ARMS-68.6.3
AEC Distribution Category UC-41

AERIAL RADIOLOGICAL MEASURING SURVEY OF THE AREA SURROUNDING BIG ROCK POINT NUCLEAR PLANT, BIG ROCK POINT, MICHIGAN, 1968

by

M. D. Sevart
EG&G, Inc., Las Vegas, Nevada

This report is part of a series on the continuing activities of the Aerial Radiological Measuring System operated for the U. S. Atomic Energy Commission. The ARMS program is managed by the Division of Operational Safety and is a cooperative effort among various offices and divisions of the Commission.

Issuance Date: October 1973

Published by
Technical Information Center, Office of Information Services
UNITED STATES ATOMIC ENERGY COMMISSION

DISCLAIMER

ABSTRACT

The Aerial Radiological Measuring System (ARMS), operated for the U. S. Atomic Energy Commission, was used to perform aerial surveys of several operational and non-operational reactor sites during the summer months of 1968.

The data collected on these surveys included aerial photographs of the installations, aerial radiation survey data consisting of exposure rates normalized to 3 feet above the ground plus gamma-ray spectral charts, effluent characterization for operational sites (intensity rates and isotope constituents), and pertinent descriptive information of the installation.

This report presents the data collected on the Big Rock Point reactor survey.

CONTENTS

ILLUSTRATIONS

TABLES

The Aerial Radiological Measuring System (ARMS), operated for the U. S. Atomic Energy Commission, was used to perform aerial surveys of several operational and non-operational reactor sites during the summer months of 1968.

The data collected on these surveys provide a catalog file of characteristics of each nuclear installation. Information included in the catalog file consists of: 1) aerial photographs of the installation, 2) aerial radiation survey data consisting of exposure rates normalized to 3 feet above the ground plus gamma ray spectral charts, 3) effluent characterization for operational sites (intensity rates and isotope constituents), and 4) pertinent descriptive information of the installation. The ARMS equipment and procedures employed to conduct these surveys and evaluate the results are described in a previous EG&G report.*

*Boyns, P. K.; Doyle, J. F.; and Sevart, M. D.; "Aerial Radiological Measuring Systems (ARMS)—Systems and Procedures Employed Through FY 1971," AEC Report No. ARMS-71.6, in preparation.

2. BIG ROCK POINT REACTOR AND SITE CHARACTERISTICS

The Big Rock Point reactor site is located in North Central Michigan on the shoreline of Lake Michigan, 4 miles northeast of the community of Charlevoix. Currently operating at the site is a boiling water reactor with a capacity of 75 MW(E) (gross) owned and operated by Consumers Power Company. With the exception of the community of Charlevoix, the area within a 10-mile radius of the Big Rock Point reactor can be considered sparsely populated. Table 2-1 presents a breakdown of the habitation of the region in terms of radial distance and direction from the reactor site. It is readily seen that 35 percent of the population live within a 10-mile radius of the reactor installation. Approximately 50 percent of the area within a 15-mile radius of the reactor site is comprised of the open waters of Lake Michigan. The remainder of the area consists of rolling hills interspersed with numerous lakes, the largest being Lake Charlevoix in the South Central region. Also in evidence in the area are numerous small streams and swamps.

Radio towers widely scattered throughout the survey area seemed to be the only potential hazard to low-level flights. Of the four small airfields in the area, none seemed to generate any significant activity.

Aircraft refueling, routine servicing, and major repairs are available at the Traverse City and Alpena, Wisconsin airfields. Both of these airfields are located within 65 nautical miles of the reactor site.

Table 2-1. Population distribution - Big Rock Point survey area.

Town	Direction From Reactor	Radial Distance From Reactor (Miles)		
		0-5	5-10	10-15
		Population		
Bayshore	E	250		
Burgess	SE	250		
Charlevoix	SSW	14,100		
Advance	S		250	
Barnard	WSW		250	
Horton Bay	SE		250	
Ironton	S		250	
Phelps	S		250	
Atwood	SSW			250
Boyne City	SE			5,000
East Jordan	S			5,000
Ellsworth	S			1,000
Good Hart	NNE			250
Harbor Springs	NE			5,000
Menonaqua	ENE			250
Patons Corner	NE			250
Petosky	E			10,000
Ramona	ENE			250
Roaring Brook	ENE			250
Stutsmanville	NNE			250
Wequetonsing	ENE			250
Wildwood	SE			250
Totals		14,600	1,250	28,250
Area Population Total: 44,100				

3. PLANNED SURVEY AREA

The survey area planned for the Big Rock Point reactor site included flying all land areas within a 25-mile square centered over the reactor site. (See Figure 3-1.) Flight lines were planned to provide flight paths spaced at 1-mile intervals. The resultant grid included 21 east-west oriented lines varying in length from 7 to 23 N. miles. These lines constituted the programmed gross-count and spectral environmental radiation survey.

Pre-planning for the effluent tracking and neutron sensing surveys consisted of locating the reactor site on appropriate topographic maps and performing real-time analysis of local meteorological conditions.

