2.4 PRESSURE SENSORS

The principle of all pressure systems is to measure the hydrostatic pressure of the water column at a fixed point and convert that pressure into a level.

2.4.1 PNEUMATIC BUBBLER SYSTEMS

In a pneumatic bubbler system air is passed at a metered rate through a small bore tube to a pressure point fixed below the lowest expected tide level (Figure 2.2). Provided that the air flow rate is low and the air supply tube is not too long the pressure of the air in the system will equal the hydrostatic pressure plus atmospheric pressure. A pressure recording instrument connected into the air supply tube will now record changes in water level as changes in pressure.

The measured pressure P_m is related to the water level above the pressure point outlet by the hydrostatic relationship :-

$$P_m = Dgh + P_a$$

where
- P_m = measured pressure
- D = water density
- g = gravitational acceleration
- h = water head above the pressure point outlet
- P_a = atmospheric pressure

If the pressure P_m is measured using a differential transducer then the pressure is

$$P_m = Dgh$$

It is necessary therefore to know the site water density and gravitational constant for the accurate conversion of pressure to height.

(i) Pressure Point

The pressure point normally takes the form of a short vertical cylinder with a closed top face and open at the bottom. The metered air enters through a fitting in the top of the pressure point and escapes through a small bleed hole 4mm diameter drilled 5cm from the open end of the cylinder.

The pressure point should be fixed rigidly to a stable structure with the closed end uppermost, horizontal and with the open end not less than 0.5 metres from the sea bed, ideally about two metres below LAT.

The diameter of the pressure point is dependant on the length of the air supply tube beyond the flow control valve. As a general guide the volume of the pressure point above the bleed hole should be at least equal to the volume of the air supply line.

The pressure point should be constructed of such materials to be able to resist corrosion, cracking and attack from marine organisms. It is advisable to sleeve the bleed hole with copper which will help prevent marine growth at this vital point.

