Sprinkler Precipitation Gage Errors

R. A. Kohl

ACCURATE measurement of water applied by sprinklers is needed to determine the amount applied to research plots and estimate evaporation losses. While these measurements have been made with a variety of precipitation collection units, little information has appeared on their accuracy.

Christensen (1942) published data showing relatively high evaporation losses from cylindrical, catch cans. He attempted to remedy the problem by soldering funnels into the top of the cans, but evaporation losses were reduced little. Frost (1963) used a truncated cone or frustum-shaped can in an attempt to reduce the amount of water clinging to the sides of cylindrical containers. While this design appears intuitively superior to cylindrical cans, comparisons between units in use were not published. Kraus (1966) and Wolfe (1967) attempted to improve the accuracy of cylindrical containers by coating their interior with paraffin to hasten droplet travel down the can walls. Wolfe observed that "the paraffin appeared to make an improvement, but was not entirely satisfactory." Newer, semiautomatic systems (Culver and Sinker, 1966 and Hunter, 1966) generally rely on a collection funnel with a sharp top edge. The top edge of some collection funnels is extended upward to form either cylindrical or frustum-shaped walls to keep splash and evaporation at a minimum.

My attempt to use funnel and tube-shaped 3-in. metal rain gages to measure the amount of water applied by sprinklers to research plots resulted in failure. The measured amount of sprinkler-applied water plus rainfall and change in soil moisture storage failed to account for the water used by the crop when compared with lysimeter data.

Therefore an experiment was conducted to determine the relative accuracy of precipitation collection units in use for sprinkler irrigation and to compare an improved unit with the above units. The improved unit consisted of a 250-ml plastic separatory funnel with the top removed above the maximum diameter and the upper edge sharpened. A small tube was inserted at the desired liquid level and a reservoir attached to collect the overflowing oil (Fig. 1). A separatory funnel is normally used to separate two or more immiscible fluids.

METHODS COMPARED

The sprinkler precipitation collection units compared were metal, one-quart oil cans; oil cans coated with paraffin; the Frost (1963) frustum can; 3-in. rain gages with 1-in. measuring tubes; plastic wedge-shaped rain gages; and a separatory funnel (Fig. 2). The 3-in. rain gages and plastic wedge-shaped rain gages are commercial units. These gages are representative of portable units for field use. The 3-in. rain gage also contains the essential features of funnels used in permanent installations.

All units except the 3-in. rain gage were compared with and without an evaporation-suppressing oil. No. 2 diesel fuel was chosen as the evaporation-suppressing oil over kerosene because of the tendency of fine water droplets to "float" on kerosene because of surface tension. This problem was less pronounced with the diesel fuel, but was much worse with lightweight mineral oil. Mineral oil was used in the paraffin-coated cans because the diesel fuel tended to dissolve the paraffin.

During sprinkler operation, droplets of water were observed to adhere to the inside walls of the qt oil cans and evaporate before they could travel down the side and be trapped under the oil. Similar problems were encountered with the Frost cans. While large drops tended to fall directly into the evaporation-

Article was submitted for publication on February 21, 1971; reviewed and approved for publication by the Soil and Water Division of ASAE on October 11, 1971.
Contribution from the Northwest Branch, SWCRD, ARS, USDA, Idaho Agricultural Experiment Station cooperating.
The author is: R. A. KOHL, Research Soil Scientist, Snake River Conservation Research Center, Kimberly, Idaho.

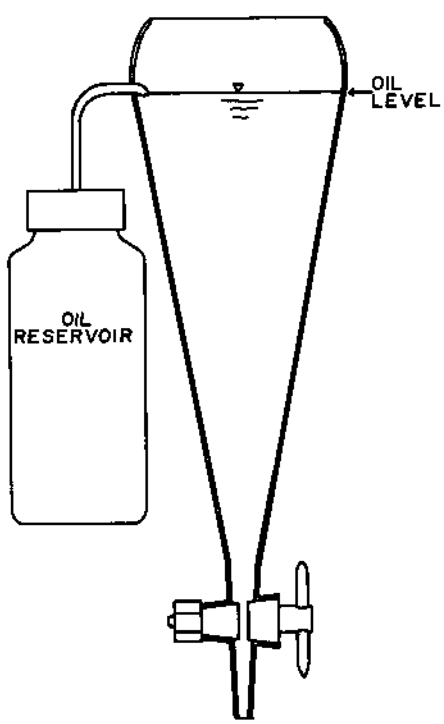

FIG. 1 Separatory funnel precipitation gage.