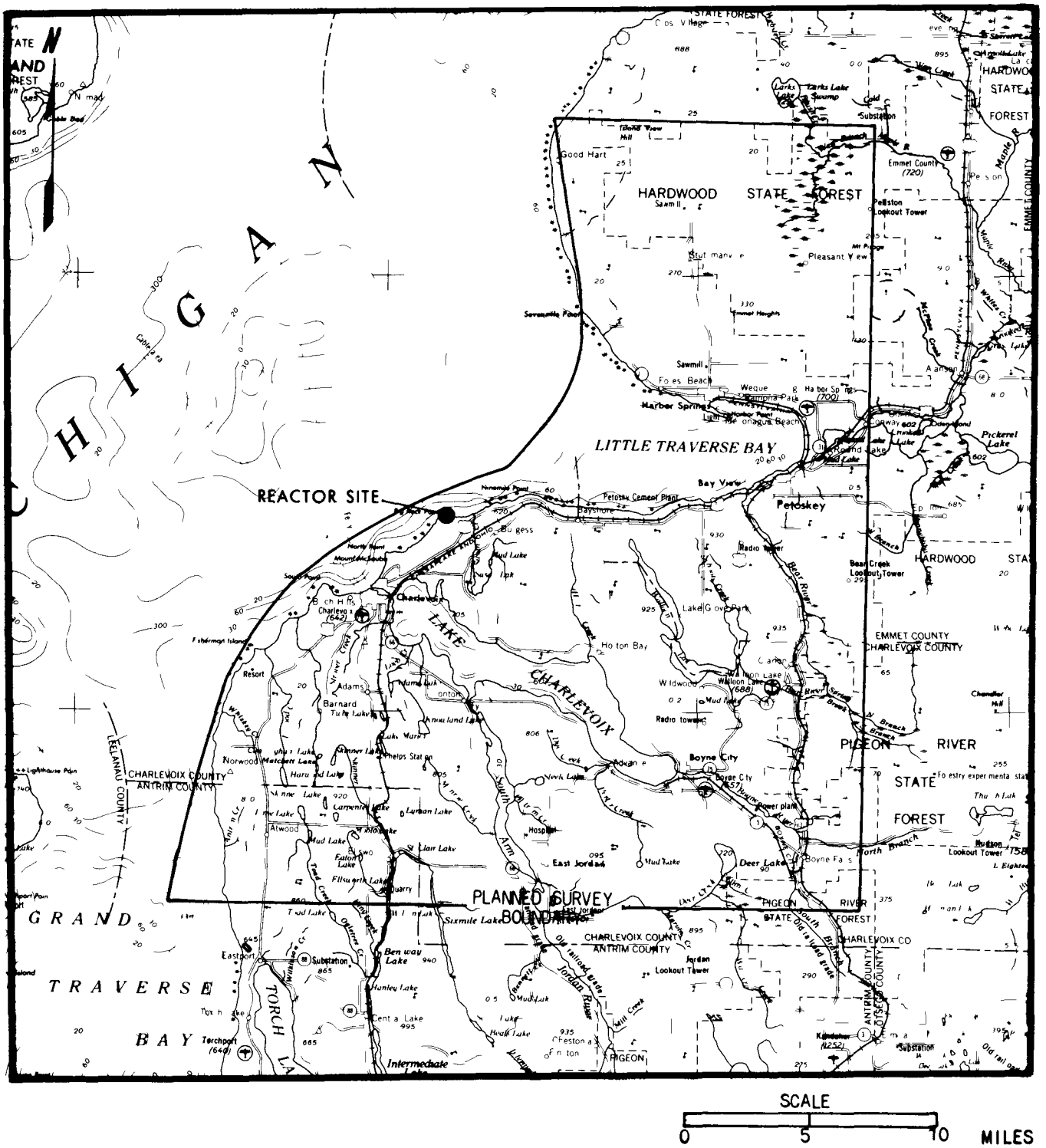


Figure 3-1. Planned survey area, Big Rock Point, Michigan.

4. TERRESTRIAL RADIATION SURVEY

The terrestrial radiation survey to collect gross-count and spectral data of the Big Rock Point area was flown on 15 July 1968. The reactor was not operating on that day.

The selected flight altitude for data collection was 300 ft above the terrain to provide simultaneous collection of gross-count and spectral data. All flight lines were flown similar to those programmed. Figure 4-1 shows the actual flight lines plotted from recorded position information.

Spectral collections were accumulated over a 4-minute live-time period. This corresponds to a distance of approximately 12 miles at survey aircraft speed. Where flight lines were shorter than 12 miles, a 4-minute collection was obtained by continuing to accumulate data on the following line.

