EG&G ENERGY MEASUREMENTS

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AN AERIAL RADIOLOGICAL SURVEY OF THE

ALVIN W. VOGTLE NUCLEAR PLANT

AND SURROUNDING AREA

WAYNESBORO, GEORGIA

DATE OF SURVEY: AUGUST-SEPTEMBER 1988

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ABSTRACT

An Aerial Radiological Survey was conducted during the period of August 24 to September 14, 1988 over an area of approximately 310 square kilometers (120 square miles) surrounding the Alvin W. Vogtle Nuclear Plant. The Vogtle Nuclear Plant is located near Augusta, Georgia, along the Savannah River and adjacent to the Savannah River Site (SRS). Several anomalous areas were identified in the portion of the survey extending into the SRS perimeter. The dominant isotopes found in these areas were cesium-137 and cobalt-60. All of these man-made anomalies identified by the aerial measurements were attributed to SRS processing.

For the remainder of the survey area, the inferred radiation exposure rates generally varied from 6 to 10 microroentgens per hour (μR/h), which was found to be due to naturally occurring uranium, thorium, and radioactive potassium gamma emitters. The reported exposure rate values included an estimated cosmic ray contribution of 3.6 μR/h.

Soil samples and pressurized ion chamber measurements were obtained at three locations within the survey boundaries to support the aerial data. The exposure rate values obtained from these ground-based measurements were in agreement with the corresponding inferred aerial values.

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1.0 INTRODUCTION

An aerial gamma survey was conducted from 24 August through 14 September 1988 over the Alvin W. Vogtle Nuclear Plant and surrounding area at Waynesboro, Georgia. The purpose of the survey, covering a 310-square-kilometer (120-square-mile) area, was to map the gamma environment of the reactor facility and surrounding area. The survey was performed at the request of the United States Nuclear Regulatory Commission (NRC).

The survey was sponsored by the United States Department of Energy (DOE) and the United States Nuclear Regulatory Commission. EG&G/EM, a prime contractor of the DOE, has conducted aerial radiological surveys for the DOE, the NRC, and other U.S. government agencies for more than 25 years. The basic utility of the aerial survey is that the coverage of the survey area approaches 100 percent.

2.0 SITE DESCRIPTION

The Alvin W. Vogtle Nuclear Plant, operated by Georgia Power, is located on the Savannah River at Waynesboro, Georgia, approximately 16 kilometers (10 miles) southeast of Augusta, Georgia. The plant is situated directly across the Savannah River from the Savannah River Site (SRS) in Aiken, South Carolina. The terrain is gently rolling and contains many small streams and wetland areas.

There are two units at the site, each with a rated net electric power output of 1079 MWe. Unit I is currently operating at 100% power; Unit II was still under construction at the time of this survey. The area immediately surrounding the Vogtle Nuclear Plant consists mostly of freshly turned earth, land fill, and an extensive parking area.

3.0 NATURAL BACKGROUND

Natural background radiation originates from radioactive elements present in the earth, airborne radon, and cosmic rays entering the earth's atmosphere from space.

The natural terrestrial radiation levels depend upon the type of soil and bedrock immediately below and surrounding the point of measurement. Within cities, the levels are also dependent on the nature of street and building materials. The gamma radiation originates primarily from the uranium decay chain, the thorium decay chain, and radioactive potassium. Local concentrations of these nuclides produce radiation levels at the surface of the earth typically ranging from 1 to 15 microroentgens per hour (μR/h) (9 to 130 millirem/year).[1] Some areas with high uranium and/or thorium concentrations in the surface minerals exhibit even higher radiation levels, especially in the western states.

One member of both the uranium and thorium radioactive decay chains is an isotope of radon, a noble gas, which can both diffuse through the soil and travel through the air to other locations. Therefore, the level of airborne radiation due to these radon isotopes and their daughter products at any specific location depends on a variety of factors, including the meteorological conditions, mineral content of the soil, and soil permeability. Typically, airborne radiation contributes from 1 to 10 percent of the natural background radiation levels.

Cosmic rays, the space component, interact with elements of the earth's atmosphere and soil. These interactions produce an additional natural source of gamma radiation. Radiation levels due to cosmic rays vary with altitude and geomagnetic latitude. Typically, values range from 3.3 μR/h at sea level in Florida to 12 μR/h at an altitude of 3 kilometers (1.9 miles) in Colorado.[2]

4.0 SURVEY PLAN

The Vogtle survey was flown in conjunction with a similar survey flown for the DOE over the Savannah River Site. The SRS portion of the survey involved a study of low levels of man-made gamma activity produced by SRS operations, requiring a narrower line spacing than the standard reactor survey. Consequently, the overlap area of the two surveys was flown with the more accurate (narrower) line spacing.

The Vogtle portion of the survey covered approximately 310 square kilometers (120 square miles). All lines northeast of the Vogtle Nuclear Plant (the overlap area) were flown at a nominal altitude of 61 meters (200 feet) above ground level (AGL), a line spacing of 76 meters (250 feet), and a speed of 36 meters per second (70 knots). Lines flown to the southwest of the plant were flown with a line spacing of 152 meters (500 feet).

The gamma ray spectral data were processed to provide a qualitative and quantitative analysis, where applicable, of the radionuclides in the survey area. During the survey operations, the data analysis van and aircraft were based at the Fort Gordon Detachment Hangar at the Bush Field airport located near Augusta, Georgia.

