A WEIGHING SYSTEM FOR LYSIMETERS

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INTRODUCTION

Lysimeters are used in the study of soil moisture used for plant growth because they isolate the system under study and permit the specific measurement of evapotranspiration, rainfall, dew formation, and water uptake by soils (Jensen[a]). Lysimetry methods were reviewed by Harrold (9). These included repeated soil sampling for gravimetric determinations (Bryan and Brown[b]) and the maintenance of a constant water table in a lysimeter (12, 18, 20, 23, 24). Another popular technique is to record lysimeter weight either periodically or continuously to determine changes so that evapotranspiration rates can be computed.

A number of methods for weighing lysimeters have been reported. The simplest, suitable only for small lysimeters, is to move the unit from the soil to a scale and weigh it (21). Larger units are frequently supported directly on a scale (6, 7, 8). This introduces the problem of maintaining the scale in the hostile environment that prevails in underground installations. Another technique is to float the lysimeter in a fluid such as oil and measure the fluid level required to maintain floatation (4, 10, 13, 15). The weight of the lysimeter can then be determined using Archimedes principle. Bloemen (1) described a hydraulic system in which the lysimeter was supported by three pressure cells. The lysimeter weight was determined by measuring the pressure in the cells. Other systems have been described in which the cells were replaced by a flexible fluid-filled container such as tubing (11). The latest technique introduced uses strain gage load cells (16) to measure the total lysimeter weight. A typical installation was described by Dyck[c]. In this instance, three load cells supporting the lysimeter had their outputs connected so that the weight on the three cells was added to give a single reading (14). Similar systems were described by Frost (3), van Bavel and Myers (22), and Ritchie and Burnett (17), except that the lysimeter mass was balanced by counter weights and levers resting on knife edges.

All the techniques described have a major inherent problem in that the changes in weight of the lysimeter due to changes in weight of the plants growing in the soil and the amount of water present are small in relation to the total mass of the system. A large mass of soil is required to obtain representative agronomic conditions. To obtain precise measurements the weighing system must be accurate and also have a high degree of resolution to detect small changes. In any measuring system the resolution is a finite amount that is dependent upon the total range to be measured. As the mass of the lysimeter increases the resolution of measurement decreases. This can be overcome by counterbalancing the lysimeter mass so that the weighing system requires a range only equal to the change in mass (3, 5). This is expensive and introduces mechanical maintenance problems. Components such as knife edges, which are severely loaded, must be carefully designed and made of special steels, preferably of a "stainless type" (19). The necessity of calibrating the weighing system and compensating for zero drift presents an additional problem. The only accurate method of doing this is by dead weights (2), which for large lysimeters, is time-consuming and expensive.

In experimental designs it is desirable to replicate treatments. This requires a number of lysimeters, and if a weighing system is installed in each the cost becomes prohibitive. The purpose here is to describe a simple system for weighing a group of lysimeters that utilizes a strain gage load cell and electronic read-out equipment selected from the wide range currently available (25) and that can be calibrated by dead weights.

DESCRIPTION OF APPARATUS

The lysimeter installation at the Lethbridge Research Station (Figure 1) has been in use for several years. It is situated in a cultivated field and is protected from rain by an automatic shelter. Twenty units, 41 cm (16 inches) in diameter by 122 cm (52 inches) deep, and 16 units, 56 cm (22 inches) in diameter by 41 cm (16 inches) deep, each weighing approximately 180 kg (400 lb) are arranged so that they can be individually lifted by an electric hoist on a travelling gantry installed at the site. During the winter the weighing equipment and several lysimeters are moved into a greenhouse, thus permitting year-round operation. Originally, the lysimeters were weighed by a beam scale on the hoist. The accuracy and resolution of measurement were inadequate for the short weighing intervals necessary when various climatic indices were related to crop evapotranspiration.

