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AN AERIAL RADIOLOGICAL SURVEY OF THE  
**SOUTH TEXAS PROJECT  
ELECTRIC GENERATING STATION**  
AND SURROUNDING AREA

BAY CITY, TEXAS

DATE OF SURVEY: MARCH-APRIL 1988

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## ABSTRACT

An aerial radiological survey was conducted over the South Texas Project Electric Generating Station (STPEGS) near Bay City, Texas, during the period 25 March to 4 April 1988. The purpose of the 259-square-kilometer (100-square-mile) survey was to document the terrestrial gamma environment of the plant and surrounding area.

An exposure rate contour map at 1 meter above ground level (AGL) was constructed from the gamma data and overlaid on an aerial photograph and map of the area. Exposure rates were observed up to  $10\ \mu\text{R/h}$  over land. No areas of enhanced exposure rates were observed.

Ground-based exposure rate measurements and soil samples were obtained to support the aerial data. Oblique aerial photographs of the plant were also acquired during the survey.

# CONTENTS

Abstract . . . . .	2
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## Sections

1.0 Introduction . . . . .	5
2.0 Site Description . . . . .	5
3.0 Natural Background . . . . .	5
4.0 Survey Equipment and Methods . . . . .	5
4.1 Aircraft System . . . . .	5
4.2 Data Van . . . . .	6
4.3 Survey Method . . . . .	6
4.4 Aerial Photographs . . . . .	7
4.5 Ground-Based Measurements . . . . .	7
5.0 General Data Reduction . . . . .	7
5.1 Gross Count Rate . . . . .	7
5.2 Spectral Windows . . . . .	9
6.0 Results . . . . .	9
6.1 Exposure Rate Contour Map . . . . .	9
6.2 Spectral Window Contour Map . . . . .	10
6.3 Ground-Based Measurement Results . . . . .	10
7.0 Summary . . . . .	10

## Figures

1 MBB BO-105 Helicopter with Detector Pods . . . . .	6
2 Mobile Computer Processing Laboratory . . . . .	6
3 Gamma Energy Spectrum Obtained 1.6 Kilometer (1 Mile) North of the South Texas Project Electric Generating Station Minus a Background Spectrum Taken Over the Cooling Pond . . . . .	6
4 Terrestrial Gamma Exposure Rate Contour Map from the March–April 1988 Survey of the South Texas Project Electric Generating Station . . . . .	8

**Table**

1 Comparison of Ground-Based and Aerial Measurements . . . . . **11**

**Appendix**

A Survey Parameters . . . . . **12**

*References* . . . . . **13**

## 1.0 INTRODUCTION

An aerial radiological survey was conducted over the South Texas Project Electric Generating Station and surrounding area from 25 March to 4 April 1988 by EG&G Energy Measurements, Inc. (EG&G/EM) of Las Vegas, Nevada. The purpose of the survey was to map the background terrestrial gamma exposure rates around the plant. This was achieved by flying survey lines at 152-meter (500-foot) intervals at an altitude of 91 meters (300 feet) over an area of 259 square kilometers (100 square miles). An exposure rate contour map of the area was derived from the aerial data. In addition, ground-based exposure rate measurements and soil samples were obtained to support the aerial measurements. Oblique aerial photographs of the plant were also taken during the survey.

The survey was sponsored by the United States Department of Energy (DOE), Office of Nuclear Safety (ONS), and the United States Nuclear Regulatory Commission (NRC). 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 square-shaped survey area encompasses 259 square kilometers (100 square miles) with the South Texas Project Electric Generating Station at the center of the square. The STPEGS is located 22 kilometers (14 miles) south of Bay City, Texas. It is situated north of a man-made cooling pond. The surrounding terrain involved in the survey area is mostly flat, cultivated farmland at a nearly uniform elevation of approximately 9 meters (30 feet) above sea level.

Presently, only one unit of the two-unit plant is operating. Unit 2 is still under construction. These are Westinghouse PWR-type reactors operated by the Houston Lighting and Power Company. The maximum electrical output of each unit is 1,250 megawatts. During the survey period, Unit 1 was in the start-up process, operating at about 5% power.

## 3.0 NATURAL BACKGROUND

Natural background radiation originates from three primary sources: 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. In urban areas, 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. In general, local concentrations of these nuclides produce radiation levels at the surface of the earth typically ranging from 1 to 15  $\mu\text{R}/\text{h}$  (9 to 130 mrem/yr).<sup>1</sup> Some areas with high uranium and/or thorium concentrations in the surface minerals may exhibit even higher levels.