5.0 SURVEY EQUIPMENT

A Messerschmitt-Bolkow-Blohm (MBB) BO-105 helicopter (Figure 1) was used for the low-altitude survey. The aircraft carried a crew of two and a lightweight version of the Radiation and Environmental Data Acquisition and Recorder system, Model IV (REDAR IV). Two detector pods were mounted on the sides of the helicopter. Each contained four 10.2-cm × 10.2-cm × 40.6-cm (4-in × 4 in × 16 in) log-type thallium-activated sodium iodide, NaI(Tℓ), gamma detectors as well as one 7.6-cm diameter × 7.6-cm (3-in by 3-in) cylindrical gamma detector of the same material.

FIGURE 1. ***MBB BO-105 HELICOPTER WITH DETECTOR PODS***

One of the log detectors, connected to an independent ADC, extended the effective dynamic range of the REDAR IV system, which is useful in examining areas exhibiting enhanced levels of radiation. The smaller detectors, looking away from the ground, were also used in estimating the radon contribution to the gross-count radiation levels.

The signal from each detector was calibrated with an Na-22 source. Normalized outputs of each detector were combined in a four-way summing amplifier for each array. The outputs of each array were matched and combined in a two-way summing amplifier. Finally, the signal was adjusted in the analog-to-digital converter (ADC) so that the calibration peaks appeared in pre-selected channels of the multichannel analyzer of the REDAR IV system.

5.1 REDAR IV System

The REDAR IV is a multi-microprocessor, portable data acquisition and real-time analysis system. It has been designed to operate in the severe environments associated with platforms such as helicopters, fixed-wing aircraft, and various ground-based vehicles. The system displays all required radiation and system information to the operator in real time via CRT displays and multiple LED readouts. All pertinent data are recorded on magnetic cartridge tapes for post-mission analysis on minicomputer systems.

The system employs five Z-80 microprocessors with AM9511 arithmetic processing chips to perform data collection and display, real-time data analysis, navigational calculations, and data recording, all of which are under operator control. The system allows access to the main processor bus through both serial and parallel data ports under control of the central processor.

The REDAR IV System consists of the following subsystems:

1. Two independent radiation data collection systems
2. A general purpose data I/O system
3. A digital magnetic tape recording system
4. A CRT display system
5. A real-time data analysis system
6. A ranging system with steering calculation and display

The REDAR IV processing system block diagram is shown in Figure 2.

Each radiation data collection system consists of a multichannel analyzer which collects 1,024 channels of gamma ray spectral data (4.0 keV/ channel) once every second during the survey operation. The 1,024 channels of data are sent to the single-channel processor, then compressed into 256 channels. Table 1 summarizes the spectral data compression performed by REDAR IV.

The spectrum is divided into three partitions with the appropriate energy coefficient to make the width of the photopeaks approximately the same

