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FLOATING SIPHON WITH A CONSTANT HEAD

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A floating siphon made up of concentric tubes is proposed as a reliable and inexpensive device to discharge water from a reservoir tank at a constant rate independent of the water level in the tank, provided the siphon is discharged freely into the atmosphere. By adjusting the opening area in the outlet tube continuously, any constant discharge can be obtained. With simple aids the siphon has been calibrated to work with an accuracy better than 5 ‰. By means of an electric Water Surface Registration System it is proved that the variation in discharge is better than 1 ‰ at a discharge of 0.3–2.4 l/s.

INTRODUCTION

To get better usage of one of the two hydraulic channels (a mobile bed, tank) at the Laboratory of Geophysics at the University of Aarhus, Denmark, the writer constructed a device which could adjust a discharge under the following conditions:

1) a constant discharge should be obtained as quickly as possible,
2) it should be possible to adjust the discharge continuously between 0.5–2.5 l/s with an accuracy of 0.5–1 %.
3) the device should be cheap and reliable.

THE FLOATING SIPHON

The idea of mounting a siphon on a float was already proposed two thousand years ago by Hero of Alexandria (Hunter & Ince 1963), and in the December 1972 edition of the Journal of Hydrology Ben Chie Yen et al. have described the use of a floating siphon which schematically looks like those parts of Fig. 1 which are drawn with solid lines.

This siphon design was not quite satisfactory. It seemed to be difficult to balance, and may be somewhat affected by friction from the steering of the float, to which can be added the inconvenience that continuous adjustment of the discharge is not possible.

The writer is of the opinion that these disadvantages are avoided if the cross section of the Yen device is revolved 360° round the axis A-B in Fig. 1. The inlet tube of the Yen version is replaced in the writer's version by the space between two concentric tubes, and the reservoir tank is changed correspondingly. The siphon thus produced has a working accuracy of 1 ‰ in discharge. With simple aids it is calibrated to work with max. relative errors of 5 ‰.

DESCRIPTION

The reservoir tank is made of 20 mm thick, transparent acrylic plastic plates. It rests on three adjustable legs by means of which the steering tube can be placed in a vertical position. The inside measurements are 99.9 cm by 96.1 cm by 70 cm.

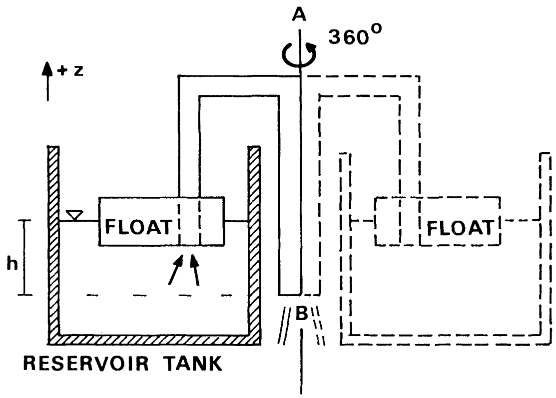

Fig. 1.
Schematic diagram of a simple floating-siphon.