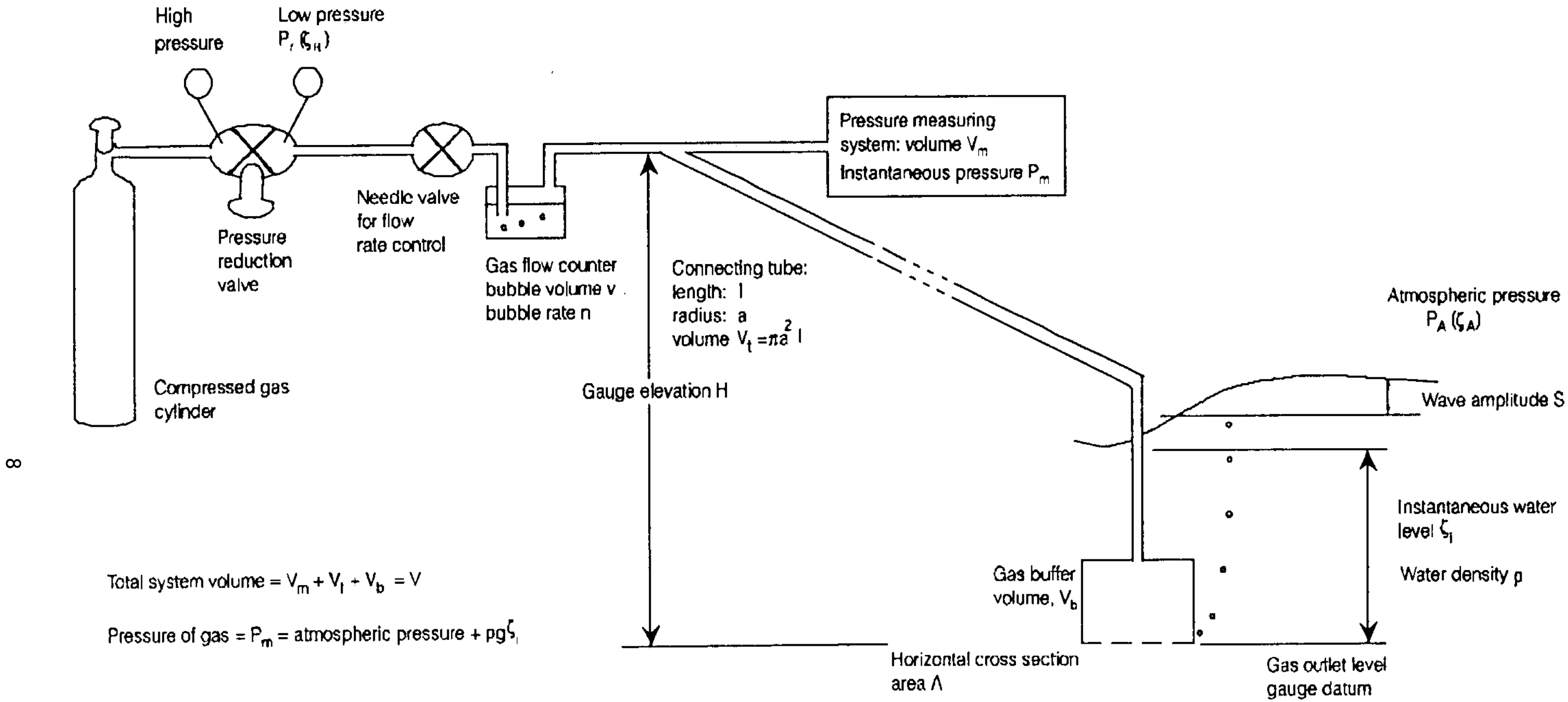

Figure 2.2

Schematic diagram of the pneumatic tide gauge and its principal system parameters

(ii) Air Supply Tube

The tube supplying air to the pressure point should be of a corrosion free non-kinking material. Nylon tube within a protective sheath should be used. Tubing with an outside diameter of 6mm and a bore of 4mm is recommended for systems with tube length up to 200 metres.

As the air enters the pressure point it becomes compressed and pushes the water down until it reaches the bleed hole where it escapes and bubbles up to the surface.

The tubing should be protected where necessary by laying it in conduit, sheathing or metal casing. It should be securely fixed to withstand the most severe weather conditions. Where tubing is laid along piers, quays or wharfs it must be positioned so as to avoid abrasive scuffing from vessels and mooring lines.

(iii) Pneumatic Controls

The pneumatic control panel should be designed to provide :-

a) Air to the pressure point metered at a constant and controllable rate.

b) The ability to purge the system with air at a very high flow rate.

c) Protection against over pressurisation for the controls and instruments.

The diagram (Figure 2.3) shows a typical circuit for a pneumatic control panel incorporating these features.

