6.6.3 Ledinegg instability

Sometimes a multiphase flow instability is the result of a non-monotonic pipeline characteristic. Perhaps the best known example is the Ledinegg instability (Ledinegg 1983) that is depicted in figure 1. This occurs in boiler tubes through which the flow is forced either by an imposed pressure difference or by a pump as sketched in figure 1. If the heat supplied to the boiler tube is roughly independent of the flow rate, then, at high flow rates, the flow will remain mostly liquid since, as discussed in section 6.2.5, $d\mathcal{X}/ds$ is inversely proportional to the flow rate (see equation 12, section 6.3.4). Therefore $\mathcal{X}$ remains small. On the other hand, at low flow rates, the flow may become mostly vapor since $d\mathcal{X}/ds$ is large. The pipeline characteristic for such a flow (graph of pressure drop versus mass flow rate) is constructed by first considering the two hypothetical characteristics for all-vapor flow and for all-liquid flow. The rough form of these are shown in figure 1; since the frictional losses at high Reynolds numbers are proportional to $\dot{m}^2/\rho$, the all-vapor characteristic lies above the all-liquid line because of the lower density. However, as the flow rate, $\dot{m}$, increases, the actual characteristic must make a transition from the all-vapor line to the all-liquid line, and may therefore have the non-monotonic form sketched in figure 1. Now the system will operate at the point where this characteristic intersects the pump characteristic (or pressure characteristic) driving the flow. This is shown by the solid line(s) in figure 1.

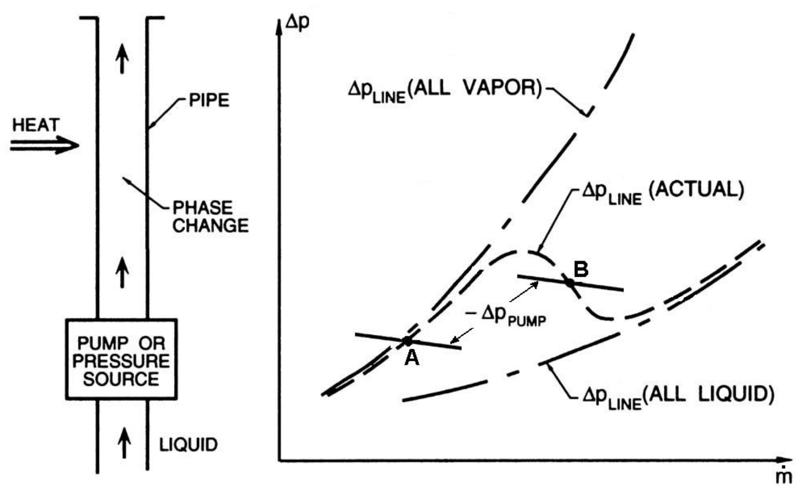

Figure 1: Sketch illustrating the Ledinegg instability.

Several examples are shown in figure 1. An operating point such as A where the slope of the pipeline characteristic is greater than the slope of the pump characteristic will be a stable operating point. This is almost always the case with single phase flow (see Brennen (2005) for further detail). On the other hand, an operating point such as B is unstable and leads in this example to the Ledinegg instability in which the operation oscillates back and forth across the unstable region producing periods of mostly liquid flow interspersed with periods of mostly vapor flow. The instability is most familiar as the phenomenon that occurs in a coffee percolator.