DETERMINATION OF TEMPERATURE, SALINITY, AND DENSITY

Variations in the distribution of ocean density control the large-scale movements of water masses, are important features in the dynamics of ocean surface currents, and drive the circulation of estuaries. Density is a function of temperature, salinity, and pressure. Whereas deep-water oceanographers need to determine each of these variables, it is usually possible to neglect the pressure effects on estuarine density, since seawater for all practical purposes is incompressible in depths less than approximately 3QO m.

Besides being able to express the equation of state of seawater with only two independent variables, estuarine oceanographers have another clear advantage over their blue-water colleagues. In the open ocean, temperature and salinity undergo only minor fluctuations as compared to estuaries. The coefficient of variation for temperature or salinity is typically of the order of 1 % in the deep ocean, 10% in the surface waters of the open ocean, and 100% or greater in estuaries. Thus, the need for very precise temperature/salinity measurements is not as great in estuaries as in the open ocean.

TEMPERATURE:

Water temperature can be measured by many means with varying accuracy and precision. Instruments commonly used include sensors based on (Besancon, 1974, p. 933). I. Expansion of matter. 2. Changes in pressure of a gas at constant volume. 3. Thermoelectric changes due to differences in the coefficient of expansion in a bimetallic strip. 4. Changes in electrical resistance.
5. Changes in thermal radiation within a narrow wave-length band. Mercury thermometers have long been used in oceanographic applications.

They measure temperature as precisely as ± 0.0 I °C and are based on the thermal expansion of mercury. Specially designed reversing mercury thermometers (Duxbury, 1971, pp. 342-6) are attached to water bottles and can be used to measure/record the *in situ* temperature at any depth.

However, with the developments and improvements in electronics, thermistors have replaced mercury-filled thermometers as preferred sensors in oceanographic temperature-measuring instruments. A thermistor is a semi conductor whose electrical resistance varies inversely with temperature. A small temperature change typically causes the resistance to vary by an order of magnitude. A thermistor can be made very small, responds almost instantaneously to temperature variations, and is capable of measuring temperature with a precision of 0.001 "C, Thermistors are commonly integrated into STD (salinity-temperature-depth) sensors used for *in situ* oceanographic measurements and salino meters intended for *in situ* measurements in estuaries and coastal waters (Bowers & Coghill, 1975).

SALINITY:

The salino meter is now the most frequently used instrument for estuarine salinity determinations. As will be discussed in some detail below, it is an instrument with which to measure water conductivity and temperature, from which the salinity can be computed. However, the salinity can be measured by a variety of techniques. The classical procedure (Strickland & Parsons, 1968, pp. 1I-19) requires a water sample which is titrated with silver nitrate. The amount of precipitable halide halogen ion from the sample is compared to the precipitate from a Standard Seawater sample. This method has a precision of approximately ± 0.0 I. Parts per thousand (ppt) or grams solute per kilogram of seawater. For convenient, quick estimates of surface salinity to within ± I ppt, a refract meter is often used. It is a relatively inexpensive piece of equipment, which may be sufficient for a pre-study survey of the estuarine salinity distribution. It is based on the principle of light refracting when passing from air through a droplet of seawater whose salinity is unknown. The refractive index varies from 1.3334 for a salinity of 0 ppt to 1.3399 for 35 ppt water at IS °C (Smith, 1974, p. 67).

However, in situ measurements of electrical conductivity are presently preferred in estuarine hydrographic surveys. They are quick and easy to make and yield approximately the same precision as the best titration method. As the salinity is not constant for a given conductivity but varies with the water temperature, it is essential to make temperature and conductivity measurements simultaneously. The electrical conductivity of water is the inverse of its resistance and is expressed in units of ohm -I em -lor mho cm -I. In estuarine environments the conductivity typically ranges from 10-3 to 50 X JO-J mho cm-I or I-50 mmhoem - I. It is either measured with an electrode system, where the conductivity cell is connected to form one arm of an a.c. Wheatstone bridge, or an inductive system, where the cell consists of two coils which are wound around an insulating core. An a.c. oscillator drives the coil, which induces a closed-loop electrical current through the core and the surrounding water. The second coil measures the induced current, which is directly proportional to the electrical conductivity of the surrounding water.

The relationship between salinity and electrical conductivity/temperature is not a simple one. Based on an extensive data set, Cox et al. (1967) developed an empirical computational procedure. They defined two conductivity ratios.

(7.3)

Where CT.S is the measured conductivity at the in situ temperature, T, and salinity, S; CI5.S is the conductivity corrected to 15°C; and the conductivity at temperature T and salinity 35 ppt is given by

CT.35 = 29.0~916(1.0+0.0297175T +0.00015551 P-0.000000789P) (7.4)

(Perkin & Walker, 1972), which for IS °C results in CJ5•J5 = 42.922 mmho cm-I. Cox et al. (1967) related R, and RI5 through a difference term where .1B is a function of T and R.

DENSITY:

Considering time-averaged estuarine conditions, spatial salinity gradients usually correlate excellently with spatial density gradients whereas the temperat~r~ typically is almost uniform. For that reason, it is often sufficient to use salinity alone in modelling estuarine density-gradients. For example Hansen & Rattray (196S) let

$$P = Po(l +kS), \qquad (7.8)$$

where P is density, Po is density of fresh water S is salinity and k is a proportionality constant.

However, in other applications it is desirable to determine density explicitly Althoug~ Grasshoff (1976) recounts recent studies that point to mino; systematic errors i,n the classical formulation of the equation of state of seaw.ater, Knudsen s (190 I) method is still generally accepted for calculating density from temperature and salinity. The computational formulae are outlined below.It is convenient to define

$$\mathbf{crr = (p - I\,000),} \qquad \mathbf{(7.9)}$$

where is density expressed in kg m-3• o -is expressed in crT units, varies from approximately I to 30 in estuaries, and is given by

$$crT = cro + 0.1324)[1 - (I) + (cro - 0.1324)], \qquad (7.10)$$

Where cro is equal to crT at 0 °C and dependent only on the salinity, S,

Thus it is possible to compute the density or crT through a series of calculations, which most conveniently can be handled on a digital computer. Tables are presented in Knudsen (1901).