomenclature

H : Column height, m
L : Liquid flow rate, kg. m^{-2}. sec^{-1}
F : F-factor, $Kg^{1/2}$. $m^{-1/2}$. sec^{-1}
U_v : Vapor velocity, m.sec^{-1}
ϱ_L : Liquid density, kg. m^{-3}
ϱ_V : Vapor density, kg. m^{-3}
ΔP : Pressure drop, mm. water per m. of column.

Introduction

Since the early years of the nineteenth century, 1818 [1], the bubble cap tray has been the foremost contacting device used in mass transfer operations. Within the last thirty years, however, despite design improvements and modifications which have greatly increased the capabilities of bubble cap trays, they are being used less frequently. The sieve tray, first used in 1832 [2], and packings, firstly patented in 1836, have been the devices competing with bubble cap trays.

Presently, there is available quite a large selection of contacting equipment [3,4] to meet various special requirements. However, studies on the development of new types of equipment are still needed to improve short comings such as poor liquid distribution, short vapor liquid contact time, high cost, excessive weight, high liquid hold-up and large pressure drop.

The present study is an effort to introduce an efficient packing for use in vacuum distillation. The packing consists of flat circular metal pieces with holes at the center through which metal rods are passed, as seen in Fig. 1. The rods are installed vertically in a square pattern (see Fig. 2) in column, so that the discs overlap each other in criss-cross fashion.

