SOME EFFECTS OF INCREASING STILLHEAD SURFACE AREA ON LIQUID ENTRAINMENT DURING DISTILLATION

By David Train and Bayardo Velasquez-Guerrero

Department of Pharmaceutics, School of Pharmacy, University of London, Brunswick Square, W.C.1

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The effect on the amount of entrainment passing during distillation when the surface area of a stillhead is increased has been investigated. The conditions suitable for supporting a liquid film on such a surface and which favour flooding at high flow rates have been observed.

Shotton and Habeeb[1] investigated the entrainment of liquid during distillation in straight vertical stillheads, and we have studied the effect of increasing the wall surface area of such a stillhead whilst maintaining constant its effective area of cross-section.

Using essentially the same apparatus and techniques as those already described[1,2], this increase in wall surface area was achieved by introducing into the stillhead a *thin* diametrical septum of phosphor-bronze (Fig. 1) which had been dull chromium plated to give it wetting characteristics similar to those of glass. The diameters of the stillheads were 1 in. and 1½ in. respectively and the length of each was maintained at 15 in. to limit one of the variables. The maximum distillation rate was increased from 18 l. to 33 l. per hour by using the main steam supply. A dry sample of this steam was passed into the reboiler containing a fluorescein solution. The quantity of liquid entrained was assessed as before, by estimating fluorimetrically the amount of fluorescein passing from the boiler to the separator and the condenser.

Results

Figure 2 summarises the results of some 450 individual fluorescein estimations. The curves are derived from points which represent the means of 2 to 4 replicate determinations. Curve A represents 31 points, B, 26 points, C, 47 points, and D, 42 points. The average increment was 500 ml. The quantity of fluorescein collected beyond the stillhead was expressed as μg./l. of distillate and represented the degree of contamination of distillate by entrainment, each μg. of fluorescein being equivalent to 0·001 ml. of original solution. Extension of the distillation rate gave new data on the behaviour of the system in the upper range.

Discussion

It has been assumed that for a given rate of distillation the amount of entrainment will be consistently the same. It was shown by Shotton and Habeeb that the diameter of the stillhead was an important factor in governing the amount of entrainment. It would be expected therefore that a reduction in a radial path by introducing a septum, whilst leaving the total cross-sectional area unchanged, would reduce the amount of entrainment passing through the stillhead. This has been demonstrated in the present study (cf. curve A with B and curve C with D in Fig. 2).

These curves have the same general form as those previously reported and may be divided into three distinct stages.

The first stage was attributed by Shotton and Habeeb to be a region where streamline flow is predominant and it is to be expected that any droplets, being carried up in the cores of vapour flowing in a streamline manner between the wall surfaces, will pass into the separator without loss. Those droplets near a wall surface will be arrested and the presence of the septum reduces the amount of entrainment for any given distillation rate. The slope of the curve is at a constant angle for a given stillhead whether with or without the septum.

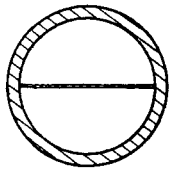

Fig. 1. Thin diametrical septum of phosphor-bronze.

The second portion of the curves shows how the additional wall area reduces the amount of entrainment passing. Since this region is in the turbulent range local eddies with radial components in the vapour stream induce droplets to move in some direction not truly along the axis of flow, so that there is a greater possibility that a droplet caught in such an eddy will be arrested on the wall. As the rate increases the degree of turbulence increases and this favours greater catchment so that the amount of entrainment passing per unit volume of distillate stays substantially the same. The presence of a septum reduces the entrainment passing, but since measurement of the *total* amount of liquid entrained in the vapour stream was not possible, we have been unable to assess whether the increase in entrainment is in proportion to the increase in perimeter caused by the insertion of the septum.

