



ARMS



AERIAL RADIOLOGICAL MEASURING SYSTEM

**RADIOLOGICAL SURVEY OF
THE AREA SURROUNDING
THE HADDAM NECK PLANT,
HADDAM NECK, CONNECTICUT.
DATE OF SURVEY: 27, 28 AUGUST 1969**

MASTER

11 MAY 1973

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ABSTRACT

The Aerial Radiological Measuring System (ARMS) was used to survey the area surrounding the Haddam Neck nuclear power plant during August 1969. The survey measured terrestrial gamma radiation.

A high-sensitivity detection system collected gamma-ray spectral and gross-count data. The data were then computer-processed into a map of a 900-square-mile area showing isoexposure contours three feet above the ground. Exposure rates and isotopes identified are consistent with normal terrestrial background radiation.

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CONTENTS

1.	INTRODUCTION	1
	1.1 Identification of Surveyed Plant and Area	1
	1.2 ARMS Program	1
	1.3 ARMS Equipment and Procedures	1
	1.4 Reduction and Presentation of Data	4
2.	REACTOR AND SITE CHARACTERISTICS	5
	2.1 Reactor Characteristics	5
	2.2 Site Area Characteristics	6
3.	SURVEY PLAN	8
	3.1 Specification of Flight Lines	8
	3.2 Coordination with Local Authorities	8
4.	RADIOLOGICAL SURVEY	9
	4.1 Survey Missions	9
	4.2 Gross-Count Data	9
	4.3 Spectral Data	9
5.	SUMMARY AND CONCLUSIONS	15

ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
1	View of the interior of the Aerial Radiological Measuring System (ARMS) aircraft, showing detector package and electronic data-collection system	3
2	Gamma exposure rate contours, Haddam Neck Plant, Connecticut, August 1969	10
3	Typical gamma pulse-height spectrum for survey area .	12
4	Spectrum taken in the vicinity of the Guilford stone quarry anomaly	14

TABLES

<u>Table</u>		<u>Page</u>
1	Reactor facility specifications	5
2	Principal population centers within the Haddam Neck area	7
3	Gamma-ray energies and isotopes consistent with spectral data of Figure 3	13

1. INTRODUCTION

1.1 Identification of Surveyed Plant and Area

The Aerial Radiological Measuring System (ARMS) (Ref. 1) operated by EG&G, Inc., Las Vegas, Nevada, for the U. S. Atomic Energy Commission was used to perform a gamma radiation survey of an extensive area surrounding the Haddam Neck nuclear power plant during August 1969. The Haddam Neck plant, operated by the Connecticut Yankee Atomic Power Co., is located near Haddam Neck, Connecticut. The size of the survey area was 900 square miles.

1.2 ARMS Program

The present survey was made as part of a continuing nationwide ARMS program started in 1958 to monitor radiation levels surrounding facilities producing or utilizing radioactive materials. This is the first such survey performed in the Haddam Neck area since the station began operation in 1967.

The detection system on board the aircraft collects gamma-ray gross-count and spectral data on each flight line of the survey. The gamma radiation and aircraft position information are processed by a computer into an isoexposure contour map of the area surveyed.

1.3 ARMS Equipment and Procedures

The ARMS aircraft and its on-board radiation detection equipment were used in the survey. Since the ARMS equipment and procedures have been discussed in detail elsewhere (Ref. 1), they will only be described briefly here.

The ARMS surveys are flown in a Beechcraft Twin Bonanza at an altitude of 300 to 500 feet above terrain and a ground speed of about 140 knots (235 ft/sec). The ground position of the aircraft and its altitude above terrain are measured and recorded every other second by a radar navigation computer system. The position and altitude measurements are accurate to ± 350 ft and ± 5 ft, respectively.

A typical flight pattern consists of a series of parallel lines spaced one nautical mile (6080 feet) apart, covering all of the land area within a twelve and one-half nautical mile radius of the facility.

At an altitude of 300 feet the field of view of the detectors is approximately 1/4 mile wide for a mean gamma energy of naturally occurring isotopes.

