CHAPTER V
CONCLUSIONS

Viscosity effect on flow regime boundaries of each flow regime was determined and illustrated. As liquid viscosity increases, the boundaries of the bubble, the bubble-slug and the slug flow regimes in aqueous glycerol solution shift to the right relative to those of pure water. However, the boundaries for the churn, the annular and the mist flow regimes remained nearly the same. In the bubble, the bubble-slug and the slug flows, the critical Reynolds numbers of air, $(Re_{air})_{critical}$ were low and the flow was evidently laminar. So, the effect of viscosity was more pronounced in these regimes. For the churn, the annular and the mist flows, critical Reynolds numbers of air, $(Re_{air})_{critical}$ were high and flows were clearly turbulent. So, the effect of viscosity in these regimes is relatively less.

The viscosity effect on fluctuations of pressure gradients was clearly evident in all flow regimes. The fluctuation of pressure gradients, $(-dp/dz)_{exp}$, were less in the aqueous glycerol solution than those in pure water. The highest fluctuations occurred in the slug and the slug-churn transition regimes for both pure water and the aqueous glycerol solutions.

The proposed theories for the pressure gradient by Nicklin, Wilkes, and Davidson (1962) for the bubble and the slug flow regimes and are moderately in good agreement with measured values. For the bubble flow regime, the pressure gradient can be predicted from the following equation:

$$\left(-\frac{dp}{dz}\right) = \rho_L\, g\,(1-\varepsilon) \quad ; \qquad \varepsilon = \frac{Q_G}{(Q_G + Q_L) + u_b\, A}$$

For the slug flow regime, the pressure gradient can be predicted from the following equation:

$$\left(-\frac{dp}{dz}\right) = (1-\varepsilon)\left[\rho_L\, g + \left(\frac{dp}{dz}\right)_{sp}\right] \; ; \quad \left(-\frac{dp}{dz}\right)_{sp} = \frac{2 f_F\, \rho_L \overline{u_L}^{\,2}}{D}$$

$$\varepsilon = \frac{Q_G}{1.2(Q_G + Q_L) + u_b\, A}$$

The proposed theories for the pressure gradient by Wallis (1969) for the annular and the mist flow regimes are moderately in good agreement with measured values. For the annular and the mist flow regimes, the pressure gradient can be predicted from the following equation:

$$\left(\frac{dp}{dz}\right)_{tp} = \left(\frac{dp}{dz}\right)_{g} = -\frac{2f_F\ \rho_g\ v_g^2}{D_g} - \rho_g g = \phi_g^2\left(\frac{dp}{dz}\right)_{go} - \rho_g g$$

$$\left(\frac{dp}{dz}\right)_{tp} = \phi_l^2\left(\frac{dp}{dz}\right)_{lo} - \left[\varepsilon\rho_g + (1-\varepsilon)\rho_l\right]g$$

At low water Reynolds number, Re_{water}, the predicted $(-dp/dz)_{cal}$ values from the theory agree well with the measured $(-dp/dz)_{exp}$ values. At high water Reynolds number, the predicted $(-dp/dz)_{cal}$ values were lower than the measured values in the annular and the mist flow regimes. For 50 vol% glycerol solution, the predicted $(-dp/dz)_{cal}$ values are always lower than the measured $(-dp/dz)_{exp}$ values.

The predicted values agree with the measured data within an accuracy of $\pm$20% for the bubble flow, $\pm$15% for the slug flow, and $\pm$40% for annular and mist flow for the air-pure water mixture.

For air-50 vol% glycerol solution mixture, the predicted values agreed with measured data within an accuracy of $\pm$15% for the bubble flow, $\pm$30% for the slug flow, and $\pm$40% for the annular and the mist flow.