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A STUDY OF THE PERFORMANCE OF A DOWNCOMER

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Performance of a downcomer, using O_2-air-aqueous glycerine system 50% by wt. has been investigated. Mass transfer efficiencies and mean residence time, have been measured as a function of liquid and air flow rates. It has been demonstrated that downcomer does play a significant role in the mass transfer, in a unit, therefore a serious thought should be given while designing a downcomer.

Key words: Downcomers, Sieve trays, Mass transfer plates.

INTRODUCTION

Although, the importance of the downcomer, as a contributor to the mass transfer in a distillation unit was pointed out as early as [1], but very limited data is reported in the literature and that too is very much contradactory. It has been stated by Thomas and Campbell [2] that the behaviour of the tray plus downcomer, as a unit may be very important in certain circumstances. Due to paucity of data the design of downcomer is still mainly based on empirical equations.

The present study was carried out to establish the overall performance of a downcomer.

Downcomer theory. The mechanism of bubble and froth formation in a downcomer is unexplored. Small bubbles of almost uniform sizes are collected at the base of the downcomer. As we pass upwards these bubbles grow and a gradual transition to froth occurs. A large deal depend upon the mode of entry of the liquid from the tray above.

The earlier workers [1 ,3, 4] were of the opinion that column would flood, when the aerated liquid reaches the top of the exit weir. Thomas and Shah [5] has shown that the most important design factor is clear liquid height, the froth height contributes little to the tendency of flooding. The clear liquid height in the downcomer can be calculated from the following equation.

$$Z_d = P + L_b + (h_f/\rho_L) - h \quad \ldots\ldots (1)$$

The liquid throw over the weir is no longer considered to be a limiting factor in tray designing [2].

Relative foam density values in the downcomer are not available in the literature. Since specific foam density varies approximately from ρ_L at the bottom of the downcomer to ρ_f at the foam vapor interface. Therefore, a conservative average value of the relative of the density $\phi = 0.5$ is widely used in the design of the downcomers [3].

A certain residence time of liquid in the downcomer is necessary in order to allow collapse of foam. It is common practice to base this residence time on the total downcomer volume. The minimum allowable residence time should be based on the foamability of the system.

A true residence time of the aerated mass in the downcomer is given as [3].

$$t = 0.083 \cdot \frac{(A.Z_f)}{q/\phi} = 0.083 \frac{A.Z_d}{q} \quad \ldots\ldots (2)$$

Where Z_f. $\phi = Z_d$ and $A.Z_d$ is equivalent to the clear liquid volume. q is the liquid flow rate. Then t as given in the above equation 2 represent to " Plug flow".

A value of 5 seconds for plug flow in the downcomer is suggested by Davis [1]. Observations made by Thomas *et al* [2, 5] certainly leads one to expect anything but a plug flow in the downcomer.

EXPERIMENTAL

Since the circular downcomer provides very low downflow area and poor vapor disengaging space and usually constitute the first bottle neck to column capacity, therefore a segmental downcomer was selected for the present studies. The downcomer was 12.5 cm deep, 30.5 cm wide and 60 cm long with the provision of measuring points.

The pilot plant [2] was operated, as under the normal conditions, using O_2 desorption from aqueous glycerine (50% by wt.) solution. Froth height and clear liquid heights were measured visually, as the downcomer was constructed from transparent material. For mass transfer efficiency studies, liquid samples were withdrawn at inlet, and outlet and were analysed for dissolved O_2 concentration in the liquid phase continuously with the help of O_2 detection cell, (manufactured by Cambridge Instrument Ltd. of England).

For mean residence time studies, a dye injection (Nigrocine) technique was selected. The dye was injected in inlet-weir and its concentration in solution against time was measured at downcomer outlet, with the help of a photoelectric cell and was recorded by an ultra violet recorder continuously [6].

RESULTS AND DISCUSSION

In Fig. 1 is shown the effect of liquid flow rates on the froth height and static liquid head in the downcomer at two different air flow rates. The froth height, on top of clear liquid increases with liquid and air flow rates which gradually tails off at higher liquid rates. This is expected, since with increasing liquid and air flow rates more froth will be generated on the tray above, which will pass over the exit weir into the downcomer. At higher liquid flow the cascading liquid from the exit weir distrupt and mechanically breaks the froth, which results in lowering its height in the downcomer.

The clear liquid height in downcomer increases with increasing liquid and air flow rates Fig. 1(b). This build up of liquid in the downcomer is mainly due to the increase in liquid flow over the exit weir into the downcomer. Secondly, the increasing flow rates, increases the pressure drop across the trays, which results in additional hold up of the liquid in the downcomer. The liquid hold up in the downcomer can be calculated very accurately by equation 1. It was observed that there is no possibility of closing of the mouth of downcomer by cascading liquid flowing over the exit weir into the downcomer. The clear liquid height should be considered as the main design parameter, as the light froth contributes very little to the total head, hence to the flooding of the downcomer [5, 7].