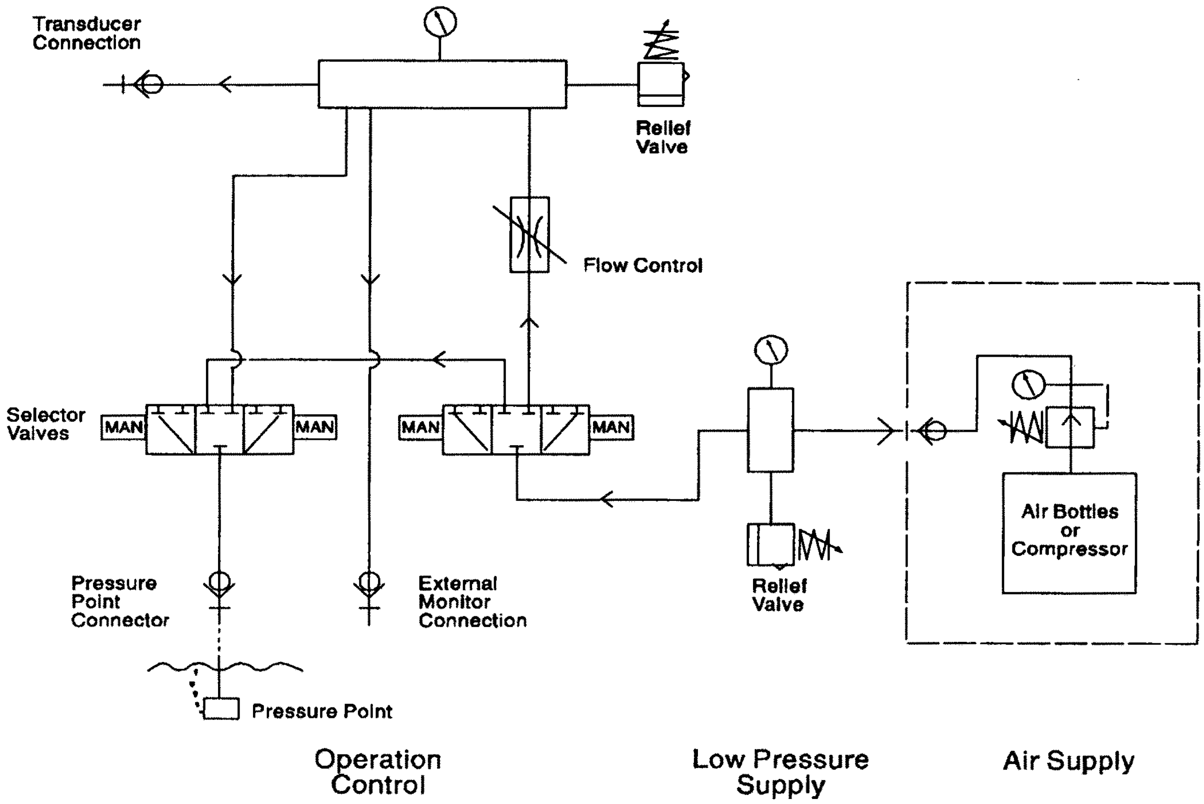

Figure 2.3

Schematic diagram of control equipment

The air supply may be derived from high pressure air bottles or a compressor. Where a compressor is used the air receiver should be large enough to provide a supply for five days in the event of compressor breakdown or failure of the electricity supply.

The air must be passed through moisture and particle filters before being regulated to supply a constant pressure of between 3 to 4 bars. A pressure gauge should be fitted to the unit to indicate this pressure. A relief valve is required to prevent the pressure downstream of this regulator exceeding 5 bars.

A flow control valve and indicator operating from the supply pressure is required to meter air to the pressure point. The flow rate required is dependant on the tidal range and the volume of the system but must be sufficient to maintain a flow of bubbles from the pressure point on the fastest rising tide.

Tappings for the tidal recording instruments are taken from a point on the supply to the pressure point downstream of the flow control valve. A pressure gauge should be incorporated to indicate this downstream pressure. A relief valve must be incorporated to protect the instruments from overpressurising.

A purging system is required to enable an unrestricted air flow to pass from the supply to the pressure point. During purging the instrument must be isolated from the supply.

It is essential that all pneumatic valves, connectors and fittings used in the construction of the pneumatic panel are of the highest quality since any leakage in the system downstream of the flow control valve will produce an error in the indicated system pressure. Leakage elsewhere in the system will increase the volume of air consumed which can be critical when the air is supplied from high pressure air cylinders.

(iv) Design Criteria for Pneumatic Bubbler Systems

Care must be exercised in the design of pneumatic systems in order to minimise errors in measurement. Where sources of error cannot be eliminated their effect must be known so that corrections can be applied to the measured pressures. The major criteria are listed below together with equations from which the magnitude of measuring errors can be deduced.