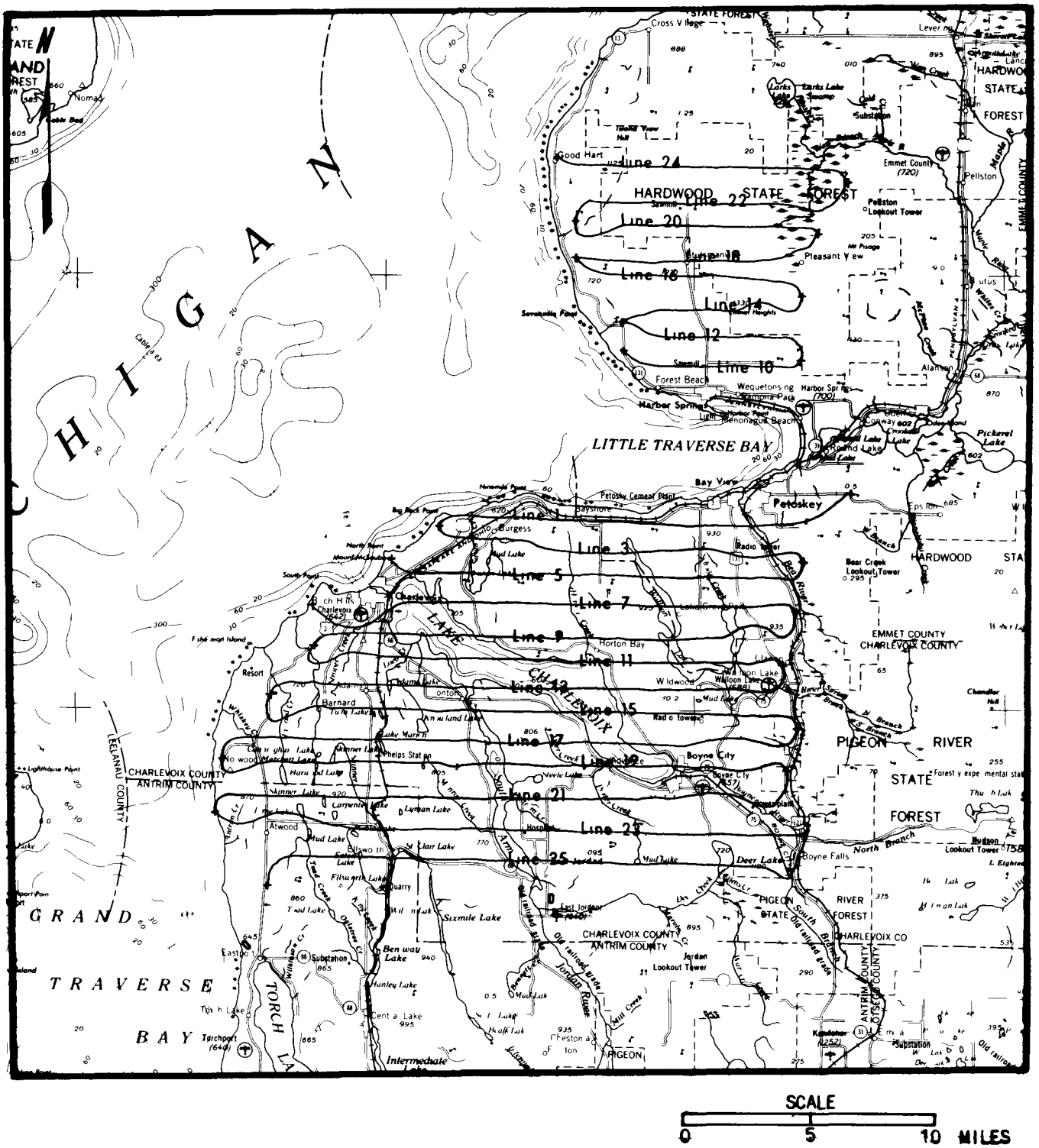


Figure 4-1. Flight lines - Big Rock Point reactor.

5. EFFLUENT CHARACTERIZATION

A mission to document effluent characteristics and radiation signature was flown on 30 September 1968. In-plume neutron measurements were made for comparison with measurements from an area upwind from the reactor installation. Following an inflight equipment change, the gamma-ray detection equipment was utilized to outline the effluent boundaries and obtain gross-gamma intensities. Spectral collections and air-filter samples were taken along the effluent centerline and periphery. At the time the plume track was performed, the reactor was at full power with a release rate of approximately 5,000 μCi/cc.

6. DATA ANALYSIS AND DISCUSSION

The data recorded on all survey missions have been compiled and analyzed to provide a summary of environmental radiation characteristics relevant to the Big Rock Point reactor site. These results as recorded will provide baseline data should future surveys be conducted in this area.

6.1 GROSS-COUNT DATA

Figure 6-1 shows the resultant radiation pattern mapped from the data recorded. The exposure rate values are in μR/hr, at the 3-foot level above the terrain.

The average exposure rate values for most of the area appear to be in the 4 to 6 μR/hr range. Results for areas with lower than average intensities can be attributed to the many lakes and marshy areas interspersed throughout the survey area.

The exposure rate data is a composite of the gamma rays eminating from the terrestrial surface plus the cosmic ray contribution which normally constitutes approximately 2 to 4 μR/hr of the total.

6.2 SPECTRAL DATA

The spectral data collected provide characteristic isotopic contributions from the grid line area flown as part of the terrestrial radiation survey. These spectral traces are included in the Appendix and the table preceding the traces lists the energies and isotopes present in all of these charts. The isotopic constituents appear to be consistent between the charts although individual intensities vary in some instances. Only significant photopeak energies of each nuclide have been included in the tabulation.

Three energies evident in all spectra taken during the terrestrial radiation survey were a direct result of on-board calibration sources. The isotopes and their associated energies are as follows: CS-137, 0.66 MeV; Co-60, 1.17 MeV; Co-60, 1.33 MeV. These sources were removed for the effluent characterization mission.

Background spectral collections were recorded prior to each survey mission at altitudes free from terrestrial effects.