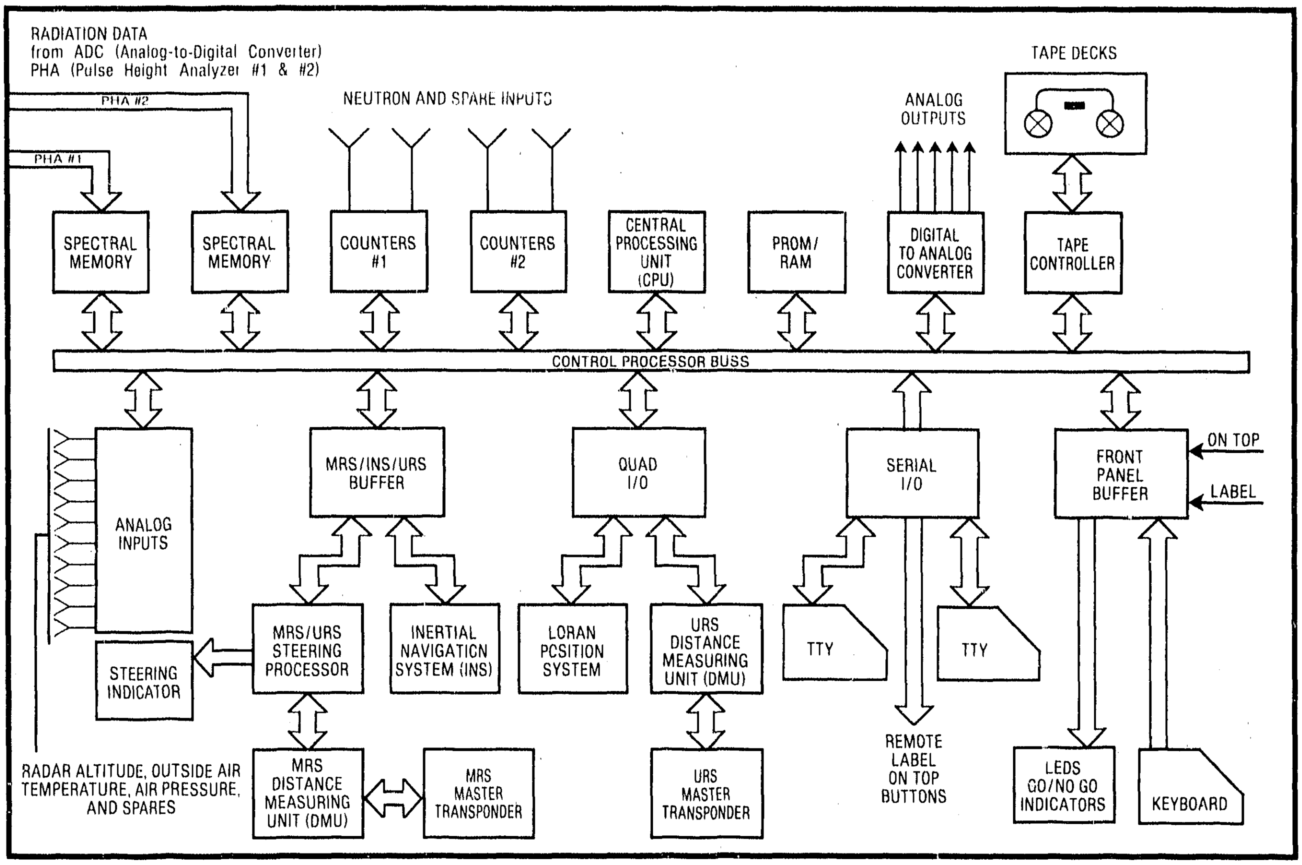

FIGURE 2. ***REDAR IV PROCESSOR SYSTEM BLOCK DIAGRAM***

in each partition. The resolution of the NaI(Tℓ) crystals varies with energy, permitting the compression of the spectral data without compromising photopeak identification and stripping techniques. In the first partition (channels 0-75), the data are not compressed to permit stripping of low-energy photopeaks such as the 60-keV photopeak from Am-241. The spectral compression technique reduces the amount of data storage required by a factor of four.

Table 1. REDAR Spectral Data Compression			
Eγ (keV) At Channel Center	**Channel Input**	**Energy Coefficient ΔE (keV/channel)**	**Compressed Channel Output**
0 - 300	0 - 75	4	0 - 75
304 - 1620	76 - 405	12	76 - 185
1624 - 4068	406 - 1017	36	186 - 253
4072 - 4088	1018 - 1022	N/A	254
>4088 - Analog Cutoff	1023	N/A	255
	1024	Unused	256

The 256 channels of spectral data are continuously stored every second. The REDAR IV system has two sets of spectral memories; each memory can accumulate four individual spectra. The two memories are operated in a flip-flop mode every 4 seconds for continuous data accumulation. While one memory is being used to store data, the data in the other memory are being transferred to magnetic tape.

The REDAR IV data acquisition system is shown in Figure 3.

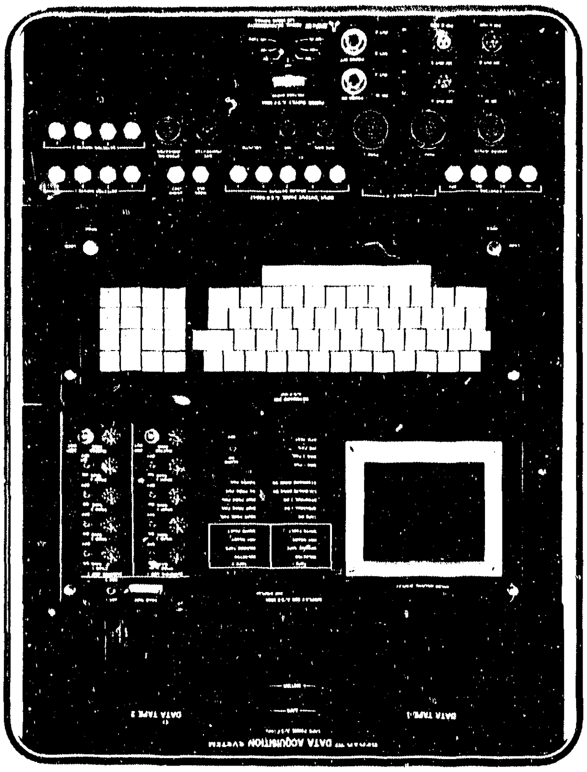

FIGURE 3. ***REDAR IV DATA ACQUISITION SYSTEM***

5.2 Helicopter Positioning Method

The helicopter position was established by two systems: an ultrahigh-frequency ranging system (URS) and a radar altimeter.

The URS master station, mounted in the helicopter, interrogated two remote transponder located outside the survey area. By measuring the roundtrip propagation time between the master and remote stations, the master unit computed the distance to each. The distances were recorded on magnetic tape once each second with the radiation data. Simultaneously, these distances were converted to position coordinates for the steering indicator to direct the aircraft along the predetermined flight lines.

The radar altimeter similarly measured the time lag for the return of a pulsed signal and converted this delay to aircraft altitude. For altitudes up to 610 meters (2,000 feet), the accuracy was ± 0.6 meter or $\pm 2\%$, whichever was greater. These data were also recorded on magnetic tape so that any variation in gamma signal strength caused by altitude fluctuations could be compensated.

The detectors and electronics systems which accumulated and recorded the data are described in considerable detail in a separate publication.[3]

6.0 DATA PROCESSING

Data processing was begun in the field with the Radiation and Environmental Data Analyzer and Computer (REDAC) system which is mounted in a mobile van (Figure 4). The REDAC system consists primarily of a 32-bit CPU with four megabytes of memory and a floating point processor; two disks with a total of 500 megabytes of storage; two 800/1600-byte-per-inch, 9-track, 1/2-inch tape drives; two 4-track, 1/4-inch cartridge tape drives for reading REDAR tapes; a 36-inch-wide carriage incremental plotter; a laser printer; a system CRT display; and three alpha/graphics CRT displays and hardcopy units. This system has an extensive series of software routines available for complete data processing in the field.

