AN ELECTRO-MECHANICAL TIDE GAUGE

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1. INTRODUCTION

A variety of tide sensing and recording systems are finding increasing use in hydrography. One sensor is the gas bubbler (figure 1) which transmits pressure signals from the sensing point to a recorder on a dry and reasonably stable platform. Its operating principle has been exploited since 1900 (Roumegoux, 1964) and has been extensively analysed (Iberall, 1950; Pugh, 1972). One new recorder is the simple mechanical device

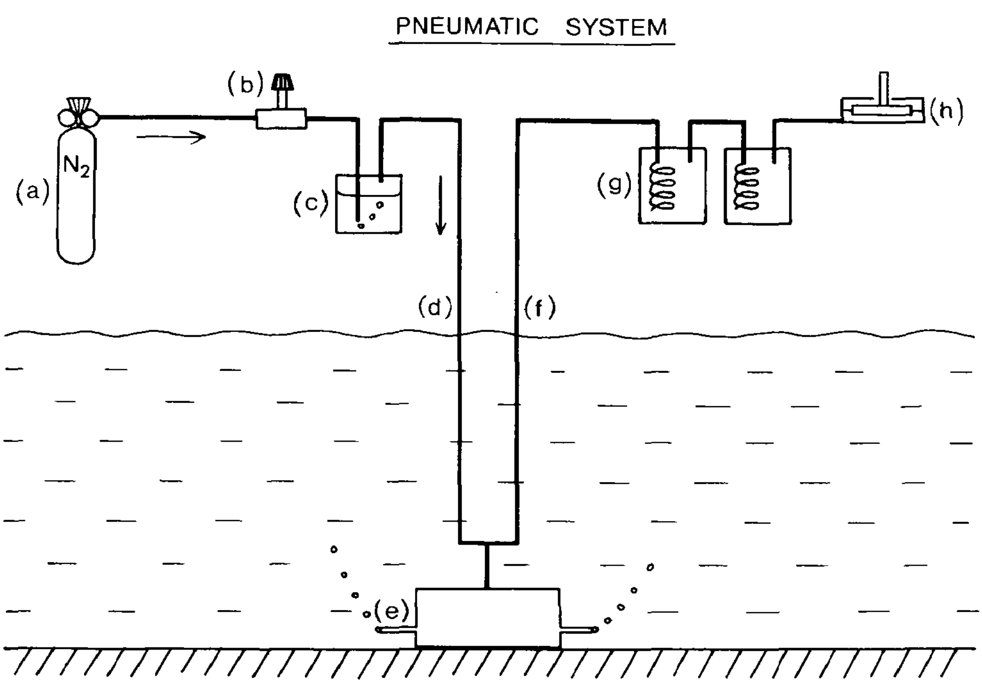

Fig. 1. — Gas Bubbler.
(a) Gas supply. (b) Flow regulator. (c) Flow visualizer. (d) Delivery tube. (e) Buffered orifice. (f) Static tube. (g) Low-pass filters. (h) Pressure transducer.

which counts the number of rotations of a shaft and punches the number in code on wide paper tape. The recorders were introduced into the tidal measurement programme of the USC&GS by BARBEE (1965).

To combine these two systems, the Geophysical Fluid Dynamics Laboratory at Monash University has developed a transducer which converts gas pressure changes to shaft rotations. The transducer was built in a small workshop with modest funds, but with care may be made highly accurate if so desired.

2. PRESSURE TRANSDUCER

2.1. Piston and Cylinder

The gas pressure is integrated to a force by a zero-displacement piston and cylinder. The latter is in three pieces: base, cylinder and limit ring (figure 2). A sheet of thin Mylar (available as household food wrapping) is placed between the cylinder and the base. The piston is captive between cylinder and limit ring, with a free vertical movement of 0.02 cm. The side wall clearance is 0.01 cm so there is no friction. The Mylar provides a gas tight seal.