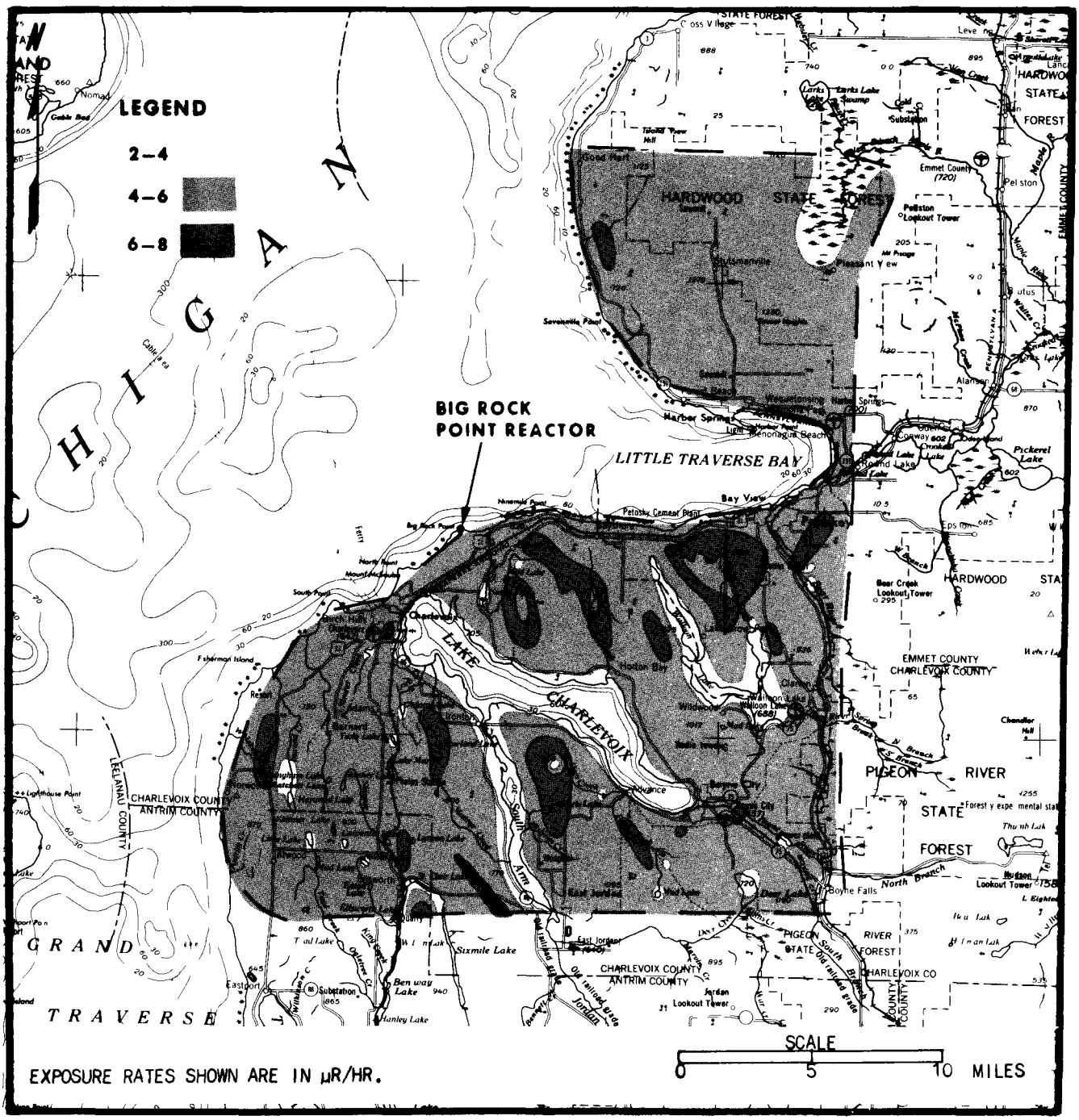


Figure 6-1. Exposure rate contours, Big Rock Point reactor, 15 July 1968.

6.3 EFFLUENT NEUTRON SENSING

Since the presence of delayed neutron emitters in the downwind effluent would suggest a possible filter failure, it is believed that neutron measurements in the plume could be a meaningful contribution to the characterization endeavor. The results of the collections made in the effluent showed an absence of the delayed neutron emitters. The neutron activity appeared consistent with the background collections made in the areas remote from the effluent.

6.4 EFFLUENT GAMMA-RAY MEASUREMENTS

The effluent plume as outlined by gamma-ray detection equipment is illustrated in Figure 6-2. This pattern will vary, of course, with changing meteorological conditions and reactor release rates.

After completing a peripheral track, penetrations along the centerline were made to record gross-count intensities, collect air filter samples, and accumulate spectral information. The maximum gross-count intensity recorded along the centerline was approximately 10 to 15 times background.

The spectral data collected along the effluent centerline are shown in Figure 6-3. The spectral data shown in Figure 6-3 was accumulated with the crystal array. Table 6-1 lists the isotopes identified from the energies present in this spectral trace.

Gamma ray analysis of the exposed air-filter samples was performed immediately upon their removal from the air stream. The resultant spectral trace is shown in Figure 6-4, and Table 6-2 lists the isotopes identified from the energies present. The spectral data in Figure 6-4 was accumulated using a 3 x 3 inch crystal with an air filter placed on the face of the crystal in a plastic dish. These filter samples were returned to Las Vegas laboratory analysis to search for possible long-lived contributors. This analysis was performed approximately 2 weeks after collection and showed no significant activity.

The complex direct emission spectra obtained during effluent characterization makes a qualitative isotopic interpretation difficult because of the resolution of sodium iodide crystals. The direct emission spectra contains both gaseous and particulate isotopes; however, the air filter spectra contains only the particulate isotopes. This enhances the capability of interpretation of the complex direct emission spectra. Also, the identification of prominent members of decay series aids in the identification of other members of the series, which must be present and are not as easily recognized from the spectral data.

