WOULD A SIPHON FLOW IN A VACUUM? EXPERIMENTAL ANSWERS.

By Ralph S. Minor,
University of California, Berkeley.

Present-day high school and college text-books in general physics (printed in English) are practically agreed upon two points concerning the siphon.

The first is that the effective driving force is proportional to the difference in length of the two arms of the siphon. The second point is that the siphon is an appliance which depends upon atmospheric pressure for its action and would not work in a vacuum, nor would it work if the length of the short arm were greater than the barometric height of the liquid used.

Let us consider a siphon whose arms have the lengths h_1 — h_2 respectively, then "if we let H be the height of the column of liquid which the atmospheric pressure will support at the time and place of the experiment and d the density of the liquid, the pressure to the right on a plane through the highest point of the tube is $Hdg - h_1dg$ and the pressure to the left is $Hdg - h_2dg$ or the difference in pressure tending to produce flow is

$$(Hdg - h_1dg) - (Hdg - h_2dg) = (h_2 - h_1)dg."[1]$$

Three important conclusions may be drawn from this expression for the value of the driving force. First, that its magnitude depends directly upon the difference in length of the two arms of the siphon; second, that the direction of flow is out of the longer arm; and third, that its value is independent of atmospheric pressure.

The explanation of the siphon in many texts is, unfortunately, so worded and arranged that the reader is led to look upon this expression for the driving force as *proof* that the atmospheric pressure is essential to the action of the siphon. As Steinbrinck[2] has pointed out, the fallacy arises from the fact that we unconsciously carry into the result the idea of atmospheric pressure although, on account of its appearance with both positive and negative sign, it cancels out.

The only valid answers to the question as to the limit of height over which the siphon will work, or to the question as to whether or not it would work in a vacuum, are the answers of experiment —for experiment gives us two answers.

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[1] Reed and Guthe, College Physics, p. 94.
[2] C. Steinbrinck, Flora, Vol. 93, p. 130, 1903-1904.

Limiting Height for the Broken Siphon.

Making use of the admirable lecture demonstration suggested by Baker,[3] in which the siphon is broken at the top by means of a tube D through which the air may be removed, it is clear that in such a *broken* siphon the atmospheric pressure is continuously active in pushing the liquid up the short arm.

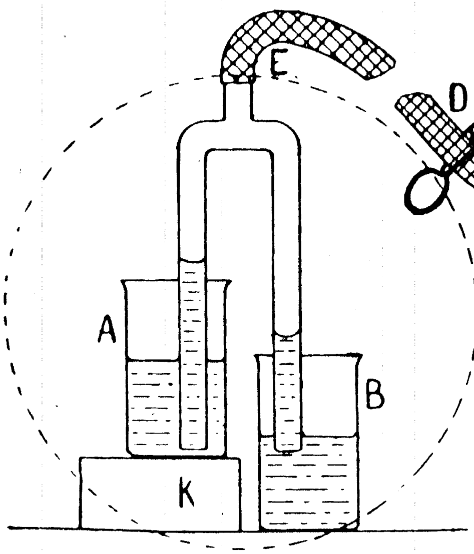

Figure 1.

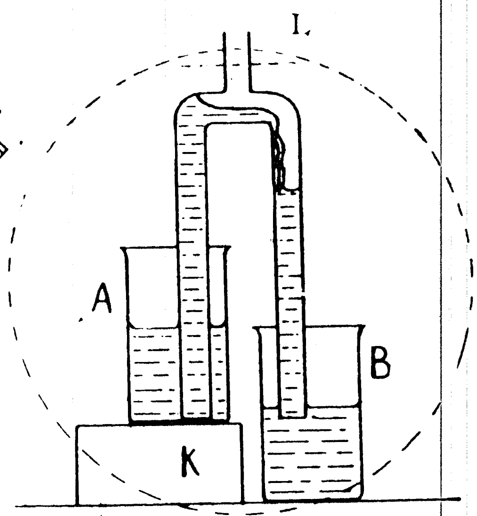

Figure 2.

The "dissected siphon" of Sinclair[4] also illustrates this point; as does the familiar so-called "vacuum siphon" in figure 3.

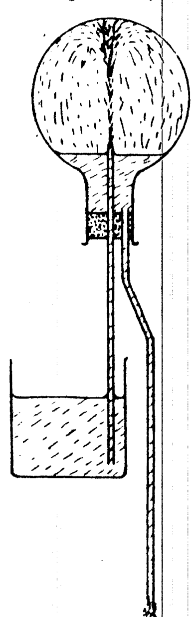

Figure 3.

It is experimentally true that the limiting height of such a broken siphon is the barometric height of the liquid used.

Limiting Height for the Unbroken Siphon.

Suppose we use as our siphon a continuous tube of uniform bore. If we place a gauge alongside the siphon tube and cover both with a bell jar, we find, on exhausting the air with as little jarring as possible, that the siphon continues to act long after the mercury in the gauge has dropped below the bend in the siphon tube. The liquid colmun is now under tension and the long column of liquid pulls the short one over the bend in the tube. The limiting height is here evidently determined by the force of cohesion

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[3] W. C. Baker, School Science and Mathematics, Vol. 7, p. 748, 1907.
[4] J. E. Sinclair, School Science and Mathematics, Vol. II, p. 416, 1911.

of the liquid which we know[5] to be many times greater than atmospheric pressure.