Gamma spectral windows can be selected for any portion of the spectrum. Weighted combinations of such windows can be summed or subtracted and the results plotted as a function of time or distance. By the proper selection of windows and weighting factors, it is possible to extract the photopeak count rates for radioisotopes deposited on the terrain by human activity. Such isotopes disturb the spectral pattern of soil radioactivity. These photopeak count rates can then be converted to isotope concentrations or exposure rates. Spectral data can be summed over any portion of a survey flight line.

The spectral data can also be decompressed into a linear plot. The REDAC can display the spectral data or plot it on the incremental plotter for isotopic identification and documentation.

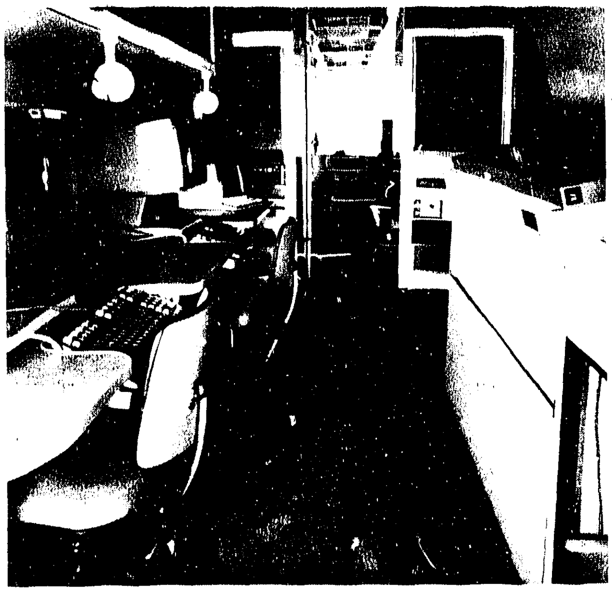

FIGURE 4. ***MOBILE COMPUTER PROCESSING LABORATORY***

7.0 DATA ANALYSIS

The aerial radiation data consisted, in general, of contributions from the naturally occurring radioisotopes, aircraft and detector background, and cosmic rays. For this survey, the major emphasis was placed on mapping the terrestrial gamma radiation area surrounding the plant as well as locating and identifying any existing sources of man-made radiation. Isopleth maps were produced by processing the data two different ways: gross count (GC) and man-made gross count (MMGC) extractions.

7.1 Gross Count

The gross count method was based on the integral counting rate in that portion of the gamma spectrum between 0.04 and 3.0 MeV. This count rate (measured at survey altitude) was converted to exposure rate (microroentgens/hour) at 1 meter above ground level by application of a predetermined conversion factor. This factor assumes a uniformly distributed source covering an area which is large compared with the field-of-view of the detector (approximately 120 to 240 meters at the survey altitude of 61 meters). The exposure rate values could be one or two orders of magnitude higher for a source localized in a small area. Because of the effect of averaging over large areas, the AMS tends to underestimate the activity level of point sources.

7.2 Man-Made Gross Count

The man-made gross count rate algorithm is designed to sense the presence of changes in spectral shape. Large changes in gross counting rates from natural radiation usually produce only small changes in spectral shape because the natural emitters change in more or less a constant ratio as the detector moves from one location to another. The algorithm senses counts in the lower portion of the spectrum in excess of those predicted on the premise that these counts bear a constant ratio to counts in the upper portion. Since the algorithm is designed to be most sensitive to man-made nuclides, the spectrum dividing line is chosen at an energy (1.4 MeV) above which most long-lived, man-made nuclides do not emit gamma rays. It is analytically expressed in MeV as:

$$\text{MMGC} = \sum_{E=0.04}^{1.40} (\text{counts})_E - K \sum_{E=1.40}^{3.00} (\text{counts})_E \quad (1)$$

The counts in the upper energy window (1.4 to 3.0 MeV) are multiplied by a constant, K, to equal the counts in the lower energy window (0.04 to 1.40 MeV), and the resultant MMGC is equal to zero for areas containing normal background radiation.

Because the man-made gross count algorithm is general and will respond to a wide range of nuclides, its sensitivity to specific nuclides is less than optimum. If the search nuclide is known, more sensitive algorithms can be devised.

8.0 GROUND-BASED MEASUREMENTS

Exposure rates were measured, and soil samples were obtained at three locations (see Figure 5) during the Vogtle survey to support the integrity of the aerial results. The locations for the ground-

