CONF-871018--2

AUTOMATION OF THE RADIOLOGICAL SURVEY PROCESS: USRADS ULTRASONIC RANGING AND DATA SYSTEM*

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CONF-871018--2

DE87 010588

INTRODUCTION

The Radiological Survey Activities (RASA) program at Oak Ridge National Laboratory (ORNL) serves as the Inclusion Survey Contractor (ISC) in the Department of Energy's (DOE) Uranium Mill Tailings Remedial Action Project (UMTRAP). The ISC is to identify properties in the vicinity of 24 inactive uranium mill sites suspected of having ^{226}Ra-bearing uranium mill tailings by-product material originating from the processing of uranium ore contamination. Mobile gamma scanning was the primary method used to identify these properties.[1] Once identified, the ISC conducts an inclusion survey. The objective of this survey is to perform sufficient radiological measurements to determine if uranium mill tailing contamination is present, and, if so, if it is in excess of relevant Environmental Protection Agency (EPA) criteria.[2] Radon emanating from ^{226}Ra is the primary pathway of exposure to human occupants at these sites. EPA criteria focus on controlling ^{226}Ra concentration in soil. (^{226}Ra concentrations in soil shall not exceed background levels by 5 pCi/g in the top 15 cm of soil averaged over 100 m^2 area, or 15 pCi/g in any subsequent 15-cm depth averaged over a 100 m^2 area beneath the upper 15 cm). The concentration of ^{226}Ra in soil can be measured directly by soil sampling and subsequent gamma spectrographic analysis of the sample, or by direct measurement of the gamma exposure rate at the soil surface using portable instrumentation in the field. In both methods, the concentration of ^{226}Ra is inferred by examining the frequency of gamma emission of ^{214}Bi, a radioactive decay product in the ^{238}U decay chain.

ORNL was requested to perform 8,000 vicinity property inclusion surveys in three years in the communities near 24 inactive mill sites. In an effort to conduct this radiological survey activity in the most cost-effective manner possible, ORNL has developed a technology to automate

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Research was performed by members of the Environmental Assessments Group of the Health and Safety Research Division at Oak Ridge National Laboratory under U.S. DOE contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

much of the radiological survey process and provide tabular and graphical survey data output in the field following the survey or in the office for report generation. This technological development is called the Ultra-Sonic Ranging and Data System (USRADS).

SYSTEM DESCRIPTION

System Application

The primary component of the inclusion radiological survey is the gamma scan across the entire surface of a suspected vicinity property. The gamma scan consists of a field technician traversing a property in parallel transections while observing and noting the ambient gamma exposure rate on an analog portable meter attached to a NaI(Tl) detector. Usually, every square meter of the accessible property is covered by this survey technique and any anomalous gamma radiation fields are noted in field logbooks. If elevated levels of gamma radiation relative to background are observed, the areal extent of that anomaly is also recorded and a soil sample is collected. The radiological survey information is transcribed into a microcomputer (PC) and later formatted into a survey report. The report recommends to DOE the property be included into or excluded from the UMTRA Project based on extant radiation levels present compared to EPA criteria.

The USRAD system was developed to automatically locate a surveyor's position on a property and transmit that information along with the instantaneous instrument measurement to a PC in the field. The system conserves technician time in the field by eliminating gridding of the property to locate measurements taken. USRADS conserves time in the office by automatically transcribing data into a PC and reduces report production time by preformatting information into report-ready output. The automation process reduces errors in instrument readout and errors of data transcription, and, because information from the USRAD system is transmitted every second, more information is gathered and available to base assessment decisions.

System Hardware

The USRAD system consists of a surveyor's backpack (SB), fifteen stationary receivers (SR), a master receiver (MR), custom computer interface or counter timer module (CTM), Compaq Portable II personal computer (PC), and a small trailer to transport this equipment. The SB contains the interface circuitry to receive the signal from the portable gamma detector, an ultrasonic transmitter and rf equipment to establish a bidirectional communication link with the PC mounted in the trailer. The ultrasonic transmitter is a lead-ziconate-titaninate crystal that is in the form of a circular cylinder with a hollow core. The crystal dimensions are 2.2 in. in diameter and 1.445 in. in height. This crystalline material and its dimension result in a natural resonating frequency of 19.5 kHz. The crystal is pulsed for 10 msec each second as the data from the portable survey instrument are transmitted to the PC via the rf telemetry link. If the PC detects any problems, either with the data or in determining the surveyor's location, a message is transmitted to the surveyor and displayed on the handheld terminal to alert the surveyor of the malfunction. The SB can be operated for a normal eight-hour day from the rechargeable gel-cell located in the SB.

