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An Automatic Locating and Data Logging System for Radiological Walkover Surveys

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ABSTRACT

Oak Ridge National Laboratory has developed an Ultrasonic Ranging and Data System (USRADS) to track a radiation surveyor in the field, to log his instrument's reading automatically, and to provide tabular and graphical data display in the field or in the office. Once each second, USRADS computes the position of the radiation surveyor by using the time-of-flight of an ultrasonic chirp, emitted by a transducer carried in a backpack, to stationary receivers deployed in the field. When the ultrasonic transducer is pulsed, a microprocessor in the backpack radios the start time and survey instrument's reading to the master receiver at the base station (a van or truck). A portable computer connected to the master receiver plots the surveyor's position on the display, and stores his position and instrument reading.

The CHEMRAD corporation has just completed a survey of the ORNL main plant area using two radiation survey instruments simultaneously: (1) a ratemeter connected to a NaI crystal that is swung in a arc near the ground, to look for surface contamination, and (2) a small pressurized ionization chamber (PIC), attached to the backpack frame at a height of 3 ft, to measure the exposure rate.

INTRODUCTION

Soil contamination is seldom uniform, typically elevated concentrations are found in small, isolated "hotspots." Attempts to locate hotspots by analyzing soil samples collected on a regularly spacing grid will fail unless the grid spacing is small. Gilbert (1982), for example, shows that to locate 3 ft, circular hotspots successfully 90% of the time requires a grid spacing of at most 5.4 ft. To survey an area as small as acre would require locating 150 grid points and analyzing 150 soil samples -- a slow and costly process.

When the contamination is surficial, such as the deposition of particles from stack emissions, hotspots can be located by walking over the site with a portable radiation survey instrument. It is difficult, however, to transcribe walkover survey data. Generally the approximate location, approximate shape, and range of instrument readings are recorded in a field notebook. Later this information must be digitized before it can be entered on computerized drawings of the survey area for the final report.

As part of the Uranium Mill Tailings Remedial Action Program (UMTRAP, 1987), the U.S. Department of Energy contracted ORNL to survey, in three years, over 8,000 public and private properties, including sidewalks, backyards, and roadbeds, in the vicinity of 24 inactive mill sites. To facilitate these surveys, ORNL developed an Ultrasonic Ranging and Data System (USRADS) to track the surveyor during a walkover survey and automatically log his position and the survey instrument reading once each second.

DESCRIPTION OF USRADS

Figure 1 illustrates the operation of the system. The technician's position is calculated using travel times from an ultrasonic crystal carried in a backpack to a number of stationary receivers. Once each second the USRADS backpack pulses the ultrasonic crystal and radios the survey instrument reading to the master receiver. The stationary receivers radio the master receiver when they detect an ultrasonic pulse. The travel times recorded by the master receiver are the delays between the radio signal from the backpack and from each of the stationary

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receivers. A portable computer connected to the master receiver records the survey instrument reading, then calculates the backpack crystal's location from the travel times. Thus, USRADS records both the radiation surveyor's position and his instrument's automatically.

USRADS HARDWARE

USRADS consists of a surveyor's backpack, fifteen stationary receivers, a master receiver, a custom computer interface and counter timer module, a Compaq Portable II personal computer, and a small trailer or a van to transport this equipment (Figure 2). The backpack contains the interface circuitry to receive the signal from the field instrument, an ultrasonic transmitter and radio frequency equipment to establish two-way communication with a computer mounted in the trailer.

The ultrasonic transmitter is a lead-zirconate-titanate crystal 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 resonance 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 computer via the radio telemetry link. If the computer 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 backpack can be operated for a normal eight-hour day from a rechargeable gel-cell.

The stationary receivers contain an ultrasonic receiver, a radio transmitter and a rechargeable gel-cell battery. Each stationary receiver has a unique radio frequency so that the master receiver can identify which stationary receivers heard an ultrasonic signal. The master receiver contains 15 radio receivers, one for each stationary receiver, and a receiver and transmitter for communication with the backpack. Both the master receiver and the computer are powered by a gasoline-operated generator also carried in the trailer.