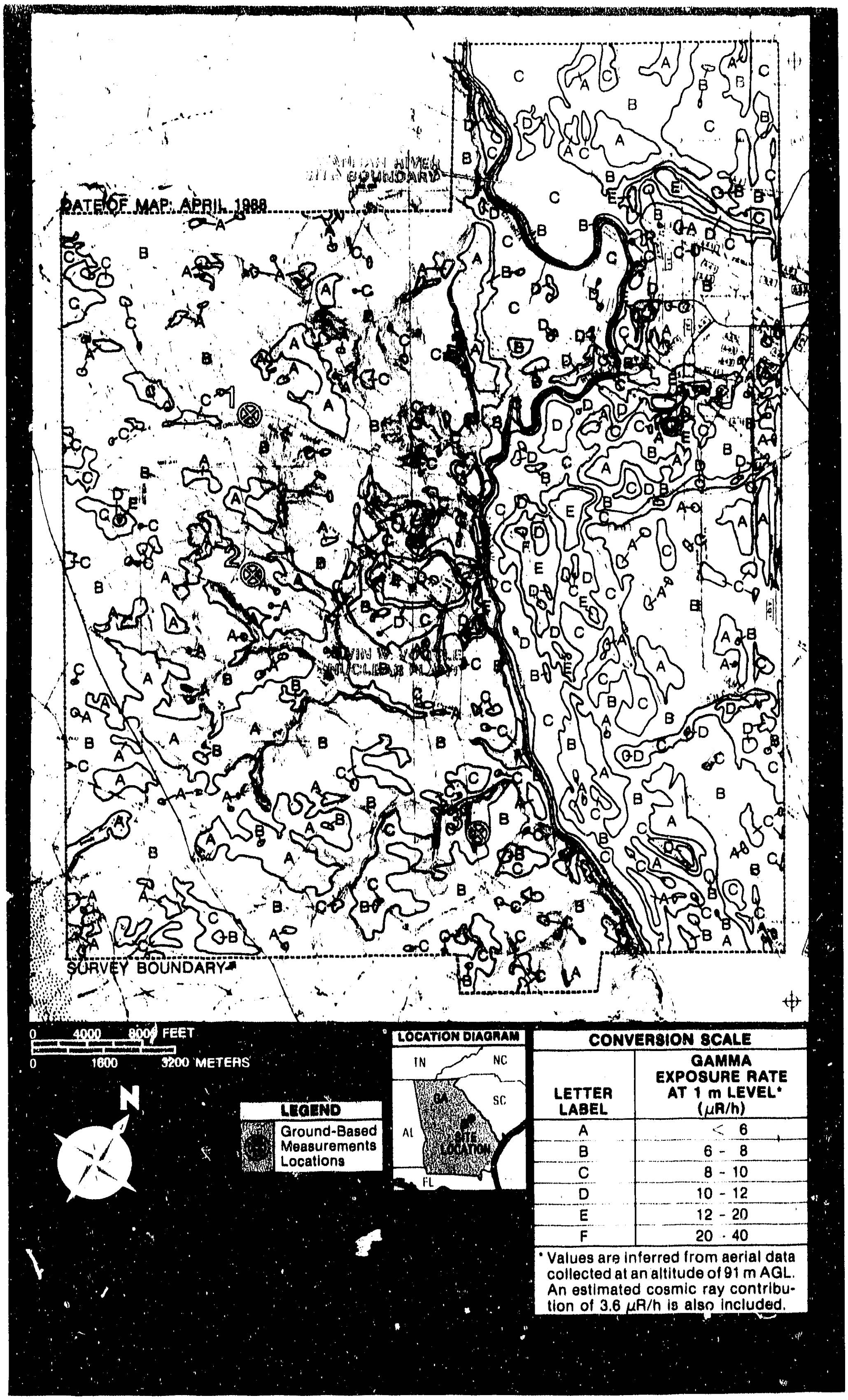

FIGURE 5. *GAMMA RADIATION EXPOSURE RATE CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN AUGUST-SEPTEMBER 1988 OVER THE VOGTLE NUCLEAR PLANT AND SURROUNDING AREA*

based measurements were chosen on the basis of assumed normal background radiation levels and were taken away from any obvious anomalies. A Reuter-Stokes pressurized ionization chamber was used for each exposure measurement at a 1-meter height at the center of a 120-meter (394-foot) diameter measurement area. Soil samples, to a depth of 15.0 centimeters, were also obtained at the center and at four points of the compass on the circumference of the circular area. The soil samples were dried, and their gamma activities were measured on a germanium-based detector system located at EG&G/EM's Santa Barbara laboratory. Detailed descriptions of the systems and procedures used for soil sample data collection and analysis are outlined in separate publications.[4,5]

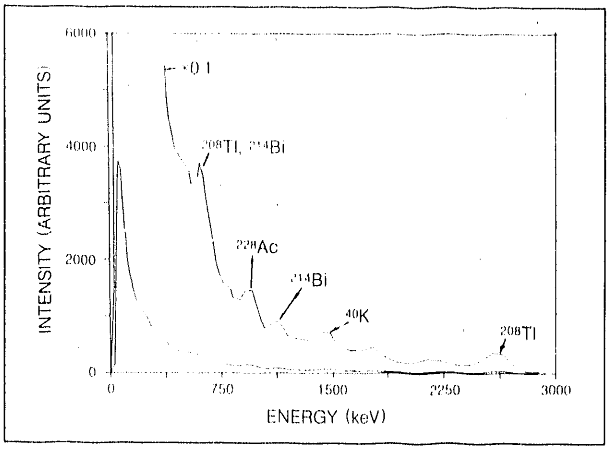

FIGURE 6. *GAMMA RAY ENERGY SPECTRUM TYPICAL OF THE NATURAL BACKGROUND IN THE SURVEY AREA*

9.0 DISCUSSION OF RESULTS

9.1 Gamma Exposure Rates

The gamma exposure rates within the survey area are shown as a contour map in Figure 5. The levels shown in the contours include an estimated cosmic-ray contribution of 3.6 μR/h at 1 meter above the ground. Over most of the survey area, the levels shown represent normal fluctuations in background due to varying amounts of K-40, the U-238 decay series, and the Th-232 decay series in the terrain. The survey area includes large areas of swamp and a number of small streams. The areas of standing water will contribute to fluctuations in the background level through shielding of the underlying terrain. The background levels generally vary from 6 to 10 μR/h. A typical background energy spectrum from a dry region is shown in Figure 6.