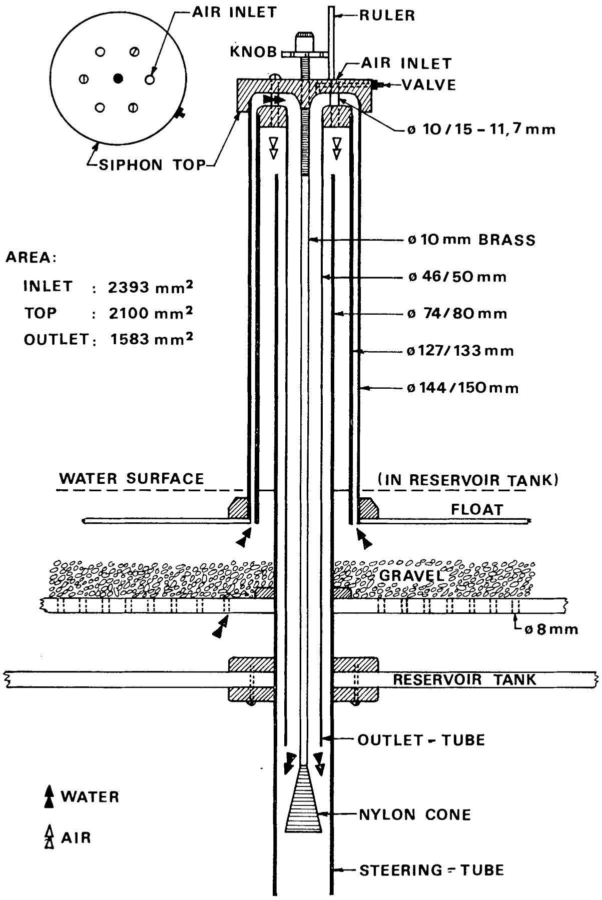

Fig. 2.
Siphon. Cross section.

The tank has been constructed with a double bottom, and in the upper plate 230 holes have been made, each with a diameter of 8 mm. On this plate there is a 50 mm thick layer of gravel (8–15 mm) which ensures a uniform distribution of the water and a smooth water surface.

The float and the siphon are made of transparent, acrylic plastic (see Figs. 2, 3).

The siphon consists of three concentric tubes. These tubes are held in place by three bolts through the top of the siphon. Air is let through the siphon via three tubes (ø 10/15–11.7 mm), which is necessary, because the outlet works as an air pump that would otherwise cause the siphon to be sucked in. By placing gravel in the ballast tanks (see Fig. 3) the outlet tube is brought to a vertical position. The outlet tube is equipped with a nylon cone which has three functions:

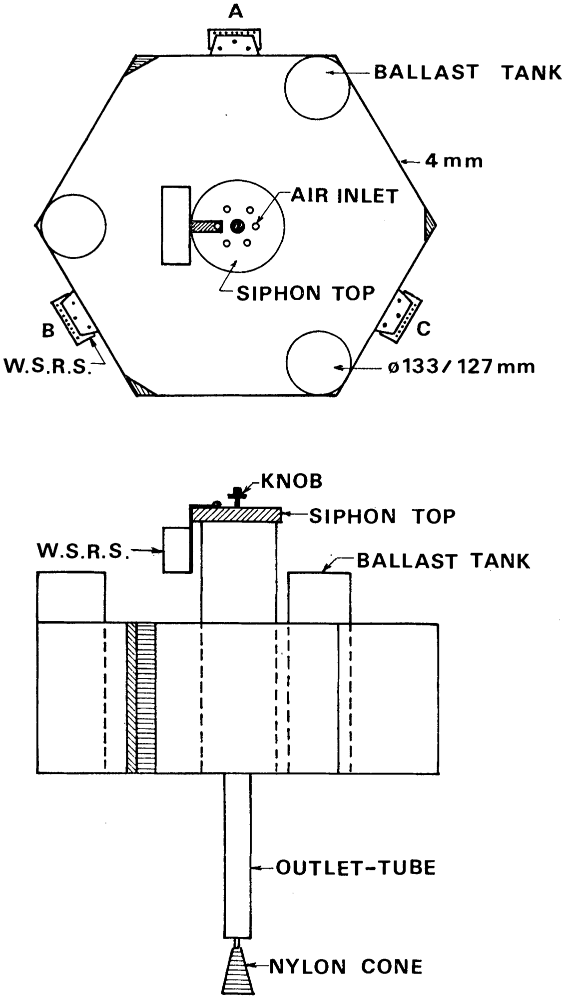

Fig. 3.
Siphon and float.

1. to adjust discharge,
2. to spread the water, thereby keeping the siphon clear of the steering tube,
3. to secure an airtight siphon when starting.

Three bolts through the outlet wall keep the 10 mm brass rod in the axes of the tube.

