THE SOLARTRON TRANSDEPTOR

by W. E. Abbotts
The Solartron Electronic Group Ltd, Farnborough,
Hampshire, England

1. Depth Measurement by Pressure

The pressure at a point in a liquid depends on the weight of liquid above that point and on the pressure at the liquid surface. Liquid density, gravitational acceleration, atmospheric pressure and height of liquid will therefore define the pressure. Provided that the first three parameters are known, the depth can be determined by pressure measurement.

The accuracy attainable in depth measurement by pressure is discussed later in this article.

2. Depth Measurement using the Solartron Transdeptor

The pressure sensing element of the Transdeptor is a steel cylinder vibrated in mechanical resonance. The resonant frequency varies with the applied pressure in a similar way to that in which the frequency of a stretched string varies with tension. The advantages of using the frequency of a steel cylinder in this way are two-fold. The first point is that the measurement depends almost entirely on the characteristics of the cylinder and its surrounding fluid. In fact error sources can be compared with those which affect the frequency of an electronically maintained tuning fork. The transducer calibration is thus very stable and maintenance work is practically nil. The second advantage is that the output signal is a frequency and therefore has no error due to transmission. A two-wire or co-axial line may be used for both power supply and output signal, and the electrical characteristics of the line are not important.

3. Design of the Transdeptor

The unit consists of a container immersed at the depth to be measured. It must therefore be well sealed and also be strong enough to withstand the applied pressure. Further, it must not be corroded by sea water. A photograph of a 100 ft. unit is shown. The surfaces presented to the water are either gunmetal or a suitable elastomer, with the exception of the cable gland which contains 60/40 soft solder.

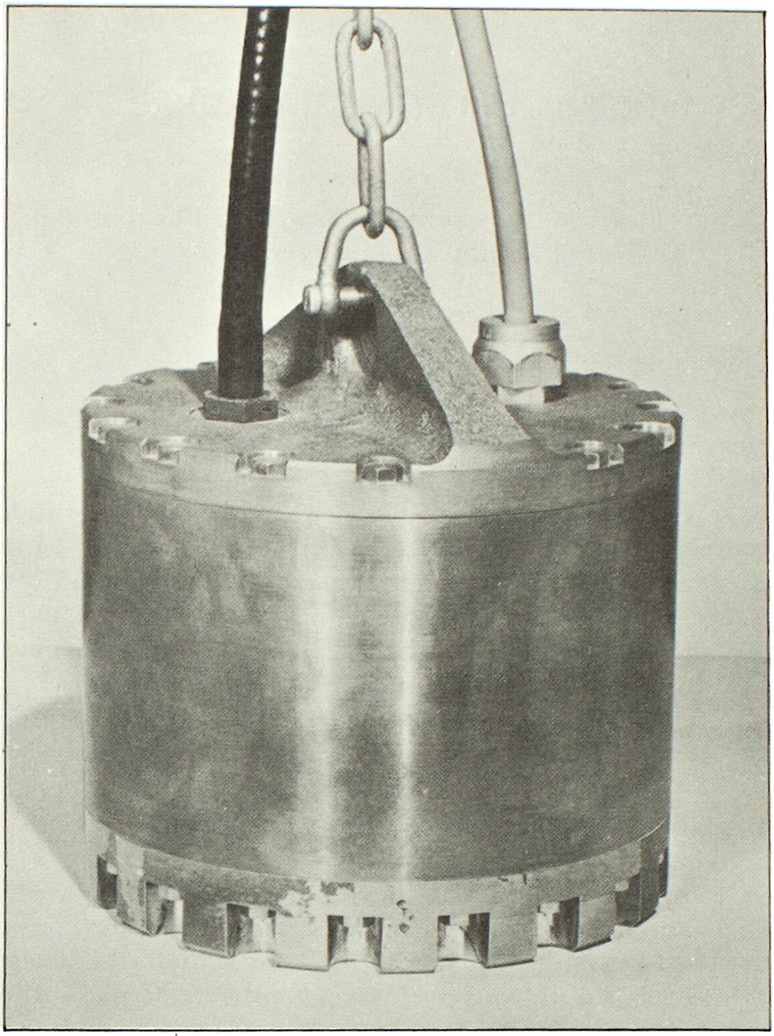

Fig. 1. — 100 ft Transdeptor.

The Transdeptor is connected to the surface in the ideal case by a composite cable (not shown) carrying the electrical lines and a vent pipe. The vent pipe is used automatically to eliminate atmospheric pressure variation, but it can be dispensed with where correction is otherwise applied or the depth error may be neglected. The electrical line carries power down to the maintaining amplifier, and also takes the signal to the surface. The water enters the Transdeptor by a series of holes in the base of the housing, and is separated from the cylinder itself by a diaphragm or bellows. This diaphragm travels to full stroke under 1 inch of water gauge. Air is used as a pressure transmitting fluid up to 100 psi (200 ft.) and a liquid up to 10 000 psi (20 000 ft.). This pressure is applied to one side of the cylinder wall only. The other side of the cylinder wall may be vented or sealed.