USRADS SOFTWARE

Two people are required to operate USRADS: one to walk the survey area, and one at the base station to operate the computer, monitoring the data as it arrives. During the survey the computer displays the location of all the stationary receivers and plots a dot once each second to indicate the current position of the backpack, or if the instrument reading exceeds a preset threshold, a solid square (Figure 3). 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. All data are stored on the hard disk every 30 seconds.

Analysis of the data in the field is a major advantage of USRADS over conventional radiation surveys. The operator can use a number of routines that are part of USRADS to ensure that sufficient data has been obtained to characterize the property before leaving the site. The graphics routines included in USRADS are Replay, Block Statistics, Contour, and 3-D plots of the 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. By indicating preset thresholds, anomalous areas can be identified and vital statistics can be calculated (area, number of measurements, measurement range, average and standard deviation). Graphical representations are made in two- and three-dimensional display. The Contour routine generates a summary report and outlines the areas that exceeded the user input threshold.

SURVEY INSTRUMENTS

USRADS is designed to interface with both analog and digital instruments, and is not limited to radiation surveys. To date, we have used USRADS to look for soil contaminated with radionuclides using a Thyac III Survey meter connected to a NaI detector and exposure rates with a Victoreen 450P portable pressure ion chamber (PIC); to look for buried metal objects and to delineate waste trench boundaries using an EM31 terrain conductivity meter which measures the electrical conductivity of the ground (Nyquist and Blair, 1990); and are testing USRADS combined with a portable x-ray fluorescent analyzer to screen for metals such as lead and arsenic in soils.

CASE STUDY: SURVEY OF ORNL PLANT

After the initial development of USRADS was completed, the system was licensed through the ORNL Technology Transfer Office to the CHEMRAD Tennessee Corporation. CHEMRAD just completed a radiation survey of the ORNL main plant area as part of the ORNL's remedial action program. For this survey USRADS was configured to collect the readings from both the a gamma scintillometer and a portable PIC simultaneously. The data from the gamma scintillometer, where the NaI detector is suspended within 6 in of the ground, will be used to guide later soil sample collection. The data from the portable PIC, held fixed at 3 ft from the ground, will be used to assess radiation exposure at part of the baseline risk assessment required before remedial action.

For this example one-acre block, XG55A, a threshold of 45 μR/hr was selected. The small hotspots highlighted could have easily been missed with a conventional survey grid (Figure 3). As this data is automatically logged on a portable computer, it is immediately available for further analysis such as gridding and contouring (Figure 4).

The path ABCDEF was chosen to illustrate a potential use of this very dense data. Assume a worker regularity walks this path once a day, five days a week, 50 weeks per year, for 25 years. What is the cumulative excess exposure? Assuming the worker walks at a steady rate of 4 mph an integrating the exposure profile along this walking path (Figure 5), then subtracting the typical ORNL background exposure rate (13 μR/hr) yield a total 25 year dose of about 3 mrem. This is not intended to be a realistic scenario, since the grid block and path were chosen arbitrarily, but it illustrates a potential application of the extensive data set (over 750,000 data points) that will be available once this survey is complete.

SUMMARY AND CONCLUSIONS

The ultrasonic ranging and data system developed at ORNL allows for rapid data collection and analysis in the field without a predetermined measurement grid. The system illustrates how nuclear safeguard technology (health physics instrumentation) can be adapted to environmental applications.

REFERENCES

Gilbert, R. O., 1982, Some statistical aspects of finding hot spots and buried radioactivity, PNL-SA-10274, 27 pp.

Uranium Mill Tailings Remedial Action Project, 1987, Vicinity Properties Management and Implementation Manual, UMTRA-DOE-AL-050601, Revision D.

Nyquist, J. E., and M. S, Blair, An automated locating and data logging system for geophysical surveys, in Proceedings of the Fourth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, May 14-17, 1990, Las Vegas, Nevada, ISBN-1-56034-085-1, p. 99-113.

FIGURE CAPTIONS

Figure 1.

Figure 2. Instruments shown include Compaq Portable II computer, master receiver, stationary receivers (on truck tailgate), and backpack with handheld terminal. The EM31 terrain conductivity meter (on the ground) is one of several survey instruments that has been tested with USRADS.