(v) Minimum Gas Flow Rate

Gas must be passed into the bubbler system at a rate that is sufficient to maintain the system pressure equal to the water pressure at the pressure point at the fastest rising tide, so that the bleed hole emits bubbles at all times.

$$f > \frac{V}{10} R_{max} \text{ (ml/sec)}$$

where f = gas flow rate

V = total volume of system (ml)

R_{max} = max rate of rise in water level (m/sec)

(vi) Static Pressure Head

For all designs the measuring point will be at higher elevation than the pressure point outlet. Consequently the pressure of the gas in the system will differ at the two points in accordance with the difference in elevation and the gas pressure :-

$$P_m = (\rho - P_{oa}(\frac{H}{\gamma_A} + 1))\ gh$$

where	P_m	=	measured pressure
	ρ	=	water density
	P_{oa}	=	air density at atmospheric pressure
	H	=	elevation of measuring point above pressure point outlet
	γ_A	=	water level equivalent of atmospheric pressure
	h	=	depth of water above pressure point outlet
	g	=	gravitational acceleration

(vii) Dynamic Pressure Gradient

When gas is passed through a tube a pressure gradient along the tube will result due to the gas viscosity, the magnitude of the pressure drop being dependent on tube dimensions and gas flow rate in the following relationship :-

$$\Delta P = \frac{8\eta l}{\Pi a^2}\left(f - \frac{\Delta P_m}{P_m}\left(V_m + \frac{\Pi a^2 l}{2} \right) \right)$$

where	ΔP	=	pressure drop
	η	=	gas viscosity at system temperature
	l	=	length of tube
	a	=	radius of tube
	f	=	gas flow rate
	ΔP_m	=	incremental change in Pm in unit time
	P_m	=	instantaneous pressure at measuring device
	V_m	=	volume of measuring device

In most designs of pressure transducer V_m is very small and can be ignored; the relation then becomes :-

$$\Delta P = \frac{8\eta l}{\Pi a^2}\left(f - \frac{\Delta P_m}{2P_m} \Pi a^2 l \right)$$

2.4.2 DIRECT READING SYSTEMS

The sea level may be measured by fixing a waterproof pressure transducer below the lowest expected tide level (Figure 2.4) with the power/signal cable connected to an on-shore data logging unit. If a vented power/signal cable is used a differential transducer may be fitted with the reference side of the transducer vented to atmosphere providing continuous correction for changes in atmospheric pressure.