The frequency maintaining system is electromagnetic, and consists of two coils wound about ferrous cores which are ground to have a small clearance from the cylinder. One coil drives the cylinder and the second senses the motion. A transistor amplifier links the two coils and provides the necessary gain to maintain vibration. Since the mechanical Q of the cylinder is about 1 000, the true mechanical resonance frequency of the cylinder will be maintained within 0.1 % for ± 10° variation of the phase shift through the maintaining system. It is thus possible to measure frequency without important dependence on the characteristics of the electronic circuit.

4. Manufacturing Details

The pressure transducer sensing element is a hollow steel cylinder. Two cylinders are illustrated. The maintaining electromagnets, in an

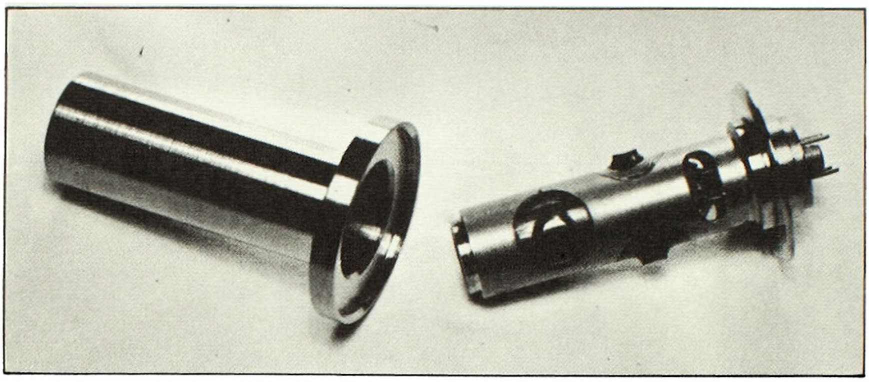

FIG. 2. — Low pressure sensing element and spoolbody.

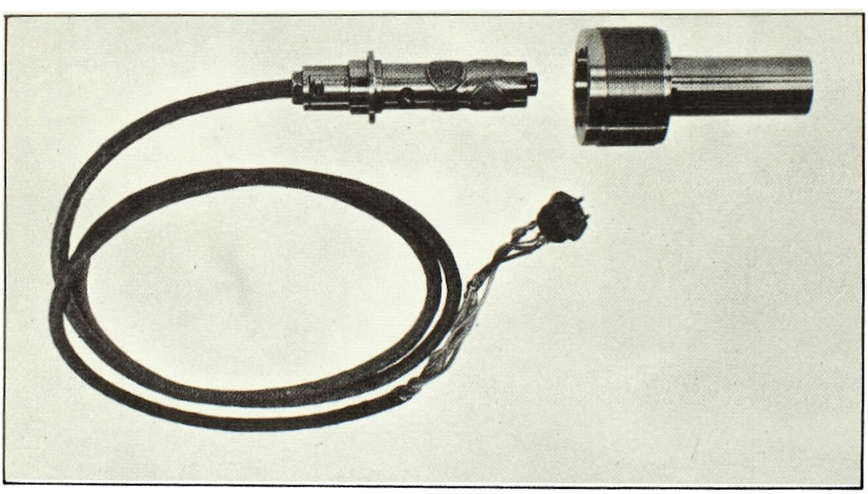

FIG. 3. — High pressure sensing element and spoolbody.

assembly called a spoolbody, are also shown. Photographs of complete pressure transducers indicate the method of assembly and show the moulded amplifier. The construction of a Transdeptor is illustrated by the sketch and the photograph already referred to.