The pressure drop in the downcomer is very small and is almost independent of the air flow rates. This is expected since very narrow flow rates were investigated. The pressure drop is slightly dependent on the liquid flow rates i.e. increases with increasing flow rates, but is not significant as shown in Fig. 2.

Mean residence time (MRT) is highly dependent on the liquid flow rates. It decreases with increasing liquid flow rates Fig. 3. For high flow rates (in case of industrial operation) MRT in downcomer of 2s seems to be more realistic figure rather than 5s as suggested by Davis [1].

The mass transfer efficiency of the downcomer increases with liquid flow rates Fig. 4. At 511 LPM/m weir liquid flow rates, mass transfer efficiency as high as 12% is

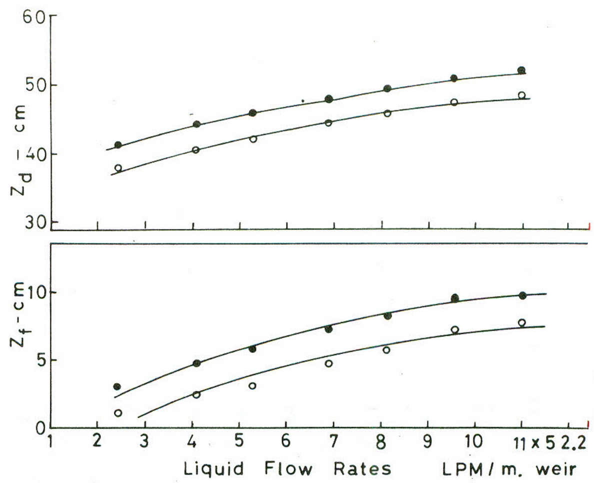

Fig. 1. A plot of (a) froth height and (b) clear liquid height verses liquid flow rates at different air flow rates.

(a) Froth height (Z_f) (b) Static liquid height (Z_d)
O-F_A = 2.1 O-F_A = 2.1
●-F_A = 2.43 ●-F_A = 2.43

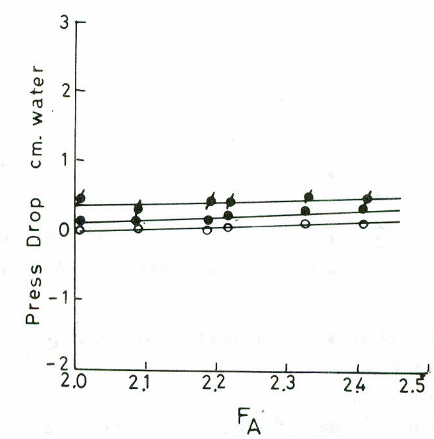

Fig. 2. Plot of pressure drop in the downcomer verses air flow rates at different liquid flow rates.

O - 269.1 LPM/m of weir; ● - 401.2 LPM/m of weir; ♦ - 536.7 LPM/m of weir.

obtained, which is a high contribution to mass transfer, when the combined unit of tray plus downcomer is considered. This is supported by the data of earlier workers [2] which is reported alongwith the present data in Fig. 4. This suggests that role of the downcomer should be considered carefully while designing a distillation column.

Number of transfer units, NL, are shown as a function of air flow rate and MRT in Fig. 5 and 6 respectively. The positive role of the downcomer towards mass transfer is demonstrated as shown in Fig. 5, NL is independent of air flow rates over the narrow range investigated. Number of transfer units, increase with increase in MRT of the liquid Fig. 6. The scatter in data at the lower values of MRT (or

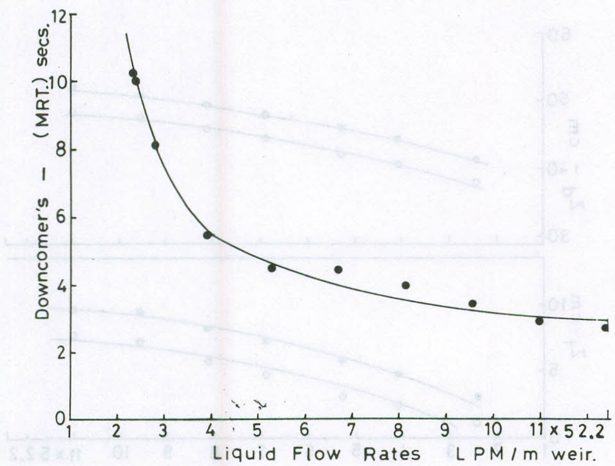

Fig. 3. Plot of MRT against liquid flow rate at F_A = 2.1 air flow rate.