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 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 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 from 3.3  $\mu\text{R}/\text{h}$  at sea level to 12  $\mu\text{R}/\text{h}$  at an altitude of 3 kilometers.<sup>2</sup> For STPEGS, the altitude is about 9 meters (30 feet), and the cosmic ray contribution is about 3.3  $\mu\text{R}/\text{h}$ .

## 4.0 SURVEY EQUIPMENT AND METHODS

### 4.1 Aircraft System

A Messerschmitt-Bolkow-Blohm (MBB) BO-105 helicopter was used as the aerial platform (Figure 1). The aircraft carried two detector pods, each containing four 5.1-cm  $\times$  10.2-cm  $\times$  40.6-cm (2-in.  $\times$  4-in.  $\times$  16-in.) log-type thallium-activated sodium iodide, NaI(Tl), gamma detectors.

Gamma signals originating in the NaI(Tl) detectors were routed to the Radiation and Environmental Data Acquisition and Recorder (REDAR IV) system for conversion and storage on magnetic tape. Pressure, temperature, and radar altitude



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

transducer data were also acquired and stored by the REDAR. Real-time gamma energy spectra, total gamma count rates, and other data were output to a small CRT screen for the system operator.

The aircraft pilot was guided over the programmed flight lines by an indicator that derived its signal from range measurements taken by two ultrahigh-frequency (UHF) transponders on the ground and a master unit in the aircraft. These position data were also stored by the REDAR.

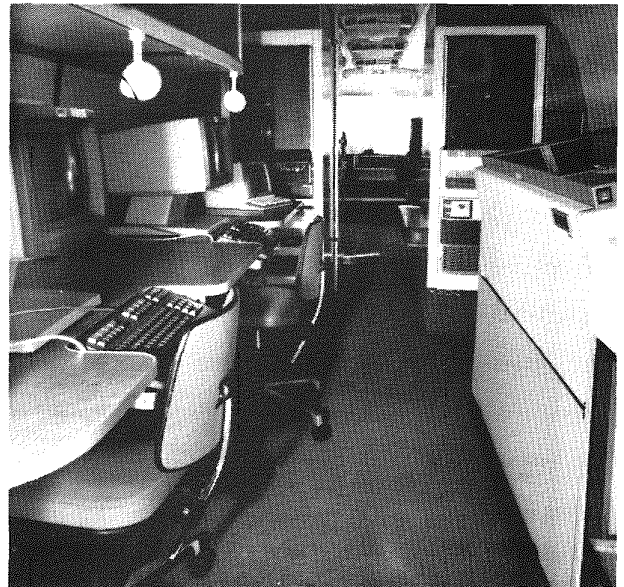
#### 4.2 Data Van

A minicomputer-based system (Figure 2) housed in a van was used during the survey to evaluate the aerial data immediately following each survey flight. The system contains hardware and software that operate on the survey data stored on magnetic tape. The system operator can plot gamma energy spectra from any portion of the gamma survey and count rate isopleths scaled to a map or photograph. In this manner the gamma emitters, their intensity, and their location can be identified. A typical terrestrial gamma spectrum collected during the survey is shown in Figure 3.

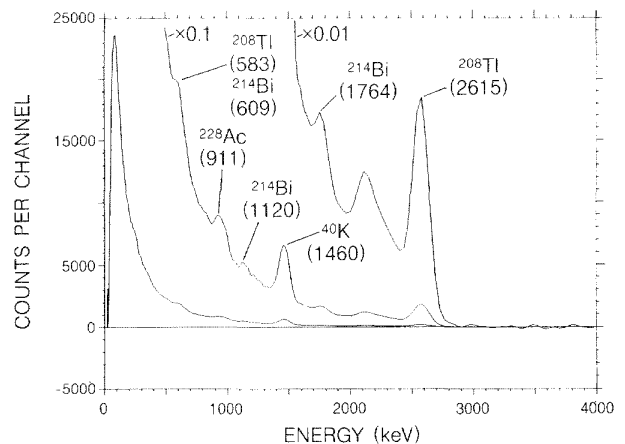
#### 4.3 Survey Method

A standardized procedure for aerial gamma surveys was followed during the survey of the STPEGS. Steps in the procedure are as follows:

1. Two UHF transponders were placed outside the survey area: one at the west end of Bay City, Texas, and the other at the Bay City Municipal Airport. These two locations and



**FIGURE 2. MOBILE COMPUTER PROCESSING LABORATORY**



**FIGURE 3. GAMMA ENERGY SPECTRUM OBTAINED 1.6 KILOMETER (ONE MILE) NORTH OF THE SOUTH TEXAS PROJECT ELECTRIC GENERATING STATION MINUS A BACKGROUND SPECTRUM TAKEN OVER THE COOLING POND**

the STPEGS formed an approximate equilateral triangle that optimized the positioning and steering of the aircraft during the survey.