Figure 3. Replay of the image on the monitor during the survey of block XG55A. Stationary receiver locations are marked with a cross and tagged with an identification number; nine out of a possible fifteen receivers were deployed for this survey. The surveyor's location is plotted as solid block if the instrument reading is above the preset threshold, otherwise it in plotted as a dot.

Figure 4. Upon completion of the survey, the data was put into ORNL grid coordinates and contoured. The path ABCDEF represents a hypothetical walking path for an ORNL worker.

Figure 5. The exposure rate along path ABCDEF (see Figure 4).

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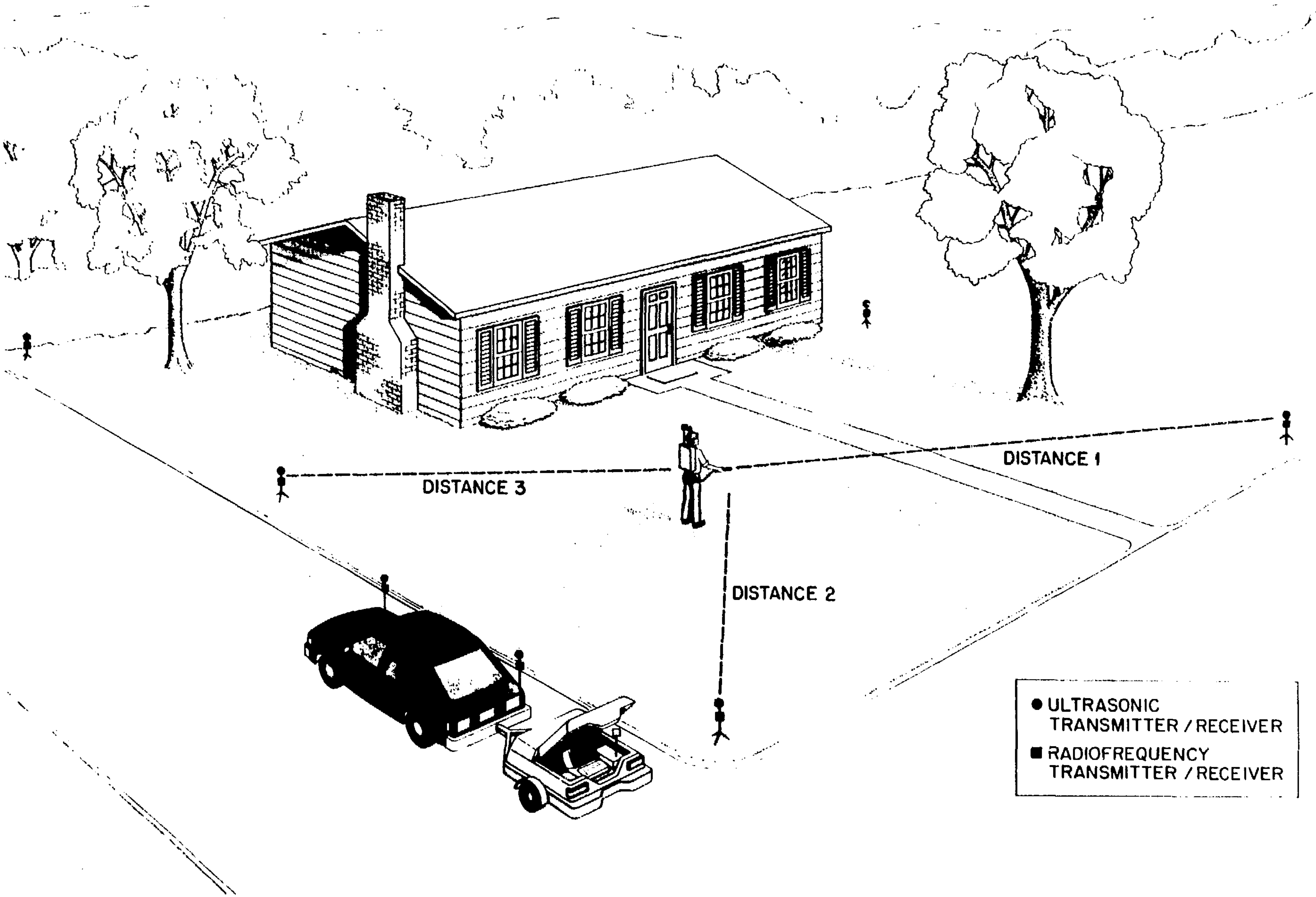
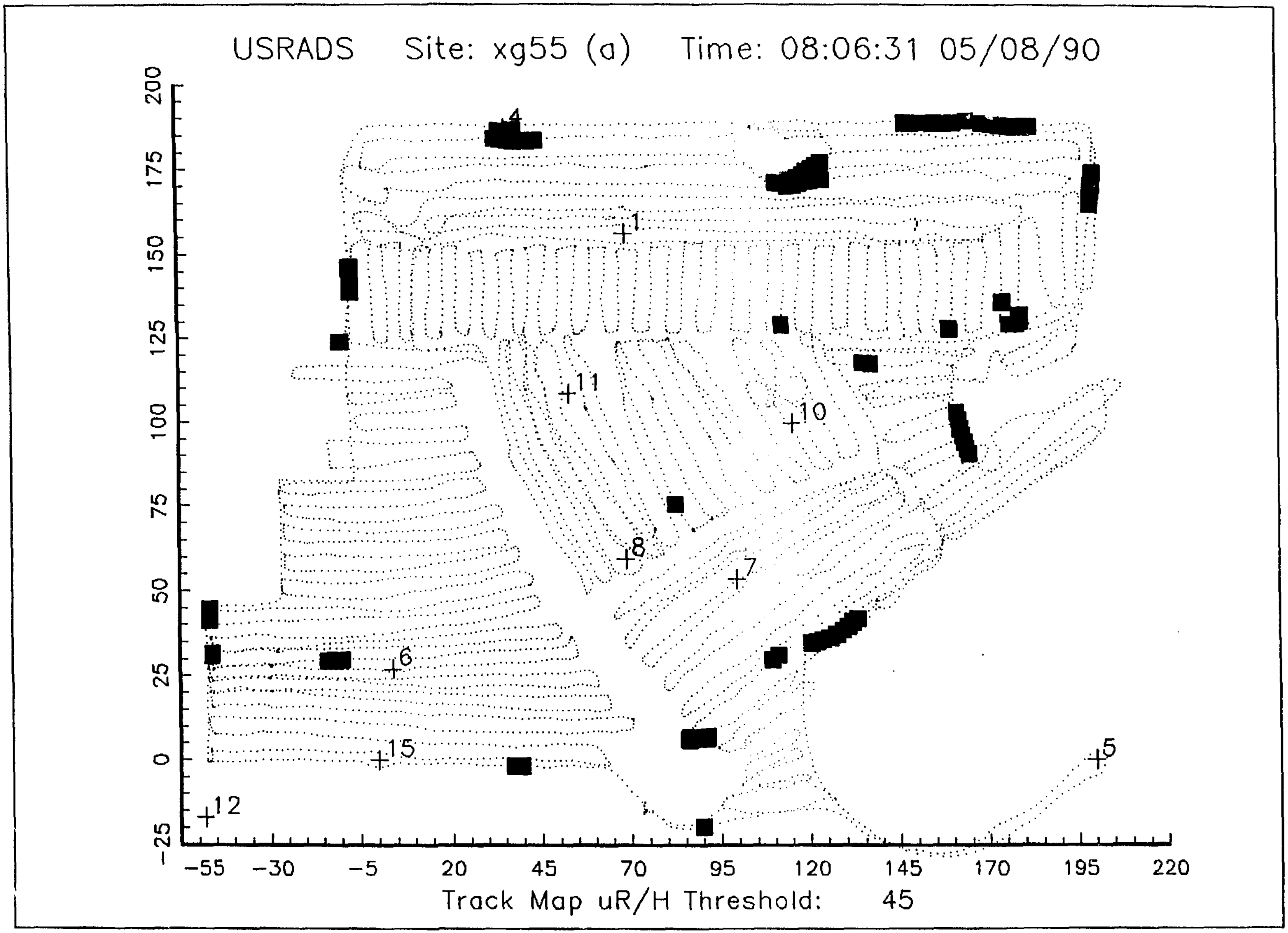
LOCATING THE USRADS SURVEYOR BY TRIANGULATION

