REAL-TIME, AUTOMATED CHARACTERIZATION OF SURFACES FOR ALPHA AND BETA RADIATION

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ABSTRACT

A new data collection system, called ABACUS™, has been developed by CHEMRAD Tennessee Corporation that automates and expedites the collection, conversion, and reporting of radiological survey data of surfaces. Field testing of the system by Oak Ridge National Laboratory/Environmental Technology Section is currently underway. Preliminary results are presented. The system detects, discriminates, and separately displays the results for alpha and beta contamination scans on floors and walls with a single pass. Fixed-position static counting is also possible for quantitative measuring. The system is currently configured with five 100 cm² dual-phosphor plastic scintillation detectors mounted in a lightweight aluminum fixture that holds the detectors in a fixed array. ABACUS™ can be configured with other detectors if desired. Rate-meter/scalers traditionally coupled to individual detectors have been replaced by a single unit that houses the power supply and discriminator circuit boards to support up to five detectors. The system is designed to be used by a single operator.

ABACUS™ is made possible by the real-time positioning capabilities of a previous prototype system, INRADS™, which in turn, was a result of re-engineering the patented USRADS® positioning technology to determine the detector’s location indoors each second. The current relative precision for scans using ABACUS is less than 2 cm between adjacent readings. The absolute precision for any one point is typically within 15 cm to benchmarks within 30 m. Greater precision is available with static counting.

Each detector’s position and data are transmitted once per second and recorded on a nearby laptop computer. The data are converted to appropriate units, color-coded, and mapped to display graphically the findings for each detector in real-time. Reports can be generated immediately following the survey. Survey data can be exported in a variety of formats. Benefits of ABACUS™ are: 1) immediate feedback to decision makers using the observational approach to characterization or remediation, 2) thorough documentation of survey results, 3) increased statistical confidence in scans by recording counts every second, 4) reduced paperwork and elimination of transcription errors, and 5) time and cost savings for collection, conversion, mapping, evaluating, and reporting data over traditional methods.

Key words: radiation detection, scanning, minimum detectable activity, automated data handling.

INTRODUCTION

A new data collection system, called ABACUS™, has been developed by CHEMRAD Tennessee Corporation1 that automates and expedites the collection, conversion, and reporting of radiological survey data of smooth surfaces. The system detects, discriminates, and separately displays the results for alpha and beta contamination scans on floors and walls with a single pass. Fixed-position static counting is also possible for quantitative measuring. The system is designed to be used by a single operator. Field testing of the system by Oak Ridge National Laboratory/Environmental Technology Section2 is currently underway. Preliminary results are presented.

Radiological surveys for characterization or release of surfaces involve a combination of scans, direct measurements, smears for determination of removable contamination, and samples for laboratory analysis. Depending on the survey protocol being used on a given project, up to 100% of the surface area being surveyed requires scanning. This is a time-consuming and labor-intensive task. The
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quality and quantity of data generated by the scans can be affected by many factors, including source-detector geometry, minimum detectable activity (MDA) of the instrumentation, and the response of the surveyor to a change in response of the instrument (NRC 1995). Conversion of the data from counts to units of activity or exposure rate, as well as data input into a database or spreadsheet for analysis of the data, can take as long as the actual survey itself.

DESCRIPTION OF SYSTEM
The system consists of five major components (Fig. 1.):

- the ABACUS™ detector array,
- the ABACUS™ instrumentation pack;
- the INRADS™ telemetry and positioning package which consists of a stationary receiver, a master receiver, and an ultrasonic crystal (located on the detector array),
- a laptop computer with the Stepper™ software package for system control and data analysis, and
- a Hand-held terminal for remote operation (not shown in Fig. 1).

![Figure 1. Simplified Schematic of System Components](image)

Alpha and beta counts are collected by each detector and transmitted by INRADS™ once per second. A hand-held data terminal is connected to the INRADS™ data pack which allows the surveyor to control the system while surveying. INRADS™ sends the data to the laptop using FM radio frequency (rf) along with positional data calculated using ultrasonics. The laptop is connected to a radio receiver that collects the data sent by INRADS™. The Stepper™ software then records the position and data for each detector each second. As the detector array is moved along the wall or floor, the position and data are displayed on the computer screen, allowing instant evaluation of the data. Detailed descriptions of the system follows.

ABACUS™ DETECTOR ARRAY
The detector assembly is currently configured with five Ludlum³ model 43-89 100 cm² dual-phosphor plastic scintillation detectors mounted in a lightweight aluminum fixture that holds the detectors in a fixed array (Fig. 2). Three detectors are arrayed end-to-end and the other two are offset behind the first three to ensure complete coverage of the area being scanned. Individual 100 cm² detectors were chosen so as to be able to compare readings to guideline values. ABACUS™ can be configured with other detectors if desired. Large-area detectors are available for gross scanning, but cover too large an area (~ 560 cm²) to convert to activity. Gamma scintillation detectors have also been utilized during prototype testing.

