Examples of Flow Regime Maps

Despite the issues and reservations discussed in the preceding section it is useful to provide some examples of flow regime maps along with the definitions that help distinguish the various regimes. We choose to select the first examples from the flows of mixtures of gas and liquid in horizontal and vertical tubes, mostly because these flows are of considerable industrial interest. However, many other types of flow regime maps could be used as examples and some appear elsewhere in this book; examples are the flow regimes described in the next section and those for granular flows indicated in section (Np).

We begin with gas/liquid flows in horizontal pipes (see, for example, Hubbard and Dukler 1966, Wallis 1969, Weisman 1983). Figure 1 shows the occurence of different flow regimes for the flow of an air/water mixture in a horizontal, $5.1cm$ diameter pipe where the regimes are distinguished visually using the definitions in figure 2. The experimentally observed transition regions are shown by the hatched areas in figure 1. The solid lines represent theoretical predictions some of which are discussed later in this chapter. Note that in a mass flux map like this the ratio of the ordinate to the abscissa is $\mathcal{X}/(1-\mathcal{X})$ and therefore the mass quality, $\mathcal{X}$, is known at every point in the map. There are many industrial processes in which the mass quality is a key flow parameter and therefore mass flux maps are often preferred.

Other examples of flow regime maps for horizontal air/water flow (by different investigators) are shown in figures 3 and 4. These maps plot the volumetric fluxes rather than the mass fluxes but since the densities of the liquid and gas in these experiments are relatively constant, there is a rough equivalence. Note that in a volumetric flux map the ratio of the ordinate to the abscissa is $\beta/(1-\beta)$and therefore the volumetric quality, β, is known at every point in the map.

Figure 4 shows how the boundaries were observed to change with pipe diameter. Moreover, figures 1 and 4

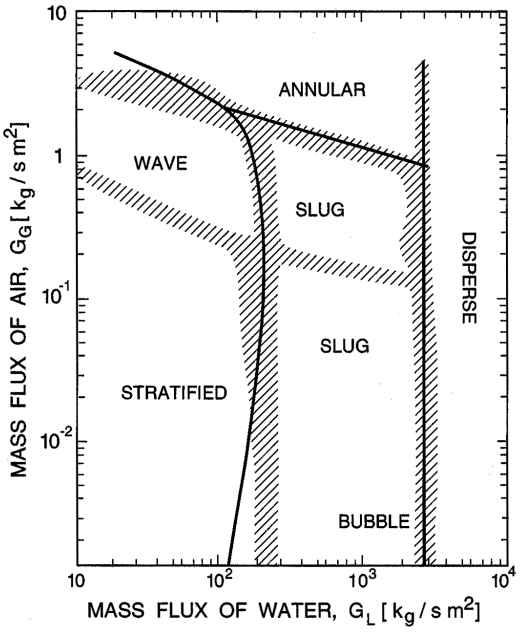

Figure 1: Flow regime map for the horizontal flow of an air/water mixture in a $5.1cm$ diameter pipe with flow regimes as defined in figure 2. Hatched regions are observed regime boundaries, lines are theoretical predictions. Adapted from Weisman (1983).

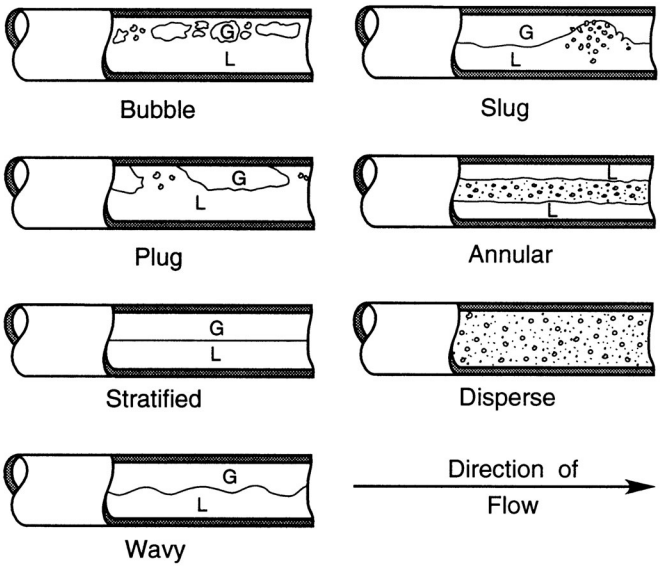

Figure 2: Sketches of flow regimes for flow of air/water mixtures in a horizontal, 5.1cm diameter pipe. Adapted from Weisman (1983).

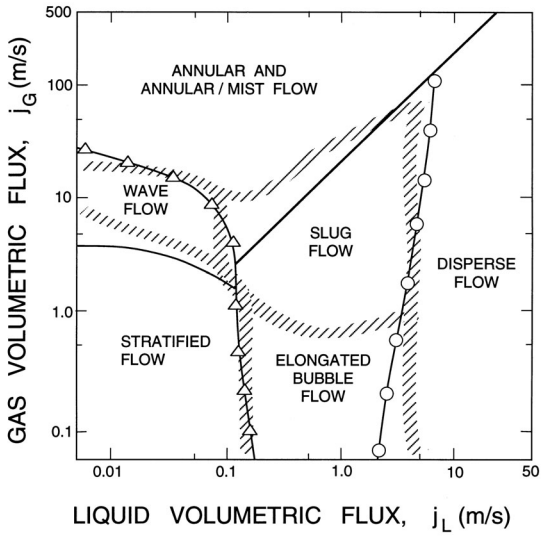

Figure 3: A flow regime map for the flow of an air/water mixture in a horizontal, 2.5cm diameter pipe at 25°C and 1bar. Solid lines and points are experimental observations of the transition conditions while the hatched zones represent theoretical predictions. From Mandhane *et al.* (1974).

appear to correspond fairly closely. Note that both show well-mixed regimes occuring above some critical liquid flux and above some critical gas flux; we expand further on this in section (Njf).

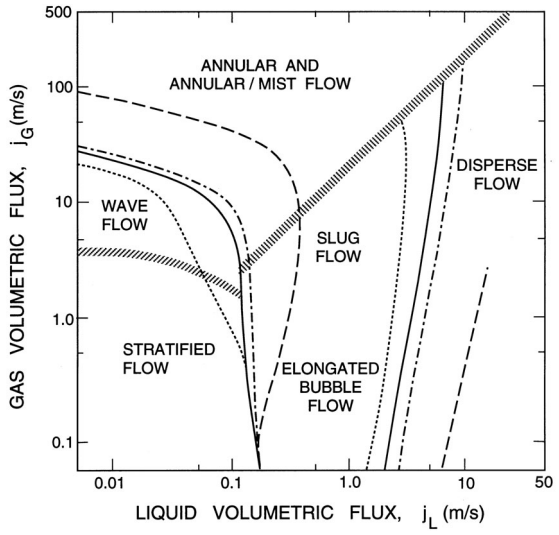

Figure 4: Same as figure 3 but showing changes in the flow regime boundaries for various pipe diameters: $1.25cm$ (dotted lines), $2.5cm$ (solid lines), $5cm$ (dash-dot lines) and $30cm$ (dashed lines). From Mandhane *et al.* (1974).