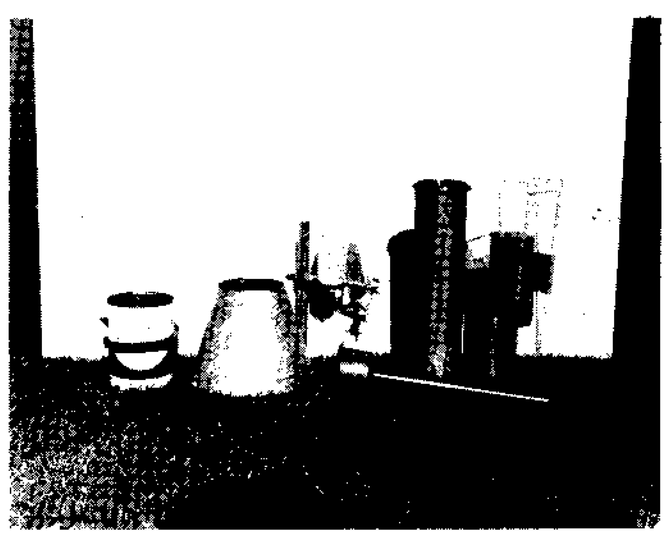

FIG. 2 Types of precipitation collection units compared from left to right: metal quart oil can, Frost can, modified separatory funnel, 3-in. rain gage and inner funnel, and plastic rain gage.

This article is reprinted from the TRANSACTIONS of the ASAE (Vol. 15, No. 2, pp. 264, 265, and 271, 1972)
Published by the American Society of Agricultural Engineers, St. Joseph, Michigan

TABLE 1 A COMPARISON OF PRECIPITATION COLLECTION UNITS WITH THE SEPARATORY FUNNEL UNIT AT VARIOUS APPLICATION RATES

Average application rate, in. per hr separatory funnel	Oil can	Oil can with oil	Paraffin-coated oil can	Paraffin-coated oil can with oil	Frost can	Frost can with oil	3-in. rain gage	Plastic rain gage	Plastic rain gage with oil
	Percent of catch in separatory funnel								
Day									
0.035	6	69	41	52	10	87	15	36	35
0.087	54	67	63	70	58	90	60	58	59
0.162	62	78			78	88	79	70	70
0.243	76	88			77	90	87	76	74
0.371	81	89			81	91	88	82	81
Night									
0.088	96	97			87	102	96	83	83
0.158	100	101			96	104	98	95	92

suppressing oil, the slightest wind caused small droplets to swirl into contact with the inner walls and provide opportunity for evaporation loss. Because of this problem, a unit with a minimum of exposed interior walls on which droplets might cling and evaporate was needed. Separatory funnels were chosen for their convenient size, steep interior walls below liquid level to aid in water droplet concentration, and ease of separating water from the evaporation-suppressing oil. Separatory funnels larger than 250 ml may be preferable when sampling mist drift or very low application rates to increase the amount of water being measured.

The separatory funnel was initially filled with No. 2 diesel fuel until a small quantity overflowed into the reservoir. At the conclusion of a run, the water was drawn off into a graduated cylinder along with a small quantity of oil to insure complete water removal. The oil in the reservoir was then returned to the separatory funnel.

The depth of water in the 3-in. rain gages was measured with a dip stick, while the plastic gage was read directly. With all other units, the catch was measured volumetrically and divided by the area of the opening to yield the depth of application.

The precipitation collection units were placed over mowed grass. Measurement stations were located on arcs of different radii from the sprinkler head. A measurement site consisted of one each separatory funnel with oil, Frost can with and without oil, plastic rain gage with and without oil, parafin-coated oil can with and without oil, three 1-qt oil cans with and without oil, and three 3-in. rain gages. The units were placed as close to each other as possible without mutual interference. The interior of the cans containing diesel fuel were initially coated with the oil.

Standard agricultural sprinklers were used with 5/64, 5/32, and 3/16-in. nozzles and operated at 55 psi pressure. Application rates were varied by varying nozzle size and distance from nozzle to collection units. The highest sprinkler application rates necessitated the use of two 3/16-in. nozzles.

Using the application rate indicated by the separatory funnel as that representative for a given test, the runs were grouped between the following limits: 0.02 to 0.05; 0.07 to 0.10; 0.12 to 0.19; 0.22 to 0.27; 0.32 to 0.42 iph. This grouping resulted in from two to ten tests being averaged for each set of limits. The paraffin-coated cans were used only during the last nine tests run within the range of the two lowest application rate groups.

Runs were of 1 to 3-hr duration, the longer runs being associated with the lower precipitation rates in order to collect enough water to assure desired measurement accuracy. Tests were performed on clear, sunny days with the exception of several simultaneous runs conducted between 2 and 5 a.m. to compare the day runs against runs conducted at lower temperatures, higher humidity and without solar radiation.