Owing to impurities in the mercury or roughness in the tube the column is often broken and the siphon will not start until the column is reunited.

A quick sharp tap on the tube will also break the column, and it seems quite likely that the jarring of the older type of air pump is the reason for the negative result described in the various editions of Carhart and Chute's *High School Physics*.

In presenting this experiment before the Pacific Coast Science Teachers' Association the following convenient method of starting the siphon *after* a bell jar was placed over it was used. Fasten the unfilled siphon with wax to a dish of mercury A (Figure 4), with the long arm just sealed by a little mercury in

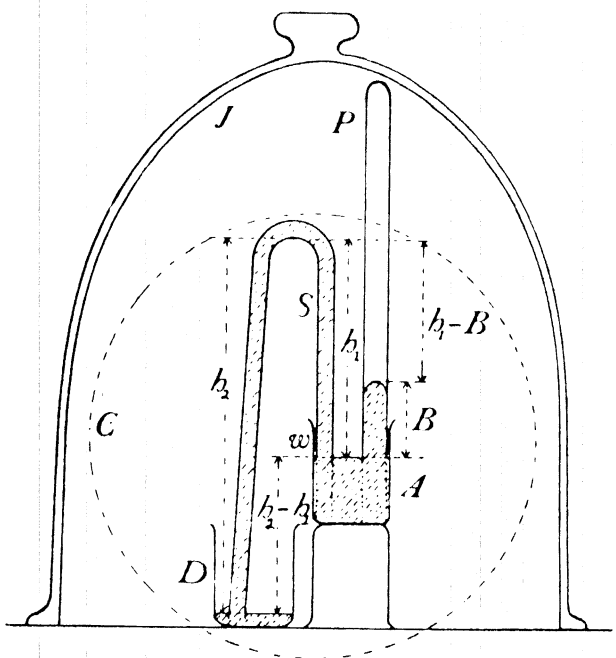

FIGURE 4.

a second beaker B. A carefully filled mercury gauge is placed alongside the siphon. Upon starting the pump, air is removed both from the bell jar and from the inside of the siphon as well. After the pressure has been considerably reduced, slowly admit air into the receiver; the mercury will then rise on both arms of the siphon but will reach the top on the short side first. As it flows over the bend it will drive the remaining air with it. If the receiver is then immediately connected with the pump again,

[5] Some 50 atmospheres for pure water. See account of Berthelot's experiment, Tait's Properties of Matter, p. 204, 5th Ed. and Ann. de Chim. et de Phys. XXX. p. 232. 1850.

the pressure will soon fall below h_1, while the siphon continues in action. Success has been obtained with tubes varying in diameter from 1 to 7 mm., and a length of arm as great as 16 cm. with a difference $h_1 - B$ varying from 10 to 30 cm. With tubes of large diameter, it is more difficult to drive out the remaining air as the mercury tends to flow around the bubble instead of pushing it out of the tube. In constructing the siphon care should be taken not to reduce the diameter of the tube in making the bends. The arrangement described permits of projection, the dotted line in the figure representing approximately the field of view on the screen.

The common siphon as used for the transference of liquids containing more or less air is a *broken* siphon. The unbroken siphon is of particular interest to botanists[6], who have made its action an essential part of one explanation of the rise of sap in trees.

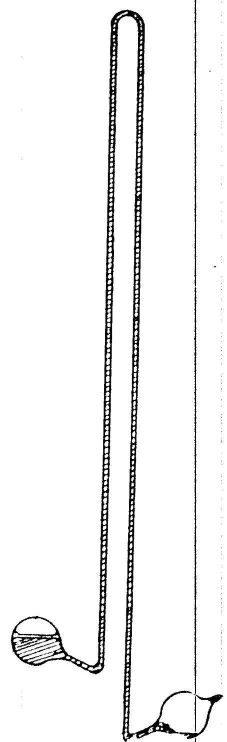

FIGURE 5.

Weinhold[7] has designed apparatus to illustrate the working of the cohesion siphon. In the form shown in Figure 5 it is now on the market[8] and readily enables one to show a mercury siphon in action with the length of the short arm some 110 centimeters. While it is difficult to hinder the breaking of such a long column of dry mercury it has been found that the addition of a little water overcomes this difficulty. The tube is sealed off after boiling the water to remove all air, the pressure inside being that of saturated water vapor. The siphon is started by holding it nearly horizontal. After it is in action it is carefully raised until the arms are vertical.

[6] Dixon and Joly, On the Ascent of Sap. Phil. Trans. Royal Soc., London, B1895, p. 563-576. Askenasy, Ueber das Saftsteigen, Verhandl. des Naturhist.-Mediz. Vereins zu Heidelberg, N. F. V., 1895.

[7] Weinhold, Zeitschrift fur den phys. und chem. Unterricht. Vol. 17, 1904, p. 152. Jahrbuch fur wissenschaft. Botanik, Vol. 42, pt. 4, pp. 585.

[8] Max Kohl, Catalog 50, No. 52664-52665.

A NEW JOURNAL.

There has recently come to our desk a new journal by the name of *Rural School Advocate*. This is a paper published in the interests of rural schools, and the aim of its promoters is to circulate it among teachers, trustees and pupils of all rural schools. There is a great field for this kind of work. The rural schools should have a journal promoting their interests and welfare, as well as those of the city. It will help greatly in the betterment of the rural school in all directions. We wish for it the greatest success.