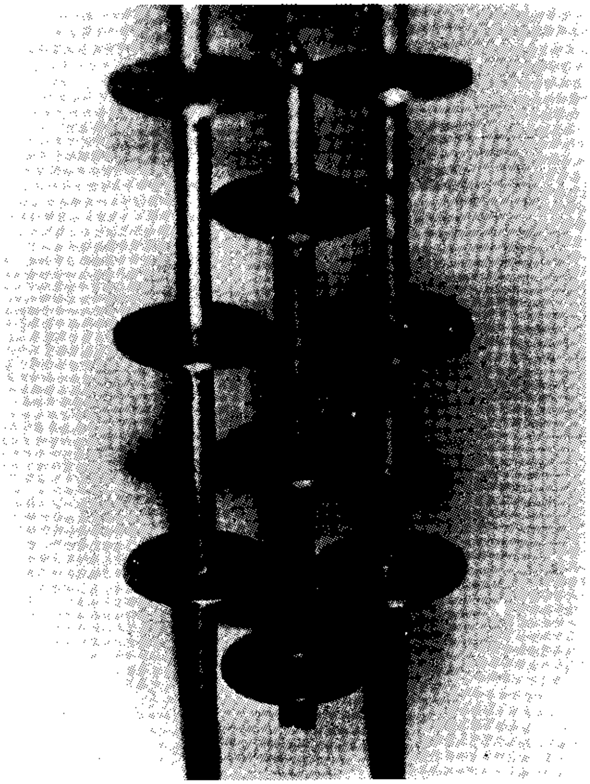

Fig. 1. Pieces of disc packing cut from the assembly used in the experiments

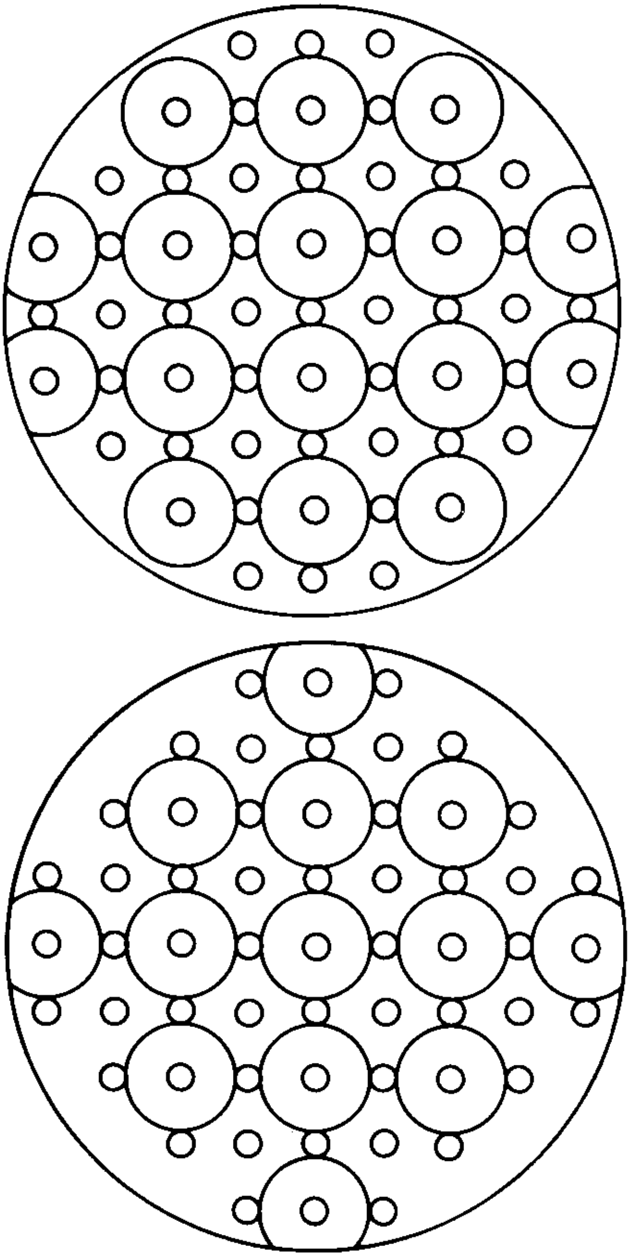

Fig. 2. Configuration of the discs (large circles) and rods (small circles) at two horizontal cross-sections in the column

With this configuration each layer of circular discs is perfectly horizontal and the liquid flows through a uniform bed; thus, a good liquid distribution is expected. The liquid suddenly stops when it comes on a disc, then spreads over the disc horizontally as a thin film. As it comes on a rod it is collected and directed down by the rod, which acts as a guide for the liquid. The direction of the liquid changes from vertical on the rods to horizontal on the discs to achieve good mixing. Thus, the liquid does not stay in pockets at any point in the column.

The vapor passes through the discs in a zig-zag path, so a good mixing and a higher contact time is provided for mass transfer. The vapor liquid contacting in this packing resembles that in a showerdeck and that in packed columns. Since at high liquid rates the liquid film may start to flow down from the periphery of the circular discs in the form of cylinder, the rising vapor in criss-cross movement intercepts this film as it does in the showerdeck. The portions on the vertical rods and the discs coated with liquid flowing downward bring the phases in contact as on a packing.

Pressure drop occurs mainly due to the changes in the cross-sectional flow area for the gas. However, the porosity is quite high so that the drag and the pressure drop are low.

In order to test the performance of the packing, the following data were obtained on a pilot scale packed column at atmospheric pressure:

1. The dry and irrigated packing pressure drop.
2. The operation range (flooding rates).
3. Efficiency of the packing for distillation of a binary mixture.

Experimental

The discs used for making the packing for the preliminary studies are 17mm in diameter and 1 mm in thickness, and the rods are 4 mm in diameter. Rods and the discs are made of brass. The vertical distance between each layer of discs is equal to the radius of the discs; this condition is believed to give the best compromise between pressure drop and mass transfer efficiency. Thus, a packing was prepared with a voidage of 0.85 (empty volume/total volume) and dry surface area of 191.5 m^2/m^3. The packing was contained in a steel column of 0.096 m inside diameter and 0.875 m height.

The flooding point experiments were performed using air and water. Each flooding point was determined by performing the pressure drop measurements twice at constant water flow rate by changing the air flow rate. In every second experiment the pressure drop values were measured around the flooding point indicated by the first experiment, so that a precise value was obtained for the flooding F-factor.