RESULTS AND DISCUSSION

The results are presented in Table 1. During data collection, the average air temperature ranged from 77 to 82 F and the relative humidity from 14 to 33 percent for the day runs. The night runs had a 55 F average air temperature and 84 percent average relative humidity. The data for the collection units under study are presented as a percentage of the catch in the separatory funnel. The daytime catch of only 6 to 91 percent of the catch of the separatory funnel raises serious questions concerning the significance of studies on evaporation losses measured with cans and rain gages. Most of the evaporation loss charged against sprinkler irrigation should probably be charged against the catch unit itself.

A comparison of precipitation measuring units with and without oil provides a rough estimate of the amount of water evaporated from the bottom of the catch can. The percentage of water lost from the containers with oil provides an estimate of the catch that evaporated from the can walls. The plastic wedge-shaped unit exposes a small liquid surface compared to the side wall area. As a result, the unit lost as much water with oil as without.

Examining the data collected at night, one observes that the Frost can with oil caught more water than the separatory funnel. A small quantity of the diesel fuel from the separatory funnels splashed out onto the grass, and a small quantity of water may have been lost along with the diesel fuel. More splash loss would be expected at the higher application rates because of the larger drop sizes resulting from the larger nozzles. Splash loss from the separatory funnel introduces a small bias in favor of the other units which did not experience splash loss.

It was observed that large droplets tended to travel faster down the walls of paraffin-coated cans than noncoated cans. However, small drops remained on the paraffin and evaporated. Thus the paraffin treatment did not provide sufficient improvement to produce a desirable unit.

With the exception of the Frost can containing oil, evaporation from all other units increased as the application rates decreased. When these or similar units have been used to characterize sprinkler patterns, the patterns would be biased toward the areas of higher application rates, the catch units in the areas of lower rates having lost a greater percentage of the applied water. Since it is likely that all of the water reaching plants is useful in supplying the water requirement (McMillan and Burgy, 1960), uniformity coefficients would also be biased against the sprinklers under test.

Using incoming solar radiation data and estimates for albedo, latent heat of vaporization and effective can area, estimates of the evaporation loss attributable to radiation for the oil cans without oil were made. At the higher application rates, evaporation roughly equaled the available radiation energy. Lower application rates did not keep the containers wet, and less water was evaporated than radiation energy available for evaporation. However, the evaporation loss at the lower application

(Continued on page 271)

Sprinkler Precipitation Gage Errors

(Continued from page 265)

rates represented a greater percentage of the total catch.

A greater proportion of the small droplets adhered to the collection unit walls and evaporated as compared to large droplets. As a result, the evaporation loss from collection units becomes a function of the drop size distribution of the sprinkler and therefore a function of nozzle size and shape, water pressure, windspeed and turbulance, and distance and direction from the sprinkler. Therefore the data in Table 1 are representative, but cannot be applied to other studies reported in the literature except to give an order-of-magnitude estimate of possible catch can losses.

A good precipitation collection unit for sprinklers should have four design features. First, the inner surface of the unit above the oil line should be as small as possible to reduce the area from which water droplets could evaporate. Coating the can surface with oil or paraffin did not prevent small droplets from adhering to the surface. The same results were obtained when the can walls were coated with a silicone water-repellant compound or tetrafloroethylene spray in a separate study. Second, the walls above the liquid surface should be shaped so as to minimize splash losses while preventing splash into the unit from the outside. Third, the walls should be painted white to minimize absorption of solar radiation, and perhaps insulated to minimize the transfer of sensible heat energy for evaporating water from inner surfaces. Fourth, the unit should be portable and allow for ease of catch measurement.

The modified separatory funnel provided a large improvement over the other units tested. It tends to meet the above-stated criteria with the exception of avoiding splash loss.

References

1 Christiansen, J. E. 1942. Irrigation by sprinkling. University of California, Agricultural Experiment Station, Berkeley. Bull. 670, 124 p.

2 Culver, R. and R. F. Sinker. 1966. Rapid assessment of sprinkler performance. Proc. of ASCE, J. Irrig. and Drain. Div. 92:1-17.

3 Frost, K. R. 1963. Factors affecting evapotranspiration losses during sprinkling. TRANSACTIONS OF THE ASAE 6(4):282-283, 287.

4 Hunter, E. J. 1966. Visual analysis of sprinkler test results. In: Proceedings of the Sprinkler Irrigation Association, p. 81-86.

5 Kraus, J. H. 1966. Application efficiency of sprinkler irrigation and its effects on microclimate. TRANSACTIONS OF THE ASAE 9(5):642-645.

6 McMillan, W. D. and R. H. Burgy. 1960. Interception loss from grass. J. Geophys. Res. 65(8):2389-2394.

7 Wolfe, J. W. 1967. Uniformity of distribution of water from small solid-set irrigation sprinklers. Paper presented at the 22nd Ann. Meeting, Pacific Northwest Region, ASAE, Spokane, Wn.