The stationary receivers contain an ultrasonic receiver and a rf transmitter. The dimensions of the metal box that houses the ultrasonic receiver card, rf transmitter card, and rechargeable gel-cell battery pack that provides sufficient power for eight hours of operation are 10 x 10 x 15 cm. Each SR has a unique rf frequency so that the MR can identify which SRs heard a valid ultrasonic signal. The MR therefore contains 15 rf receivers, one for each SR and a receiver and transmitter for communication with the SB. Both the MR and PC are powered by a gasoline-operated generator also carried in the trailer.

System Operation

The hardware and software interface is crucial to the system operation. The system snychronization is obtained through the different rf links. The SB is the master timer for the system since the data are transmitted from the SB at the same instant that the ultrasonic crystal is pulsed. This data transmission occurs each second and instructs the MR to "start" the timers on the CTM card associated with each of the SR. As an SR hears a valid ultrasonic signal, it relays a "stop" signal to the MR via its unique rf channel. The "stop" signal from the SR instructs the MR to disable the timer on the CTM card associated with that SR, thus the time-of-flight of the ultrasonic signal from the SB to that SR has been recorded. With a simple calculation, the distance from the SB to that particular SR can be calculated (Fig. 1).

The conversion factor to determine the distance is the speed-of-sound which is determined during the setup phase of the system operation. During the system setup, the SRs are placed on the property so that the surveyor should be in view of at least three of the SRs from any location on the property. Once the SRs have been placed on the property, the speed-of-sound is determined and the locations of the SRs that were placed on the property are computed. A display of the computerized location is plotted on the CRT along with the property plat fro the operator to view. When the operator has completed the system setup, which usually takes only about fifteen minutes, the surveyor begins the property survey.

As the surveyor begins to survey the property, the ultrasonic crystal is pulsed each second as the data from the survey instrument are transmitted to the PC. Each second, the PC reads the time-of-flight data from the fifteen SRs, determines which ones are valid, triangulates the surveyor's location, plots the surveyor's location on the CRT, and stores all raw data. By plotting the surveyor's location each second, the surveyor can view the surveyor coverage of the property at any time during the survey. In addition to plotting the surveyor location, the CRT displays on the plot any data point that exceeds a threshold entered by the surveyor, so that any areas of concern are identified on the display, to ensure that sufficient data have been obtained to characterize that area.

System Software

The digitized schematic drawing of the property is stored in the PC prior to the survey using AutoCAD, a commercial computer-assisted drawing software package. The survey data are added to this information. The property schematic is displayed on the PC's monitor (CRT). As the surveyor traverses the property, his past and present position are displayed to denote the completeness of coverage by the surveyor. During the survey, the software checks incoming information and alerts the surveyor (via the backpack terminal) if errors are detected either in the survey data or position data. To ensure data integrity, all data are stored on the hard disk every 30 seconds.

Onsite data reduction is accomplished by several software packages. The USRAD system enables the surveyor to analyze the survey data to ensure sufficient data is obtained to characterize the property before leaving the site. The surveyor can view the data in a number of different graphical formats as well as obtain summary reports. The graphical formats supported by the USRADS are Replay, Block Statistics, Contour, and 3-D plots of the radiation data. The Replay program will generate the same display that the surveyor viewed when the survey of the property was completed. The data are replayed in the same order as the data were taken. The Block Statistics routine enables the operator to select a grid block size and have the data analyzed for each block. If the mean of the data for a particular grid block is greater than the operator-entered threshold, then that block is highlighted on the CRT, and the statistical information for that grid block are stored in the summary report. Raw data are converted to appropriate units and displayed or printed out in tabular or graphical format. By indicating preset thresholds, areas of contamination can be identified and vital statistics can be calculated (area size, number of measurements, measurement range, average and standard deviation). Graphical representations are made in two- and three-dimensional display (Fig. 2). The contour routine generates a summary report and outlines the areas that exceeded the user input threshold. The 3-D plot generates two different views of the data and provides a means by which the surveyor can view the entire data obtained during the survey. Information can be displayed in the field and is output directly into a report-ready format without transcription.

BENEFITS OF THE SYSTEM

The USRAD system is a hardware/software ranging and data transmission system that provides real-time position data and combines it with other portable instrument measurements. Live display of position data and onsite data reduction, presentaiton, and formatting for reports and automatic transfer into databases are among the unusual attributes of USRADS.

Approximately 25% of any survey-to-survey report process is dedicated to data recording and formatting, which is eliminated by USRADS. Cost savings are realized by the elimination of manual transcription of instrument readout in the field and clerical formatting of data in the office. Increased data reliability is realized by ensuring complete survey coverage of an area in the field, by elimination of mathematical errors in conversion of instrument readout to unit concentration, and by elimination of errors associated with transcribing data from the field into report format. In one DOE-sponsored program, this represents a savings of almost $500/survey (over 9,000 surveys performed, e.g., $4,500,000 savings).