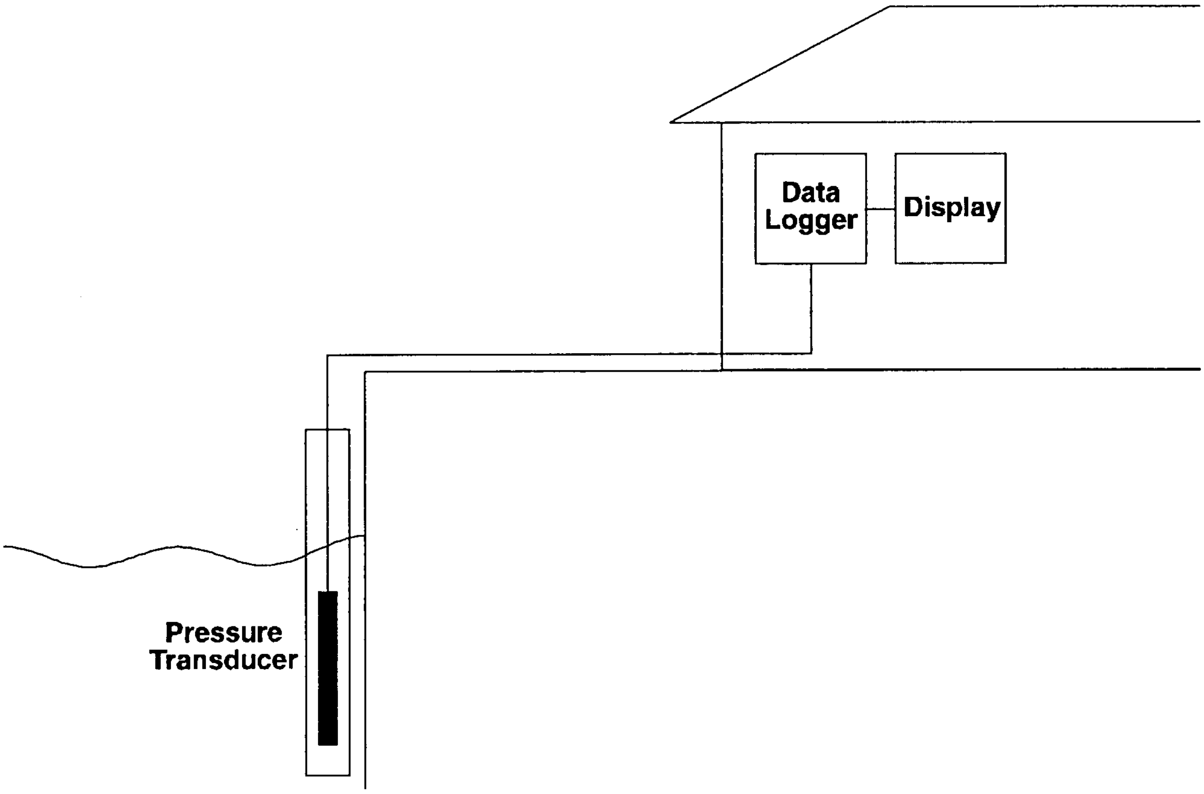

Figure 2.4

The majority of these pressure sensors use strain gauge or ceramic technology. Changes in water pressure causes changes in resistance or capacitance in the pressure element. The signal is amplified and may be displayed and stored in shore based data logging equipment.

The maintenance and calibration of these transducers is more demanding than pneumatic bubbler systems as the transducer is fixed underwater where it is susceptible to temperature variation and fouling (see section 2.5 for possible datum control methods).

(i) Temperature Effects

All pressure transducers are sensitive to temperature variations and this must be borne in mind when purchasing instruments. The expected range of temperatures to be experienced at the site should not produce an error greater than 0.01% of the full working range. If this is not possible then it is recommended that the transducer temperature is monitored for later correction of the recorded data or the transducer is housed in a constant temperature enclosure.

(ii) Pressure Systems Datum

The datum of a pneumatic system is the elevation of the pressure point bleed hole. The datum of a transducer mounted underwater is the sensor diaphragm or pressure cell.

2.4.3 HOSTILE CONDITIONS

All systems must be built and installed to withstand the severest weather conditions with protection against damage from vessels and flotsam.

(i) Effect of Waves

Surface waves will produce a rapid cyclic change in pressure in a bubbler system. The error so produced is dependent on wave amplitude in the following relation

$$E = \frac{V}{A}\frac{S}{P_o}$$

where	E	=	error
	V	=	total system volume
	A	=	horizontal cross sectional area of pressure point
	S	=	pressure amplitude of short period wave
	P_o	=	water head pressure at outlet below trough of a wave

In general the average error will not exceed 0.05% of the wave amplitude.

(ii) Effect of Currents

Areas of strong currents should be avoided when siting bubbler measuring systems. The presence of a pressure point in the tidal current will distort the velocity field, so that the pressure sensed cannot be interpreted simply as the undisturbed hydrostatic pressure. Depending on whether the bleed hole faces into or away from the current the measured pressure will be greater or less than the hydrostatic pressure. If a pressure point has to be fixed in strong currents it should be positioned so that the bleed hole is tangential to the main current flow to minimise the error.

(iii) Density Variations

Since the water levels measured by pressure systems are a function of the water pressure at the pressure point outlet, variations in the water density can lead to errors in both bubbler and direct reading systems. Such density variations are most pronounced at sites situated close to or on river estuaries. If an estuarine site must be used, specific gravity measurements should be taken and corrections applied.

2.5 PRECISE DATUM CONTROL FOR PRESSURE TIDE GAUGES

Many different types of tide gauge are now in use around the world. These include traditional float and stilling well gauges (Noye, 1974a, b, c; IOC, 1985; Pugh, 1987), acoustic gauges (Gill and Mero, 1990a) and gauges based on the principle of measuring sub-surface pressure (Pugh, 1972). Pressure tide gauges are more convenient to use than others, especially in