THE ASCE NEUTRON PROBE CALIBRATION STUDY: OVERVIEW

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ABSTRACT

A workshop was held at Logan, Utah to gather field information on neutron probe calibration and operation. Several techniques and instruments were compared. This paper serves to establish the background information for the work and describe the overall approaches, conditions, and equipment. Other papers presented at this conference provide detailed procedures and results.

INTRODUCTION

Neutron meters have been a staple of worldwide engineering technology ever since practical, self contained, portable instruments were introduced in the 1950's. These have proven to be durable, practical devices which characterize accurately the water contents of soil profiles. For such applications, the technology is yet to be superseded. The method is capable of a high degree of accuracy with proper application. The authors of this paper possess more than a century of combined experience with the method and perceive a variance in its implementation sometimes suspected to compromise accuracy.

In 1989, a neutron probe subcommittee of the ASCE Irrigation Water Requirements Committee was established. This committee sponsored two special sessions on the subject at the ID meetings in Durango, CO in July, 1990 (Harris, 1990). These ten papers and discussions established reasons for more standardization for calibration and use of the neutron probe method. Some of the specifics included a need for a more comprehensive manual describing

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recommended methodology. Users need more detailed instruction as to how specific a calibration is warranted, i.e., does one calibrate for each access tube,soil site, or region? What is the best method for installing access tubes, and what is the best access tube material? Accordingly, the subcommittee recommended appointment of a Task Committee to collectively study the matter at a central field site and to make recommendations for possible standardizations. The Task Committee was approved by the Technical Activities Committee to begin Oct. 1, 1991.

Three sites near Logan, UT were selected which provided a range of soil types. Each site had a wet profile and a dry profile condition a few meters apart. The workshop began on July 20, 1992 and ended on July 24, 1992.

The principal task at the workshop was to perform all measurements needed to calibrate several different types of neutron probes at six sites (three soil types and two moisture profiles at each soil type). Papers presented at the 1990 Durango program left uncertainty about geographical application of calibration. Secondarily, a set of special tasks related to calibration and use was performed. In the latter exercises, neutron probe performance with an end-mounted source was compared with a neutron probe with a center-mounted source.

OBJECTIVES

There were three objectives:

1) Measure bulk density by several volumetric soil sampling techniques to assess best overall method for accuracy and suitability for applications to measurement of volumetric soil water content for neutron probe calibration.

This objective furnishes information needed for making recommendations to users in their particular applications.

2) Calculate volumetric water content of soils from soil samples, and perform neutron measurements for calibration of several neutron probes.

Accomplishment of this objective permits comparison of calibration characteristics of several probes of different design and for several different methods of access tube installation. In addition, since some of the probes have been calibrated for other soils, this comparison would indicate how a wide range of soil types affects calibration.

3) Compare performance of end-positioned and center-positioned neutron sources for (a) proximity of probe to soil surface, (b) hydrogenous layer in the soil and at the surface, (c) cavity at the side of access tube, and (d) depth of auger hole below the lowest intended probe reading.

This objective evaluates the degree of error conditioned by the location of the neutron source in the probe when non-homogeneity in the soil is encountered by the instrument. This will help establish the range of these factors for the successful operation for the different types of probes.

OVERVIEW OF TECHNIQUES

A range of field approaches had been routinely used at home sites by the workshop participants. (We felt this range of experience would adequately encompass the needs of the study). Participants routinely used probes with either end-positioned sources (CPN, Martinez, CA) or centered sources (Troxler Electronic Laboratories, Research Triangle Park, NC). Some workers used aluminum or aluminum alloy access tubes and some used plastic or steel. Also, various field calibration approaches were used. Some participants used a multiple sampling of the soil in the region surrounding the access tube where neutron probe readings were made. Some removed samples from the hole being made for the access tube and let this represent the moisture and bulk density profile for calibration. Some used a calibration from each hole to represent a site specific calibration for the individual access tube. Various sizes of access tubes were represented also, although steel was of one size, aluminum a second and PVC a third. In general, commercial manufacturers provide neutron probes for fits to several diameters and wall thicknesses of access tubes.

The committee wanted to examine results of these methodologies performed simultaneously over a range of soil types and water contents.