The USRAD system can be adapted to measure other types of pollutants or physical/chemical/geological/biological conditions in which portable instrumentation exists. Applications may include chronically contaminated areas; emergency response in mapping pollution areas where accidents have occurred; and, combined with the use of robotics, contaminated areas may be assessed which are too hazardous to human access (i.e., nuclear reactor cores, highly contaminated areas, etc.). Additionally, it may be used for biological or geological characterization of an area. As a surveyor traverses a region of interest, geological formation, magnetic fields, species of trees, and insects could be noted and transmitted.

The USRAD system fills a void in the automatic data collection/correlation/reduction system's arena, particularly for the outdoor suburban environment. In addition, USRADS fills this void in a very cost-effective and innovative manner that allows a surveyor to rapidly collect spatially high quality data with a minimum amount of training. System setup time is minimal and easy. Repeatability of the survey results from multiple surveys is excellent. The versatility inherent in USRADS allows a wide variety of sensors to be utilized and even multiple sensors simultaneously. Onsite verification of the completeness of the survey is automatic. While approximately half the savings of field data collection costs may be attributed to the field portion of the USRADS data collection, the other half of the savings has to be attributed to the data reduction, presentation, and integration into computer-assisted-drafting electronic files and into electronic databases where reports and plots are automated.

REFERENCES

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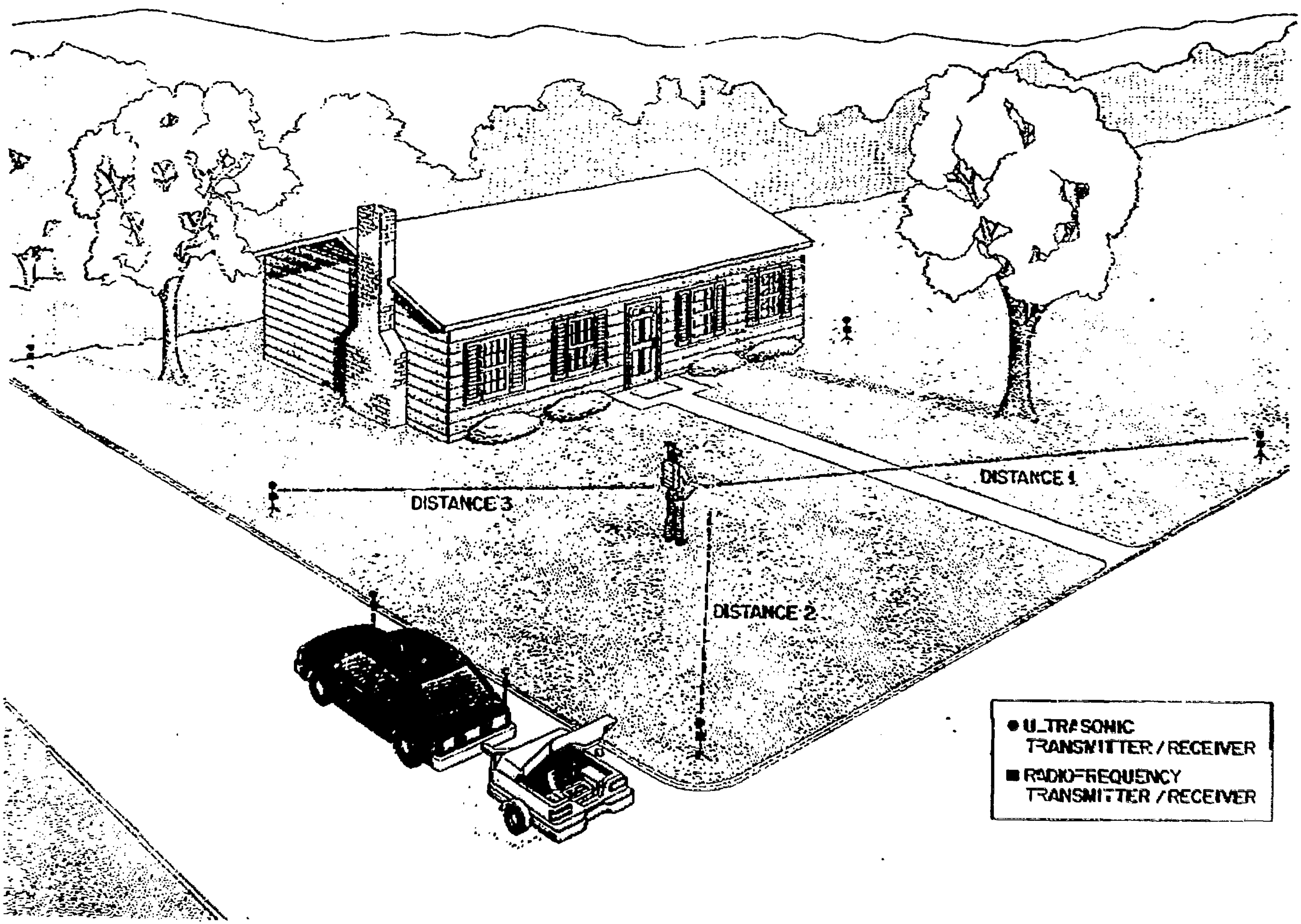
2. Environmental Protection Agency, "Final Environmental Impact Statement for Remedial Action Standards for Inactive Uranium Processing Sites (40 CFR 192), Vol. 1 and 2," EPA Office of Radiation Programs, Washington, D.C., October 1982.

