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An Economical Lysimeter for Evapotranspiration Studies[1]

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AN ECONOMICAL lysimeter has been developed and tested which appears to be very useful for many studies. The principle of the lysimeter is not original with the authors. Ekern[3] in Hawaii and Tanner[3] in Wisconsin have used this type of lysimeter for several years. Glover and Forsgate[4] have described a similar lysimeter installation in Kenya. The purpose of this note is to describe some problems associated with this type of lysimeter and the solutions we have devised.

Figure 1 shows the lysimeter. The total weight of the lysimeter is distributed over the 2 wooden blocks which sit on 2 rubber bags. The pressure of the fluid in the bags is equal to total weight of the inner tank and contents, divided by the area of the two wooden blocks. The wooden blocks are used to maintain a constant area over which the weight is distributed. The pressure is measured as the height of fluid in the standpipe (active tube). The "dummy" standpipe is used for temperature correction.

The dimensions of the lysimeters given in Figure 1 are not critical. The size of the tanks can be adjusted to fit the needs. Tanner has used lysimeters having areas up to 3 × 6 meters. The number and shape of the rubber bags could also be adjusted. We used nylon-reinforced butyl rubber irrigation tubing to minimize long-time drift errors.[5]

Bags were constructed by cutting the irrigation tubing to the proper length, making a double fold at each end, and vulcanizing the two ends. A valve stem was also vulcanized into the bag to connect to the standpipe. Drift was minimized by using the bag as flat as possible (only about 1 inch thick), and by supporting the free ends of the bag in a box (Figure 1). The long-time drift with this arrangement is very small as indicated by the difference in slope of the "dummy" standpipe height compared to the active standpipe height shown in Figure 2. Tanner has used a clamp for sealing the ends which was more satisfactory than vulcanizing when pressures were as high as 35 to 50 psi.

As presently designed, the inner tank of the lysimeter is quite stable—we believe we could get by without any supports connecting the inner and outer tanks. However, we have installed four stabilizing arms in each installation as a safety factor. These arms are ¼-inch-diameter rods which extend from the corners of outside tank horizontally to the inner tank about 2 feet from the corners. The arms touch the outer tank only at corners and the inner tank only at the point of attachment. This arrangement allows the tank to move freely vertically, but not horizontally. We have detected no binding with this arrangement.

The main costs of the lysimeter are the tanks and the installation. The rubber bags, copper tubing, and standpipe material cost less than $20.

The problems that we have encountered with the lysimeter involve temperature-induced errors and long-time drift errors. We have minimized the temperature drift errors by installing a "dummy" standpipe (Figure 1) of the same height as the active standpipe and extending into the soil to the same depth. Figure 2 shows the comparison of the reading of the active standpipe to the reading of the "dummy" standpipe as a function of temperature for a covered lysimeter (no ET). The readings were taken under field conditions at Akron, Colorado, during several

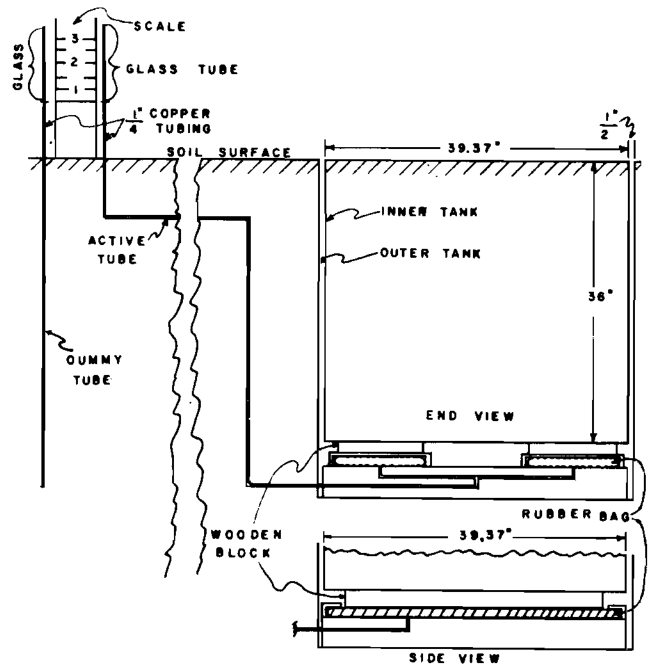

Figure 1. Schematic diagram of the lysimeter installation.