DESCRIPTION OF FIELD TESTS

Field procedures were designed to be commensurate with the nature of the soils and distances separating the sites. Work schedules and equipment assignments were made considering logistics. The plan considered laboratory needs for balances and ovens as well as field sites and equipment. Group meetings were scheduled so that on-site coordination and adjustment could be made. Participants were assigned equipment and methodology by teams as follows: Teams used equipment furnished by several laboratories: Utah State University (USU); Soil Conservation Service, USDA, Ft. Collins, CO (SCS); Agricultural Research Service, USDA, Kimberly, ID (ARS); and Oklahoma State University (OSU).

The USU, SCS and ARS teams each installed an aluminum alloy tube, using their respective procedures, in a triangular pattern with tubes about 45 cm apart. The alloy tubes were "2.00-inch OD, 1.9-inch ID, ASTM B210 No. 6061 T-6," and were 6-ft (1.83 m) in length.

USU: Hole: Used a "1.9 inch hand auger" to make the hole to greater than 150 cm deep.
Bulk Density: 55.5 mm x 18.5 mm id "Down the hole" small volumetric sampler.
Water Content: Use the bulk density sample. Aluminum tube was later replaced with PVC.

SCS: Hole: Used "1.9-inch hand auger" to make the hole to greater than 150 cm deep.
Bulk Density: "Down the hole" volumetric sampler (SCS design) 62.7 mm x 34.7 mm ID.
Water Content: Use bulk density sample. Aluminum tube was later replaced with PVC.

ARS: Hole: Used "2.125-in" OD coring tool inserted by tractor mounted core sampler to greater than 150 cm.
Bulk Density: Cored sample cut into lengths centering on neutron reading depths.
Water Content: Use the bulk density sample.

OSU: Tube: "Nominal 1.5-inch" steel thinwall electrical-mechanical tubing (44.3 mm OD x 40.7 mm ID).
Hole: Used trailer mounted sampler to insert 44 mm coring tool to 90 cm.
Bulk Density: Three volumetric cores surrounding the access tube within a radius of 15 cm.
Water Content: use the bulk density sample.

Calibration

The three aluminum tubes were sequentially installed by the respective teams at each wet and dry site. Interactions of probe reading and soil sampling cited below affected the closest tube proximity (45 cm). After all tests were made with neutron probes, further sampling with cores of at least 76 mm diameter were made at some sites as a further check on bulk density values at the sites. The group invited the Troxler Corp. to incorporate readings with their recently developed capacitance-type probe. It is purportedly compatible with the plastic access tube used in the neutron probe calibration. In order to reduce disturbance of soil at the sites, the probes to be calibrated with PVC tubes were used in the same holes as the aluminum access tubes. The access tubes were pulled and, after slightly enlarging the hole, the PVC tubes were inserted.

As noted above, some teams (USU, SCS, and ARS) obtained "down the hole" soil samples for bulk density and water content prior to reading the profiles with a neutron probe. They installed a nominal 2-inch (55.5 mm) tube which was subsequently used for reading both CPN and Troxler neutron probes. The installation of the nominal 1.5-inch (44 mm) steel access tube by the OSU team permitted soil sampling during the installation of the access tube also, but required immediate sampling outside the tube just after reading with the neutron probe. Since this would have been destructive to the sampling site, the 44 mm steel tube was installed at least 1 m from the other tubes. Only one Troxler probe and one CPN were available for sampling the 44 mm access tube.

The ARS calibration included taking two additional cores for bulk density. These were taken about 15 cm from the tube hole after all tubes had been read with each probe.

Sampling depths for neutron probes were standardized to start 15 cm below the surface and proceed in 15 cm increments to 150 cm. Soil samples were to be centered on these depths. All of the neutron probes had factory installed marks on the probe from which depths were to be measured. Positioning stops on the probe cables were adjusted to provide these distances for the exercise. Access tubes were installed with 10 cm protruding above ground level. All probes were calibrated for the ratio method. At each site probes were positioned on a common access tube to make the reading in the shield. (This served as the standard count for determining count ratios for a given probe). An access tube projecting 1.5 m above ground level was installed at each site for shield counts. Shield cuts were made with each neutron meter when measurements were made at the site.

Special Tasks

Some tasks were designed to ascertain differences between end-positioned and centered-position of neutron sources on the detectors. A number of these effects were reported for an end-positioned design at the Durango conference (Allen and Segura, 1990). Specifically, we investigated (1) above ground distance for positioning the probe in the shield for obtaining a standard count, (2) plotting count rate vs. distance of probe beneath the surface, (3) effect of a buried paraffin layer on count, (4) effect on count of a buried cavity at the side of the access tube, (5) effect of a paraffin layer at the surface, and (6) effect of removing soil from the bottom of the access tube. These tasks were all conducted at Site 3W (see next section) and are discussed by Stone et al. (1993).