![Figure 2. ABACUS Detector Array](image)

INSTRUMENTATION
Ratemeter/scalars traditionally coupled to individual detectors have been replaced by a single unit that houses the power supply and discriminator circuit boards (Ludlum 1995) to support the five detectors (Fig. 3). The instrument unit has connectors for the detector cable, high voltage adjustment pots, and an indicator light if the detector is overloaded. Data output from the instrumentation pack is

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fed by serial cable to the INRADS™ data pack for instantaneous transmission to the laptop computer. The instrumentation pack can be either mounted on a backpack for wall surveys or a cart for floor surveys.

INRADS™ TELEMETRY AND POSITIONING PACKAGE

The core of the INRADS™ hardware is the data pack component carried by the surveyor on the backpack and contains the instrument package interface, rf telemetry link between the data pack microcomputer and the laptop computer, and circuitry that enables the handheld terminal to communicate with the laptop computer (Fig. 3).

The survey instrument interface can accept a variety of different types of signals (pulses, analog, or RS-232) as data input. Depending on the signal type, data is either accumulated for one second, sampled each second or relayed as the data becomes available to the laptop via the rf telemetry link at the start of the next ultrasonic pulse.

Data collected by the ABACUS™ system is tied to position utilizing real-time positioning capabilities of INRADS™, which in turn, was a result of re-engineering the patented USRADS® positioning technology to determine the detector's location each second (Berven, Little, and Blair 1991).

The rf telemetry link operates on 216.025 MHz (forward data link) and on 218.870 MHz (reverse data link) to form the bi-directional radio link between the INRADS™ data pack and the laptop computer. It is used to indicate when the ultrasonic crystal was fired and to transfer the most recent data from the survey instruments to the laptop computer. During certain portions of the system's use, the rf link can be used to transfer messages between the data pack and the laptop computer. The rf link enables the laptop computer to signal the surveyor in the event of any system malfunction.

The stationary receivers are equipped with an ultrasonic receiver, special signal-identification electronics, and an rf transmitter, and has a rechargeable battery mounted internally which can operate for approximately 8 - 10 hours before needing recharging. A voltage meter is mounted on each stationary receiver to indicate the condition of its battery. Each stationary receiver operates on its own unique rf frequency, allowing the physical location and the stop signal from each stationary receiver to be automatically and positively identified.

The master receiver is equipped with 17 unique rf channels, 16 of which are receive channels and one transmit channel. The first 15 receive channels are assigned on the basis of one to each stationary receiver (for use with USRADS®), with channel 16 designated as the receive channel for instrument data from the data pack. The 17th and only transmit channel is for communications from the laptop computer to the data pack. The master receiver has rows of indicator lights to show the presence of an rf carrier signal from the stationary receiver and a second set of lights indicate the time-of-flight of the ultrasonic signals. There are also a set of toggle switches to allow selective receiving from active stationary receivers (Chemrad 1995).

LAPTOP COMPUTER

The system ORNL/ETS evaluated utilizes a Southwind™4 laptop computer with an expansion base (to hold the timer card) and a Pentium™ processor with a minimum clock speed of 100 Megahertz, and 16 megabytes of RAM. The system will run under either Windows® 3.x or Windows 95®6.

HANDHELD TERMINAL

A handheld data terminal (Two Technologies Model 8045)7 is used for operator control of the system while surveying. The command set of the system allows for viewing of raw data on the handheld terminal as well as start/pause/resume survey commands.

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DESIGN CHANGES FROM USRADS TO INRADS™

Certain changes have been designed into ABACUS/INRADS™ system from the original USRADS® system. They are:
1. Only one stationary receiver with two microphones is required.
2. The ultrasonic crystal is mounted on the detector array instead of the instrumentation backpack to yield better location precision.
3. The location of the stationary receiver is entered manually into the system and is used to calculate the speed of sound and calibrate the system.
4. The system ORNL/ETS used to evaluate the system is an older analog-based rf system. The current Chemrad system utilizes spread-spectrum rf technology and is digital based.
5. ABACUS/INRADS™ can collect data and position for multiple detectors; whereas USRADS® was originally configured for one detector.

STEPPERTM SOFTWARE

The Stepper™ software consists of four modules, they are:
1. Configure,
2. Check Equipment,
3. Survey, and
4. Analyze.

The Configure module allows for programming and storing various detector configurations and calibration factors. The system is designed to work with many different survey instruments. When changing from one instrument to another, or when changing configuration of the detector array, it may be necessary to adjust the system to accommodate for the differences between detectors.

The Check Equipment module is for testing of system integrity before starting a survey. It is a quality control check to confirm that the equipment is working properly and that data is being received by the laptop computer.

The Survey module is used when performing surveys with the ABACUS/INRADS™ system. It has functions for:
- assigning names to surveys,
- calibrating time-of-flight of the ultrasonics for the particular survey,
- control of survey progress (start, pause, stop),
- tracking the location of the detector array on the screen to ensure adequate coverage,
- plotting the data real-time in a color-coded format for identification of elevated areas,
- data smoothing and data statistics, and
- merging of surveys.