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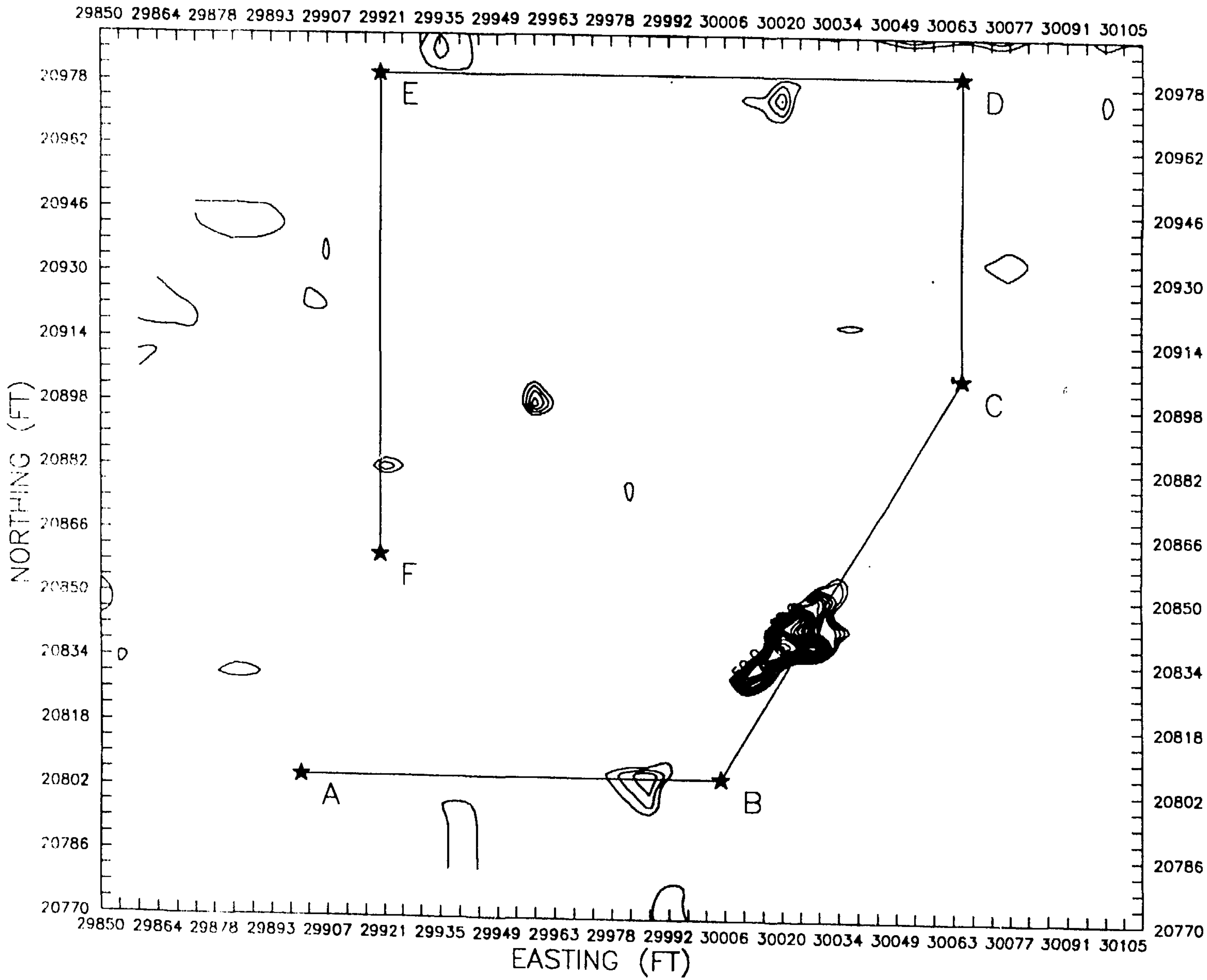