Adjustment of the opening a′ (see Fig. 5) is made with a knob (see Fig. 2), and by means of the ruler on top of the siphon and a scale on the knob, a measure (a) of the opening a′ can be read. Eleven turns are equal to 10.00 mm, and the knob has 24 marks per turn. The siphon is started by closing the outlet tube with the nylon cone, after which the air is pumped out through a valve (a bicycle pump with its piston turned has been used as a suction pump). After having passed the siphon, the water falls freely through the steering tube down into the hydraulic channel, where it is calmed completely by passing over a layer of gravel.

ACCURACY IN DISCHARGE

Naturally, the inflow into the reservoir cannot be held as constant as the outflow through the siphon. Therefore, it is of special interest to study the possible relative level changes between the siphon and the water surface in the reservoir tank, i.e. changes in the head h.

The discharge through a siphon can be approximated with the following formula [1]

$$Q = C_a \cdot h^{1/2}$$

If the head is changed to $h + \triangle z$, the water discharge will be

$$Q' \equiv C_a' \cdot (h + \triangle z)^{1/2}$$

Notations:

Q = water discharge (l/s)
$\triangle Q \equiv$ deviation in discharge
C_a = function of area
h = head
$\triangle z \equiv$ deviation of water surface compared with the float – positive when the water surface is rising
a = measure of the opening in the outlet
a' $\equiv$ the opening in the outlet · a′ differs from a because of error in zero set.

If the difference between Q′ and Q is small, the difference between C_a' and C_a will be small, and the relative error in discharge can be approximated to

$$\frac{Q'-Q}{\sim Q} = \frac{1}{2}\,\frac{\Delta z}{h}$$

In order to measure exactly the changes in level betwen the water surface and the siphon, an electric water surface registration system "W.S.R.S." has been constructed (see Fig. 4).

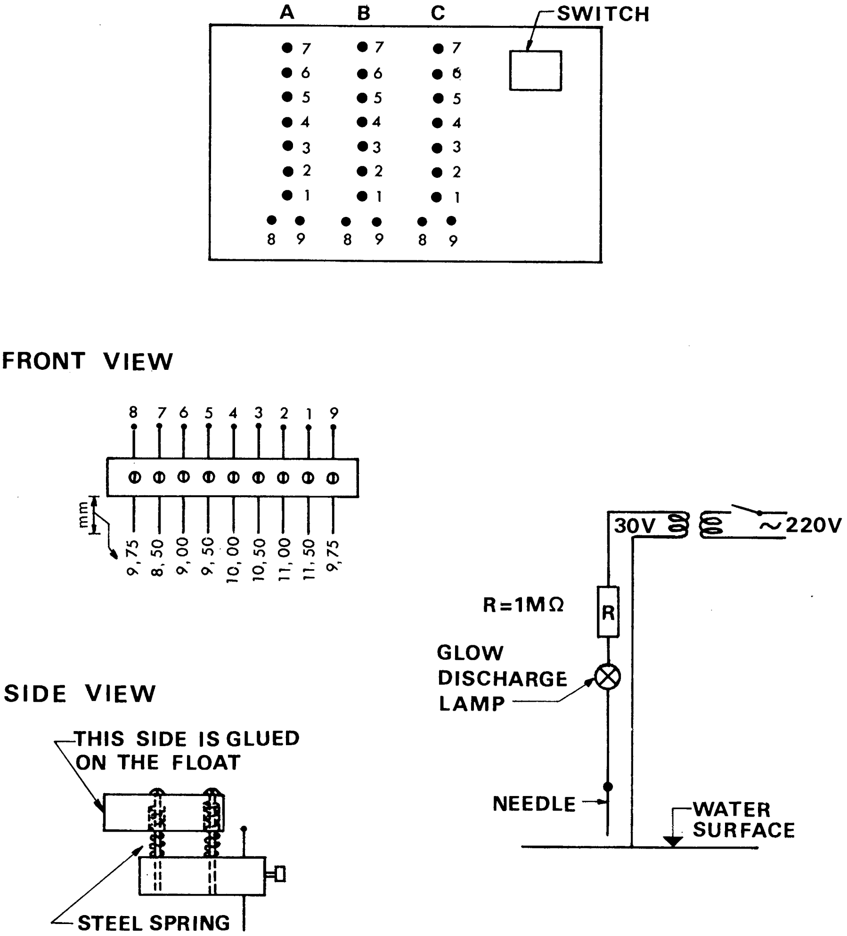

Fig. 4.
Water surface registration system.