Distillation experiments were performed with the benzene-toluene system at atomspheric pressure and at total reflux. As seen in Fig. 3, a steam heated reboiler

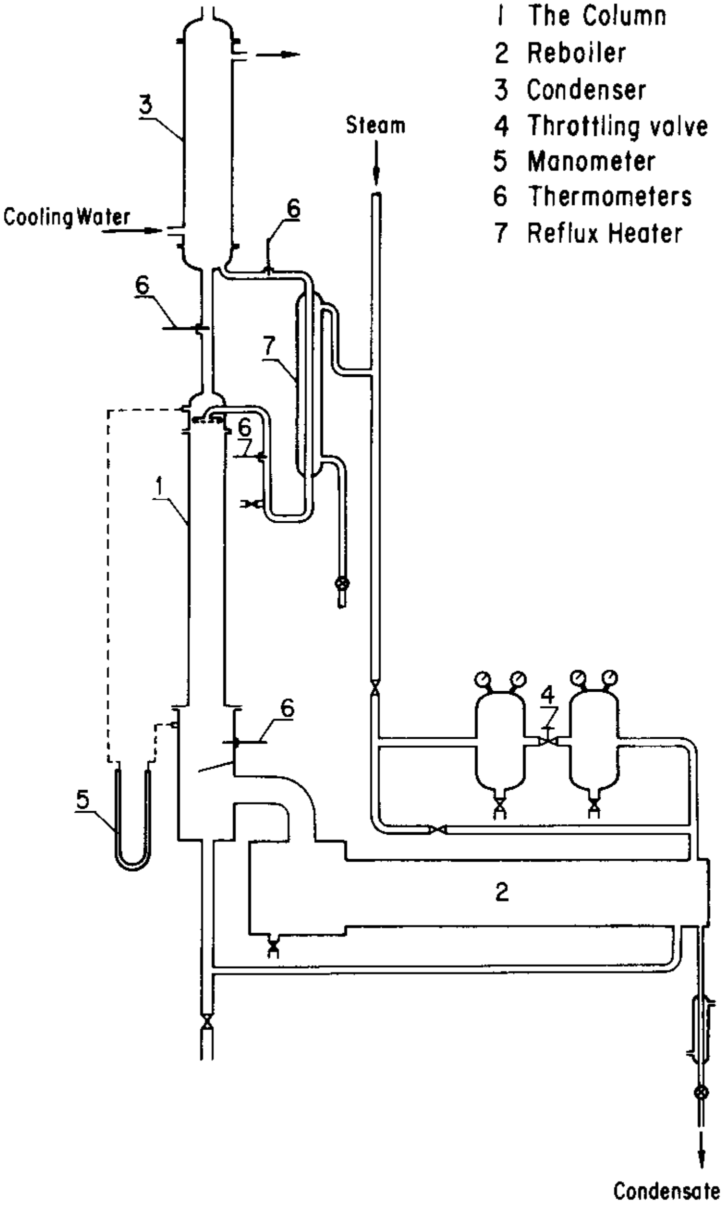

Fig. 3. The apparatus used in distillation experiments

of 0.045 m^3 volume and a coil type condenser with 0.47 m^2 heat transfer area were used. The quality of the steam fed to the reboiler was determined by measuring its temperature and pressure before and after an adiabatic throttling valve. The reflux line can be heated by steam to supply the reflux as saturated liquid. In order to have adiabatic operation, the steel column was heat insulated with 2-in thick glass wool, and could be electrically heated from outside to compensate for heat losses. For the determination of actual vapor rates, the steam condensation rates in the reboiler were measured carefully and allowance was made for heat losses from the reboiler.

The heat input (vapor from the reboiler) and output (reflux) rates were calculated and the difference was supplied by the electrical heating tapes wrapped around the column to maintain adiabatic operation. When steady state was reached samples were collected from the reflux line and the reboiler for composition measurements with both refractive index and chromatography. The number of transfer units was found using equilibrium data of E. Rollet *et al.* [5]. Pressure drop was measured by a water manometer. Spills of liquid occured through the manometer taps; however, the manometer lines were kept open by containing the spills in spherical recievers next to the taps. Water in the manometer arms fluctuated all the time due to the turbulence in the column. For each pressure drop data a series of pressure drop readings were taken and averaged until a constant average value was reached.

