Chapter 5 Concluding Remarks and Recommendations for Future Work

5.1 Concluding Remarks

Several investigations are reported for single discharge and dual discharge employing different sizes of the branches mounted on the vertical flat surface or circular surface of the test chamber. Thus, when multiple branches mounted on both the sides of circular surface, no information is available in the open literature for determining the onset of gas entrainment. Therefore, the experiments were conducted to understand the effect of branch discharges by selecting the dimensions of the circular surface and branches in direct proportion to the PHWR header-feeder system. Experimental data are reported at the onset of gas entrainment, Froude number during discharge from a large stratified region through small circular branches of 9.0 mm diameter. Data were generated for five groups; each group corresponds to a particular branch combination. Group no. 1 contains the data of a single discharge, group no. 2 corresponds to dual discharge, group no. 3 corresponds to triple discharge, group no. 4 corresponds to quadruple discharge, and group no. 5 corresponds to quintuple discharge. The test matrix in these groups was designed to include data for various combinations of the branches.

The cases in various groups were investigated under the conditions of equal Froude number across the branches. Six hundred and forty data were collected in group nos. 1 to 5 covering the ranges of $6.4 < Fr_L < 27.5$ for different branch combinations. The independent variables were varied in a systematic way in order to facilitate the study of the influence of each variable separately. The following conclusions were drawn from the group nos. 1 to 5:

1. The diemensionless critical gas entrainment height for multiple discharges were mostly different from the single discharge.
2. Empirical relations were developed for the prediction of onset of gas entrainment. Comparisons between the empirical relations and experimental data were in very good agreement. However, these relations are empirical and therefore their accuracy is assured within the range of conditions covered in the present investigation.
3. Typically C_1 was different for single and multiple discharges.
4. Various branch combinations showed typically different C_1 for the branches.
5. The correaltin constant C_1 for inclined branch deviates significantly from the side and bottom branches durng single discharge.
6. In case of dual discharge (case nos. 2-A and 2-B), the discharge from the side branch lowered the C_1 of bottom branch and inclined branch mounted below it. On the other hand, the discharge from the inclined branch mounted opposite to the side branch could not be affected by the discharge from the side branch (case no 2-C).

The discharge from the inclined and bottom branches increased the C_1 of both the branches (case no. 2-E)

The simultaneious discharge from the two side branches (case no. 2-D) and two inclined branches (case no. 2-F) produced significantly different results. The change in C_1 of two inclined branches was significant compared to two side branches.

7. The C_1 was same for side, inclined, and bottom branches mounted on the same side of the circular surface during the simultaneous diacharge from them (case no. 3-A).

   During the discharges from two inclined and side branch (case no. 3-B), C_1 of inclined branch mounted on opposite to the side branch was higher than inclined branch mounted below the side branch. This effect disagree with the case no. 2-C.

   The case nos. 3-C, 3-D, 3-E, and 3-F showed the similar effects on the C_1 as dual discharge.

8. The effect of discharges from active branches on C_1, during quadruple and quintuple discharges were in agreement with dual discharge and/or triple discharge condition.

First time the experimental data are reported for side branches, inclinced branches, and bottom branch mounted on circular surface for various branch combinations during single and multiple discharge condition. A set of new correlaltions are presented for all the branch combinations during single and multiple discharges incorporating the following:

1. The effect of circular surface on onset of gas entrainment of the branches.
2. The effects of multiple discharges on onset of gas entrainment with different branch combinations.
3. It can be concluded that a set of correlations developed during the present study may be used for validation of existing thermal-hydraulic codes of PHWR.

5.2 Recommendations for Future Work

The present study has shown that the critical height at the onset of gas entrainment in small branches are dependent on the Froude number of the branch and different branch combinations during single and multiple discharges. The following recommendations are made for future work:

1. Experiments be conducted with wider range of Froude number of the branch.
2. Similar experiments be conducted on large and/or small scale PHWR header-feeder system to see how the scaling factor affects the dependent variables in experiment.
3. The present correlations be used to test and improve the existing computer codes to predict critical height at the onset of gas entrainment in header-feeder system of PHWR in postulated LOCA scenarios.
4. Experiments be conducted by using automatic control system which may provide better control over the variables. This could reduce the variation of Froude number among the branches.
5. The experiments be conducted by keeping the Froude number of one branch constant and varying the Froude number of the other branch/branches. This will

help to know the effect of variation of Froude number of the branch/branches on the onset of gas entrainment.

6. The experiments be conducted by lowering the interface height beyond the onset of gas entrainment and measuring the gas and liquid flow to know the quality of liquid-gas mixtures from the branches.
7. CFD analysis be attempted and the results could be compared with present experimental data.
8. Similar experiments be conducted by using different diameters of branches that are used in header to know the effect of branch diameter on the onset of gas entrainment.
9. The experiments be conducted by imposing axial velocity of liquid in the test chamber to know the effect of this on the critical height of the onset of gas entrainment of the branches.
10. The experiments be conducted by using more than one bank of header-feeder system to know the effect of one header-feeder bank on the other.
11. Theoretical model be developed to predict the critical height at the onset of gas entrainment for different branch combinations of single and multiple discharges.
12. The header design be optimized by carrying out the experiments at different branch angles.