DESCRIPTION OF SOILS

Three sites with substantially differing soil types were used. These were (1) Millville silt loam on the Utah State University North Logan Farm. The field was in alfalfa, previously used in a study of variable sprinkler irrigation. The wet site was within 1 m of the irrigation lateral and the dry site was 3 to 4 m beyond the sprinkler pattern of the lateral. (2) Nibley heavy silty clay loam on the Utah State University Evans Farm. The wet site was adjacent to a sprinkler irrigation lateral and the dry site was in a fallow area about 25 m away. (3) Kidman fine sandy loam on the Richard Allsop turf farm (bluegrass) near Lewiston, UT. A field of recently reestablished turf irrigated by a center pivot system contained the wet site at the perimeter. The dry site, about 30 m from the wet site in an unirrigated area, and was barley stubble. Sites were identified by the site number followed by a W or D designator. For example, the irrigated site on Kidman soil was called Site 3W. Sites 1 and 2 were on opposite sides of Logan and were about 8 km apart. Site 3 was about 25 km form Logan.

The following descriptions for soils at the tree sites were abstracted from a published soil survey (USDA, 1974). Dimensions are as specified in the survey (1-inch is 2.54 cm).

1. Millville silt loam: A1 horizon thickness varies from 7 to 15 inches, and is calcareous. Texture is silt loam. C horizon is silt loam. **Horizons:** Ap, 0 to 6 inches; A12, 6 to 12 inches; AC, 12 to 24 inches; C1, 24 to 35 inches; C2, 35 to 65 inches.

2. Nibley silty clay loam: A horizon texture ranges from silty clay loam to heavy silt loam. Reaction is neutral to mildly alkaline. Thickness ranges from 6 to 15 inches. B2t horizon texture ranges from heavy silty clay loam to silty clay. B2tca and B3ca texture ranges from silty clay to heavy silty clay loam. C horizon texture ranges from silt loam to silty clay. Reaction is moderately alkaline to strongly alkaline. The depth to water table generally is 30 to 40 inches in undrained areas and is 50 inches to more than 60 inches in drained areas. (No team encountered a water table during the workshop).
   Horizons: Ap, 0 to 7 inches; A1, 7 to 13 inches; B1, 13 to 20 inches; B22tca, 20 to 32 inches; B3ca, 32 to 43 inches, C, 43 to 60 inches.

3. Kidman fine sandy loam: A horizon texture ranges from fine sandy loam to very fine sandy loam or light loam. Thickness ranges from 8 to 20 inches. B2 horizon ranges from fine sandy loam to light loam. Cca and C horizon texture ranges from fine sandy loam to fine sand. Reaction is moderately alkaline to strongly alkaline.
   Horizons: Ap, 0 to 8 inches; B1, 8 to 12 inches; B2, 12 to 20 inches; C1, 20 to 27 inches; C2ca, 27 to 43 inches; IIC3, 43 to 60 inches.

General Activities

On soil 1, the dry profile was somewhat hard and was sampled with some difficulty, although most teams were successful in sampling. On soil 2, the surface of the dry soil was hard and crumbly, and not all teams were successful in sampling in the allotted time. The "wet" site was sampled with difficulty, owing to friction resistance on the coring equipment. Site 3 provided easy sampling, but a compaction problem was noted in both the wet and dry areas, particularly at depths below 90 cm. During soil sampling, the fresh samples were placed in sample tins and stored in insulated coolers for transport to the laboratory for weighing and drying. To reduce the effect of foot traffic at the sites, the operators stood on a plywood platform (1 m on a side) while sampling.

Soil samples were weighed on the day they were taken. Two ovens and two balances were available. One oven overheated by 15° C on one day. Balance calibration and oven temperature were checked several times a day.

The eight papers in this session describe in detail the equipment used, specific methodology, and results. In general, each person responsible for a combination of device and method will report on each. Several persons commented that the conditions necessary to make the measurements in close proximity probably perturbed the procedures they would normally follow if performing the same tasks in isolation. We intended that such inconvenience would not bias the results to any erroneous conclusion. In general persons were more than accommodative to others who were working at the same or nearby site. On several occasions participants needed to wait for others to clear a site. Such delays did not seem to degrade integrity of samples or interrupt continuity of neutron readings once begun. In general, such inconveniences provided opportunity to relax and learn of experiences of others in use of the neutron method.

Appendix I. References

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APPENDIX II. ACKNOWLEDGEMENTS

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