The aerial radiation measurements are of two distinct types, made simultaneously: (1) gross gamma-count (intensity) measurements and (2) gamma-spectral measurements. The detector system consists of an array of fourteen 4 x 4 in. NaI (Tl) scintillation crystals, each coupled to its own photomultiplier assembly. The detector system output is directed both to the gross gamma-count computing system and to the multichannel spectrum analyzer. The data-collecting system is shown in Figure 1.

The gross gamma-count system consists of an amplifier-discriminator-computer unit that counts and records the total number of gamma rays of energy greater than 50 keV that are detected during a 1-second time interval. The gross gamma-count rate (number of gamma rays detected per second) is digitally recorded along with aircraft position and altitude every other second. Aircraft position data are supplied by a track navigational computer and Doppler radar. Altitude above terrain is measured with a radar altimeter. As a backup and complement to the digital recording of the gross-count data, a record is made on a continuous strip chart of both gross gamma count rate and radar altitude as a function of distance. Typical gross-count rates for natural background are several thousand per second.

Whereas the gross gamma-count data specify the intensity of radiation as a function of position, the gamma-spectral data are useful in identifying particular radioactive isotopes. A pulse-height analyzer automatically sorts detected gamma rays according to energy, thereby generating a number per unit energy versus energy spectrum. Although gamma rays occur only at well-known discrete energies characteristic of the emitting species, air scattering tends to smear the detected distribution. Nevertheless, characteristic peaks that permit isotope identification are readily observable. In wide-area surveys the typical acquisition time for a gamma-ray spectrum is several minutes; thus the spectrum represents the average radiological properties of a tract several miles in length. However, if an area of interest is indicated by an increase in the gross gamma-count rate, spectral data acquisition times of only a few seconds are used to isolate the area spatially. If further investigation is warranted, a ground mobile unit with equipment similar to that in the aircraft is available to provide greater spatial and energy resolution.