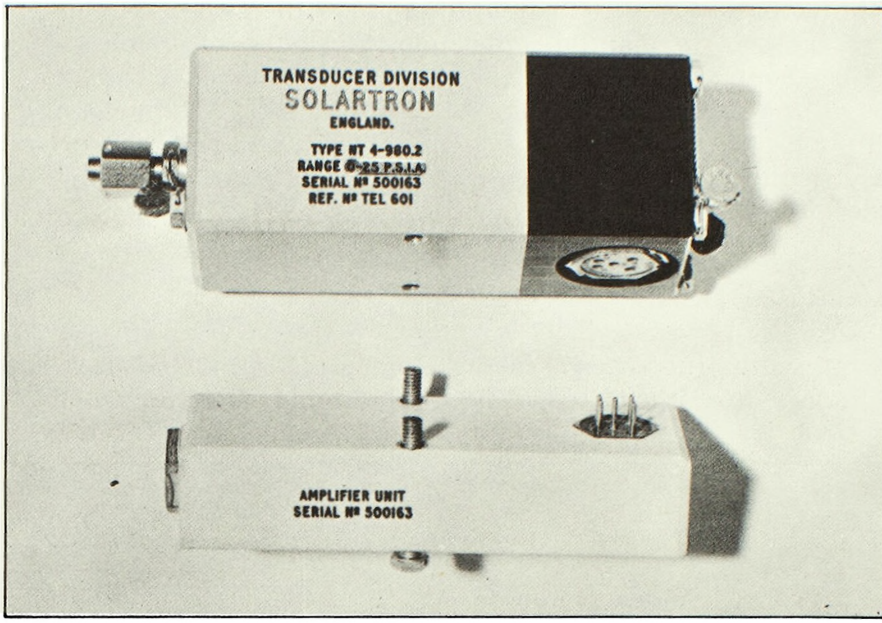

Fig. 4. — Complete low pressure transducer.

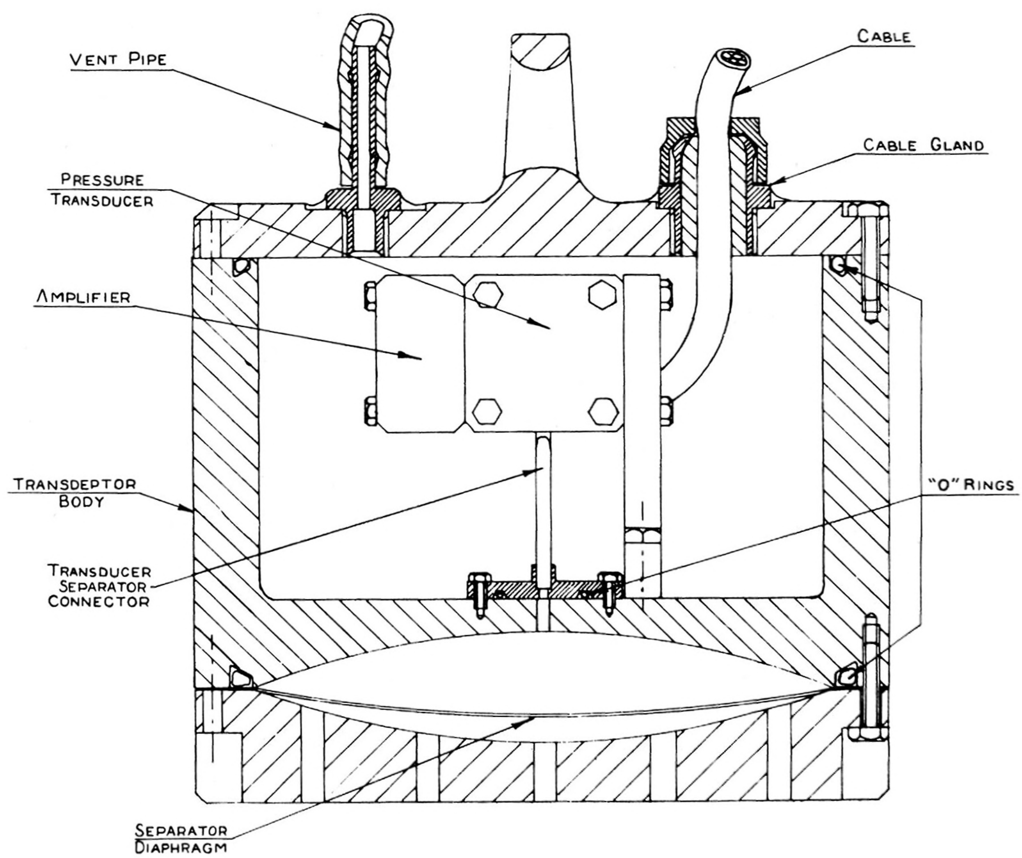

Fig. 5. — Section through Transdeptor.

5. Accuracy of Depth Measurement by Pressure

5.1 *Static Errors*

Knowledge of liquid density, atmospheric pressure and gravitational acceleration will define the depth of a point in a stationary sea when the pressure is known. Mean values and maximum deviation from the mean are given below for the above parameters, together with their maximum contribution to depth measurement error.

Parameter	Mean Value	Maximum Deviation	Maximum Depth Error
Atmospheric Pressure	29.93 in. Hg.	± 2.7 in. Hg.	± 37 in. Water
Liquid Density	1.024	± 0.004 g/m[1].	± 0.4 % of depth
Gravitational Acceleration ..	981.0 cm/s^2	± 3.0 cm/s^2	± 0.3 % of depth

More detailed knowledge of the three parameters at a particular time and place can reduce the depth error.