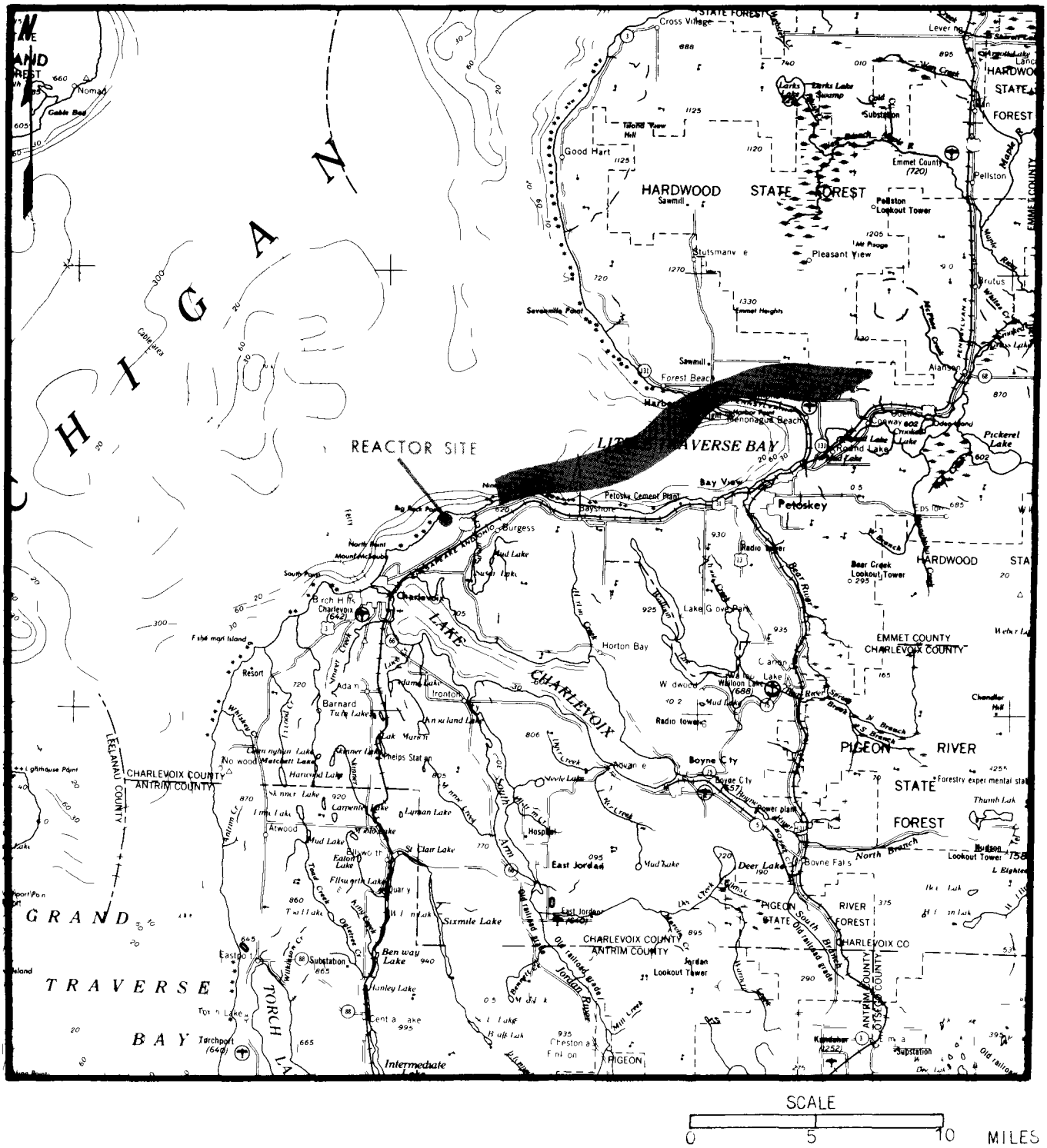


Figure 6-2. Effluent plume, Big Rock Point reactor, 30 September 1968.

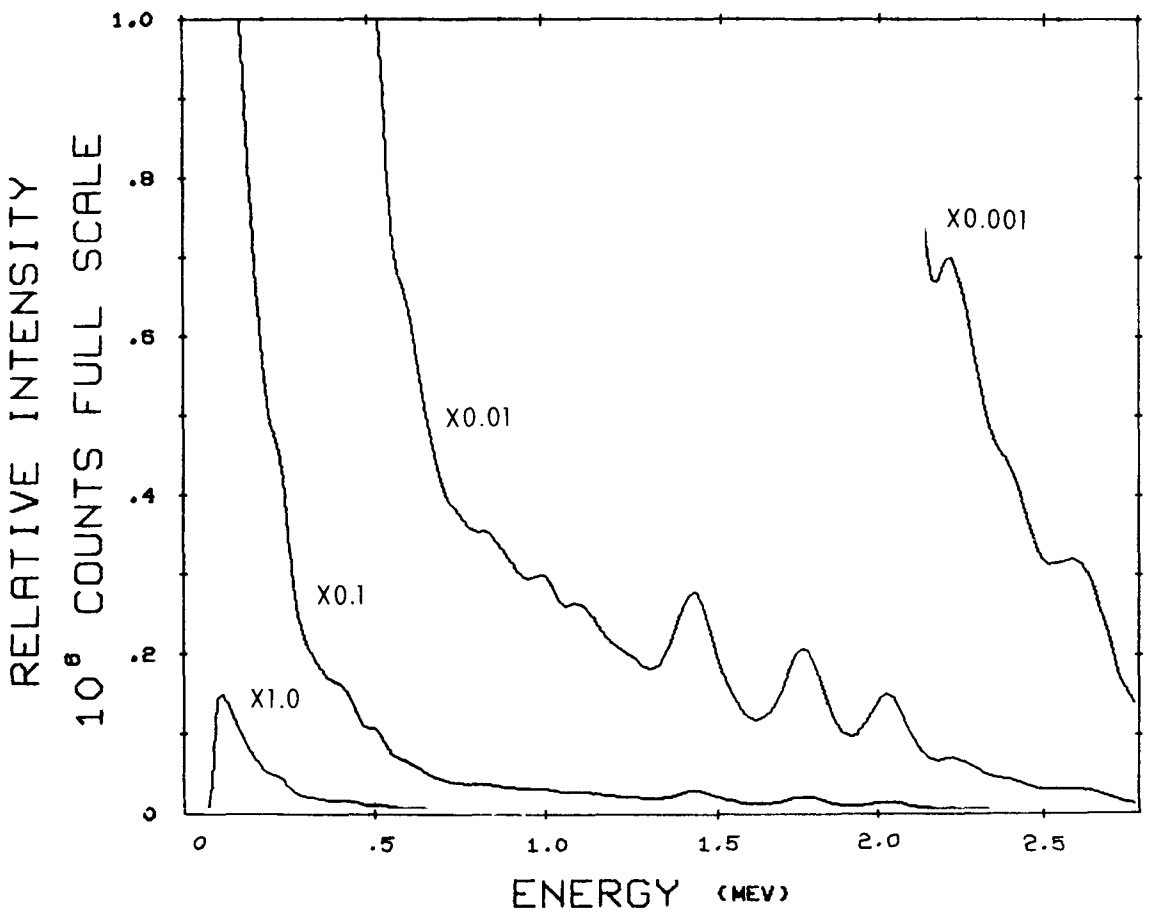


Figure 6-3. Effluent plume centerline spectra, Big Rock Point reactor, 30 September 1968.