The beam scale was replaced by a strain gage load cell having a capacity of 454 kg (1000 lb). The load cell (Model

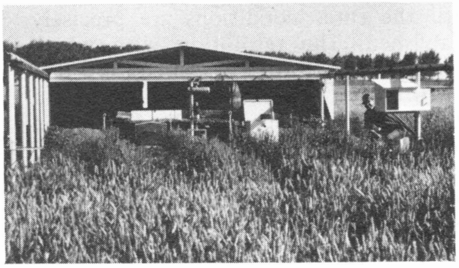

Figure 1. Lysimeter installation at the Lethbridge Research Station showing weighing equipment, gantry, and automatic rain shelter.

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[a] Jensen, M.E. (ed.) 1966. Evapotranspiration and its role in water resources management. Amer. Soc. Agr. Eng., Chicago, Illinois.

[b] Bryan, B.B. and D.A. Brown. 1961. Field measurement of evapotranspiration rates in cotton in Arkansas. Paper No. 61-715. Winter Meet. Amer. Soc. Agr. Eng., Chicago, Illinois.

[c] Dyck, F.B. 1969. An electronic weighing system for a lysimeter. Paper presented at Aug. Meet., Can. Soc. Agr. Eng., Saskatoon, Saskatchewan.

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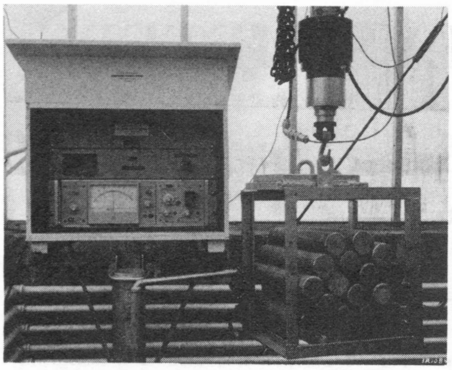

Figure 2. Load cell, calibration weights, and read out equipment used in the greenhouse.

DRM, Instron Canada Ltd., Burlington, Ontario) was connected to an amplifier (Model 300D-93-V, Daytronic Inc., Dayton, Ohio) and the amplifier output connected to a digital panel meter (Model AN25101A, Analogic Inc., Wakefield, Massachusetts). Total cost for this system is about $2000. The amplifier and meter are mounted in a standard electronic component cabinet that is placed in waterproof housing (Figure 2).

The amplifier is initially adjusted according to the manufacturer's instructions to match the load cell. Calibration is then performed using dead weights, in this instance in English units, but metric can be used if desired. The calibration procedure is designed to eliminate the nominal lysimeter weight of 180 kg (400 lb) from the measurement. With zero weight on the load cell the amplifier is adjusted so that the meter reads zero. A 180-kg (400-lb) weight is then lifted and the amplifier zero suppression control adjusted until the meter again reads zero. The weight is a steel frame filled with lengths of mill shafting, each length weighing about 10 kg (22 lb). The weight is then lowered and an accurate weight of 22.7 kg (50 lb) is added and the total weight (202.7 kg) is lifted (Figure 2). The amplifier sensitivity is then adjusted so that the change in weight produces a reading of 500 (or any other selected reading up to 1999) on the meter. These adjustments are repeated several times until the three conditions are precisely established. The resolution with which weight can be read on the meter is 0.045 kg (0.1 lb). This is equivalent to a 0.018-cm (0.007-inch) depth of water on the surface of the large lysimeters and about twice as much on the small lysimeters. It is also equivalent to the weight loss occurring in about 20 min during peak summer water-use periods.

The weight used to simulate the nominal lysimeter weight is not critical. It need only be approximately equal because the meter can read both positive and negative loads, i.e., above and below that of the dead weight. The objective is to offset the zero of the system by a constant amount that can be readily checked. The calibration accuracy of the system is governed by the accuracy of the 22.7-kg (50-lb) weight used. The system is thus calibrated over the range ±22.7 kg (±50 lb) producing a reading of ±500 about some nominal weight. Other calibration ranges can be selected providing the capacity of the load cell is not exceeded.

