HYDRAULIC LOAD CELL LYSIMETERS

H.C. Korven
Member CSAE
Research Station
Research Branch, Canada Agriculture
Swift Current, Saskatchewan

W.L. Pelton
Research Station
Research Branch, Canada Agriculture
Swift Current, Saskatchewan

INTRODUCTION

A study designed to measure the effect of advection of evapotranspiration at seventeen sites. Since lysimeters measure evapotranspiration directly, it was decided to install a lysimeter at each site. Because low cost of each unit was paramount in a multiple lysimeter installation, the hydraulic load cell lysimeter was selected. The purpose of this paper is to describe and compare the performance of two types of hydraulic load cell.

DESIGN

A good review of lysimeters, including the hydraulic load cells, has been provided by Tanner (6). The first attempt by the authors was to support the lysimeter on three bags made from 30-cm diameter butyl-nylon pipe connected to a 3-well differential mercury-water manometer (6) located in a manhole below ground surface. Since it was difficult to space three rectangular bags under a circular tank 0.86 m in diameter and to keep a supply of mercury in the reservoirs if the tank leaned, it was decided to simplify the device by using a coil of 5-cm diameter lay-flat butyl tubing (Figure 1) connected to a single well differential mercury manometer, but it was difficult and time-consuming to remove the air from the tube. Another weakness suggested is the problem of the folds in the tubing causing changes in the area of contact (7).

Figure 1. Hydraulic system of 5-cm diameter lay-flat butyl tubing in a coil.

Tube Load Cell and Standpipe

In the spring of 1968 the mercury-water manometer was replaced with a standpipe, and the butyl tubing was folded back and forth (Figure 2) to increase the area of contact so the height of water column would be about 2 m. Temperature effects were corrected by means of a dummy standpipe (1) and both the lysimeter and dummy standpipe were housed in a shaded box. This system produced more reliable readings than the coiled tube and mercury-water manometer, but it was difficult and time-consuming to remove the air from the tube. Another weakness suggested is the problem of the folds in the tubing causing changes in the area of contact (7).

Figure 2. Hydraulic system of 5-cm diameter lay-flat butyl tube folded back and forth.

Diaphragm Load Cell and Standpipe

One means of overcoming the weaknesses of the tube load cell is to replace it with a diaphragm or "waffle" such as the one described by Middleton and Jensen (4). Middleton's waffle was constructed completely of rubber and was 5 cm high. The design reported herein differs from Middleton's in that the rubber sheets were clamped between metal hoops and was only 1.2 cm high.

Each diaphragm load cell was made of two sheets of 1.6 mm nylon reinforced butyl rubber clamped between three metal hoops (Figure 3). The top and centre hoops were made of 12.7 mm x 12.7 mm square rod, and the bottom hoop of 3.2 mm x 12.7 mm flat iron. The outside diameter of the hoops was 12.7 mm less than the inside diameter of the outside tank. The inlet was located in the centre hoop, and the outlet, or air escape vent, in the top she...

Figure 3. General view of diaphragm.

INSTALLATION

Filling the Lysimeters

The procedure during the initial filling of the lysimeters was as follows. A suction plate was centred in the bottom of the lysimeter in a sand envelope about 5 cm thick. The suction plate consisted of a porous ceramic disc 30 cm in diameter backed by a neoprene diaphragm to which was attached a thick-walled suction hose with an inside diameter of 1 cm. The plate was placed horizontally in the sand layer, with the ceramic disc up. The hose was led along the floor and then brought...
up along the inside of the tank so that a pump could be attached to remove any buildup of water in the bottom of the lysimeter. Soil from a hole of the same dimensions as the inside of the lysimeter was removed in 15-cm layers and stockpiled on plywood sheets. Each layer, starting with the lowest, was placed in the lysimeter and tamped to the same volume as it had occupied in the field.

Hydraulic Load Cell Installation

The tube load cell was filled with liquid and the air removed before being folded back and forth in the bottom of the outside tank which was a corrugated culvert 0.91 m in diameter and 1.4 m long with a 3-mm thick steel sheet welded in the end to form the floor.

The diaphragm was lowered into the tank, connected to the copper tubing and filled with liquid from the top of the standpipe from a pressurized container. During filling, the centre of the top sheet was held up so the air could escape through the vent. When the liquid level reached the vent, the pressure was released, and the top sheet lowered slowly while the vent was being closed.

A sheet of plywood 2.5 cm thick was placed on top of the tube or diaphragm. A hole was cut in the centre of the plywood sheet to provide clearance for the vent in the top sheet of the diaphragm.