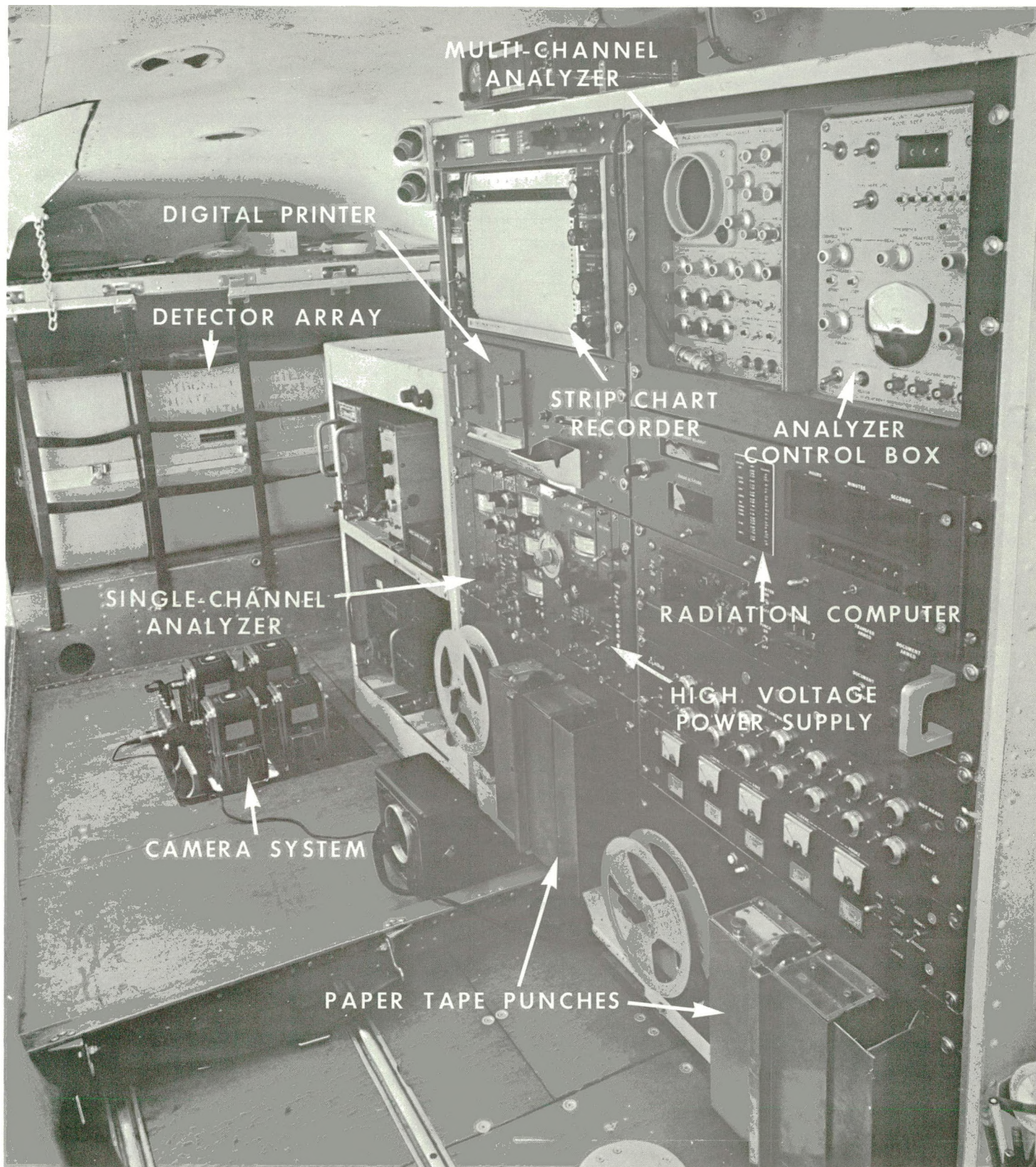


FIGURE 1. View of the interior of the Aerial Radiological Measuring System (ARMS) aircraft showing detector package and electronic data collection system.

In addition to the equipment just described, the ARMS aircraft also carries an air sampling and analysis system for the measurement of airborne radioactivity.

1.4 Reduction and Presentation of Data

The raw data from the gross gamma-count and the gamma-spectral measurements are permanently recorded on paper tape, which is computer-processed and analyzed to characterize the radiological properties of the area surveyed. Using an altitude-dependent conversion factor obtained from prior calibration measurements, the raw gross-count rate is converted to exposure rate ($\mu\text{R/hr}$) at three feet above ground.

The exposure-rate conversion factor was obtained from repeated flights 200 to 1000 feet above terrain containing known distributions of natural isotopes. Such conversion factors have proved valid over distributed fission product fields, with a variation of less than 25%. In practice, variations of 2 $\mu\text{R/hr}$ or greater can be reliably observed in repeated flights over the same area.

2. REACTOR AND SITE CHARACTERISTICS

2.1 Reactor Characteristics

The Haddam Neck Reactor is located in Middlesex County, Connecticut, two miles west of the town of Haddam Neck.

The principal nuclear contractor is the Westinghouse Electric Company. The facility is operated by the Connecticut Yankee Atomic Power Company.

Table 1 gives the specifications of the reactor facility at the time of the survey.

TABLE 1. Reactor facility specifications.

Reactor Unit	Reactor Type	Start-Up Date	Power Levels (Megawatts)		Status
			Electrical	Thermal	
1	Pressurized Water	1967	575	1,825	Non-operational

2.2 Site Area Characteristics

The most prominent terrain feature in the survey region is the Connecticut River, which runs through the center of the area. Vegetation cover is a mixture of forest, brushwood, and orchards. The area also contains numerous small lakes and marshes.

Table 2 lists the towns in the survey area with significant populations, by distance and direction from the reactor site.

TABLE 2. Principal population centers within the Haddam Neck area.

Town	Direction from Power Station	Population*		
		Distance from Station (Miles)		
		0 - 5	5 - 10	10 - 15
Berlin	NW			14,149
Chester	SE		2,982	
Colchester	ENE			6,603
Cromwell	NE		7,400	
Deep River	SE		3,690	
Durham	W		4,489	
East Haddam	SE	4,474		
East Hampton	W		7,078	
Essex	SSE			4,911
Glastonbury	N			20,651
Haddam	S	4,934		
Hebron	NE			3,815
Killingworth	S		2,435	
Marlboro	NNE		2,991	
Meriden	W			55,959
Middletown	W		4,132	
Moodus	E	1,352		
Portland	NW		8,812	
Rocky Hill	NW			11,013
Salem	E			1,453
Wallingford	WSW			35,714
Totals		10,760	44,009	154,268
Grand Total				209,037

*1970 census figures (Ref. 2).