2. A perimeter flight of roads in the survey area was then made. The transponder data from this flight were used to scale distances to a

road map of the survey area. In this way, each subsequent gamma datum could be plotted accurately (within about 9 meters) on the map.

3. Both a test line and a water line were located during the perimeter flight. Matagorda Bay and the cooling pond provided expanses of water from which changing background atmospheric radon could be measured. The 3.2-kilometer (2-mile) test line was directed from north to south at the west end of the survey area. A series of test lines flown before and after every individual flight served to monitor possible changes in system sensitivity and is part of the survey data quality control. Water lines were flown at approximately daily intervals.
4. Following the perimeter, test line, and water line flights, routine flight began. All survey lines were flown at an altitude of 91 meters (300 feet) above ground level. Each flight was preceded by a preflight in which the system was calibrated and a test data tape was analyzed for proper system operation. A flight consisted of:
  - a. A pass over the test line at survey altitude
  - b. Passes in a north/south direction following preprogrammed lines over the survey area
  - c. A pass over the test line at survey altitude

Following each survey flight, test data were examined to verify system integrity and validate data quality.

5. The aerial data were extrapolated to 1 meter (3.3 feet) above the ground, and a contour map was drawn of the exposure rates. A contour map was also drawn from an algorithm designed to reveal possible man-made gamma activity.

#### 4.4 Aerial Photographs

Oblique documentary aerial photographs were taken of the STPEGS during the survey period. The photographs are stored at EG&G/EM and are available to qualified users. A high-altitude vertical photograph of the plant was taken on 23 May 1988. This photograph serves as part of the map underlay in Figure 4.

#### 4.5 Ground-Based Measurements

Exposure rates were measured and soil samples were obtained at four locations immediately following the aerial survey. These measurements were taken to support the integrity of the aerial results. A Reuter-Stokes pressurized ionization chamber was used for each exposure measurement. Soil samples, to a depth of 15.0 cm, were also obtained at the center and at four points of the compass on the circumference of a 120-meter (400-foot) diameter circular area centered at the position where the measurement was performed using the ionization chamber. The soil samples were dried, and their gamma activities were measured on a germanium-based detector system at the EG&G/EM Santa Barbara laboratory.<sup>3,4,5</sup>

#### 5.0 GENERAL DATA REDUCTION

Two primary methods are used to evaluate the gamma flux measurements made with the aerial system's NaI(Tl) detectors. The first is the gross count (GC) technique which is used to determine exposure rate. The second is the spectral window technique which is used to measure concentrations of specific nuclides. These and other methods are described in detail in a separate publication.<sup>6</sup>

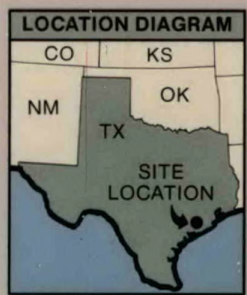
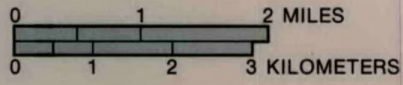
#### 5.1 Gross Count Rate

The gross count rate is defined as the integral count for 1 second in the energy spectrum between nominal values of 40 keV and 3,000 keV.

$$GC = \sum_{E = 40 \text{ keV}}^{3,000 \text{ keV}} \text{Energy Spectrum} \quad (1)$$

The integral includes all the natural gammas from potassium-40 (K-40), uranium-238 (U-238), thorium-232 (Th-232), and their decay products (the major terrestrial natural gamma emitters). Other natural contributors to this integral are cosmic rays, aircraft background, and airborne radon daughters.