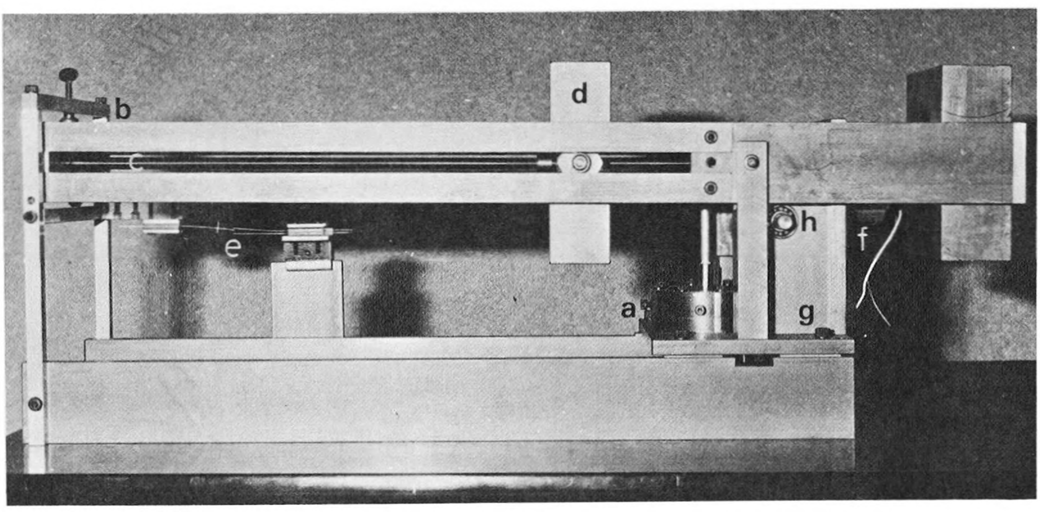

FIG. 2. — Pressure Transducer and Force Balance.
(a) Cylinder (note three sections). (b) Balance beam. (c) Screw. (d) Travelling weight. (e) Electrical contacts. (f) Servo motor. (g) Gear box. (h) "Output" shaft.

2.2. Force Balance Servo

The piston force is measured by a force balance servo. The balance is a steel beam pivoted on precision ball races. The piston rod, which has a tool steel tip, applies its force to the beam via a tool steel knife-edge. The latter is mounted in the beam rather than on the rod so that the moment of the force about the pivot is not affected by the side play of the piston.

A motor driven travelling weight allows the beam to be balanced over a range of piston forces. The rotations of the screw upon which the weight travels are proportional to the changes in gas pressure. An unbalance condition is detected at the extremity of the beam by electrical contacts which supply power to the driving motor via a twin-diode silicone controlled rectifier (SCR) circuit. The motor is coupled to the screw by two spur gears; the one attached to the screw is machined to a thin section to allow flexibility in the drive. The motor also drives an 'output shaft' at the same rate as the screw.

Rapid vibrations of a jetty or beacon which may be supporting the instrument will disturb the delicately balanced beam. However, the vibrations will not be recorded because a half-second delay in the SCR trigger circuit prevents them from activating the servo motor.

2.3. Temperature Compensation

Thermal stability of the balance is achieved by making both the beam and screw of steel, and by making the piston and cylinder of a low expansion alloy such as Invar or Nilo 36.

The pressure in the open-ended gas bubbler system is not affected by diurnal temperature changes.

2.4. Digital Recorder

The transducer output shaft is connected to a modified Leupold and Stevens ADR 7000 which is a mechanical analogue-to-digital recorder and motor-driven paper tape punch. The tape format is described by BARBEE (1965). A one minute signal from a 1 MHz quartz timer starts the 5 volt DC punch motor with an 18 volt capacitor discharge. A bank of micro-switches driven by the motor controls the balancing of the beam and the timing of the punch cycle. An optical reader built by the Monash University Computer Centre and interfaced to a CDC 3200 computer reads the paper tape at 2000 frames per second.

2.5. Accuracy

The required accuracy A may be defined to be $A = R_1 \times R_2$ where R_1 is the required relative error in the measured tidal amplitude and R_2 is the ratio of the tidal amplitude to the depth of the datum. A reasonable requirement for R_1 is 10^{-2}. The ratio R_2 should be as small as possible to protect the bubbler orifice from surface swell and to enable observation of the tide free from shallow water effects. If $10^{-2} \leqslant R_2 \leqslant 10^{-1}$ then $10^{-4} \leqslant A \leqslant 10^{-2}$. Temperature compensation is needed if the higher accuracy is required over a temperature range of the order of 20°.