3. SURVEY PLAN

3.1 Specification of Flight Lines

The flight pattern for the Haddam Neck survey consisted of 25 flight lines approximately 25 nautical miles long and spaced one nautical mile apart. The lines were oriented in a north-south direction. Radiation data together with aircraft position and meteorological information were collected along each flight line. The area covered by the survey was about 680 square nautical miles, or 900 square statute miles.

3.2 Coordination with Local Authorities

ARMS survey missions are conducted under special waiver from the Federal Aviation Administration. The survey plan was discussed with the appropriate General Aviation District Office, and public announcements were published in the local newspapers prior to the survey operation in accordance with the FAA waiver for low-level flights.

The base of operations for the survey mission was Springfield, Massachusetts.

4. RADIOLOGICAL SURVEY

4.1 Survey Missions

The aerial survey of the Haddam Neck area was conducted on 27 and 28 August 1969. This survey required a total flying time of 7.5 hours.

Gamma gross-count and spectral data were simultaneously collected at an altitude of 300 feet. Spectral collections were accumulated over 4-minute intervals during which the aircraft traveled approximately 12 miles; consequently two spectra per line were collected.

4.2 Gross-Count Data

As a first step in the analysis of the gross-count data, the background due to nonterrestrial radiation was subtracted. This background consists of cosmic-ray, aircraft, and airborne radioactivity contributions (Ref. 3). After correction for background, the data were normalized to a standard air mass. The resultant net-count data were then converted to exposure rate in microroentgens per hour ($\mu\text{R/hr}$) at the 3-foot level above the ground. The cosmic-ray exposure rate was then added back to the terrestrial exposure rate. Finally, the composite exposure-rate data, together with aircraft position information, were processed into an isoexposure contour map for overlay on U. S. Geological Survey topographic maps of the survey area.

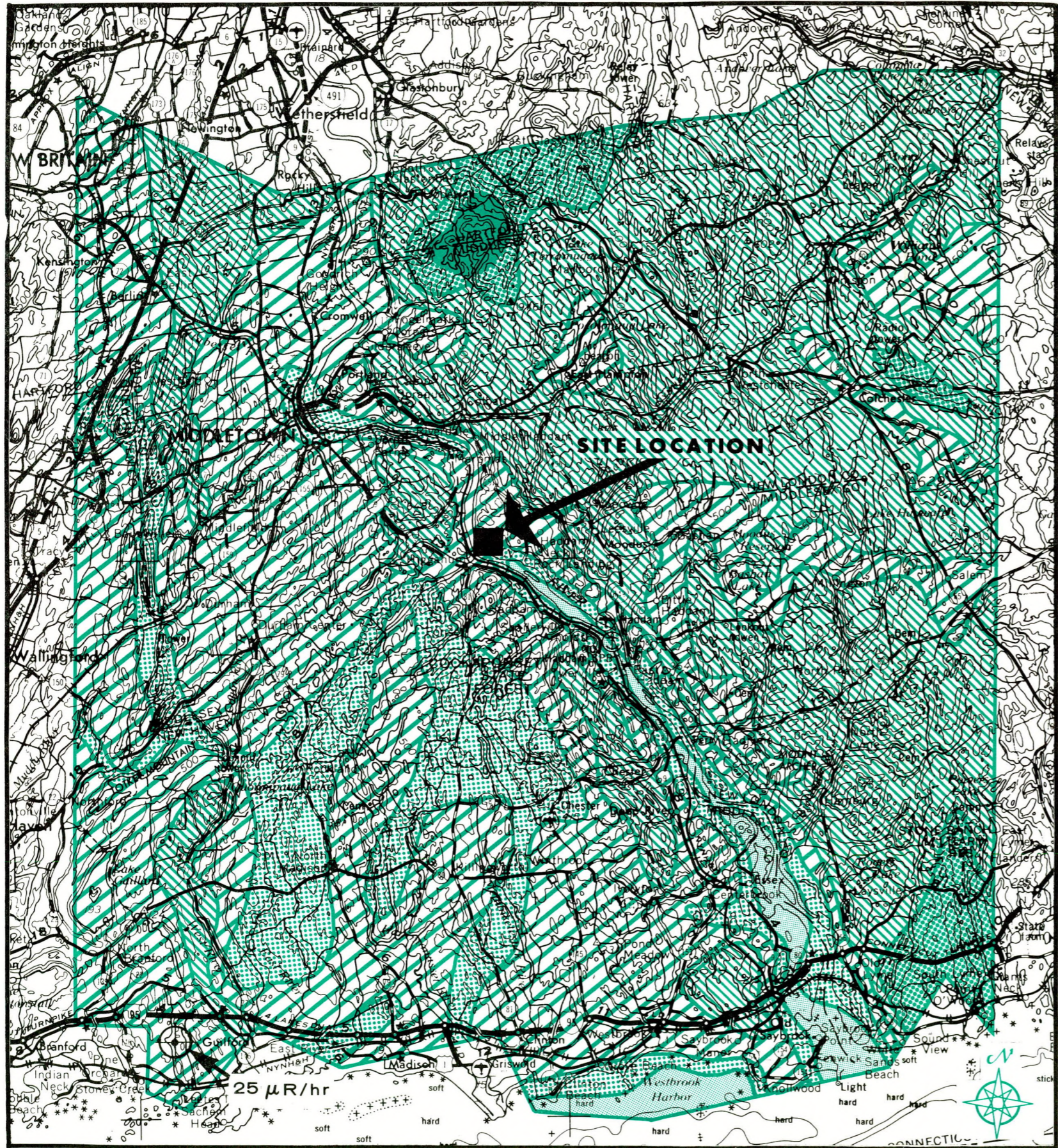
An isoexposure map of the Haddam Neck Plant area is shown in Figure 2. The data shown on the map include a cosmic radiation contribution of 2 to 4 $\mu\text{R/hr}$. Spatial resolution of the exposure-rate data is determined by the field of view of the detector system, which is about 1/4 mile.