A previous aerial radiological survey of the Savannah River Floodplain,[6] conducted in 1983, included a portion which partially overlaps the present survey. A comparison of the corresponding contours indicates good agreement between the survey results.

9.2 Man-Made Gamma Emitters

Figure 7 shows the contours derived from the man-made gross count algorithm. A number of anomalies evident in this plot are identified in Table 2, and their locations are displayed in Figure 7.

A number of regions of elevated exposure rates in the MMGC contour appear on the SRS reservation. These anomalies are due both to natural and man-made sources. Area 1, Upper Three Runs Creek, contains elevated levels of Bi-214, possibly due to the creek originating in soil rich in naturally occurring uranium. The gamma energy spectra for Areas 1 through 6 are shown in Figures 8 through 13; the presence of Cs-137 and of Co-60 are the result of SRS processing. The presence of these man-made isotopes has already been documented in Reference 6.

Vogtle Unit I has been in operation for about one year at the time of this survey. A previous survey indicating the presence of the man-made radioisotopes was completed in December 1983. Current water flow patterns would indicate that none of the observed man-made anomalies should be attributed to Vogtle Nuclear Plant operations. A detailed analysis of the SRS portion of the current survey is to be published in a separate report at a later date.

9.3 Ground-Based Measurements

Pressurized ionization chamber measurements and soil samples were collected at three sites during the aerial survey. The site locations are shown in Figure 5. The soil analysis exposure rates were computed from the primary isotopic concentrations in the soil samples and included the effect of soil moisture (Table 3). The calculated soil exposure rate values are compared with the ion chamber measurements and the aerial

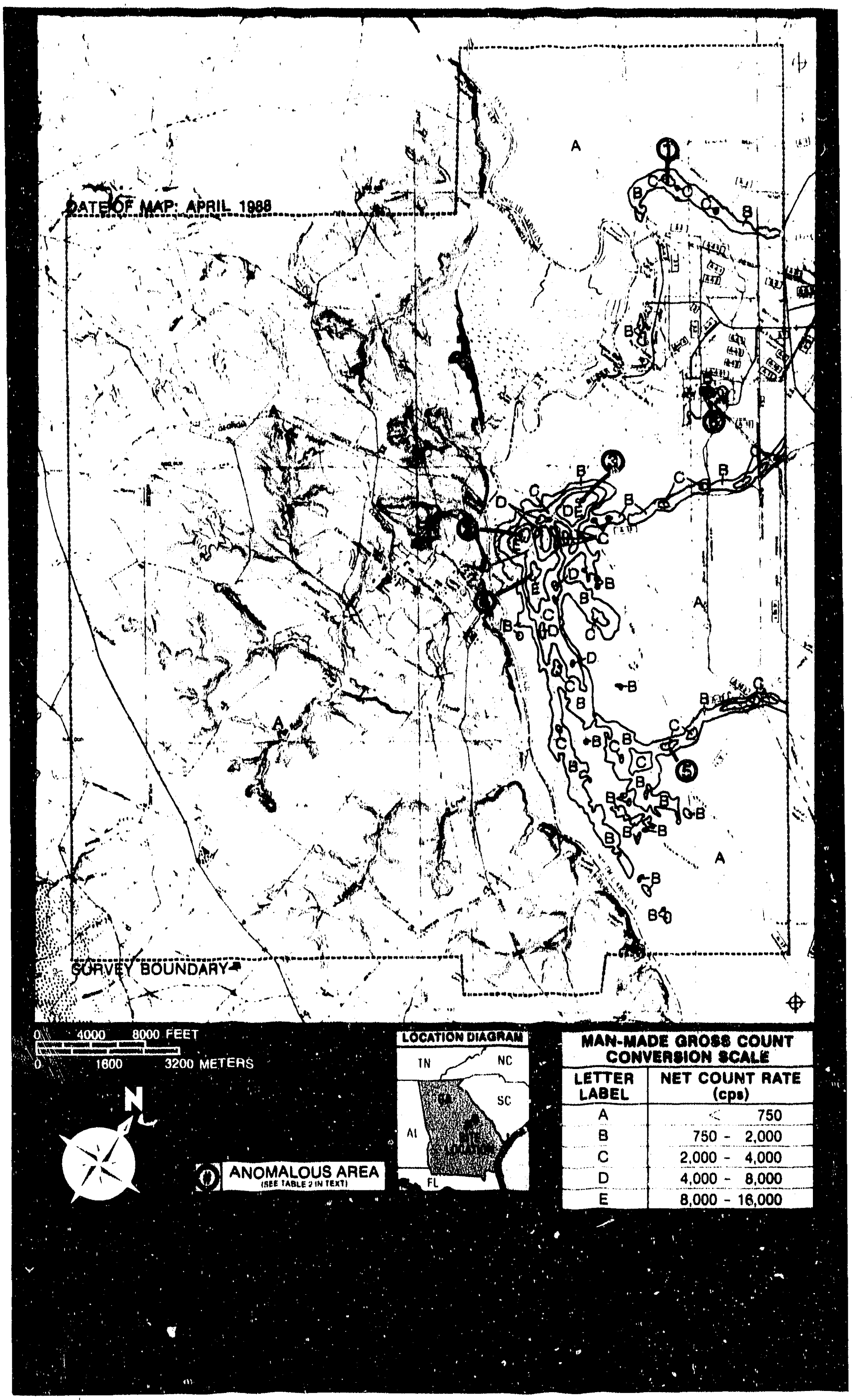

FIGURE 7. *MAN-MADE RADIATION GROSS COUNT CONTOURS DERIVED FROM AERIAL DATA OBTAINED IN AUGUST-SEPTEMBER 1988 OVER THE VOGTLE NUCLEAR POWER PLANT AND SURROUNDING AREA*

