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NUCL 355

Experiment 9: Air-Water Two-Phase Flow Patterns in Vertical Pipe

Objectives

1. Visualize and identify two-phase flow patterns in vertical pipe.
2. Develop flow pattern map and compare with maps in the literate for vertical two-phase flow.
3. Study pressure drop in vertical two-phase flow

Experimental Apparatus:

Schematic of the fully assembled experimental apparatus is show in Fig.1. The apparatus consist of:

(1) A 5.08 cm (2 inch) ID acrylic transparent test pipe of length about 3.3 meters
(2) Two-phase air-water injection system with air bubbler. The air-bubbler is made of sintered metal pipe with 10-micron pore size.
(3) The separator section at pipe exit with a return line to drain water back to the storage tank.
(4) Water feed line with a control valve and a magnetic flow meter to measure the liquid flow rate.
(5) Air supply line with a valve and rotameter to measure the air velocity.
(6) A DP cell connected across the length of the test section.

Experiment Procedure:

1. First start the air-supply to the rotameter before starting the water flow into the test section. Keep the air supply valve still closed.
2. Then start the air supply to the test section at slow rate.
3. Start the water supply to the test section and establish a two-phase flow in the test section.
4. Set required airflow rate and the water flow rate with valves and monitoring the magnetic flow mater and the rotameter readings. Initially start with small flow rates of air and water.
5. Observe and identify the flow patterns and make sketch of the flow pattern.
6. Record the pressure drop across the test section.
7. Keep water flow rate at one valve and vary the airflow rate in increasing steps. For each combination of air and water flow rates repeat step 5 and 6.
8. Increase the water flow rate in increasing steps and repeat step 7.
9. Make sure you cover all flow patterns possible with this loop.
10. After completion of the experiment, first reduce the water flow rate and stop the water flow by closing the valve. This will ensure there is no water flow back into the air-bubble system and to the rotameter. Following this close the air supply line valve.

Data Analysis

1. Your data comprises of (1) water flow rate, (2) air flow rate, (3) flow pattern Identification label, (4) pressure drop across the test section and (5) any other observation.