Table 6-1. Isotopic tabulation of spectra in Figure 6-3.

Obs. Energy (MeV)	Radionuclides Consistent with Spectral Photopeaks		
	Fission Products	Activation Products	Background
0.25	Xe 135		
0.40-0.46	Kr 87, Xe 138, Cs 138		
0.51-0.55	Xe 138, Xe 135m, Cs 138		Annih.
0.61	Xe 135		Bi 214
0.65-0.66	Sr 91		
0.75	Sr 91		
0.85-0.91	Kr 87, Kr 88, Rb 88		
1.02-1.05	Sr 91		
1.12	- - - - - - - - - - - - - - - -		Bi 214
1.42-1.55	Cs 138, Kr 88, Sr 91		K 40
1.75-1.85	Kr 87, Rb 88, Xe 138		Bi 214
2.01-2.11	Rb 88, Kr 87, Xe 138		
2.20	Cs 138		B 214
2.40	Kr 88		
2.57-2.68	Kr 87, Rb 88 Cs 138		

Table 6-2. Isotopic tabulation of air filter spectra in Figure 6-4.

Obs. Energy (MeV)	Radionuclides Consistent with Spectral Photopeaks		
	Fission Products	Activation Products	Background
0.46-0.65	CS 138 + Sr 91		
0.75-0.93	Sr 91 + Rb 88		
1.01-1.03	Sr 91 + Cs 138		
1.41-1.43	Sr 91 + Cs 138		
1.86	Rb 88		
2.21	Cs 138		
2.63 - 2.68	Rb 88 + Cs 138		

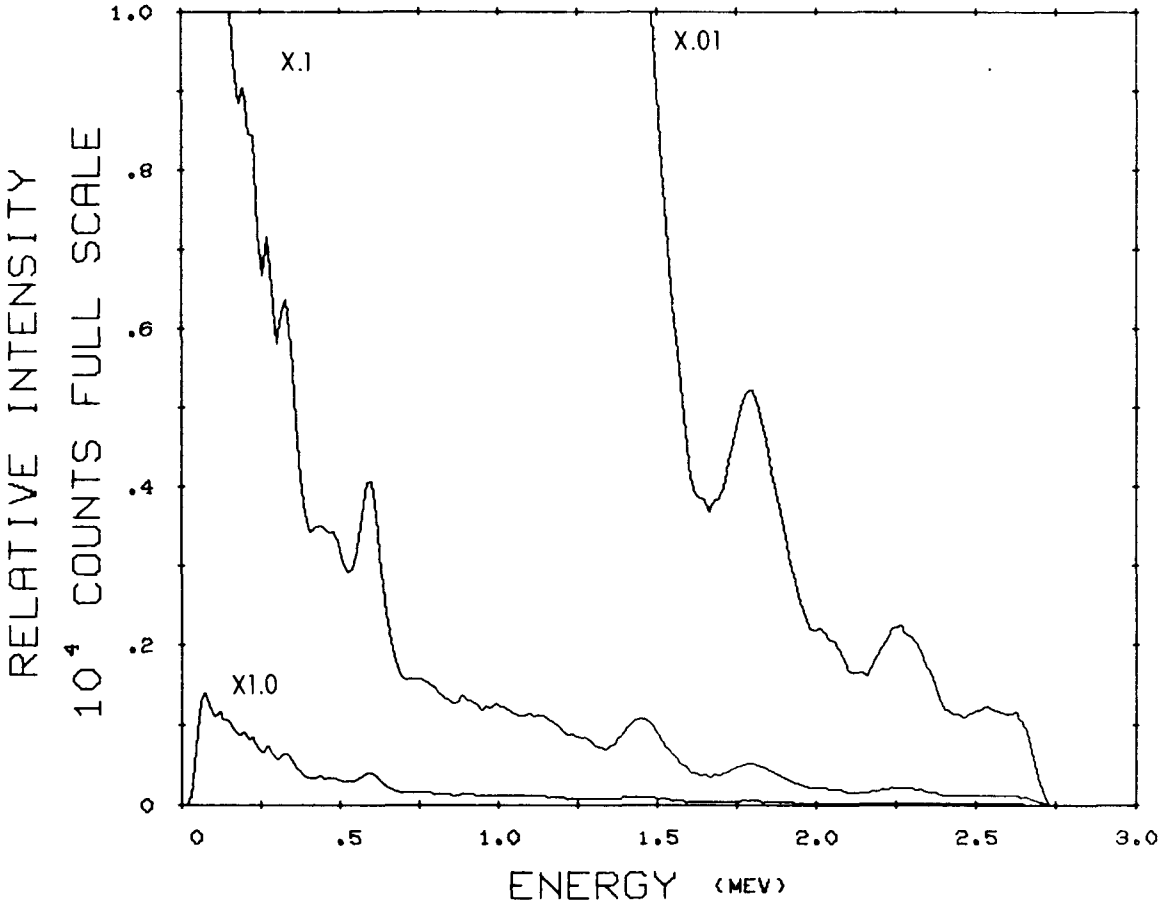


Figure 6-4. Air filter sample spectra of the plume of the Big Rock Point reactor, 30 September 1968.

7. SUMMARY AND CONCLUSIONS

The Big Rock Point power reactor site was surveyed from the air during both operational and non-operational status. Results of the survey can be summarized as follows:

1. The terrestrial radiation survey was performed during a non-operational mode. The exposure rates mapped during the survey were predominantly in the 4- to 6-μR/hr range. No anomalies were detected that might be attributed to Big Rock Point reactor operations.