Experimental Results and Comparison with Other Contact Equipment

Fig. 4 shows that at low liquid rates flooding would be possible only with very high vapor rates. The pressure drop lines appear to be very close to each other at low liquid rates but as the liquid rate exceeds 25 m^3/m^2. hr the separation between the lines becomes apparent. This indicates that the cross-sectional area available for gas flow is reduced at high liquid rates.

The pressure drop vs F-factor for two irrigated packing experiments are presented in Fig. 5 together with those of conventional packing equipment [6,7]. The pressure drop values for the new packing are smaller than those of the conventional packings of the same size range.

In Figs. 6,7 and 8 the performance of the new packing is compared with those of the relatively new contact equipment recommended for use in vacuum distillation. In Figs. 7 and 8 mass transfer efficiency and pressure drop characteristics of 25 mm metal pall rings and the disc packing are compared for the same binary system, benzene-toluene [7]. Both efficiency and pressure drop curves are smooth for pall rings while a change in the performance of the new packing is observed at around F-factor 1.5. This behaviour suggests that, at vapor velocities corresponding to F-factor 1.5 the kinetic energy of vapor becomes high enough to deflect the liquid towards the walls of the column. The liquid cannot descend any more in the way described in the introduction section, the contact area is decreased and consequently the mass transfer efficiency declines.

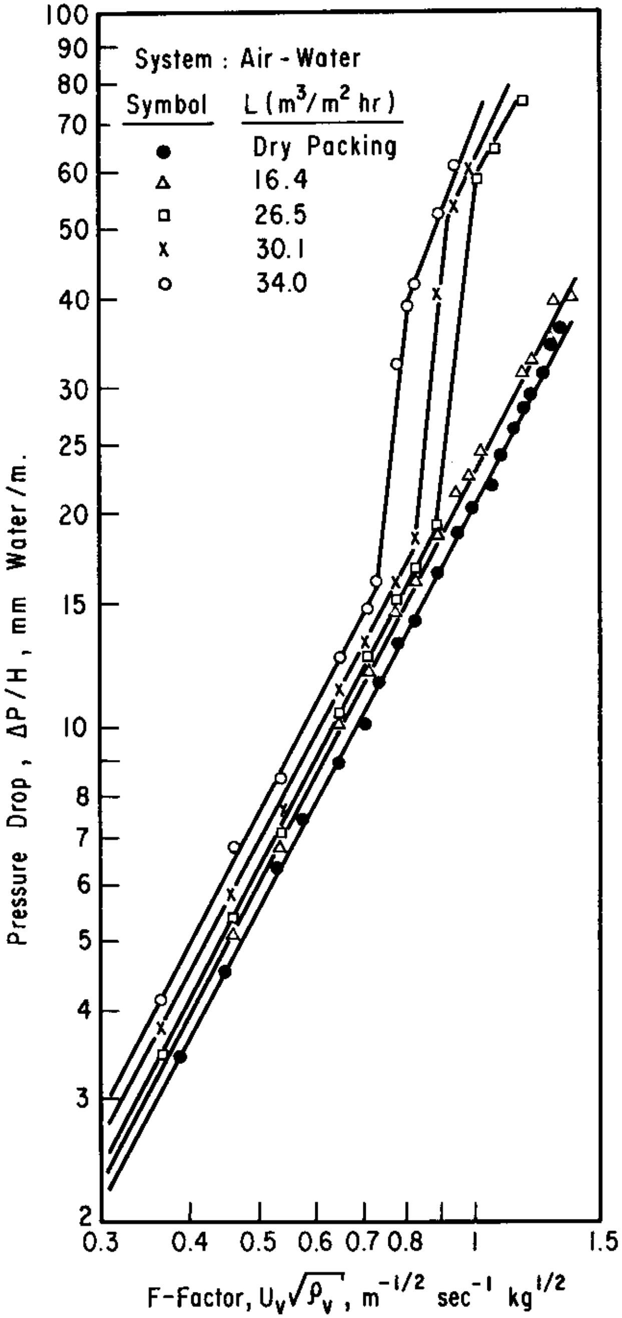

Fig. 4. Pressure drop data obtained in the dry and irrigated packing experiments.