Table 2. Identification of Anomalous Areas				
Area No.	**Figure No.**	**Description**	**Dominant Gamma[1] Emitter**	**Possible Source**
1	8	Upper Three Runs	Bi-214	Natural Ores
2	9	Four Mile Branch Delta	Cs-137	SRS Processing
3	10	Four Mile Branch Delta	Cs-137, Co-60	SRS Processing
4	11	Four Mile Branch Delta	Cs-137, Co-60	SRS Processing
5	12	Pen Branch Delta	Cs-137, Co-60	SRS Processing
6	13	SRS - "D" Area	Co-60	SRS Processing

[1] Refers to the net gamma spectrum.

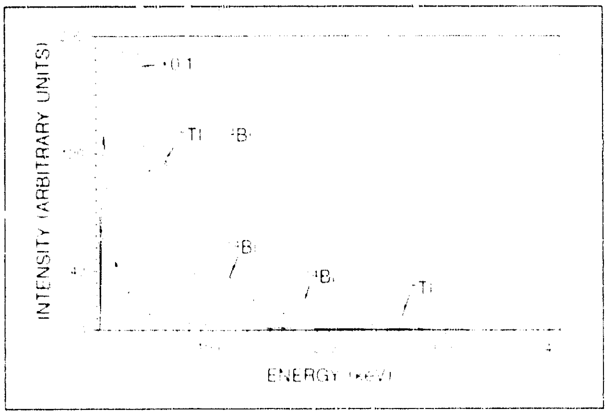

FIGURE 8. ***NET GAMMA RAY ENERGY SPECTRUM OBTAINED OVER AREA 1***

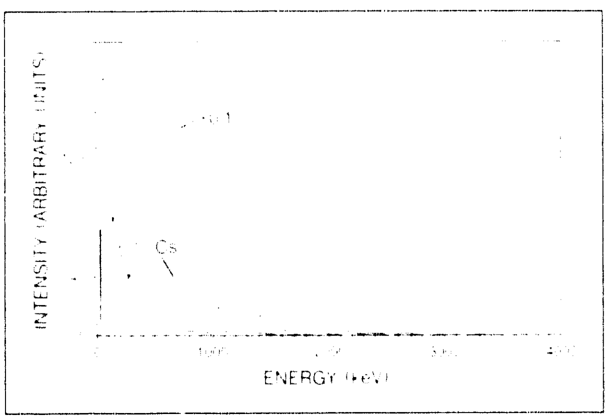

FIGURE 9. ***NET GAMMA RAY ENERGY SPECTRUM OBTAINED OVER AREA 2***

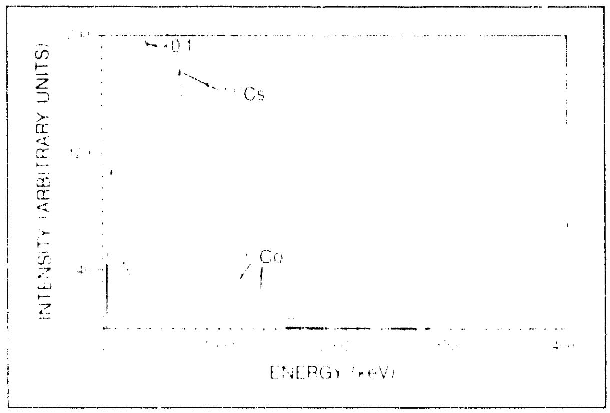

FIGURE 10. ***NET GAMMA RAY ENERGY SPECTRUM OBTAINED OVER AREA 3***

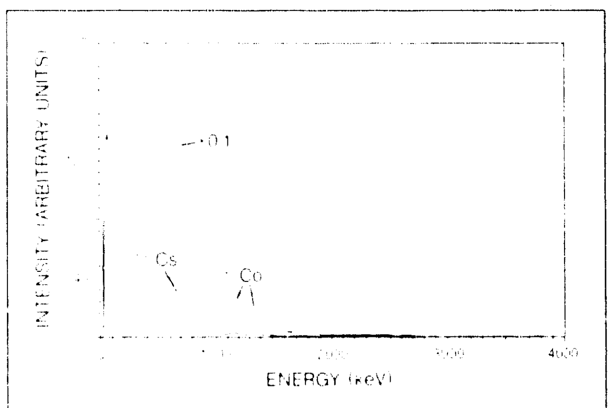

FIGURE 11. ***NET GAMMA RAY ENERGY SPECTRUM OBTAINED OVER AREA 4***

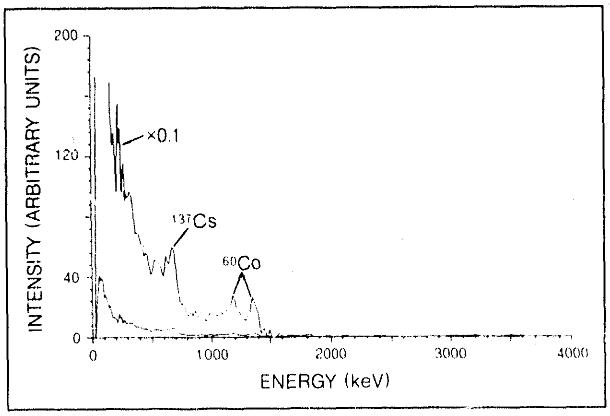

FIGURE 12. ***NET GAMMA RAY ENERGY SPECTRUM OBTAINED OVER AREA 5***

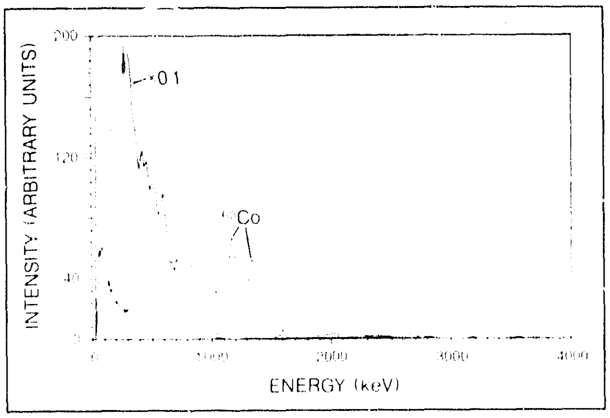

FIGURE 13. ***NET GAMMA RAY ENERGY SPECTRUM OBTAINED OVER AREA 6***

measurements in Table 4. These exposure values represent the terrestrial plus the cosmic-ray radiation components only. The isotopic and ion chamber measurements generally agree with the inferred aerial measurement results for each site. Differences among the methods arise from slight differences in the position of the measurements and the surface area viewed by the detectors. Additionally, vegetation covering the ground can reduce the computed isotopic exposure by as much as 5 percent.

10.0 SUMMARY

A 310-square-kilometer (120-square-mile) area centered roughly on the Alvin W. Vogtle Nuclear Plant was radiologically surveyed at an altitude of 61 meters (200 feet) utilizing the Aerial Measurements System (AMS). The presence of Cs-137 and Co-60 was observed in several locations within the SRS reservation, and these activities were expected results of SRS processing. The remainder of the survey area (outside of the SRS) showed no evidence of other than naturally occurring radioisotopes.

