Xenon Ionization Detector for Cone Penetrometer Applications

Gary C. Tepper (gctepper@saturn.vcu.edu; 804-827-4079)
Sentor Technologies, Inc.
9467 Manorwood Drive
Mechanicsville, VA 23116
&
Virginia Commonwealth University
Department of Chemical Engineering
Richmond, VA 23284

Robert L. Palmer (rpalmer@ucsd.edu; 858-822-1037)
Sentor Technologies, Inc
1876 Burnt Maple Way
Vista, CA 92083
&
University of California, San Diego
Department of Applied Mechanics & Engineering Sciences
San Diego, CA 92093-0411

Gamma ray spectroscopy is well recognized as an important diagnostic tool for the remediation of radioactive contamination sites. In particular, sufficiently accurate measurements of gross environmental gamma ray spectra can be used to identify the constituent radioactive nuclides and determine their concentrations. However, the practical implementation of spectroscopic measurements "in the field" introduces additional difficulties beyond those encountered in a controlled laboratory environment. On the other hand, because of the complicated mix of contaminant species and their widely varying concentrations, the accuracies needed in real field environments are often even more stringent than those required in the laboratory. Adding to these measurement difficulties is the fact that these spectra must be obtained, not in air, but in a relatively highly attenuating and often heterogeneous soil matrix. None of the foregoing problems is insurmountable, however, given the availability of gamma ray sensors with sufficient resolution and stability, and which are suitable for implementation in field-deployable devices such as cone penetrometers.

The currently most widely used method for obtaining gamma ray spectra in the field is based on measurement of the light output of scintillators such as thallium doped sodium iodide or bismuth germanate. Light pulse intensities produced by gamma ray interactions in these scintillation materials are detected and amplified by means of sensitive photomultipliers. These distributions of scintillation pulse heights can be correlated with the distribution of gamma ray energies that produced them. The primary drawbacks of this technology are the intrinsically low energy resolution of scintillators, especially for energies below 1 MeV, and the temperature sensitivity of the scintillation pulses. The latter problem is particularly problematic in the field where environmental conditions are difficult to control and ambient temperatures can vary both spatially and temporally.

A promising alternative to scintillation detectors is based on one of the earliest methods for radiation detection, the ionization chamber. Because of the intrinsically higher energy efficiency of ionization versus scintillation, ionization detectors are capable of better sensitivity and energy resolution. However, gas-filled ionization chambers have the problem of low density and, hence, low interaction probability with highly penetrating gamma radiation. This problem has been largely overcome with the development of ionization chambers using xenon, a high atomic number noble gas, compressed to high density. The phase diagram of xenon is very favorable for obtaining high densities at reasonable temperatures and pressures. For example, densities in the range of 0.5-1.0 g/cc can be obtained at pressures in the range of 50-65 atmospheres and for typical ambient temperatures. This density coupled with the high atomic number of xenon (54) gives all overall detection efficiency approximately one-fourth to one-fifth that of the same size sodium iodide scintillator at the standard reference energy of 0.662 MeV (Cs-137). On the other hand, the obtainable energy resolution for xenon ionization devices is four to five times better than sodium iodide. Moreover, improved resolution is often more desirable than detection efficiency in many applications, especially those involving the characterization of radioactive wastes where a multiplicity of radioactive species produces complex, overlapping spectra and where the problem is often one of too high counting rates rather than too low. In addition to the greatly improved energy resolution, another favorable characteristic of xenon is its temperature stability with respect to ionization response. This characteristic promises to greatly simplify the problem of calibration in the field by eliminating the need for temperature-based data correction.

In July 1998, Sentor Technologies was awarded a contract by the U.S. Department of Energy, Federal Energy Technology Center to develop a high-pressure xenon ionization detector specifically designed for deployment via cone penetrometer probes. Three of these devices have now been built and are at various stages of testing in preparation for calibration and field-testing. These detectors, 1.125” in diameter and approximately seven inches long, are intended to replace the similar sized sodium iodide detectors previously used in this application. The design of the detector and the issues involved will be discussed along with the results of the testing done so far, including gamma ray spectra for representative radionuclides. Plans will be presented for calibration and field-testing of the cone penetrometer probes with the goal of producing a superior solution for *in situ* characterization of radioactive waste and contamination sites.