CHAPTER V

CRITICAL ANALYSIS OF THE LITERATURE SURVEY ON VARIOUS TYPES OF ABSORPTION EQUIPMENT AND THE OBJECTIVE OF THE PRESENT WORK
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5.1 Advantages and Disadvantages of Various Types of Absorption Equipment

The survey of literature on mass transfer in different types of equipment under different conditions clearly indicates that the efficiency of a mass transfer equipment can be increased by increasing (i) interfacial area, (ii) time of contact, and (iii) turbulence. For economical operation of the equipment, the pressure drop in the equipment should be kept as low as possible and throughput of gas and liquid should be as large as possible. It is generally not possible to take advantage of all the above factors in any particular equipment.

The apparatus that is most extensively used in the industry for absorption is the packed column. The packing assures a uniform distribution of gas and liquid across the cross-section of the column, but due to a high resistance to the flow of gas, pressure drop is comparatively large, and it is impossible to operate the equipment at high velocities. The high hydraulic resistance of packed absorption column made it necessary to develop other types of apparatus design which would allow higher throughput of gas and liquid and would work under low pressure drop. Columns with plane-o-parallel packings were the next step in the development of
boards, and other similar materials serve as the packing, which are placed on top of each other as parallel blocks in the tower. Raschig ring, when laid in an oriented fashion also belong to this category. Columns with such parallel packings are used mainly in various types of cooling chambers. Columns of this type have as yet not found extensive use in typical absorption processes for the reason that it is quite difficult to achieve uniformity of distribution of liquid and gas at a comparatively low flow rate of absorbent.

Similarly bubble cap columns also become inoperative at high throughput of gas and liquid as is evident from table-5.1. Pressure drop is also quite high. In case of spray towers, although it is possible to reduce the total weight of the apparatus and pressure drop still desired high throughput may not be achieved in the apparatus. The reason for this behaviour is to be found in the complex inter-relationship existing between the diffusion and hydrodynamic factors of the process. Another disadvantage of this type of apparatus is the high cost of fabrication and the difficulty of achieving a countercurrent regime of operation. Spray towers are best suited to those operations, such as air conditioning or deaeration of water, which requires very few transfer units. Agitated vessels are more suitable when there is a slow gas liquid reaction involving two or more phases than when there is only physical absorption, as
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Equipment</th>
<th>Optimum Gas Velocity meters/sec.</th>
<th>Wetting Density meters/hr.</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sieve Tray</td>
<td>1.5 - 2.0</td>
<td>50 - 150</td>
<td>165</td>
</tr>
<tr>
<td>2.</td>
<td>Bubble Cap</td>
<td>0.26 - 0.6</td>
<td></td>
<td>165</td>
</tr>
<tr>
<td>3.</td>
<td>Spiral Pipe Grid</td>
<td>0.40 - 1.8</td>
<td>13 - 94.5</td>
<td>165</td>
</tr>
<tr>
<td>4.</td>
<td>Pipe grid with vertical tube</td>
<td>1.32 - 1.67</td>
<td>15 - 25</td>
<td>165</td>
</tr>
<tr>
<td>5.</td>
<td>Plain grid timber</td>
<td>1.58 - 2.14</td>
<td>7.3</td>
<td>165</td>
</tr>
<tr>
<td>6.</td>
<td>Serrated grid timber</td>
<td>2.14 - 3.06</td>
<td>3.2</td>
<td>102</td>
</tr>
<tr>
<td>7.</td>
<td>Random ring ceramic</td>
<td>0.82 - 1.07</td>
<td>5.9</td>
<td>202</td>
</tr>
<tr>
<td>8.</td>
<td>Stacked ring ceramic</td>
<td>0.091</td>
<td>9.7</td>
<td>120</td>
</tr>
<tr>
<td>9.</td>
<td>Helical wire spiral column</td>
<td>4 - 7</td>
<td>1.0</td>
<td>166</td>
</tr>
</tbody>
</table>
The bubbles soon become depleted of solute gas and further contact with the liquid then serves very little purpose. These agitated vessels have an added disadvantage of large power requirements and large pressure drops.

Tubular absorbers with wetted surface are widely used for absorbing readily soluble gases from concentrated gas mixtures when heat is simultaneously removed. The hydraulic resistance of tubular absorbers and of absorbers with sheet packing is not great, even when gas velocities are comparatively high (4-5 m/sec). Absorber with ascending film operating at high gas velocities (above 15-20 m/sec.) are highly efficient, but their hydraulic resistance is considerable. The chief drawback of such absorber is the difficulty of ensuring uniform liquid feed over the wetted perimeter. Therefore, high wetting density must be applied. The interfacial area per unit volume is also relatively small. Stopcock type absorbers cannot be used in industry due to small contact time and small interfacial area and the complete absence of turbulence which result in low mass transfer rates. Vertical wire absorber suffers from the disadvantage of extremely small throughput of liquid thus rendering it unsuitable for industrial use. In case of venturi scrubber it is not possible to obtain a counterflow. It shows better performance when used for liquids having lower interfacial
tension such as certain industrial wastes. The beneficial effect of turbulence due to pulsation in a pulsating column is offset by the increased power input. Rotary column is more suited for the study of mass transfer mechanism than for being used as an industrial unit due to increased power input and small throughput of liquid as well as gas. Surface area available for mass transfer is not very large while the power input is very large due to friction caused by rotation of cylinders. Tubular columns with spiralling liquid flowing down the walls also suffer from these defects thus making them unsuitable for industrial use inspite of the fact that the residence time of the liquid in the columns is large as compared to the wetted wall columns.