5.2 *Dynamic Errors*

The pressure due to wave motion is sensed close to the surface, and an effect can also be gained by rise and fall of the instrument due to its attachment to a surface vessel subject to wave motion. In these cases the mean of depth readings taken over sufficient time can be used.

At depths greater than one wavelength of the waves their effect is negligible and a steady reading will be given by transdeptor at a fixed location. Rise and fall of a vessel still has an influence. An instrument/water relative velocity of 10 knots can give at worst a depth error of 4.4 feet of water, and this can be reduced to about a tenth by streamlining the housing.

6. Theoretical Aspects

The cylinder can vibrate in an infinite number of modes. Four simple ones are shown in the diagram. The frequency of a particular mode is of the form : —

$$fo^2 = \text{constant (1)} \times \frac{E}{\rho}$$

where the constant (1) depends on the shape and size of the cylinder, E = Youngs Modulus; ρ = metal density.

Application of a pressure differential changes the frequency : —

$$f^2 = fo^2 \pm \text{constant (2)} \times \text{Pressure}.$$

The frequency is raised when the internal pressure is larger, lowered when the external pressure is larger. The constant (2) depends only on cylinder shape.

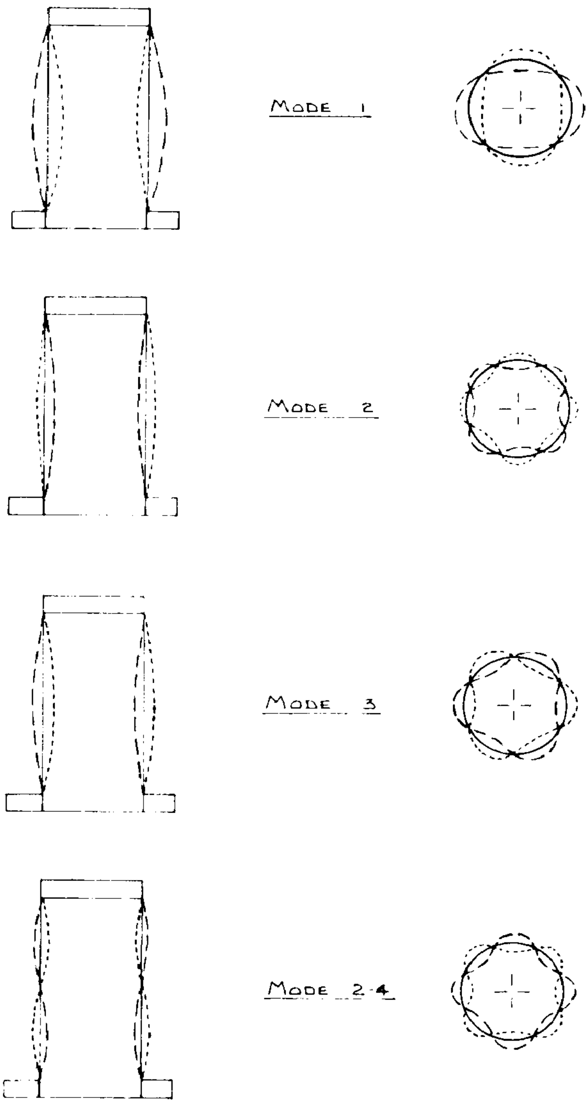

FIG. 6. — Four simple modes of cylinder resonance.

The density of the pressurising fluid also has an effect.

$$f^2 = \frac{fo^2 \pm \text{constant (2)} \times \text{Pressure}}{1 \pm \text{constant (3)} \times \text{Density}}.$$

In practice the density effect is controlled to be small and is used to compensate the changes of cylinder parameters with temperature.

The pressure transducer is operated in modes (2) and (4) in most applications. It is calibrated over the temperature range required, pressure is equated to depth, and this calibration serves through the life of the Transdeptor.

7. Accuracy of the Transdeptor

The measuring accuracy of the pressure transducer is usually better than 0.1 % of maximum pressure, and the stability is of the same order. It is therefore normal to use the original calibration figures for most accuracy requirements. Temperature correction is applied in some cases, but can often be neglected. The temperature co-efficient will generally be in the range 0.01 to 0.05 % of maximum pressure per degree Centigrade. The inherent accuracy of the sensing unit is possibly greater than that of any other pressure transducer.

8. Support Equipment

A straightforward frequency counter is sufficient to monitor the frequency. Digital displays of depth operating digitally on the input frequency are currently being manufactured.

The power requirement at the transducer is 12 $\pm$ 2 volts DC at 20 mA, and the frequency output is in the range 4 to 15 kc/s. at zero depth, the frequency decreasing about 20 % at maximum pressure.