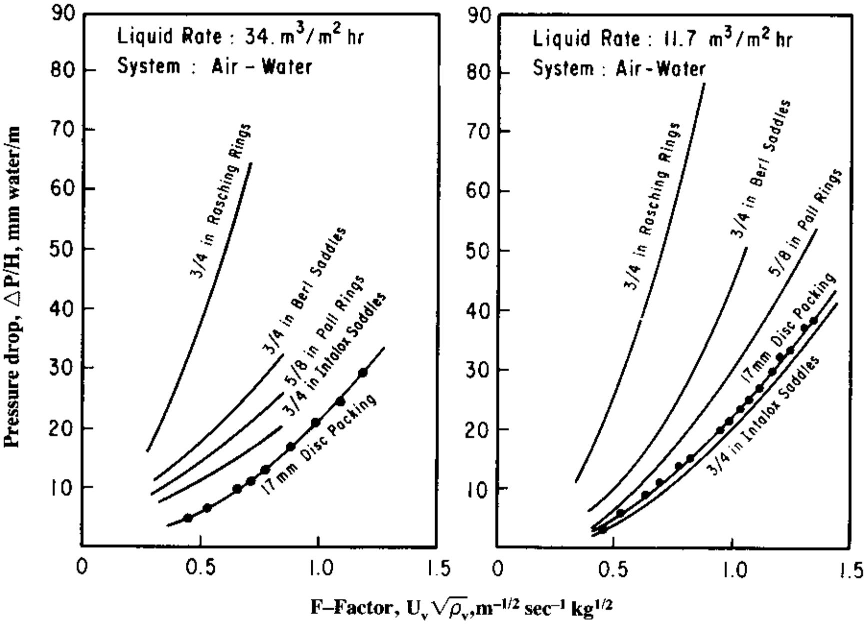

Fig. 5. Comparison of experimental pressure drop values with those of conventional packings.

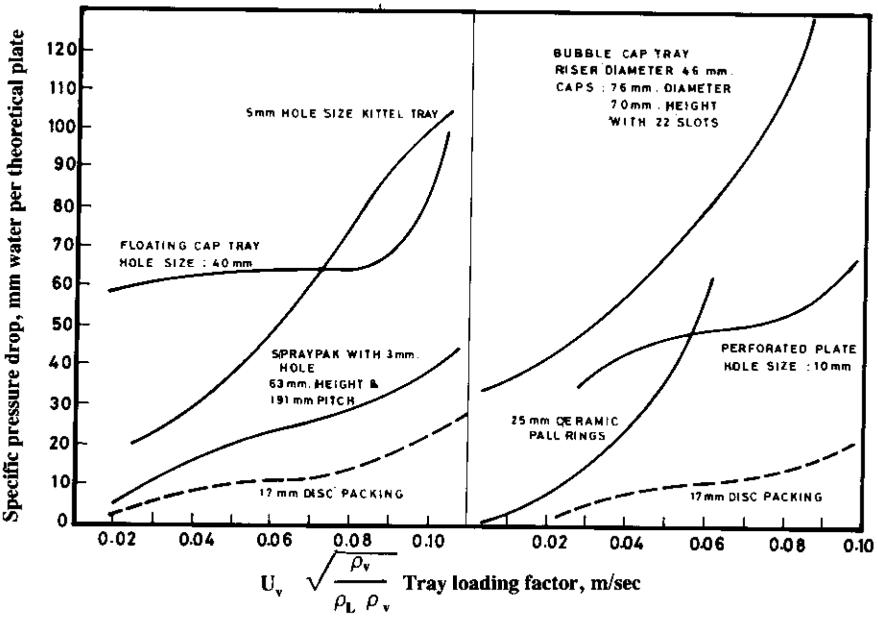

Fig. 6. Comparison of specific pressure drop data with those of conventional contact devices.