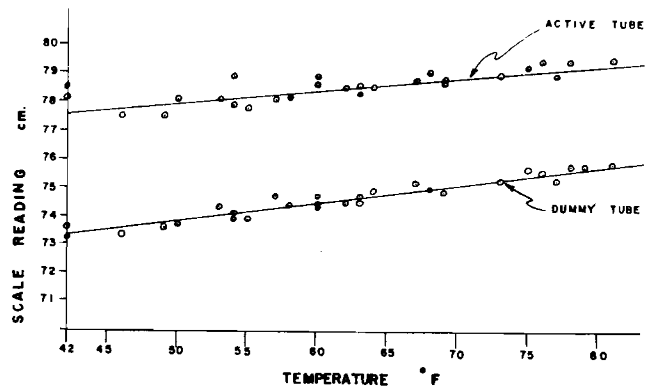

Figure 2. Comparison of "active" and "dummy" standpipe readings for a covered (no weight change) lysimeter as a function of temperature.

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[3] Personal communication.

[4] Glover, J., and Forsgate, J. A. Measurement of evapotranspiration from large tanks of soil. Nature 195:1330. 1962.

[5] Eight-inch-diameter tubing costs $1.24 per foot in 50-foot rolls and is available from Carlisle Tire and Rubber Company, distributed by Watersaver Company, 3560 Wynkoop, Denver, Colorado. Company names are mentioned for convenience of the reader and do not imply endorsement by the U. S. Department of Agriculture.

weeks in the summer of 1964. Temperature measurements were made with mercury thermometers about 3 feet above the ground in a shaded, insulated box enclosing the standpipes. The effect of temperature in both readings is evident, and is essentially the same for both conditions. The temperature-induced changes can be attributed to changes in density of the water in the standpipe. A change in temperature from 50° to 86° F. (about the maximum expected at Akron) changes the density of water from 0.99973 g./cc. to 0.99567 g./cc. or about 0.4%. An 0.4% change in density would cause a standpipe height change of 0.96 cm. (for a standpipe 240 cm. high). This 0.96-cm. change is very significant since it is of the same magnitude as ET (0.48 cm. equivalent ET) measured in a day. Field tests at Akron indicated errors in daily and weekly ET of as much as 100% if the temperature error was not corrected for. A better method for temperature error correction than the one described here would be to have a "dummy" bag located under the lysimeter. Thus, the "dummy" standpipe would be more closely subjected to the same temperature fluctuations as the active standpipe. However, since the temperature fluctuations are largest in the above-ground portions of the standpipes, we didn't feel the additional correction would be sufficient to justify the expense.

The long-time drift errors are due to changing of the elastic properties of the membrane with time. Preliminary tests showed that a regular rubber innertube drifted badly with time. However, this drift was essentially eliminated when we replaced the innertubes with bags made out of nylon-reinforced butyl rubber (Figure 2). If there were a long-time drift, the slope of the height-temperature line of Figure 2 would be different for the active standpipe which was subject to the drift, than it would be for the "dummy" standpipe. The data of Figure 2 show that slope of the two lines is very nearly the same.

The error due to temperature fluctuations could be almost eliminated by locating a suitable pressure-measuring device at the bottom of the lysimeters near the rubber bags. Tanner has used a differential mercury manometer with suitable transducers in this manner. If measurements are desired over short time intervals, this procedure is probably necessary. However, where daily measurements are all that is desired, the method we have used is believed to give adequate accuracy.

The most important use of the lysimeter will be to measure changes in weight of the lysimeter due to evapotranspiration or precipitation. Moreover, the weight changes will be most conveniently expressed as an equivalent depth of water. The equation expressing this relation is

$$ET = \frac{\Delta h \times A}{A_1} \frac{\rho_f}{\rho_w}$$

where ET is evapotranspiration (or precipitation) in cm. of water, Δh is change in height of fluid in standpipe, A is the area over which the weight is distributed, A_1 is the area of the bottom of the lysimeter, ρ_f is the density of fluid in the standpipe, and ρ_w is the density of water.

In our lysimeter, shown in Figure 1, A_1 was slightly more than twice A, and ρ_f (anti-freeze solution) was slightly more than ρ_w which resulted in ET $\approx \Delta h/2$. By varying the ratio of A to A_1, the ratio of Δh to ET can be varied. However, this change is limited by the total height of the standpipe that can be tolerated. If the standpipe is to project out of the ground about 5 feet (a 3-foot lysimeter), then the ratio of A_1 to A will be about 2.