A small area with an exposure rate considerably higher than that of the surrounding country was observed about three miles west of Guilford, Connecticut, in the southwest corner of the survey region. Exposure-rate levels up to 25 $\mu\text{R/hr}$ occurred in this area, which was in the vicinity of an active stone quarry. Spectral data taken during further examination of the anomalous area revealed the presence of only naturally occurring isotopes.

4.3 Spectral Data

Spectral data were recorded from about 0.03 to 3.0 MeV. The recording system was calibrated prior to takeoff with an yttrium-88 source,

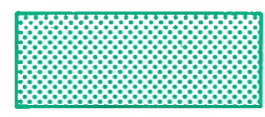
**GAMMA EXPOSURE RATE CONTOURS
HADDAM NECK PLANT, CONNECTICUT
AUGUST 1969**



LEGEND



2-4 $\mu\text{R/hr}$



4-6 $\mu\text{R/hr}$



6-8 $\mu\text{R/hr}$



8-10 $\mu\text{R/hr}$



10-12 $\mu\text{R/hr}$



12-14 $\mu\text{R/hr}$

BASE FROM USGS TOPOGRAPHIC MAP SCALE 1:250,000

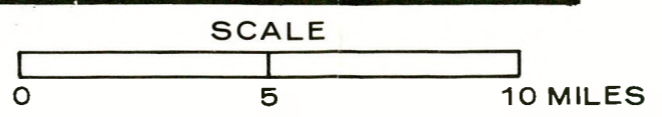


Figure 2.

which emits two prominent gamma rays of 0.898 and 1.836 MeV. The gain for each crystal in the 14-crystal detector array was set independently.

A spectrum typical of those taken during the survey is shown in Figure 3. Table 3 lists the prominent gamma-ray energies and associated source isotopes identified in the spectrum. Differences in shape between spectra taken over different portions of the survey area are minor, and the isotopes identified in all spectra are the same. Only isotopes consistent with normal background radiation are apparent.

A spectrum taken in the area of the Guilford stone quarry anomaly (Figure 4) is not significantly different from other survey area spectra, showing the natural radioactive components of ^{214}Bi , ^{40}K , and ^{208}Tl ; there is no basis for attributing this anomaly to the reactor operation.