2. The effluent plume was tracked 15 to 20 miles downwind of the reactor stack. Effluent characteristics were obtained by spectral analysis and air-filter sample collections. No significant indication of long-lived fission product activity was observed on the air filter samples.

3. No significant indication of delayed neutron emitters were detected in the downwind effluent.

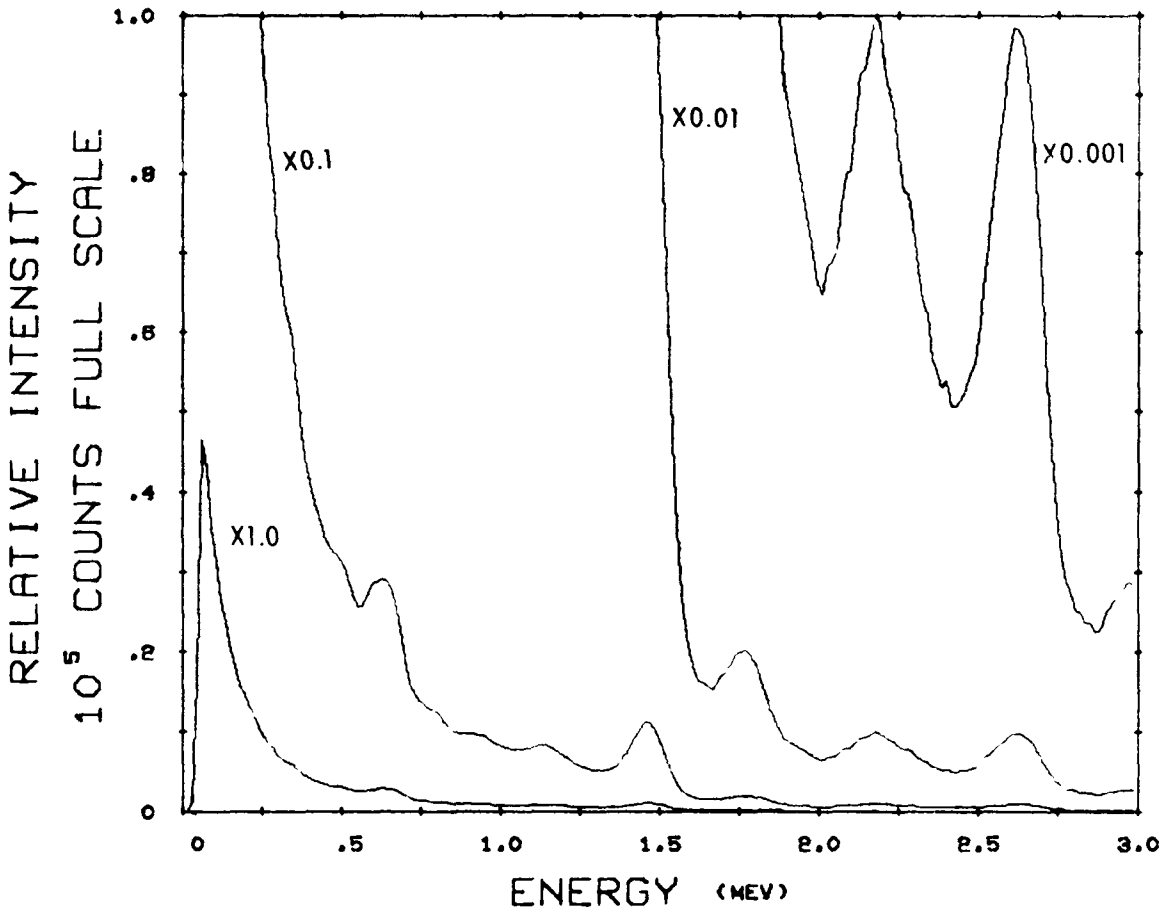
APPENDIX

GAMMA-RAY SPECTRAL CHARTS

The gamma-ray spectral charts that constitute this section are included to show energy characteristics of the flight lines making up the environmental radiation survey area of the Big Rock Point reactor.

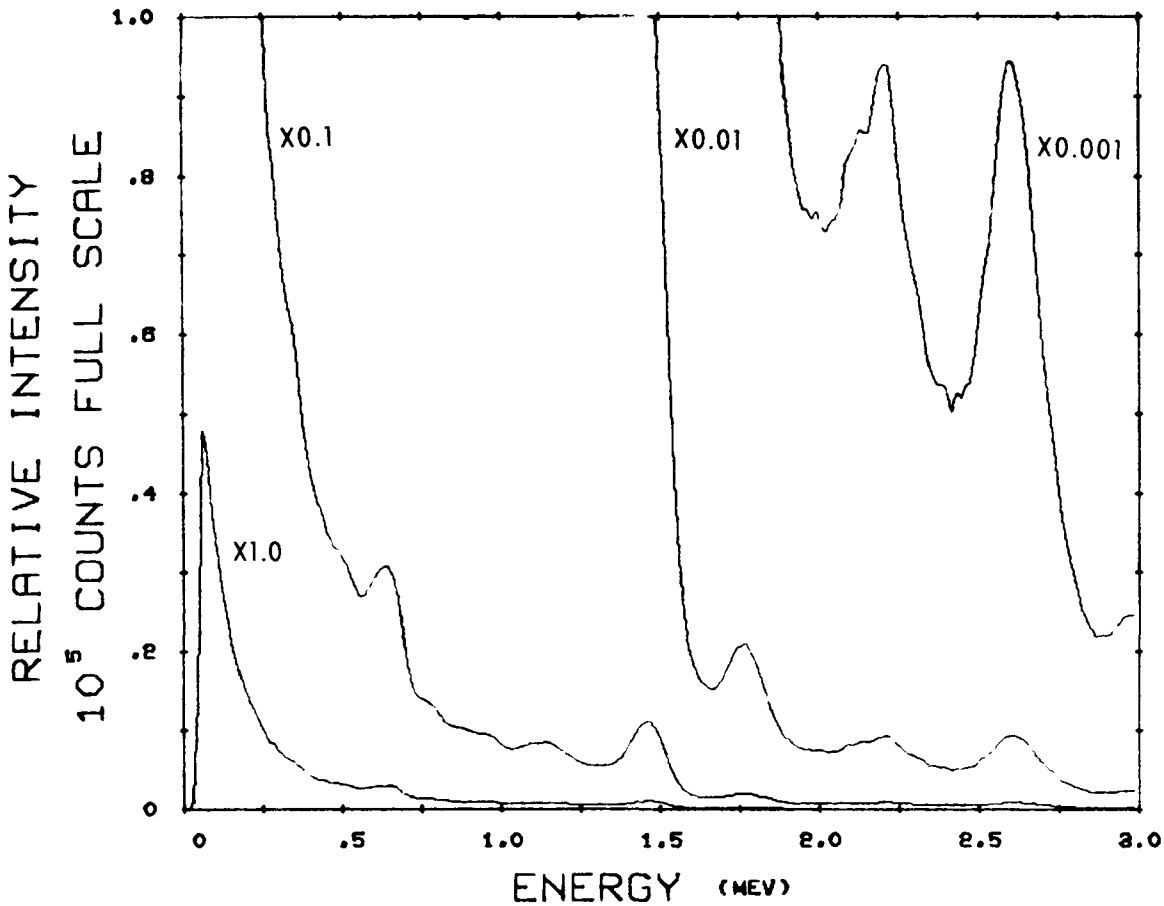
The tabulation preceding the total group of spectra shows the energies present in all charts and lists the isotopic contributor believed to be associated with the photopeaks observed.