OPERATIONAL PROCEDURES

To weigh the lysimeters the system is calibrated and the first unit lifted and weighed. The dead weight (transported to the next lysimeter) is then lifted and the amplifier adjusted to give zero on the meter. This lysimeter is then lifted and so on. As a series of weighings is accumulated during the experiment, the change in weight of each lysimeter relative to the dead weight can be calculated. The complete calibration procedure can be repeated as often as necessary. Obviously, the more frequently this procedure is performed, the greater the accuracy that can be expected.

There are several advantages to the above procedure. These are:

1. Absolute accuracy of the weighing system does not affect the accuracy of weight change determinations.
2. Zero drift in the electronic system is neutralized.
3. The weight of the lysimeter is eliminated from the measurement and a high degree of resolution is possible (0.002% of total load).
4. A constant monitoring of the system accuracy forms part of the operating procedure.
5. Any changes in load cell sensitivity are eliminated. For example, when strain gages are loaded, shear stress is imposed on the cement bonding them to the transducer surface. Under these conditions the cement tends to creep, thus altering the output. This is particularly prevalent in inexpensive load cells that should, therefore, be avoided. If regular zero and calibration checks are not performed, this could not be detected.

EVALUATION OF THE SYSTEM

The system was evaluated in the greenhouse by using the procedure outlined above to make 50 weighings of the dead weight and dead wight plus 22.7 kg (50 lb). The maximum error noted in any five readings between calibrations was 0.090 kg (0.216 lb), and the standard deviation for several trials ranged between 0.072 and 0.113 kg. In operation in the greenhouse the standard deviation of 135 zero checks over a 16-d period was 0.130 kg. It should be noted that the digital meter rounds off one digit more than is displayed, which must exceed nine before it causes the last digit to change. Thus, the maximum possible reading accuracy of the system is 0.045 kg in the configuration tested.

In field operation the system performed satisfactorily and efficiently. The 36 lysimeters could be weighed in less than 2 h. Evapotranspiration determinations were practical both over an extended period of time and for short intervals (Figure 3).

CONCLUSION

An inexpensive electronic system for measuring weight changes of ±22.7 kg (50 lb) in lysimeters weighing 180 kg (400 lb) with a resolution of 0.045 kg (0.1 lb) to an accuracy of 0.090 kg (0.216 lb) is described. The use of an electrical offset zero established by a dead weight allows this performance to be achieved.

SUMMARY

A technique is described for weighing lysimeters using a strain gage load cell and

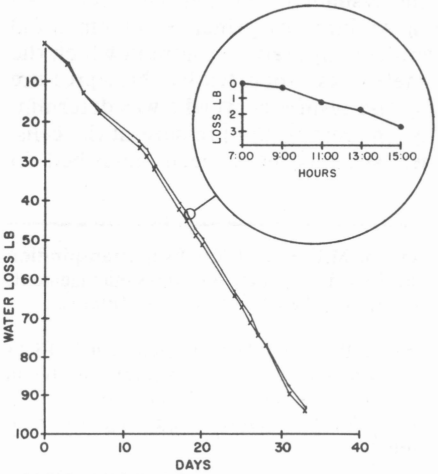

Figure 3. Evapotranspiration for wheat grown on two lysimeters during a 33-d period, summer 1971. Inset shows a record for an 8-h period on the 10th of August.

an electronic indicating system. The nominal weight of the lysimeter is eliminated from the measurement by offsetting the indicator zero electrically using a weight. This increases the possible resolution and accuracy of measurement. In the example described, weight changes of ±22.7 kilogrammes (50 pounds) in lysimeters weighing 180 kilogrammes (400 pounds) with a resolution of 0.045 kilogrammes (0.1 pounds) and accurate within 0.090 kilogrammes (0.216 pounds) were measured. Weighing of 36 such lysimeters could be accomplished in 2 hours.

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