Our gauge has a range of 30 m of water, and is sensitive to 1 mm of water. The total error, including repeatability and non-linearity, was found to be ± 5 mm over the 30 m range by comparison with a primary pressure standard. During the comparison tests we read the apparent pressure off the digital recorder so the error includes the backlash in the servo gear trains and the recorder.

3. FIELD OPERATION

3.1. The Pneumatic System

The datum is the water/gas interface and is assumed to be at the orifice of the bubbler tube. The tendency of the interface to move up the tube can be minimized by enlarging the area of the outlet. This may be achieved by fitting to the end of the bubbler a flat cylinder open to the water via small holes in its sides. The buffering effect of the cylinder reduces the gas flow requirements substantially.

The 300 m length of tube (3.2 mm internal diameter) transmits tidal pressure signals with a 7 second delay. PUGH reports usage of tubes of several kilometres; the corresponding head losses and delays may be calculated using the formulae in IBERALL.

If absolute tidal level is not required then the head loss in the gas delivery tube is of no concern and the static tube may be eliminated. Both additional strength and ballast may be given to a PVC gas tube by winding it with galvanized iron wire. The wire may be precoiled on a former in the workshop. The tube and wire are easily paid out over the stern of a small boat and moored with concrete test blocks to prevent drift in strong tidal currents (figure 3).

Old car wheels provide conveniently shaped ballast that sits well on silty bottoms when placed horizontally.

3.2. Transducer and Recorder

The transducer, recorder and a dozen 1.5 volt batteries can be housed in an insulated box which may be placed on a jetty, a bed of rocks, or any level surface (figure 4). Only the batteries can be damaged by temperature extremes.

A small bottle of gas will last up to six months. The standard roll of paper will hold 48 000 records, i.e. one taken every minute for a month. The batteries will outlast two rolls of paper.

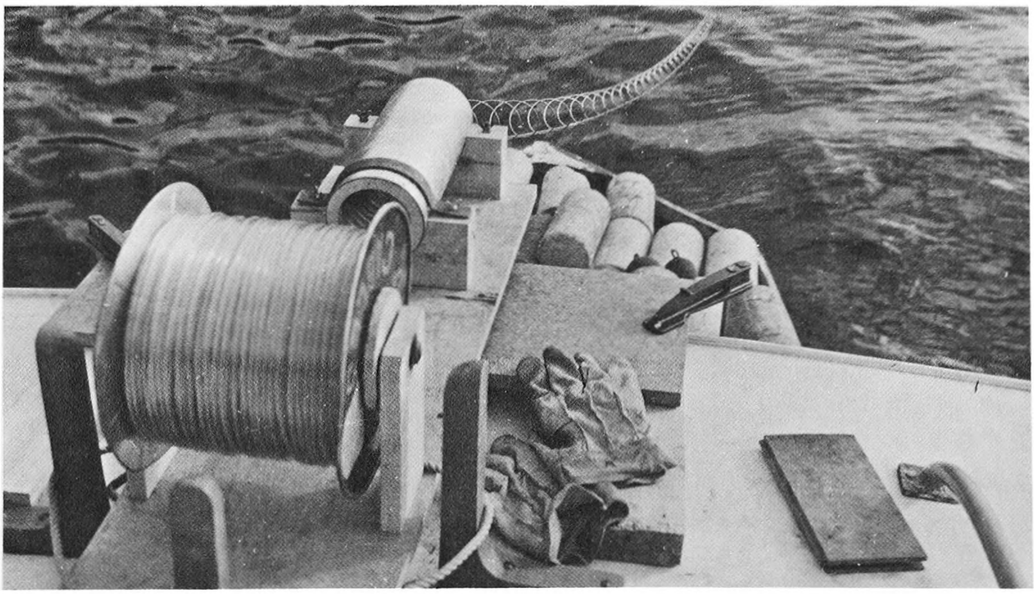

Fig. 3. — Paying out plastic gas tube and metal wire over stern of small craft. Note concrete anchor blocks, to be attached to the wire every 50 m.

Fig. 4. — Tide gauge installed far from reach of waves. Note gas bottle (left), batteries, bubbler controls, paper punch (centre), insulating lid (right).

The one-minute interval permits detailed measurement of seiches in big harbours; if these are not of interest then an extension of the sample interval would enable operation of the system, untended, for a proportionally longer period.

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