ASSESSMENT OF PERFORMANCE

During the first year of assessment, 1968, the 16 lysimeters were supported on tube load cells filled with water. Diaphragm load cells were installed under 10 of 16 lysimeters in the spring of 1969 and the liquid was changed from water to a 1:1 antifreeze-water solution in all lysimeters. The diaphragm load cell proved easy to install and functioned satisfactorily so in the spring of 1970 the remaining six lysimeters were equipped with diaphragms filled with antifreeze solution.

Sensitivity

The sensitivity of the lysimeter was measured by calibrating each lysimeter in the field. The change in liquid level in the standpipe was read for each weight on both adding and subtracting sequences. Six 11.3-kg lead weights were used which were equivalent to about a 12-cm depth of water on the lysimeter.

The lysimeters were calibrated in the spring and after the first and second cuts of alfalfa (Rambler, Medicago media) in 1968 and 1969. In 1970 and 1971 the crop studied was wheat (Manitou, Triticum aestivum) so calibrations were conducted in the spring and after harvest. Since three calibrations were available in 1968 and 1969, the spring 1971 calibration data were grouped with the two calibrations in 1970 to make a group of three calibrations.

Soil Characteristics

The soil moisture and temperature in the field and lysimeter were measured and compared at one site (No. 16) during 1971, by the psychrometer technique (3, 5). The psychrometer units were installed in the spring of 1971 at depths of 15, 45, 75, and 105 cm in the lysimeter and at depths of 15, 30, 60, 90, and 120 cm in the field. The psychrometers were placed at the same depths in the field as those used when measuring soil moisture by the neutron meter, whereas it was not possible to place a unit at the 120-cm depth in the lysimeter because of the sand layer and porous plate. The units in...
TABLE I COMPARISON OF TUBE AND DIAPHRAGM LOAD CELLS

<table>
<thead>
<tr>
<th>Year</th>
<th>1968</th>
<th>1969</th>
<th>1970 &amp; 71</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of lysimeters</td>
<td>16</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Type of hydraulic load cell</td>
<td>tube</td>
<td>tube</td>
<td>diaphragm</td>
</tr>
<tr>
<td>Fluid</td>
<td>water</td>
<td>1 : 1 antifreeze - water</td>
<td>1 : 1 antifreeze - water</td>
</tr>
<tr>
<td>Mean sensitivity of three calibrations (mm water/mm change in manometer)</td>
<td>0.94</td>
<td>0.98</td>
<td>1.04</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>±0.07</td>
<td>±0.06</td>
<td>±0.04</td>
</tr>
<tr>
<td>Standard deviation/mean, %</td>
<td>7.4</td>
<td>6.1</td>
<td>3.8</td>
</tr>
</tbody>
</table>

The lysimeter were therefore raised 15 cm, except for the top one which was placed at 15 cm. In comparing the two, the average of the 30- and 60-cm depths in the field was compared to the 45-cm depth in the lysimeter.

The soil tension data as measured by the psychrometer units are not included because values as high as 48 bars were measured, indicating improper functioning of the equipment. There was, however, a tendency for the values to be higher (soil drier) in the lysimeter than in the field. The soil in the lysimeter was generally warmer than the soil in the field, with a greater difference in temperature being exhibited in the early and late portions of the season. The 75-cm depth was selected as typical (Figure 6).

Water Buildup
The lysimeters were checked for excess water by pumping the porous plate in the spring and after heavy irrigations. This pumping indicated little, if any, buildup of a water table in the lysimeters.

Crop Yield
The alfalfa hay yield was based on two cuts per season and the wheat yields on total production (straw and grain). Three square-meter samples were taken in the vicinity of each lysimeter to compare with the yield from each lysimeter.

CONCLUSIONS
The diaphragm with 1 : 1 antifreeze – water mixture is recommended when low cost is critical for a multiple lysimeter installation because:
1. It is easier to remove the air from the diaphragm than from the tube during the filling procedure.
2. The data are less variable when using the diaphragm than when using the tube.
3. The use of an antifreeze-water solution extends the length of season for readings and simplifies field operations because the system need not be drained for winter.

The soil in the lysimeter was slightly warmer than the soil in the field and there was no indication of excess water in the lysimeter. The ratio of lysimeter yield : field yield varied from 0.5 to 1.2. The dia-
phragm is recommended over the tube because there was less variability in the readings. The use of the antifreeze-water mixture extends the length of season for readings and simplifies field operations because it is not necessary to drain the system. The diaphragm with the antifreeze solution measures evapotranspiration with a sensitivity of one millimeter depth of water on the lysimeter to within ±0.04 millimeter.

REFERENCES