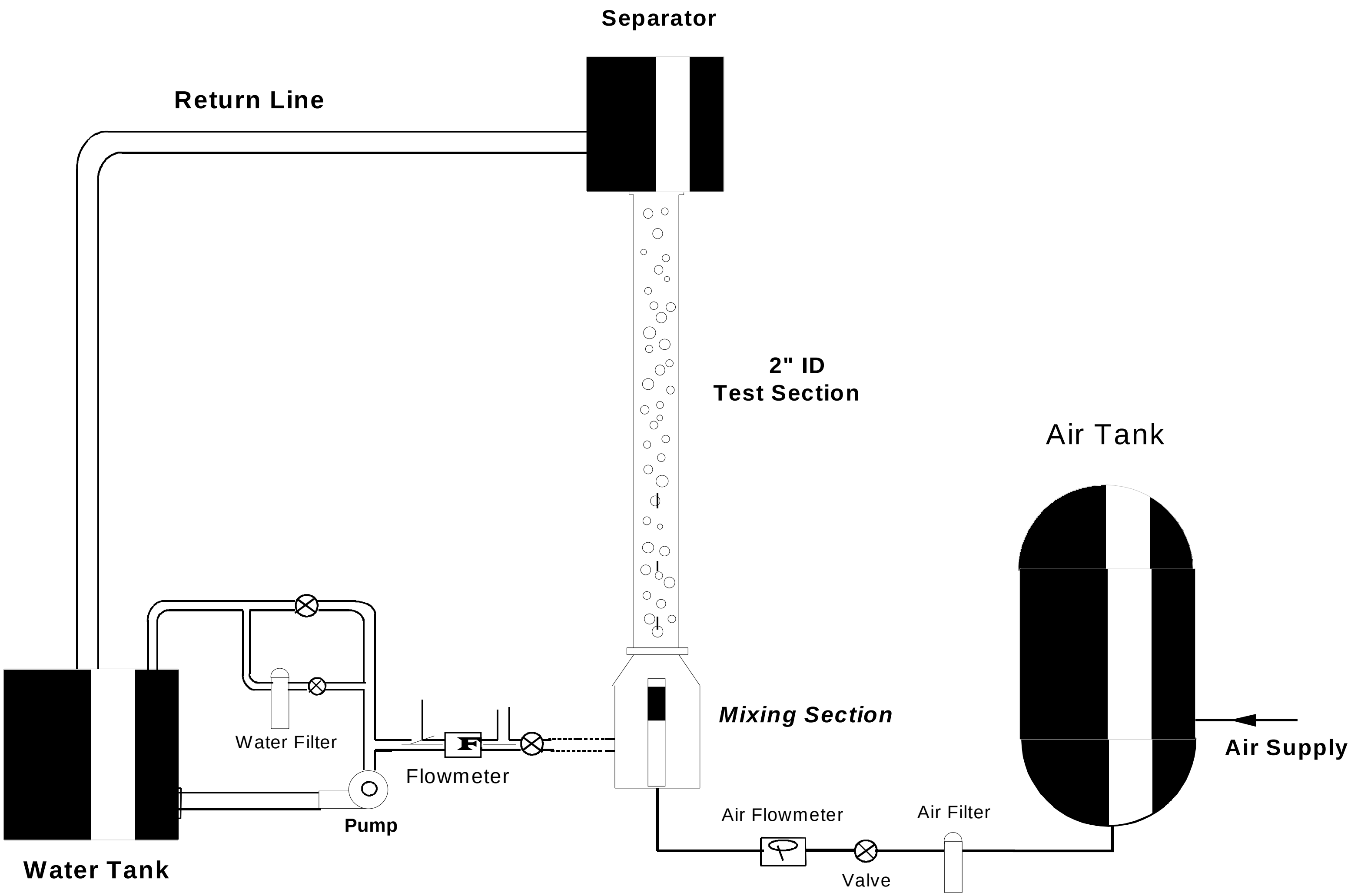
2. Calculate the superficial velocities of air and water flow.
3. Plot the flow pattern map from your data and compare with Manhane flow pattern map for the vertical pipe.
4. Calculate the dp/dx from the DP measurement and calculate the frictional pressure drop for each flow rates and plot flow rates vs dp/dx and frictional pressure drop.

Reference

1. Review the class text in Nucl-350 course.
2. Wallis, G.B., "One-Dimensional Two-Phase Flow," McGraw-Hill, 1969.
3. Lahey, R.T. and Moody, F.J., "The Thermal-Hydraulics of a Boiling Water Nuclear Reactor," American Nuclear Society, 1977.

Precautions

1. During start of the experiment do not start water flow into the test section before airflow is established.
2. At the conclusion of the experiment first close water flow and then close the air flow to avoid water ingression into the air bubble system



Two-phase Air-water Loop

Homogenous Model:

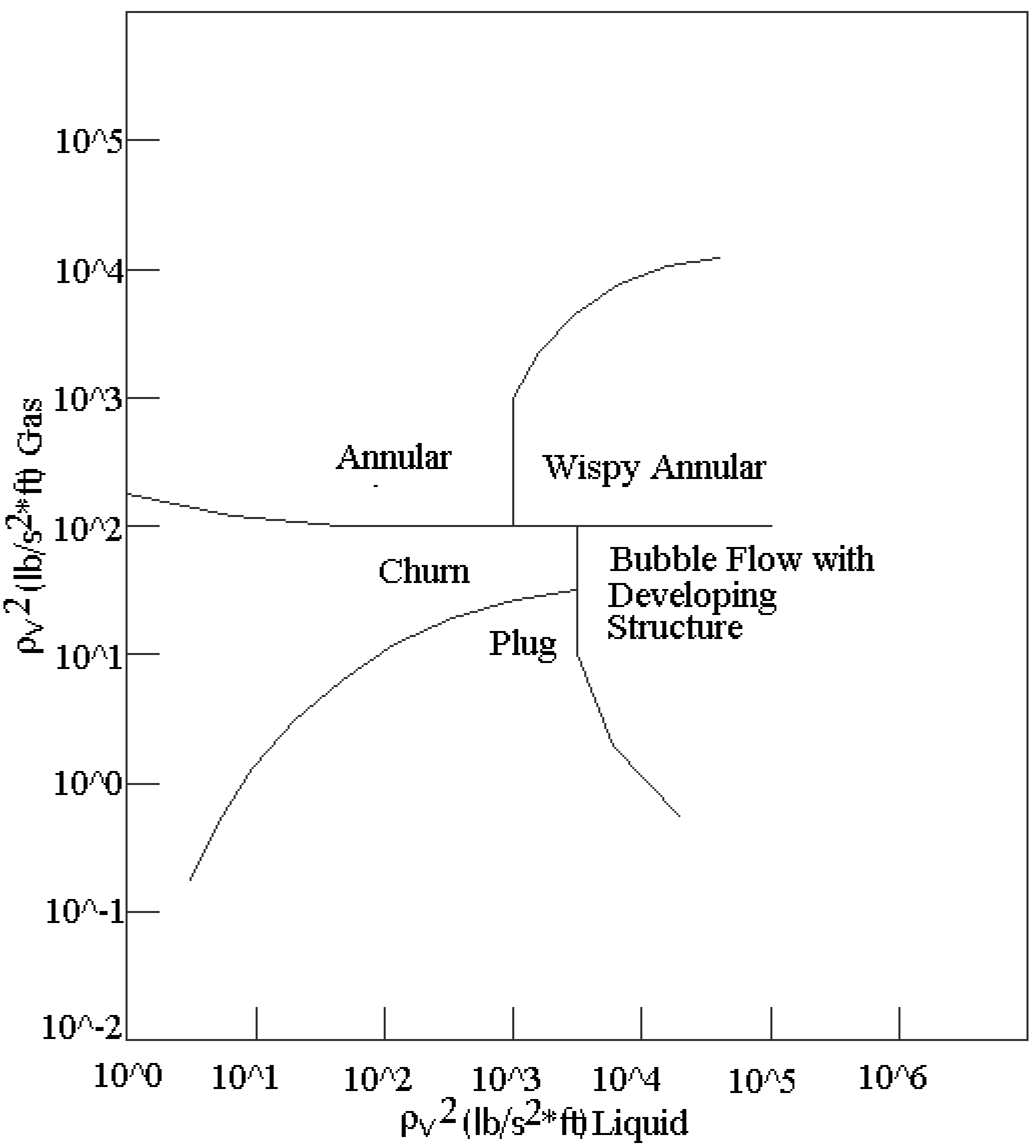
Variables:
Pf = Pressure Drop Due to Friction
Pa = Pressure Drop Due to Acceleration
Pz = Pressure Drop Due to Height Change
Vaverage = Average Specific Volume
Vwater = Water Specific Volume
Vair = Air Specific Volume
x = Flow Quality
Mrateair = Air Mass Flow Rate
Mratewater = Water Mass Flow Rate
G = Momentum Flux

Assumptions:
1.) Pa = 0
2.) Steady State Conditions
3.) Uniform Flow Velocity Distribution

$$-\left(\frac{d}{dz}P_{total}\right) := -\left(\frac{d}{dz}P_f\right) - \left(\frac{d}{dz}P_a\right) - \left(\frac{d}{dz}P_z\right) \qquad V_{average} := x\cdot V_{air} + (1-x)\cdot V_{water}$$

$$-\left(\frac{d}{dz}P_{z.}\right) := \frac{g}{V_{average}} \qquad -\left(\frac{d}{dz}P_f\right) := \frac{2\cdot f_{TP}\cdot G^2\cdot V_{average}}{D} \qquad x := \frac{M_{rateair}}{M_{rateair} + M_{ratewater}}$$

$$\left(\frac{d}{dz}P_f\right) := \left(\frac{d}{dz}P_{total}\right) + \frac{g}{V_{average}}$$



Flow Pattern Map (Vertical Channel)