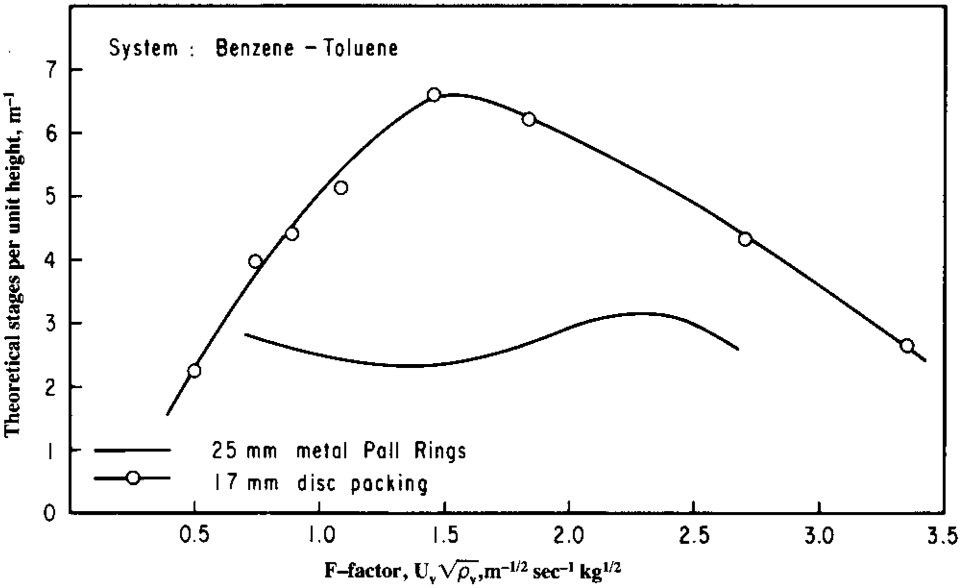

Fig. 7. Comparison of mass transfer efficiency with that of pall rings

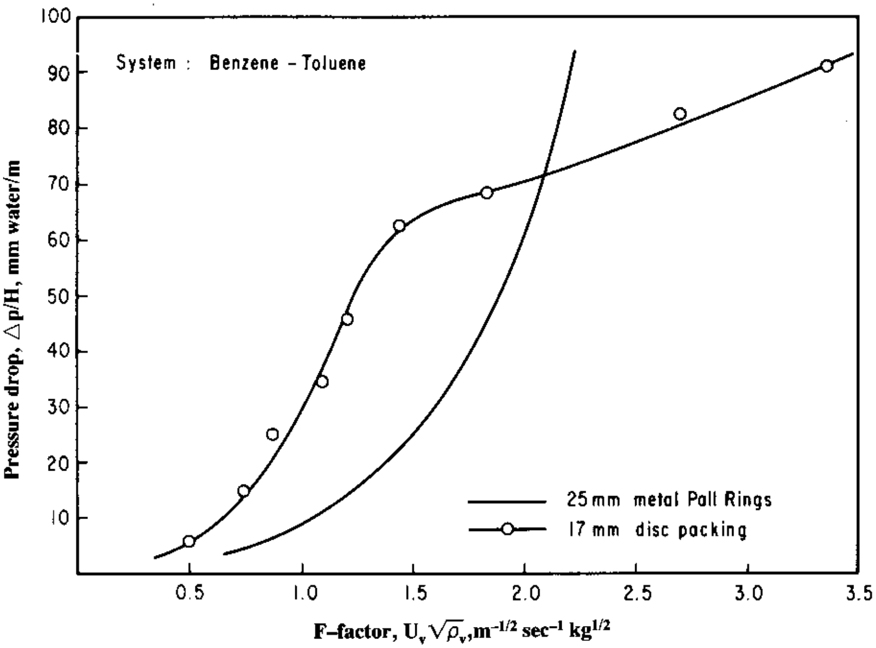

Fig. 8. Comparison of mass transfer efficiency with that of pall rings

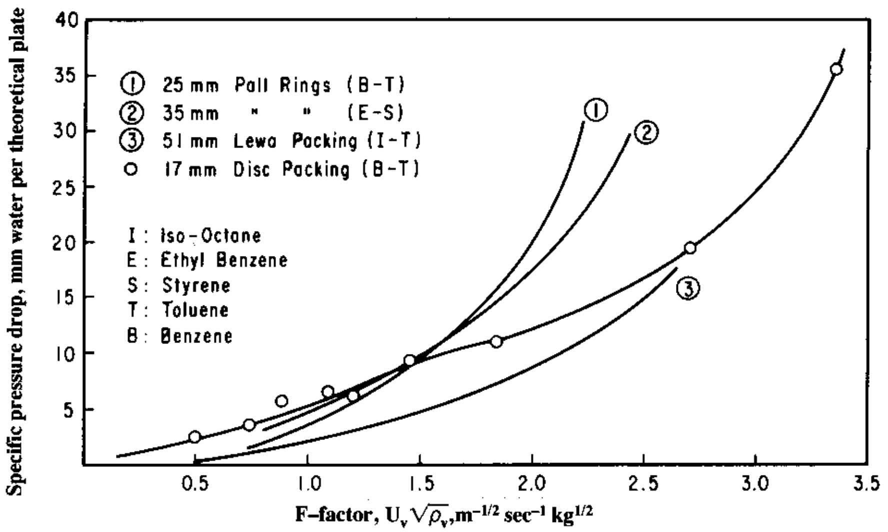

Fig. 9. Comparison of specific pressure drop data with recently commercialized packings.

In Fig. 9 specific pressure drop is compared with that of the pall rings [8] and Leva packing [9] or larger sizes. At this preliminary stage, it seems that the performance of the new packing operating at atmospheric pressure is comparable to that of these modern packings up to F = 1.5, but declines for higher vapor rates.

Conclusions

The experiments performed at atmospheric pressure in a pilot size column prove that at this operating pressure the new packing is superior to almost all conventional packings and for a limited range of F-factors gives nearly the same performance as recently commercialized packings. At vaporates up to F-factor 1.5 the packing can function as expected; the liquid flows down as a thin film from the periphery of the discs producing a large contact area with the gas