Average exposure rates in the survey area varied between 6 and 10 μR/h at 1 meter above the ground.

Table 3. Results of Soil Sample Measurements

	Soil Sample Analysis (Average Values)				
Site[1]	Soil Moisture (%)	U-238 (ppm)	Th-232 (ppm)	Cs-137 (pCi/g)	K-40 (pCi/g)
1	5.8 ± 0.4	2.0 ± 0.2	6.9 ± 0.4	0.23 ± 0.07	0.70 ± 0.05
2	5.2 ± 0.1	1.6 ± 0.1	5.4 ± 0.3	0.24 ± 0.03	0.70 ± 0.09
3	6.5 ± 0.9	2.6 ± 0.3	9 ± 1	0.15 ± 0.06	0.77 ± 0.09

[1] See site locations in Figure 5.

Table 4. Comparison of Aerial and Ground-Based Measurements[1]			
Site[2]	Soil Analysis Estimate[3]	Ion Chamber[4]	Aerial Data
1	7.0 ± 0.4	7.1 ± 0.5	6 - 8
2	6.3 ± 0.3	6.5 ± 0.5	6 - 8
3	7.8 ± 0.8	8.7 ± 0.5	8 - 10

[1] Gamma Exposure rate at 1 meter (μR/h)

[2] See site location in Figure 5.

[3] Includes a cosmic contribution of 3.6 μR/h and a moisture correction of the form 1/1+M.

[4] Reuter-Stokes Model RSS-111, Serial No. Z528.

APPENDIX A

SURVEY PARAMETERS

Site:	Alvin W. Vogtle Nuclear Plant
Location:	Waynesboro, Georgia
Survey Dates:	August 22 to September 14, 1988
Survey Coverage:	310 km^2
Survey Altitude:	61 meters (200 feet)
Line Parameters:	
Vogtle Area Only:	58 lines 152 meters spacing (500 feet) 17 kilometers long (10 miles)
SRS Overlap Area:	97 lines 76 meters spacing (250 feet) 22 kilometers long (14 miles)
Total Lines Flown:	155
Direction:	Northwest-Southeast
Survey Aircraft:	MBB BO-105 Helicopter
Acquisition System:	REDAR IV
Detector Array:	Eight 10.2-cm × 10.2-cm × 40.6-cm NaI(T*l*) crystals (Cd band shield)
Navigation System:	URS
Survey Crew:	R. McElroy, G. Feimster, J. Butler, L. Komich, W. Rae, R. Richmond, J. Stampahar, T. Stampahar, C. Ward

Data Processing:

1. Total Gamma Exposure Rate (Gross Count)
   Energy Window: 0.04 to 3.0 MeV
   Accumualtion Time: 1 second
   Conversion Factor: 1,009 cps per μR/h
   Cosmic Ray Contribution: 3.6 μR/h
2. Man-Made Gross Count Rate (MMGC)
   Source Energy Window: 0.04 to 1.4 MeV
   Background Window: 1.4 to 3.0 MeV

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