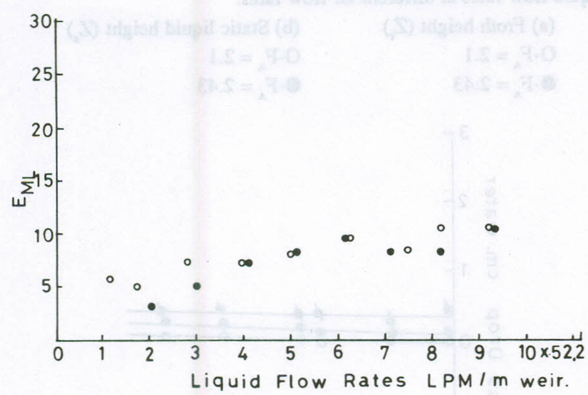

Fig. 4. Plot of Mass transfer murphree efficiency (E_{ML}) against liquid flow rates at F_A = 2.1

● - Present study;

O - Report at Thomas and Campbell's data ref. No. 2.

high liquid flow rates) is less when compared with the higher values of MRT (or low liquid flow rates). A comparison of number of transfer units, NL for tray alone and tray plus downcomer shows that they are of the same order. This phenomena can not be explained in term of NL alone since dimensionless and MRT have also to be taken into consideration as they effect the liquid phase number of transfer units, NL as well. It is also likely, that this is predominantly due to a fall in interfacial area in the downcomer itself [8].

CONCLUSIONS

It is concluded from the present study that the downcomer plays a significant role in the mass transfer process, the relative importance of which depends upon the flow rates and the nature of the system. Secondly, the design of a downcomer should be based on the clear liquid head rather than on the froth height as previously reported in the literature.

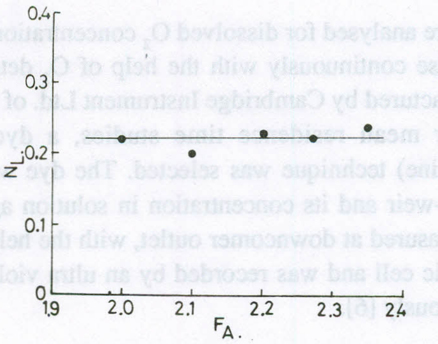

Fig. 5. Plot of number of transfer unit (N_L) verses air flow rate at ●- 269.1 LPM/m weir liquid flow rates.

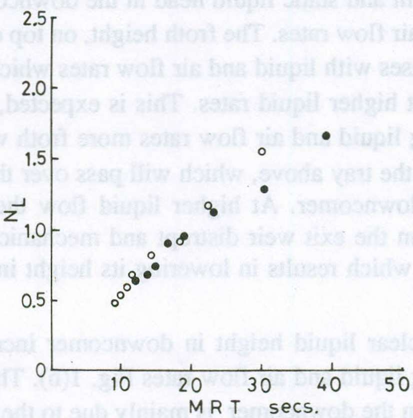

Fig. 6. Plot of number of transfer unit (N_L) against liquid mean residence time (MRT) at air flow rate F_A = 2.1; O - Tray alone; ● - Tray plus downcomer.

NOMENCLATURE

A	=	Downcomer area cm^2
E_{ML}	=	Mass transfer murphree efficiency
F_A	=	F-factor based on the perforated area of the tray air flow rate.
h	=	Pressure build up in downcomer cm of water.
h_t	=	Total pressure drop across wet try in cm of water.
L_b	=	Static liquid seal on the lower tray in cm.
MRT	=	Mean residence time of liquid. s.
N_L	=	Number of mass transfer units, liquid based.
P	=	Pressure drop through the clearance between downcomer and lower tray in cm.
q	=	Liquid flow rates in cm^3/sec.
t	=	Time. s.
Z_d	=	Height of clear liquid in downcomer - cm of liquid.
Z_f	=	Froth height in downcomer - cm.
ρ_f	=	Average foam density gm/cm^3.

ρ_L = Density of clear liquid gm/cm^3

ϕ = Froth density factor on the tray.

REFERENCES

1. J.A. Davis, Pet. Refiner, **29**, 93 (1950).
2. W.J. Thomas and M. Champbell, Trans. Inst. Chem. Eng., **45**, 53 (1967).
3. B.D. Smith *Design of Equil. Stages Processes* edited by B.D. Smith, Chapter 14 (McGraw Hill Publishers, New York., N.Y., 1963), p. 474.
4. L. Leibon, R.E. Kelley and L.A. Buttington, Pet. Refiner **26**, 127 (1957).
5. W.J. Thomas and A. Shah, Trans. Inst. Chem. Eng., **42**, 71(1964).
6. M.A. Haq, Hydrocarbon Processing, **62**, (2) (1983).
7. W.J. Thomas and M.A. Haq, Ind. Eng., Chem. Process, Des. Dev., **15**, (4) (1976).
8. M.A. Haq, Pak. j. sci. ind. res., **30**, 949 (1987).