Measurements are taken from three plates (see Fig. 3), each equipped with nine needles. The needles are adjusted as shown in Fig. 4. The plate on which the needles are mounted is fastened at three points. It is adjusted when the water surface is calm so that needle No. 4 touches the water surface, but needles No. 8 and 9 do not. On the board, lamps 1, 2, 3 and 4 will glow, but not lamps 5, 6, 7, 8 and 9. When the W.S.R.S. has been adjusted, and the siphon works within 0.3–2.4 l/s, it is possible to keep the lamps 1, 2, 3 and 4 lit, and 5, 6 and 7 unlit on all sets, as long as the inlet of water to the tank is adjusted in such a way that no waves develop in the tank.

This means that the position of the siphon deviates within 0.5 mm in relation to the water surface. With a discharge bigger than 1.5 l/s it is possible by a careful adjustment to prevent lamps 8 and 9 from glowing in at least two of the three sets. In the case of smaller discharge the siphon will be drawn to one side of the steering tube, which will affect the stability.

When calibrating the siphon it is necessary to adjust the W.S.R.S. as the discharge is increased. At larger discharges the siphon will be placed up to 1.0 mm higher than at a small discharge.

If the siphon has been affected by adjustment of the W.S.R.S. it will become calm within 5–200 s; the bigger the discharges the quicker the recovery. The siphon may revolve, especially in connection with changes in the water surface, but will seldom execute more than one full revolution, and the movement will be so slow that the W.S.R.S. will not be affected.

At a discharge of 1.69 l/s with an opening of a = 35 mm (see Table 1) the head was measured to be 354 mm. The relative error in discharge caused by uncertainty in the position of the siphon in relation to the water surface was then

$$\frac{Q'-Q}{Q} \leqq \frac{1}{2}\,\frac{\Delta z}{h} = \frac{0.5}{2 \times 354} \approx 1\,‰$$

CALIBRATION OF THE SIPHON

The siphon has been calibrated by letting it lower the water level in the tank between two marks (distance 100.00 mm), and the time consumed is measured with a stop watch (see Table 1).

The total error in the measured discharges is then max. 5 ‰. The accuracy in discharge is dependent on the outlet a′. From 0.3–0.6 l/s the graph can be approximated with a straight line. The increase in discharge from a = 0 to a = 10 mm amounts to 0.606 l/s.

10 mm equals 264 marks.

Table 1.

Opening, a mm	Average of 10 measurements s	Standard deviation s	Relative error ‰	Discharge l/s
5	321.30	0.96	3.0	0.301
10	159.51	0.27	1.7	0.606
15	109.63	0.29	2.6	0.882
20	85.72	0.24	2.8	1.128
25	72.21	0.13	1.8	1.339
30	63.46	0.27	4.3	1.524
35	57.30	0.12	2.0	1.687
40	53.07	0.10	1.9	1.822
45	49.99	0.13	2.6	1.934
50	47.56	0.13	2.7	2.033
55	45.68	0.23	5.0	2.117
60	44.15	0.11	2.5	2.190
65	42.97	0.12	2.8	2.250
70	42.15	0.13	3.1	2.294
80	40.71	0.18	4.4	2.375
90	39.88	0.17	4.3	2.424
100	39.47	0.11	2.8	2.450
110	39.30	0.17	4.3	2.460

Standard deviation = standard deviation on each measurement. Relative error in time better than 5 ‰. Measurements of the cross section area of the tank (9668.33 cm^2) revealed irregularities up to 34 cm^2. Unknown irregularities will hardly exceed 15 cm^2, and the relative error in volume is thus better than 2‰.