The Analyze module is used once the survey is completed. The Analyze routines are used to:
- view selected detector data,
- view selected point data,
- view signal limits,
- adjust thresholds,
- set color tables and unit names,
- view areas,
- modify or correct points or lines,
- create batch processing routines,
- export files to ASCII data files and either AutoCad™ or Generic CAD™ input files.

Data exported from the Analyze package can then be evaluated using a variety of software packages.

EVALUATION OF THE SYSTEM

The system was assembled in two configurations: as a floor monitor and a wall monitor. All five detectors were configured to read in counts per second (cps) for beta and alpha radiation. The detectors were factory calibrated to 99mTc and 60Sr/Y for beta radiation and 238Pu for alpha radiation at a source-to-detector geometry of 0 cm (contact). The high-voltage supplies and discriminator boards were calibrated according to Ludlum's standard procedure by Chemrad Tennesse (Ludlum 1995). The source to detector spacing used during the floor survey was approximately 1.25 cm. Minimum detectable activity for the detector array was calculated empirically by Chemrad (Egidi, Flynn and Blair 1997). The methods and results of the empirical evaluation are being peer reviewed at this time. All data collected for this evaluation are considered qualitative, and therefore have not been converted to units of activity. Background values on a linoleum-covered concrete floor were obtained by collecting data in a fixed position at four locations, and also on exposed concrete at four locations. Only the background beta data from the first survey are presented to save space here.

A scan survey was performed using the system in floor monitor mode (Fig.4). The survey covered an area of approximately 75 m² and was completed in less than one hour. A second survey was performed on a portion of the same floor, but with check sources (2.5 cm dia) of known activity introduced to see if the system could detect them. Finally, a small survey was conducted on an uncontaminated sheetrock wall with the system configured for walls (Fig.5).

Being that the Analyze portion of the Stepper™ software was not fully operational, data collected from the surveys were exported to QuatroPro® and Surfer® for review.

PRELIMINARY RESULTS

Background beta data collected on linoleum-covered concrete are presented in Table 1.

The amount of variance in the data seems to be greater than that expected from random radioactive decay. To evaluate this, data from location four are plotted and presented in Fig. 6. The cause of the variance may be due to electronic noise from the detectors or interference from the ultrasonic crystal mounted on the detector array.

The Analyze module of the Stepper software has a smoothing algorithm based on a rolling average that can be set by the operator. A median filter is also being considered to help eliminate transient "spikes" in the data. Further evaluation of this issue is currently underway.

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Graphical plots of the floor survey are presented in Figs. 7 and 8. As with the background survey, one cannot tell if the individual one-second packets of elevated activity are transient spikes or valid data without going back and re-surveying the area.

Graphical plots of the survey using check sources are presented in Figs. 9 and 10. In order to conserve space, the data from the wall survey are not presented here.

**DISCUSSION**

The ABACUS™ detector array has advantages over other large-area detectors in that it should have the ability to discriminate small areas of elevated activity that can be quantified with proper calibration. Further evaluation of the MDA and problems associated with a one-second measurement are needed before the concept can be brought to market or submitted for regulatory approval.

The volume of data collected per unit area by the automated system is greater than that normally recorded by a technician. Therefore, the statistical confidence in the data are assumed to be increased because of the larger size of the data set. In addition, the scan ranges and statistics based on the ranges are more precise because the system automatically records the range of the values as well as the number of data points. Traditionally, the surveyor has to interpret the ranges from the analog display on the instrument and record the scan ranges on field sheets and maps.
Paperwork is reduced using this system. Data from traditional surveys are recorded on field sheets and maps, then entered into computers for review. The automated data collection features of the system saves time over conventional survey techniques.

The data statistics (number of measurements, minimum count, maximum count, average counts) from the survey can be printed and can be exported in tabular format. The data can be analyzed graphically and exported as well. Set up time is minimal, and the system will work with only one person. A floor survey of the size in this evaluation (~75 m²) done by hand with one 100 cm² detector could have taken a surveyor about six hours, not including data input and conversion, and the scan ranges would be affected by human interpretation of the data. Further discussion of scan efficiency and human interferences are presented elsewhere (NRC 1995).

The survey using the check sources demonstrate that the instrument can detect small, elevated areas of activity. Conversions from counts to activity were not made because the source-to-detector geometry was changed during the evaluation. The current relative precision for scans using ABACUSTM is less than 2 cm between adjacent readings. The absolute precision for any one point is typically within 15 cm to benchmarks within 30 m. Greater precision is available with static counting.

The ability to examine the data in the field and apply the observational approach with the Analyze package can clearly be a benefit, but could not be evaluated at this time because of the software not being fully operational. However, it should be noted that even with exporting the data to other software packages, review of the data was quickly and easily accomplished.

CONCLUSION

Chemrad Tennees, Corp. is developing an automated system for conducting alpha- and beta-radiological surveys of smooth surfaces. Preliminary evaluations conducted by ORNL/ETS indicate the re-engineering of the USRADSTM technology to indoor applications has been successful.

Peer review of methodologies for calculating MDA are ongoing. Further evaluation of the off-the-shelf detectors and proprietary software are required. Additional findings will be presented by ORNL/ETS and Chemrad as the system is refined and made ready for market.
REFERENCES


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