Free sheets have a distinct advantage that for each sheet two surfaces are available for absorption. In addition, if the sheets are turbulent the mass transfer rate is expected to be high. Such equipment are also likely to have low pressure drop and low hold-up. However, the literature survey indicates that comparatively little information is available on equipment using free sheets. Bromley et al studied mass transfer using a flat free sheet and observed that the height of mass transfer unit based on gas phase was comparable to that in the packed beds while the pressure drop through the equipment was quite low. Other types of equipment like the Kloss-column and those used by Klimecek et al,119,120,
and Roy et al\textsuperscript{166,167,168} utilize spiralling free sheets. The advantage of a spiralling free sheet over a flat one is that the time of contact in the former is much more, resulting in an increased overall transfer. The hydrodynamic pattern in these equipment are complex.

Studies on Kloss column\textsuperscript{11} for rectification as well by Klimecek et al\textsuperscript{119} for absorption have been done on equipment in which large number of spirals were fixed in the column and there was every possibility of some of the spirals remaining dry due to non-uniform distribution of liquid. This has been reported by Bevers\textsuperscript{11} in his work on Kloss column. Double spirals were used for stabilization of liquid film in Kloss column, which resulted in a variable pitch and small dimensions of the resulting sheet. It has been further pointed out in this study that liquid accelerates and deaccelerates during its movement from the top to the bottom. All these factors result in complex hydrodynamic conditions. Klimecek et al\textsuperscript{119,120} in their studies used two types of liquid distributors. In their initial study they used a distribution trough with a hole punched at the bottom from which liquid was distributed over the spiral. In their later study the liquid from the top was sprayed over the helices fixed in the frame which resulted in extremely non-uniform distribution of liquid. In all these cases liquid flows vertically down under the action of gravity which hampers the helical flow quite substantially. Thus two
components namely vertically downward component due to gravity and radial component due to spiralling action act simultaneously and there is also short circuiting of liquid in the vertical direction, thus making complex hydrodynamic situation more complicated and very difficult for a theoretical analysis.

The work of Boy et al.\textsuperscript{166,168} on spiralling free sheets appear to be most encouraging as liquid distribution over the spirals is much better than in the case of Kloss and Klimecek columns. Also dimensions of the resulting sheet were larger than those of Kloss column. Experiments in Roy's work were conducted at very high gas velocities (4-7 m/sec.) and wetting densities of liquids, which sometimes resulted in a resonance with springs oscillating in the column.

5.2 Objective of the Present Work

The critical survey presented in the foregoing section indicates the tremendous possibility of mass transfer-equipment utilizing free liquid sheets. In this country no work has been reported on mass transfer studies utilizing free liquid sheets. Therefore, an experimental project was undertaken to study various aspects of this type of absorption columns.
The first part of the study consisted of investigating various methods of producing and stabilizing free-sheets in order to decide upon a suitable method of establishing a free-sheet within the experimental column. The second part of the investigation was to develop suitable apparatus/instrument for measurement of pressure drop and hold-up for hydrodynamic studies. The third part of the investigation was to study the actual performance of a suitable column or columns, to correlate the observed mass transfer rates with other variables and to compare the performance with that of other conventional types of column as well as to develop suitable theoretical equation for predicting mass transfer in free liquid sheet and apply this equation to the present work.

Literature survey indicates a wide variety of equations used by different authors to correlate their data. In order to compare these equations they were all transformed into the same form, namely,

\[ Sh = C \ Re_L^A \ Sc^B (\epsilon/2)^D \] \hspace{1cm} (2.13)

for liquid phase controlled mass transfer, and

\[ Sh = C_1 \ Re_G^A \ Sc_{g}^B \] \hspace{1cm} (2.99)

for gas phase controlled mass transfer.
These equations have already been incorporated in the literature survey (Chapter-II) and the values of constants obtained by various authors have been compared in tables 2.1 and 2.2. One of the objects of the present work was also to develop such correlations for the columns investigated.

Preliminary studies indicated that free sheets could be comparatively readily stabilized on a wire spiral or a wire gauze cylinder, in order to study their relative performance, as well as to have a comparison with a conventional column. A wetted wall column of similar dimensions was also investigated. Details of these studies are reported in the following chapters.