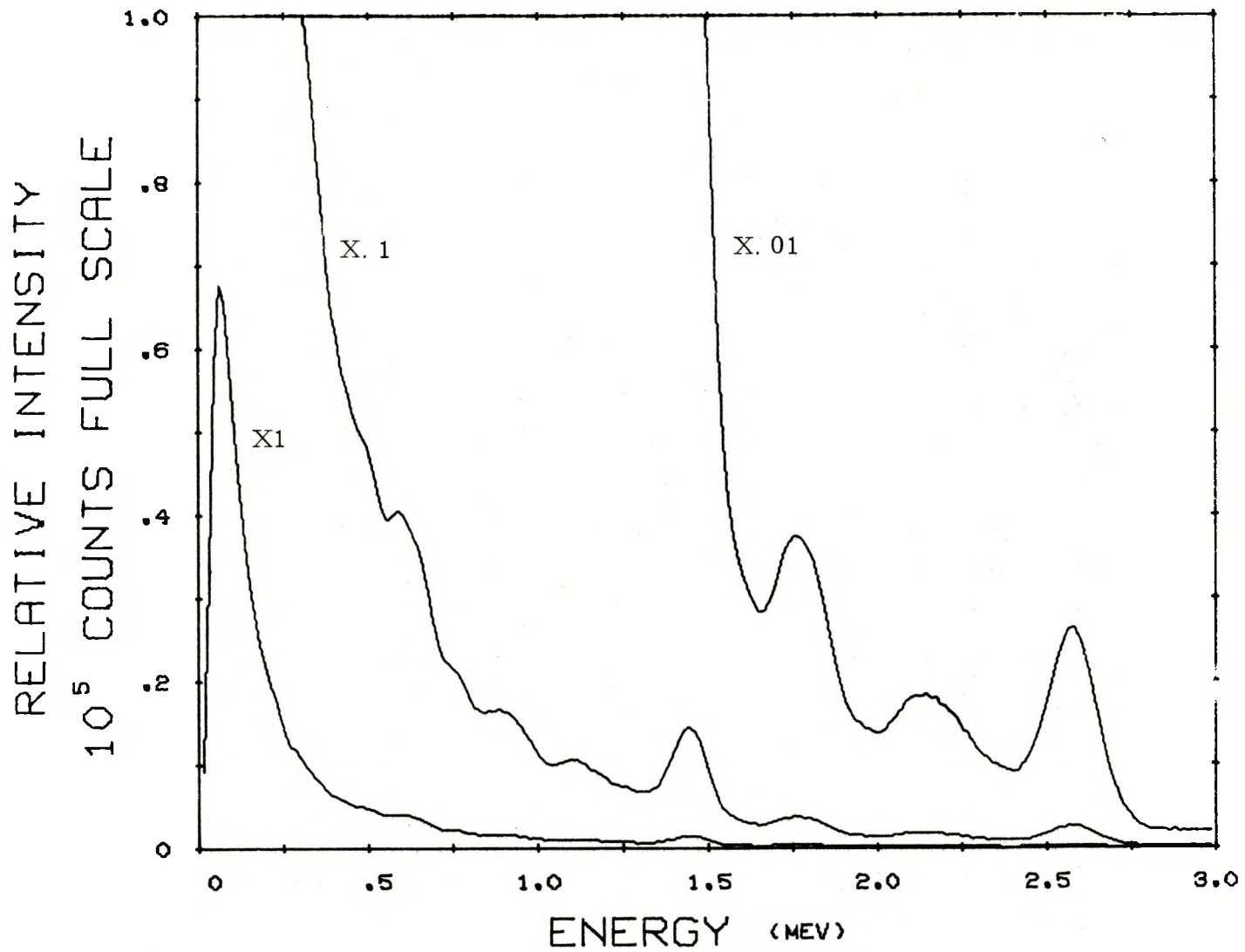


Figure 3. Typical gamma pulse-height spectrum for survey area.

TABLE 3. Gamma-ray energies and isotopes consistent with spectral data of Figure 3.