flowing up. However, improvement is needed for higher F-factor range. This will be the subject of a future study, as will the performance of the new packing at low pressures.

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أداء الأقراص الموضوعة بشكل متبادل كحشو لأبراج التقطير

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ملخص البحث. في هذا البحث يقترح نوع جديد من الحشو لغرض الاستخدام في عملية التقطير الفراغي. ويتكون هذا الحشو من أقراص دائرية لكل منها ثقب عند المركز حيث تحمل هذه الأقراص على قضبان رأسية وتفصل بينها مسافات متساوية على هذه الحوامل. ونتيجة لملامسة السائل المتجه لأسفل لهذه الأقراص، فإن حركته تكون بطيئة حيث يمزج ويرش على كل طبقة من الأقراص، بينما يتحرك الغاز المتجه لأعلى في حركة متعرجة. ولقد تم الحصول على بعض النتائج الأولية لتجارب معملية أجريت على عمود تقطير ذي حجم نصف صناعي، ولكن في ظروف الضغط الجوي العادي. ولقد أظهرت هذه النتائج أنه في ظروف الضغط الجوي العادي يكون الفقد في الضغط وكفاءة عمليات انتقال المادة للحشو المتغير أفضل من نظيرتها والتي يمكن الحصول عليها باستخدام أنواع الحشو التقليدية. كما وأن النتائج التي تم الحصول عليها تضاهي النتائج المنشورة عن الأنواع الحديثة من الحشو عند استخدام معدّلات سريان منخفضة للبخار.