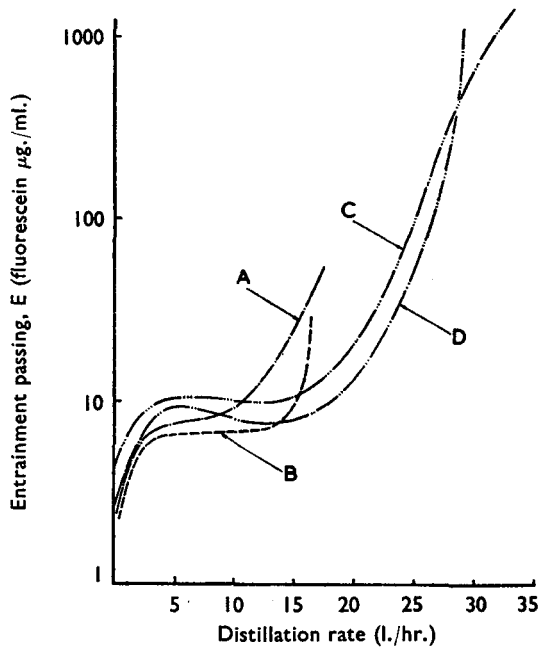

FIG. 2. Results of 450 estimations using stillheads with and without a septum.

A. Stillhead 1 inch diameter without septum.
B. ,, ,, ,, with ,,
C. ,, 1½ inches ,, without ,,
D. ,, ,, ,, with ,,

The third stage was given the name of "gross carry over" by Shotton

and Habeeb. In the present work careful observations of the conditions obtaining in the stillhead at the onset of this stage showed that the frictional drag forces of the rising vapour were sufficient to maintain a thin film of liquid on the walls of the stillhead in spite of the gravitational force tending to drain it downwards. As the distillation rate increased the wall film became thicker and finally, at extremely high rates, the film was dragged as a whole in an upward direction; it even coalesced across the head to form slugs of liquid which continued to be driven upwards by the rapidly ascending vapour. This final condition is similar to that found in the movement of two phases in wetted wall columns[3] in the condition known as "flooding".

The insertion of a septum delays the onset of gross carry over since with increased surface area in the stillhead, there is a greater area of liquid film to be supported. This requires a greater drag force which can be achieved only under the experimental conditions by increasing the rate of distillation. However, when there is sufficient liquid being held so that coalescence into liquid slugs is facilitated, the shorter radial path produced by the presence of the septum is advantageous and so flooding, as defined above, occurs at a lower distillation rate than it would have done in the same stillhead without a septum.

There is close agreement with the earlier work[1] when an analysis of the results from plain stillheads is made to relate the entrainment passing (E) with Reynolds Number ($\rho ud/\eta$). No acceptable correlation has been established which allows the incorporation of those results when a septum is used. Various possibilities for finding a relation between the area of cross-section, wetted perimeter, or mean radial path and the quantity of entrainment passing were tested without success. A possible explanation is that the particular shape of septum used gives conditions which makes the interpretation of results a difficult procedure.

Acknowledgement. We should like to thank Professor E. Shotton for his advice and interest throughout this work.

REFERENCES

1. Shotton and Habeeb, *J. Pharm. Pharmacol.*, 1954, **6**, 1023.
2. Shotton and Habeeb, *ibid.*, 1955, **7**, 456.
3. Perry, *Handbook of Chemical Engineering*, 3rd Ed., McGraw Hill, London, 1950, p. 686.

DISCUSSION

The paper was presented by MR. B. VELASQUEZ-GUERRERO.

THE CHAIRMAN. Had the authors considered the possible value of dropwise promotors in reducing entrainment?

MR. J. H. OAKLEY (London). What was the effect of increasing the number of septa, and would a septum in conjunction with a conventional baffle further reduce the entrainment?

PROFESSOR K. BULLOCK (Manchester). Was there much difference between the replicate determinations?

MR. H. B. HEATH (Sudbury). Did lagging the stillhead make any difference?

MR. J. H. OAKLEY (London) referred to the two pairs of graphs from which it appeared that an increase in the diameter of the stillhead reduced the effect of the septum.

MR. R. L. STEPHENS (Portsmouth) pointed out that if a second septum were placed in the distillation column and a voltage applied across the septa the effect might be that of electrostatic precipitation.

THE AUTHORS replied. An increase in number of septa would reduce the amount of entrainment, but flooding would occur earlier. The use of a baffle above the septum would probably reduce entrainment. The results were the average of five or six distillations. The difficulty was to keep the distillation rate constant. Lagging the stillhead made a difference because it affected the amount of condensation. It might be conjectured that the greater the scale the less the entrainment caught, but it was the difficult problem of comparing the effect of increase in surface area with that of increase in area of cross-section. There was no evidence that the particles were charged sufficiently to be affected electrostatically.