The response versus altitude of the aerial system to terrestrial gammas was measured over the test



CONVERSION SCALE	
LETTER LABEL	TERRESTRIAL GAMMA EXPOSURE RATE AT 1m LEVEL* ( $\mu$ R/h)
A	< 0.2
B	0.2 - 2.0
C	2.0 - 4.0
D	4.0 - 6.0
E	6.0 - 10.0

BLACK AND WHITE CONTOUR LINES ARE USED FOR PURPOSES OF CLARITY.

\* These levels were selected to correlate terrain characteristics with the radiation environment. The minimum interval, 0.2, does not imply the system detectability limits.

FIGURE 4. TERRESTRIAL GAMMA EXPOSURE RATE CONTOUR MAP FROM THE MARCH-APRIL 1988 SURVEY OF THE SOUTH TEXAS PROJECT ELECTRIC GENERATING STATION

line. The survey count rates were then extrapolated to 1 meter (3.3 feet) above the ground from the altitude response curve. The conversion from count rate to exposure rate was obtained from the documented test line at Temple Bar, Arizona. The conversion equation is:

$$ER(1\text{ m}) = \frac{GC(A) - B}{1,163} \cdot e^{0.00179A} \quad (2)$$

where

ER(1 m) = Exposure rate extrapolated to 1 m above ground level ( $\mu\text{R/h}$ )

GC(A) = Gross count rate at altitude A (cps)

A = Altitude (feet)

B = Cosmic, aircraft, and airborne radon background (cps)

The attenuation coefficient (0.00179) in the exponential was determined empirically by taking data at different altitudes. Equation 2 was used to compute the exposure rate from the terrestrial gross count rate. For the STPEGS survey, flown at 91 meters (300 feet), Equation 2 becomes:

$$ER(1\text{ m}) = \frac{GC - B}{680} \quad (3)$$

The gross count has been used for many years in the aerial system as a measure of exposure rate. Its simplicity yields a rapid assessment of the gamma environment.

Anomalous or non-natural gamma sources can often be found from increases in gross count rates. However, subtle anomalies are difficult to find using the gross count rate in areas where its magnitude is variable due to, for example, geologic or ground cover changes. Differential energy data reduction methods, as discussed in the next section, are used to increase the aerial system's sensitivity to anomalous gamma emitters.

## 5.2 Spectral Windows

Each second, the aerial system produces a gamma energy spectrum from which the GC is computed. Generally, the ratio of natural components in any

two integral sections (windows) of the energy spectrum will remain nearly constant in any given area:

$$\sum_{E=a}^b (ES) / \sum_{E=c}^d (ES) = K \quad (4)$$

where

K = Constant

ES = Energy spectrum

E = Energy

$d > c \geq b > a$

In practice, the value of K (Equation 4) is obtained from the natural terrestrial background of the survey area and the test line. Then Equation 4, in another form, is evaluated from the spectra obtained over the survey area:

$$S = \sum_{E=a}^b (ES) - K \times \sum_{E=c}^d (ES) \quad (5)$$

where

S = net count rate (signal) from anomalous gamma rays (cps)

The signal, S, will vary around zero and become significantly positive in the presence of anomalous gamma rays whose primary (uncollided) energy lies between a and b. The variance of S can be computed from the results of Equation 5 or from the energy window count rates.

Equation 5 was applied to the STPEGS survey data in the search for possible man-made emitters. In the search, a was set at nominal values of 40 keV, b = c was set at 1,400 keV, and d was set at 3,000 keV. These settings forced most of the long-lived, man-made gamma emitters into the signal window, S.

## 6.0 RESULTS

### 6.1 Exposure Rate Contour Map

The exposure rate contour map, Figure 4, contains the principal results from the survey of the

STPEGS. This map shows the gamma exposure rate, from terrestrial sources only, at 1 meter over the 259-square-kilometer (100-square-mile) area surrounding the site. The cosmic exposure rate<sup>7</sup> (3.3  $\mu\text{R}/\text{h}$ ) and the highly variable airborne radon component were not included in the contour levels.

The contour map consists of approximately 46,000 data points, each representing 0.6 hectares (1.4 acres). Each data point includes a 1,000-channel gamma energy spectrum, a pressure and temperature measurement, and measured spatial coordinates (altitude and two ranges from the transponders on the ground).

