TEMPERATURE STABILIZATION OF GAMMA RAY TRANSMISSION EQUIPMENT

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Abstract

Accurate measurements of water content of soil in situ can now be made using an improved gamma ray transmission method. Prior to this development, existing equipment tried in the field responded to temperature fluctuations as well as density and water content changes. With the new method, the nuclear counting system is stabilized on a reference $^{60}$Co gamma ray source attached to the detector assembly. Density changes are then measured with a $^{137}$Cs gamma ray source about 30 cm away from the detector. In laboratory tests, similar attenuated count rates were obtained for $^{137}$Cs gamma rays through a standard absorber while the temperature was varied from 5 to 35°C.

Additional Key Words for Indexing: water content, density, nondestructive measurements.

The gamma ray transmission method for measuring water content of soil in situ can give results unattainable by other methods in terms of accuracy, resolution, and absence of time lag and site disturbance. This nuclear method has been used successfully to measure density and water content of soil under controlled laboratory conditions (3, 5, 14, 15). Recent tests of the equipment under field conditions have been only partially successful because of electronic drift problems (9, 13). The electronic drift probably was caused by multiplier phototube gain changes and scintillation crystal light output and resolution changes resulting from temperature fluctuations. The temperature dependence of these components has been reported (1, 6, 8, 12). Current methods that utilize gamma emitters for stabilizing nuclear counting equipment require two detector assemblies (2, 4, 7, 10). The equipment, designed for laboratory experiments, is not readily adaptable to field use.

This note describes an improved method of stabilizing gamma ray transmission equipment against temperature fluctuations, thereby permitting use of this equipment in the changing temperature environment of a field soil.

Accurate determination of soil density or water content depends only upon counting primary photons transmitted from the source to the detector. Electronic discrimination against scattered radiation is preferred for field equipment, as collimating with lead is impractical.

An example of the effect of temperature on the energy spectrum of $^{137}$Cs is illustrated in Fig. 1. Ideally, the baseline voltage and window width, set at appropriate values for which the system was calibrated, should not change during the measurement period. Figure 1 shows that a system calibrated at 20°C with the baseline voltage and window width set to count only primary photons would detect essentially none if the system were operated at 30°C.

Equipment and Procedure

General details of the experiment and experimental setup are reported elsewhere (11). In addition, the following Hamer Electronics equipment was used (Trade names and company names are included for the benefit of the reader and do not imply any endorsement or preferential treatment of the product listed by the USDA.):

- Sealer: NS-11
- Ratemeter: N-780A
- High voltage supply: NV-13P
- Amplifier: NA-12
- Single channel analyzer: NC-11
- Spectrum stabilizer: NC-20
- Timer: KT-11

The detector assembly, $^{137}$Cs gamma ray source, glass plate sample tray, and soil cylinder were placed in a controlled temperature room. The detector assembly was connected to the counting equipment (located outside the controlled room, at ambient temperature of 23 ± 2°C) with a 45-m cable. Even though laboratory counting equipment is necessary, the 45-m cable (and longer, if necessary) should allow the detector and source to be used remotely in an experimental field.

The primary source of gamma rays, 5 mCi of $^{137}$Cs, was located about 30 cm from a Na(Tl) scintillation crystal (1.27 cm thick by 4.81 cm diameter) mounted on an RCA 6199 multiplier phototube. The window width of the single channel analyzer was set at 0.2 volt. Glass plates were used as standard absorbers. A 26.6-cm-long sample holder was designed so that the plates could be easily inserted or removed from the beam path. Density measurements were made at 22, 5, 20, 33, 5, 26, and 13°C, in that sequence.

Stabilization

One method for stabilization utilizes the NC-20 spectrum stabilizer. This unit is a special single channel analyzer which detects shifts in the spectral peak of interest. When a shift is detected, a compensating signal is generated which causes an external high voltage power supply to change its output volt-
age to correct for the shift. Our first choice was to use the 0.66 MeV $^{137}$Cs photopeak which is transmitted through the absorber. However, when the count rate is low and as the absorber thickness (density) changes, the low energy side of the $^{137}$Cs photopeak becomes skewed because of small angle Compton scattering. Under these conditions the electronics used to stabilize the spectrum are unable to accurately track the photopeak in the desired manner. Figure 2 shows count rate versus glass density for a “stabilized” and unstabilized system at $33 \pm 0.5^\circ$C. The nonlinearity of the stabilized system is evident that the transmitted $^{137}$Cs photopeak cannot be used for stabilizing purposes. This clearly shows that density changes cause variations in the spectrum shape to the degree that the electronic spectrum stabilizer fails.

Our alternative approach was the use of another reference source on which the system could be stabilized. The source was located so that it was not affected by density changes. Theoretical considerations limit this secondary source to gamma emitters, such as $^{60}$Co, which have the same energy spectrum response to temperature variations as the primary $^{137}$Cs source. A 0.4$\mu$Ci $^{60}$Co gamma ray source was incorporated into the detector assembly by attaching it to the bottom of the scintillation crystal. The photopeak of this secondary source, tracked by the electronic spectrum stabilizer, varied with temperature, but was independent of density changes. Although Compton scattering from the $^{60}$Co in the region of the $^{137}$Cs photopeak gives a relatively high and uniform background count (15 cps), it does not interfere with the density measurements.

Results and Discussion

Count rate as a function of glass density at seven temperatures from 5 to 33$^\circ$C is presented in Fig. 3. The experimentally determined count rates are designated by the open circles while the solid line was obtained from a linear regression analysis of log count versus density for all densities at seven temperatures. The linearity of the data demonstrates the high degree of stability achieved even with a wide variation in temperature and density.

Literature Cited


Fig. 2—Count rate versus glass density for unstabilized and “stabilized” conditions using $^{137}$Cs for reference photopeak at 33$^\circ$C.

Fig. 3—Count rate versus glass density for stabilized condition using $^{60}$Co for reference photopeak at temperatures from 5 to 33$^\circ$C.