CHAPTER - I

I N T R O D U C T I O N

Entrainment is defined as the carry over of liquid droplets by a gas or vapour which either passes through the liquid or is generated from the body of the liquid. It is associated with vapour-liquid contact operations, for example, in distillation columns, evaporators, gas absorbers and steam raising equipments. In distillation column, it affects the column efficiency and product quality. In evaporators, it produces contamination of the condensate and loss of concentrated products. In steam boiler, it affects the quality of steam. This poses a serious problem in industrial operations in the form of loss of efficiency and product quality, contamination in the product and corrosion in equipments. The problem of entrainment as studied by a number of workers has been presented in standard text books and designs to avoid or trap the entrainment as far as possible, are suggested.

Earlier studies in entrainment were mainly related to specific fields of application[1-13]. Attempts were made to recommend the maximum allowable vapour velocity[2,6,7] in distillation columns under different operating conditions for optimum performance. In few other studies of entrainment in bubble cap and sieve plate columns, attempts were made to relate the entrainment with vapour and liquid rates, their physical properties and operating variables like plate spacing, slot submergence and slot dimensions[1,3-6] etc. The design and performance of various types of entrainment separators[3,8,9] also received a considerable attention.

Little work, however, is reported on correlations and prediction of the drop size and the amount of entrainment in the above cases. Simkin et.al.[14] proposed an emperical correlation of entrainment from data obtained in a 15-inch diameter column with two bubble caps per tray, using air-water and air-spindle oil systems. The results were compared with previous works and the correlation of amount of entrainment was expressed in terms of vapour load, liquid surface tensions, densities of liquid and vapour, tray spacing and liquid seal. The correlation, however, was based on limited data from a few isolated systems, under limited operating range. In a study of size distribution and entrainment, Garner et.al.[15] observed that the mean drop diameter is a function of the bubble diameter and liquid properties. Increased vapour velocity and submergence increased the amount of entrainment. Also, drops were observed to form both by bubble bursting and by disintegration of liquid jets arising from the bubble craters. An empirical relationship for entrainment in sieve trays has been proposed by Hunt et.al.[16] in terms of superficial vapour velocity, surface tension of the liquid and height above the foam. Akselrod et.al.[17] measured the liquid dispersion in interplate spacings and experimentally determined the relationship among the drop size, vapour velocity and the maximum height a drop can ascend. In a study of drop size and quantity of entrainment with single nozzle at bubble frequency of 500 - 2000 bubbles per minute, entrainment was correlated with mean drop diameter[18]. Bain et.al.[19] developed an empirical correlation of entrainment in a perforated plate column as a function of liquid and gas rates, physical properties of the liquid, slot dimension, plate spacing and weir height.

Few attempts, however, have been made to explain the mechanism of entrainment. Davis[20] attempted a theoritical study of entrainment and the mechanism of drop formation and developed a relationship to predict the initial projection velocities of droplets from single bubbles and surface tension considerations. An empirical correlation of drop diameter at a height above the liquid surface in terms of the height, superficial vapour velocity, initial projection velocity of the drops at the liquid surface and the densities of liquid and vapour was also presented. High speed photographs of bubble bursting at an air-liquid interface using a single nozzle at a bubble frequency of 60 bubbles per minute by Newitt et.al.[21] gave a detailed insight into the mechanism of drop formation from bubble bursting and further carry over of the drops as entrainment. A detailed analysis of drop ballistics under different bubbling conditions, such as, bubble size, depth of submergence, etc., was presented. The function of baffles as entrainment separators and the condition of re-entrainment from baffles were defined. At a depth of less than 0.32 cm., a continuous channel was observed giving rise to finer drops. Bubbles at shallow submergence produced less number of larger drops. In a study of bubble formation by rapid air flow through slots submerged in water, Spells[22] applied Rayleighs theoritical work on instability of cylindrical fluid surfaces to relate the length of the channels, connecting the bubble and slot to quantities such as air rate and liquid properties. This led to a definition of the boundary condition of change of mechanism from bubbling to channelling as a function of critical liquid level over the slot and the slot air velocity. Aiba et.al.[23] employed a biochemical technique for measuring the size distribution of entrained drops with water, water-butanol and water-glycerine solutions. In an attempt to relate the entrainment with bubble diameter, they showed that the mean bubble diameter is a cubic root function of the volume flow rate of air and the liquid surface tension. The drop-size distribution of entrainment was found to be logarithmic in nature in a study of entrainment in sieve trays by Cheng et.al.[24] The amount of entrainment was correlated in terms of the distance from the top of liquid level, density and surface tension of the liquid and the mean drop diameter, after considering the effect of projection velocity, drag and gravity. A high speed photographic study of coalescence and entrainment in sieve trays by Teller et.al.[25] revealed that the magnitude and average drop size of entrainment are related to the bubble coalescence in the liquid phase such that they increase with decrease in slot spacing. The bubble bursts do not contribute significantly to entrainment in multiple perforation geometry and the major contribution comes from the shear of the liquid walls by vapour flumes.

No study of entrainment of slurries, however, have been reported in literature as yet.