ORNL-DWG 86-7161

Figure 1. LOCATING THE USRADS SURVEYOR BY TRIANGULATION



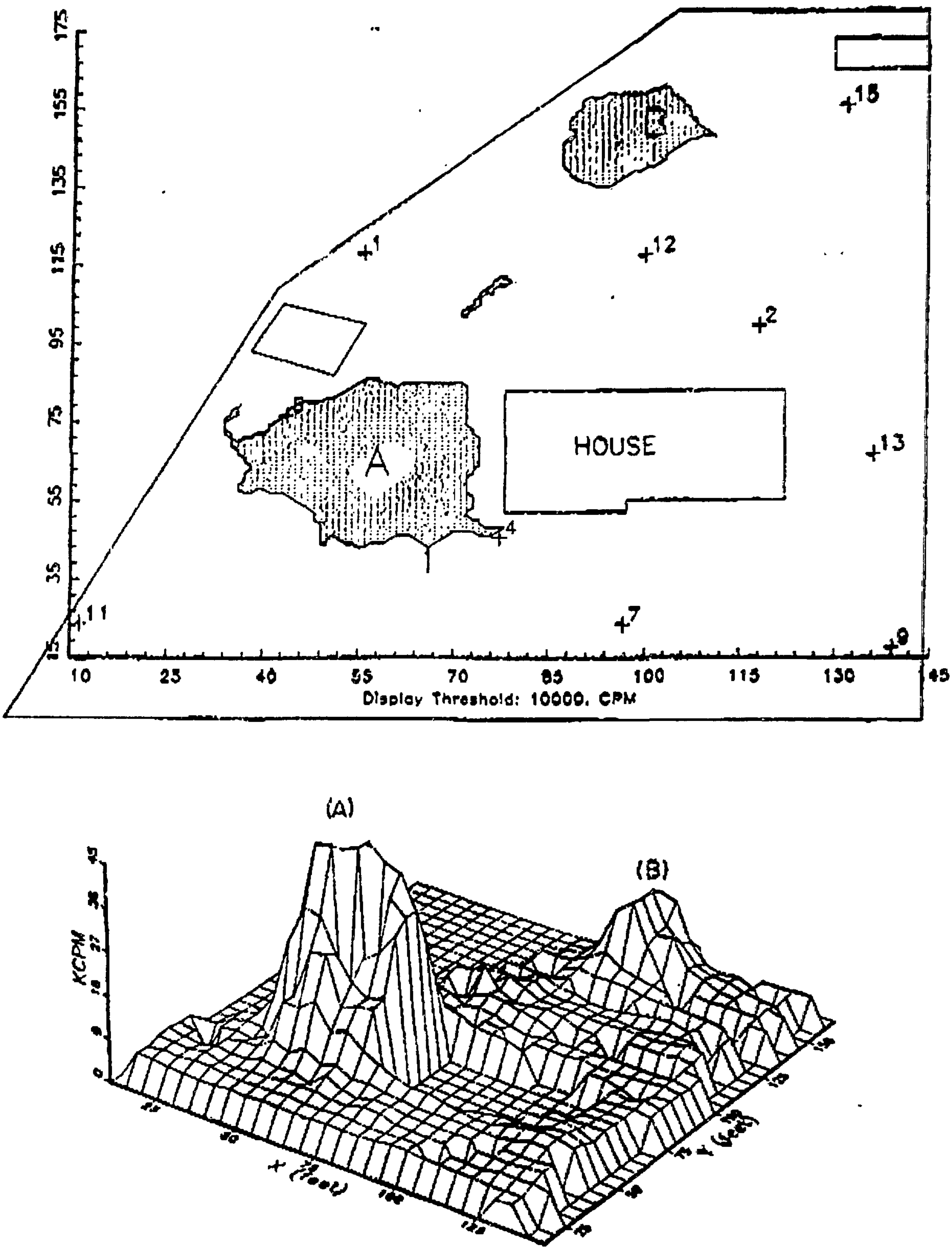


Figure 2. Graphical representation of radiological contaminants by USRADS on a private property.

DISCLAIMER