The difference in discharge caused by the difference between two marks, when the discharge is bigger than 0.3 l/s, will then be

$$\triangle Q = 0.606/264 = 0.0023 \text{ l/s}$$

The relative error caused by uncertainty in the opening a′ will then be less than

$$\triangle Q/Q = 0.0023/0.301 \approx 8 ‰$$
$$(Q > 0.3 \text{ l/s})$$

and decreases with increasing discharge.

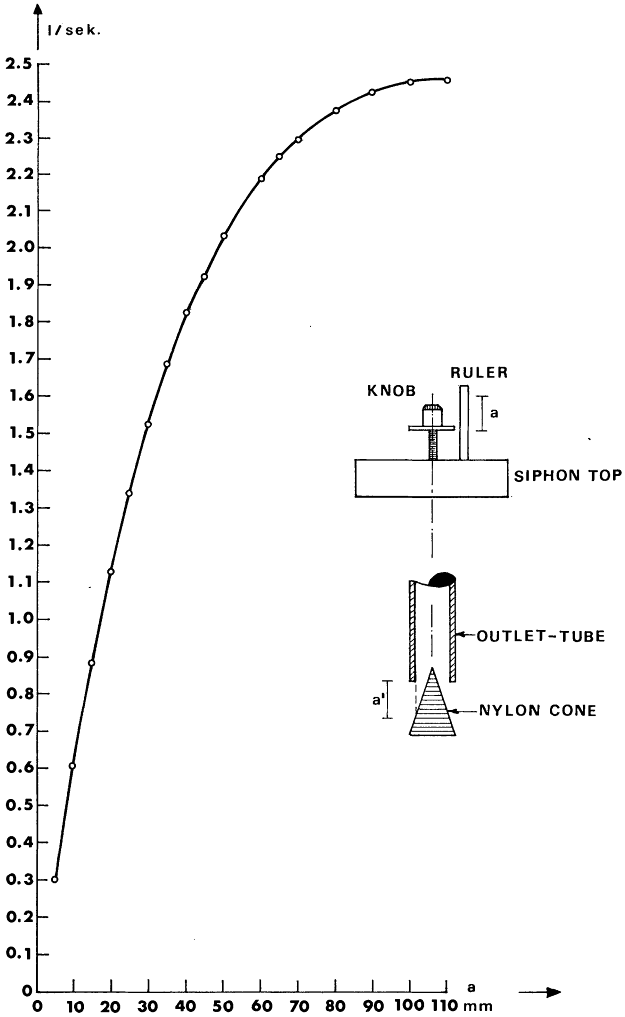

Fig. 5.

Thermal expansion in the brass rod used for adjustment of outlet a′ has not been investigated, as the siphon has been placed in a cellar with an almost constant temperature. However, it must be remembered that it is very easy to repeat the calibration at any opening a′ if an accuracy better than 5 ‰ is wanted.

RELIABILITY

If the siphon had a tendency to collect air pockets, these would cause errors in discharge, and at worst make the siphon stop. But the siphon does not stop, even if so much air is admitted ($Q = 0.9$ l/s) that an air pocket is formed in the top and as far as 20 cm down the outlet tube. In less than 100 s all the air will be sucked out of the siphon. At larger discharges air pockets of the above size will be sucked out even faster. Under normal conditions the siphon will get air bubbles only from the gravel (max 100–200 ml).

CONCLUSION

The siphon which has been described and tested is cheap and reliable. When the discharge is bigger than 0.3 l/s, a constant discharge with a relative error better than 1 ‰ can be obtained in a few minutes, and with little effort the siphon can be calibrated to work with an accuracy better than 5 ‰. Discharge can be adjusted continuously within 0–2.4 l/s.

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REFERENCES

Hunter, R. & Ince, S. (1963) *History of Hydraulics,* Dover, New York, p. 21.

Yen, B. C., Shen, Y. Y. & Chow, V. T. (1972) A Constant-Head Floating Siphon. *Journal of Hydrology 17,* 257–281.

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