Other Flow Measurements

Instruments and methods to measure other flow characteristics could include the following properties:

Void or volume fraction: In multiphase flows it is often desirable to measure the volume (or mass) fraction or the volume (or mass) quality of the flow. There are, of course, numerous types of multiphase flow and each of these may, in turn, manifest a number of different flow patterns (see section (N)). Each of these presents its own challenge in terms of measurement of the volume fraction (see, for example, Orbeck 1962, Olsen 1967, Jones and Delhaye 1976, Cimorelli and Evangelisti 1967, 1969) and it is not possible to cover all of these instruments in this book. Most of this instrumentation is experimental. But is may be appropriate to mention a few of the techniques that have been used:

- **Gamma-ray or x-ray densitometers** have frequently been used to measure an average void fraction in gas/liquid flows. A radiation source is placed on one side of the tube containing the multiphase flow and the signal collected by a detector on the other side of the tube is used to evaluate the gas volume fraction in the tube. Sometimes a tomographic arrangement such as that described in section (Kdba) and depicted in Figure 1 is used in which the volume fraction, α_k, is evaluated in K regions of the tube cross-section, $k = 1 \rightarrow K$. Instrumentation is set up around the whole region in order to measure total attenuation, a, of the radiation along J different trajectories through the region where $J > K$. The object of the tomographic data reduction is to determine the values of α_k, $k = 1 \rightarrow K$ that best fit the attenuation measurements, a_j, $j = 1 \rightarrow J$. A matrix inversion procedure is required for this purpose. This can be very computationally intensive especially when high resolution results are desired.

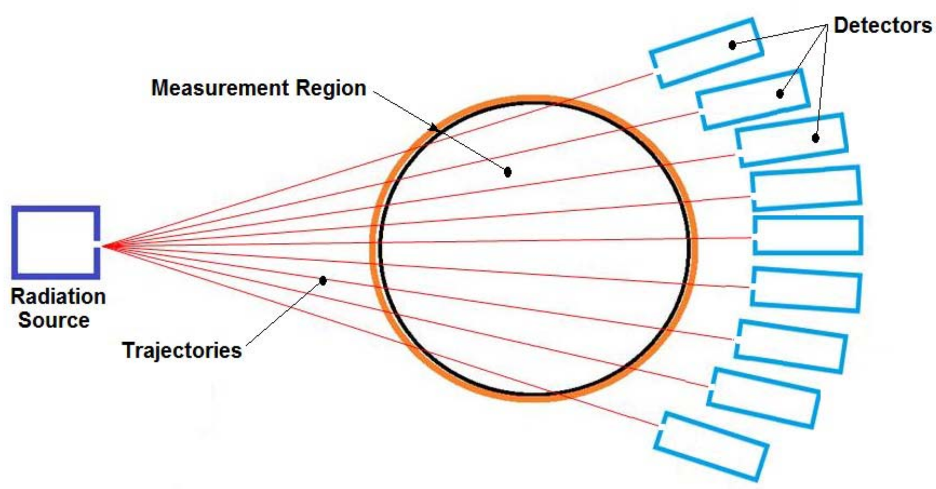

Figure 1: Schematic of a single source, tomographic arrangement deployed around a tube containing a flow.

- **Intrusive Volume Quality Probes** measure the volume quality at a location in a gas/liquid flow by detecting whether the end of the probe is surrounded by gas or liquid. Sometimes this is done optically using a fibre optic probe that registers a signal only if the probe end is surrounded by one of the phases but not the other. Then straightforward signal processing yields the local volume quality. Other electrical and thermal probes can be used for the same purpose.

A similar technique can be used to measure the solid fraction of a granular flow or suspension at a boundary wall. A fiber optic probe consisting of both transmitting and receiving fibers is positioned flush in the surface of the wall. When a particle of the granular material or suspension is located immediately on top of the probe end, light from the transmitting fibers is reflected back into the receiving fibers and the signal is registered by a photoelectric cell at the other end of the receiving fibers. By analyzing this signal the fraction of time that a particle occupies the space next to the end of the probe can be measured and, provided some system of calibration is arranged, this can be converted to a wall solid fraction.

- **An Electromagnetic Flowmeter** (see section (Kdcc)) in a two phase liquid/gas flow measures the average velocity of the continuous liquid phase provided this has some minimum electrical conductivity. Therefore is an independent measurement of the liquid flowrate is available the volume quality can be obtained. The calibration is quite independent of void fraction, flow regime, axisymmetric velocity profile, or the electrical conductivity of the continuous liquid phase. Consequently, the meter has substantial dynamic capability which can be very useful in monitoring these unsteady two-phase flows (Hori *et al.* 1966, Heineman *et al.* 1963).

Contamination and/or nucleation sites: In some fluid flows it is important to measure the number density of very small particles. For example, cavitation in liquid flows usually originates with micron-sized cavitation nuclei that are present in the liquid; these may be small micro-bubbles or other suspended material. Monitoring the number density distribution of these cavitation nuclei can be important in documenting a cavitating flow. Other flows such as air quality monitoring flows also require the measurement of the number distribution of small particles contaminating the flow. Laser scattering techniques have been developed for these kinds of purposes as have holographic methods that allow counting the particles in the holographic reconstruction.

Chemical content of a flow is sometimes desired and a variety of sophisicated but usually expensive instruments could be used for this purpose. An example is the use of magnetic resonance devices to determine the chemical content.