Observed Energy (MeV)	Radionuclides Consistent With Spectral Photopeaks		
	Fission Products	Activation Products	Background
0.51	Annihilation radiation
0.61	Bi-214
0.77	Bi-214
0.93	Bi-214
1.12	Bi-214
1.46	K-40
1.76	Bi-214
2.20	Bi-214
2.61	Tl-208

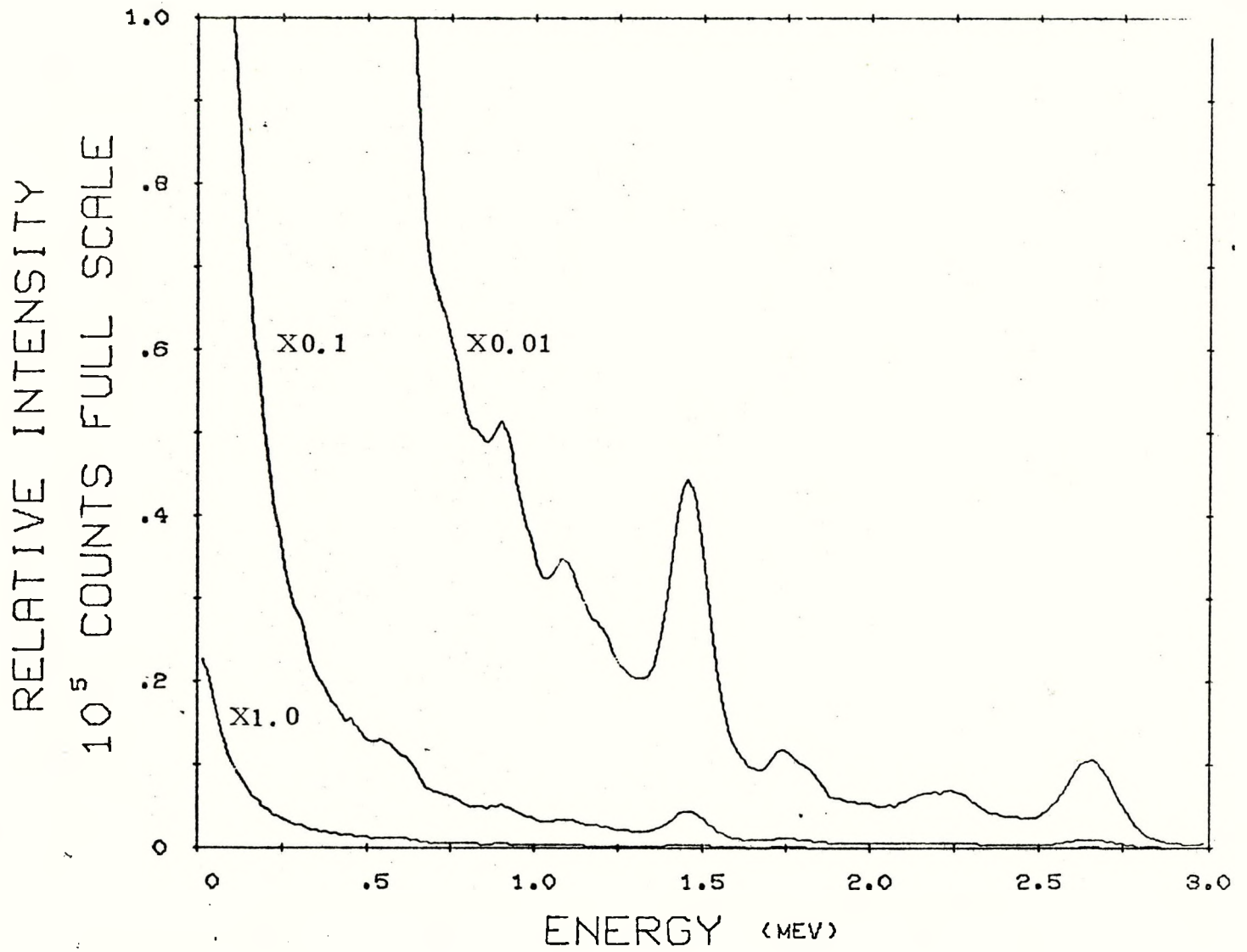


Figure 4. Spectrum taken in the vicinity of the Guilford stone quarry anomaly.

5. SUMMARY AND CONCLUSIONS

The gamma exposure rates and radioactive isotopes revealed in the survey of the area surrounding the Haddam Neck Plant are consistent with normal terrestrial background radiation. No anomalies were detected that could be attributed to reactor operations.

The 3-foot level exposure rates mapped during the survey were mostly in the 6 to 10 $\mu\text{R/hr}$ range.

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