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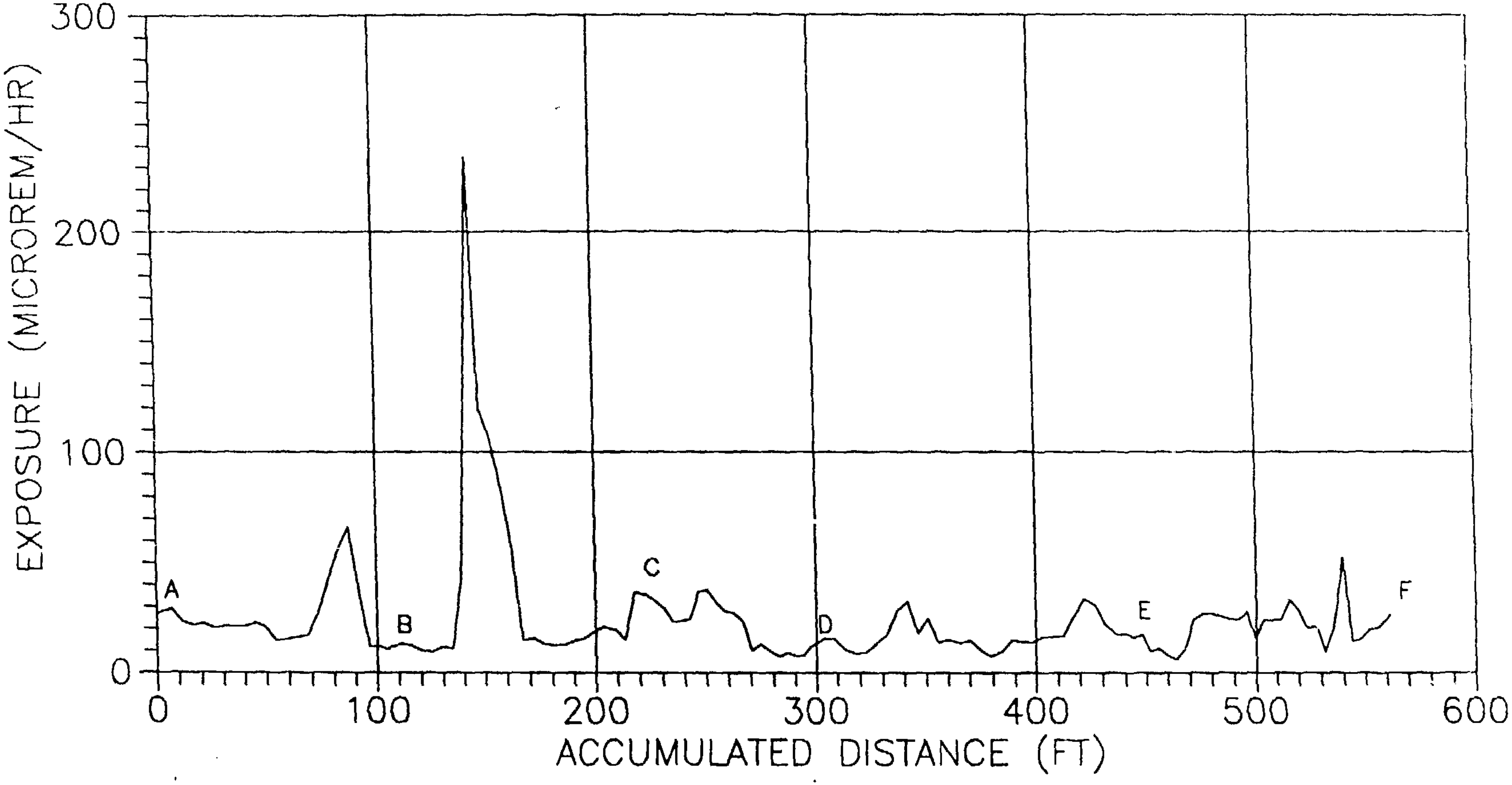

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600
ACCUMULATED DISTANCE (FT)