Transducers

The basic pressure gauge described in section (Kdda) gradually evolved into the modern pressure transducer as more devices for the measurement of deflection became available and the transducer took on the form shown in Figure 2. Today many different types of pressure transducer are available. While these types are of a variety of shapes and sizes, they also use a wide range of different devices to measure the diaphragm displacement.

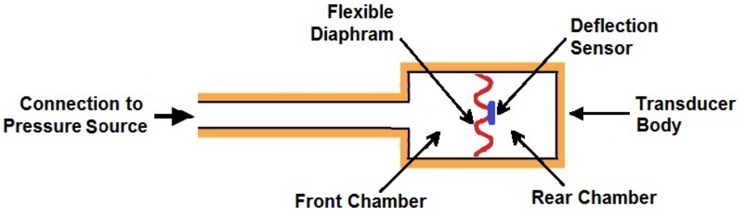

Figure 1: The basic pressure transducer for remote pressure measurement.

The commonest pressure transducer uses strain gauges (see section (Kddc)) to measure the displacement. Consequently there is a subset of transducers corresponding to the various kinds of strain gauges. The sensitivity of these common pressure transducers depends not only on the stiffness of the diaphragm but also on the gauge factor of the strain gauges used. Typically pressure transducers are labeled for a specific range of pressures and the sensitivity is normally proportional to the quoted upper limit of that range. Therefore care is required to select a pressure transducer appropriate to the range of pressure measurements anticipated. Other devices use different techniques and methods to measure the deflection. Capacitive transducers are designed to mimic a variable capacitor so that the measurement of that capacitance detects the deflection and therefore the pressure. Electromagnetic transducers use and induction coil to measure the deflection; they can come with a series of metal diaphragms and can be very useful for the measurement of small pressure differences. Optical techniques are similarly useful in measuring deflections, particularly small deflections. Piezoelectric transducers use the piezoelectric effect in certain materials such as quartz to measure the strain; they are particularly value in measuring dynamic, unsteady pressures and sound. Many variants exist but the details are beyond the scope of this book.

The measurement of unsteady pressures or sound can be particularly difficult not only because transducers may be frequency-dependent but also because they may be directionally sensitive. Therefore acoustic transducers (microphones) come not only with frequency limitations but also with directional charts indicating the dependence of the sensitivity on the direction of approach of the sound. The same is true of hydrophones designed to detect sound in a liquid environment. Some acoustic transducers or hydrophones are designed to be relatively free of this directional sensitivity though this can be difficult to achieve at high frequencies.

Transducers come in several deployment configurations. Some are flush-mounted in the wall of a tube or vessel as shown in Figure 2 and are used in this configuration in order to have an optimal dynamic response. Typically those are of the piezoelectric type. For more robust use a tube may connected a tap in the side of the pipe or vessel with the internal volume of the transducer as depicted in Figure 3.

This is referred to as a remote transducer. Sometimes a whole array of connection tubes are connected through a scanning valve to a remote transducer.

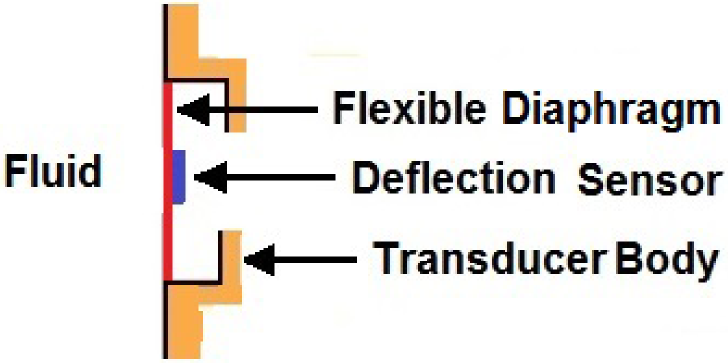

Figure 2: Schematic of a flush-mounted pressure transducer.

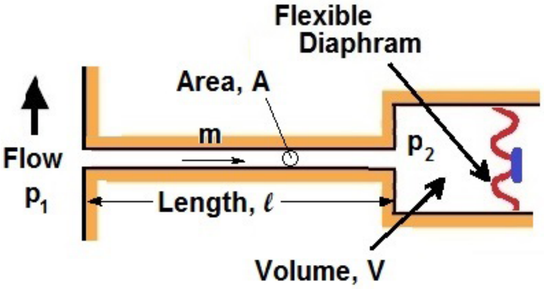

Figure 3: The attachment arrangement of a remote pressure transducer.

The frequency response of an individual remote transducer is then limited by the dynamic response of the connection tube whose length and area we denote by ℓ and A. As demonstrated in section (Bnda), the pressures, p_1 and p_2, at the two ends of the connection tube are related through the unsteady Bernoulli equation to the rate of change with time of the mass flow rate, m, in that tube:

$$p_1 - p_2 = \frac{\ell}{A}\left\{\frac{dm}{dt}\right\} \tag{Kddd1}$$

But dm/dt must be equal to $\rho(dV/dt)$ where ρ is the fluid density and V is the internal volume of the transducer which will change with the internal pressure, p_2, and be dependent on the flexibility of the transducer diaphragm. Representing that relation by $dV/dt = \kappa\ dp_2/dt$ it follows that the response of the combination of the connection tube and the transducer to the measured pressure, p_1, is

$$p_1 - p_2 = \frac{\ell}{A}\left\{\kappa\rho\frac{dp_2}{dt}\right\} \tag{Kddd2}$$

It follows that the radian resonance frequency, ω, of the combination when p_1 is constant is given by

$$\omega = \sqrt{\frac{A}{\kappa\rho\ell}} \tag{Kddd3}$$

Such an instrument will only be able to accurately measure fluctuating pressures with frequencies well below ω. Note that as the connection tube gets longer (or as its cross-sectional area gets smaller, the limiting frequency gets lower and lower. Hence the measurement of high frequencies often requires flush-mounted transducers with $\ell \rightarrow 0$.

Sometimes the frequency response of a flush-mounted transducer is desired but direct exposure of the transducer face to the flow risks damage and, perhaps, destruction of the transducer. Just is the case in cavitating liquid flows in which a very high frequency response is needed to capture the details of the shock waves caused by cavitation. in these circumstances the hybrid, nearly-flush mounted arrangement depicted in Figure 4 is used. In such an arrangement care must be taken to eliminate any air bubble from the front chamber for this will radically degrade the frequency response.

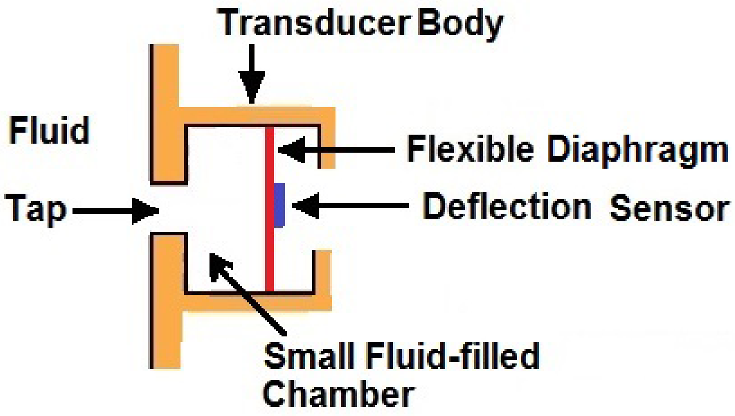

Figure 4: Schematic of a nearly-flush-mounted pressure transducer with guard.