The exposure rates ranged, in general, from 4 to 10  $\mu\text{R}/\text{h}$  over the land areas. Only a few small land areas had a lower activity, between 2  $\mu\text{R}/\text{h}$  and 4  $\mu\text{R}/\text{h}$ , due to a lower concentration of natural radioactive nuclei in the surface material relative to the surrounding terrain. These areas included most of the site and a chemical plant near the northern edge of the survey. The Colorado River, several lakes, a river dredging settling pond between the site cooling pond and the river, and a small cooling pond on the east edge of the site also showed lower exposure rates.

## 6.2 Spectral Window Contour Map

The spectral window technique was employed to produce a contour plot of S (Equation 5) over the survey area in a search for man-made emitters. This contour map showed no evidence of any man-made emitters and is not reproduced here.

## 6.3 Ground-Based Measurement Results

Ion chamber measurements and soil samples were collected immediately following the aerial

survey at four sites within the survey boundaries. The site locations are labeled in Figure 4. The soil samples were dried and counted on a calibrated gamma spectrometer in the laboratory. Exposure rates at 1 meter were computed from the primary isotopic concentrations in the soil samples<sup>8</sup> and included the effect of soil moisture.<sup>9</sup> These soil-based exposure rates are compared with the ion chamber and aerial measurements in Table 1. All exposure rates include both the terrestrial and the cosmic components, but only the ion chamber includes the small airborne component (0.2  $\mu\text{R}/\text{h}$  or less).

Exposure rate measurements on the ground at the first three sites agree well, within system uncertainties, with the measured aerial exposure rates. The ground-based exposure rates (10-11  $\mu\text{R}/\text{h}$ ) for Site 4 are slightly greater than the aerial exposure rate (9  $\mu\text{R}/\text{h}$ ). This small difference may be attributed to the larger area sampled by the aerial measurement as compared to the ground-based ones.

## 7.0 SUMMARY

A 259-square-kilometer (100-square-mile) area, centered on the the South Texas Project Electric Generating Station near Bay City, Texas, was radiologically surveyed at an altitude of 91 meters (300 feet) utilizing the AMS. No above-background levels were observed. Average terrestrial exposure rates at 1 meter above ground level over the survey area varied between approximately 4 and 10 microroentgens per hour. The presence of man-made radioisotopes in the survey area was not detected.

<b>Table 1. Comparison of Ground-Based and Aerial Measurements</b>			
<b>Site<sup>b</sup></b>	<b>Exposure Rate (<math>\mu\text{R}/\text{h}</math>) at 1 m<sup>a</sup></b>		
	<b>Soil Data</b>	<b>Ion Chamber<sup>c</sup></b>	<b>Aerial</b>
1	8.7 $\pm$ .7	8.2 $\pm$ .5	8.2 $\pm$ .5
2	8.0 $\pm$ .7	7.7 $\pm$ .5	8.4 $\pm$ .5
3	8.7 $\pm$ .4	8.1 $\pm$ .5	8.8 $\pm$ .5
4	11.0 $\pm$ .6	10.0 $\pm$ .5	9.0 $\pm$ .5

<sup>a</sup> Exposure rate includes an estimated cosmic component of 3.3  $\mu\text{R}/\text{h}$  and the effect of soil moisture.

<sup>b</sup> The site locations are shown in Figure 4.

<sup>c</sup> Reuter Stokes Model No. RSS-111, Serial No. Z528, was used to acquire these data.

## APPENDIX A

### SURVEY PARAMETERS

Survey Site: South Texas Project Electric  
Generating Station  
Bay City, Texas

Survey Coverage: 259 sq km (100 sq mi)

Survey Date: 25 March 1988 to 4 April 1988

Survey Altitude: 91 m (300 ft)

Aircraft Speed: 36 m/s (70 knots)

Line Spacing: 152 m (500 ft)

Line Length: 16 km (10 mi)

Line Direction: North-South

Number of Lines: 107

Detector Array: Eight 5.1-cm × 10.2-cm × 40.6-cm  
(2-in. × 4-in. × 6-in.) NaI(Tl) detectors

Acquisition System: REDAR IV

Aircraft: MBB BO-105 Helicopter

Survey Crew: J. Thompson, E. Feimster, D. Korthanke,  
C. Bluit, J. Villanueva, K. Roesner, E.  
Roberts, J. Holtzclaw, R. Chavez

#### Data Processing:

1. Gross Count Window: 40 to 3,000 keV
2. Conversion Factor: 680 cps per  $\mu\text{R/h}$
3. Cosmic Ray Contribution: 3.3  $\mu\text{R/h}$

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