PIEZOMETER

Type: J. Y. BUCHANAN

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This piezometer is shown in the figure in its most simple form and one in which it best lends itself in the sea to the determination of the compression of the water under the influence of the weight of a given column of sea-water, or else the integral contraction due to the cooling and the increase in pressure at the same time.

The vase A contains the sample of sea-water whose mass and density are known. This water rests upon a layer of mercury of which the mass is also known and which fills the bulb C at the lower extremity of A. The tube B, which is secured in the axis of the instrument, is immersed in the mercury at its lower end *f* and is graduated volumetrically. Its internal volume is 1 to 3% of that of A, depending upon the depths at which it is desired to operate. The tube passes through the rubber stopper at D, this being carefully inserted in the neck of A and tied in for greater security. For a skilful operator this operation offers no difficulty.

The instrument is brought to a convenient temperature, which may be that of the local surface of the water and one then observes the height *e* which corresponds to the volume *v* of the mercury in the tube B. Finally the instrument is lowered to the predetermined depth. If this depth is such that the apparent contraction of the liquid in the piezometer is less than the volume in the tube B, when the piezometer is brought up again, nothing is changed and the mercury regains its level *e*.

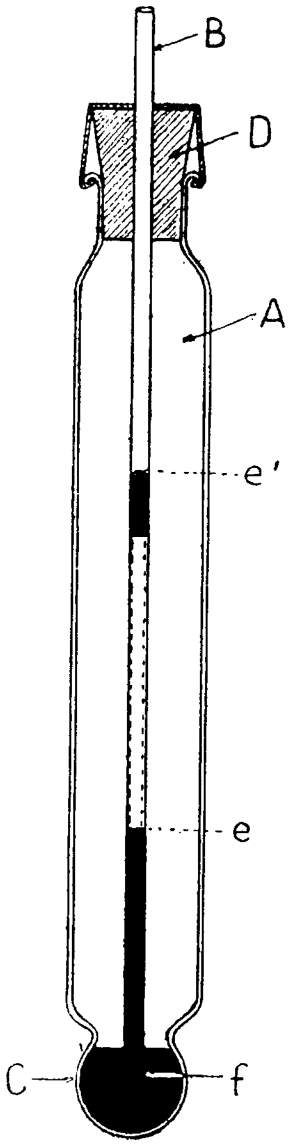
By choosing the level *e* as high as possible, it has been found possible to lower a piezometer containing 200 cm3 of distilled water to a depth of 4275 meters without the tube B becoming emptied of its mercury. On regaining the surface the mercury returns to its previous level *e*, and on testing the water with silver nitrate, no chloride was found. The repetition of this experiment shows that once the stopper has been properly inserted it does not move and remains tight even at the greatest depths.

If the volume *v* of the mercury in the axial tube is relatively small, there comes a moment during the descent when all the mercury is forced into the bulb and the tube B is completely filled with sea-water. As soon as this critical depth has been passed, the sea-water passes through the mercury and joins that which was already in A. When the descent of the piezometer is arrested, the tube B is filled with sea-water; all of the mercury is then in C, and A contains not only the sea-water which was in it at the beginning, but also that which entered into it during the descent. It is at the greatest depth that the initial conditions of temperature, pressure and volume are indicated.

During the descent, the experiment strictly speaking, is prepared and it begins only at the maximum depth. During the ascension we see the beginning of the expansion: the experiment is terminated when the piezometer is again brought to the surface and after noting the level e' which corresponds to the final volume of the mercury in the tube B at the original temperature. In order to interpret the experiment we have the following data:

Basic Data: Before lowering the instrument, we have already determined the weight of the mercury M and that of the sea-water W in the piezometer, the density S of this water and the volume v of the mercury in the tube B at the original temperature T. During this operation one observes the maximum depth D in meters and after the operation one notes the level e' which corresponds to the final volume v' in the tube B at the original temperature T. On an independent thermometer we observe the temperature *t* at the depth D.

From these data we deduce the presure in atmospheres, $p = \frac{1}{10}$ D, at the maximum depth; (v' — v), the volume at T and the atmospheric pressure of the water which has entered the instrument during the descent, from which one readily obtains its weight ω, and by adding the original weight W, we have the weight of the sea-water with which the piezometer is


B
D
A
e'
e
C
f

filled. With this weight ($W + \omega$) and using the appropriate tables, we obtain V, the volume of this mass of sea-water at temperature t and at atmospheric pressure, and V', its volume at the same pressure and at T.

For the mercury we assume 13.6°, as its density at 0.6° and 0.00018 as its coefficient of thermal expansion. According to my experiments, I found its coefficient of compressibility as 0.000004, from which we readily obtain Q_T and Q_t, the volume of the weight M of mercury at atmospheric pressure and at the temperatures T and t respectively, and Q_{tp} its volume at the maximum depth.

The container is made almost entirely of glass, except for the stopper which is of rubber. Its volume at T and atmospheric pressure is:

$$N' = V' + Q_T - v'$$

At the pressure p and temperature t, this volume becomes:

$$N = N' \left[1 - 0.00002\,(T - t) \right] (1 - 0.0000025\,p)$$

For the rubber stoppers I have found a compressibility of 0.000039. We have only to consider that part of the stopper which is tightly wedged in the neck of the piezometer. To take a practical example: the neck of a piezometer of 200cm3 had a mean internal diameter of 17mm, the tube B had an external diameter of 7 mm and the stopper penetrated 13mm into the neck in such a manner that there only entered into considération a cylinder of annular base having a volume of 2.45 cm3. When the piezometer is in the sea, the liquid and the container are compressed and one readily perceives that the compression in the transverse plan of the stopper is that of the glass container which holds it, while the longitudinal compression is that of the rubber. Since there is no movement of the stopper, the compression in length must take place in the two opposite directions, such that there is only half of the cylinder in which the compression produces an effect on the internal volume of the piezometer. In the present case the volume is 1.225 cm3 which is compressed by 0.000047 cm3 for each atmosphere. Also 200 cm3 of glass are compressed by 0.0005 cm3 per atmosphere. But the compression of the glass diminishes the volume of the piezometer while that of the stopper increases it. Consequently the resultant compression of the container in this case is 0.000453 cm3 per atmosphere. We have found that the thermal dilatation of the stopper is negligible. Designating the increase in volume of the stopper per atmosphere by c, we have for the volume of the container at the maximum depth, $N + cp$.

Thus we have for true mean compressibility of sea water, at temperature t and pressure p:

$$\eta = \frac{v' - Q_{tp} - (V' - V) + (N - cp).}{V\,p}$$

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