Obs. Energy (MeV)	Radionuclides Consistent with Spectral Photopeaks		
	Fission Products	Activation Products	Background
0.51			Annih.
0.61-67			Bi-214 + Cs-137
1.12-1.17			Bi-214 + Co-60
1.33-1.46			Co-60 + K-40
1.76			Bi-214
2.20			Bi-214
2.62			T1-208



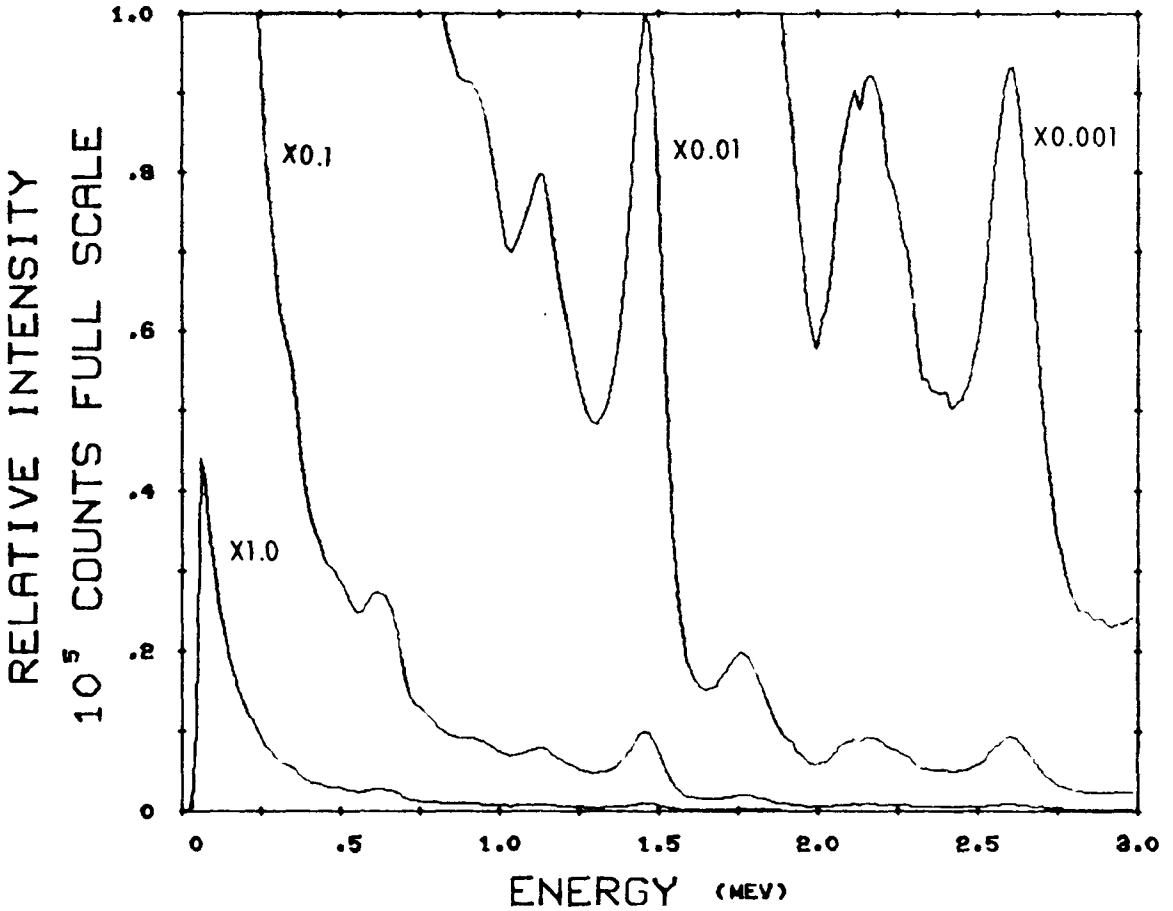
LOCATION: LINE 24 (ENTIRE FLIGHT LINE)
LINE 22 (EASTERN HALF)

SPECTRUM NO. 702
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 513640
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



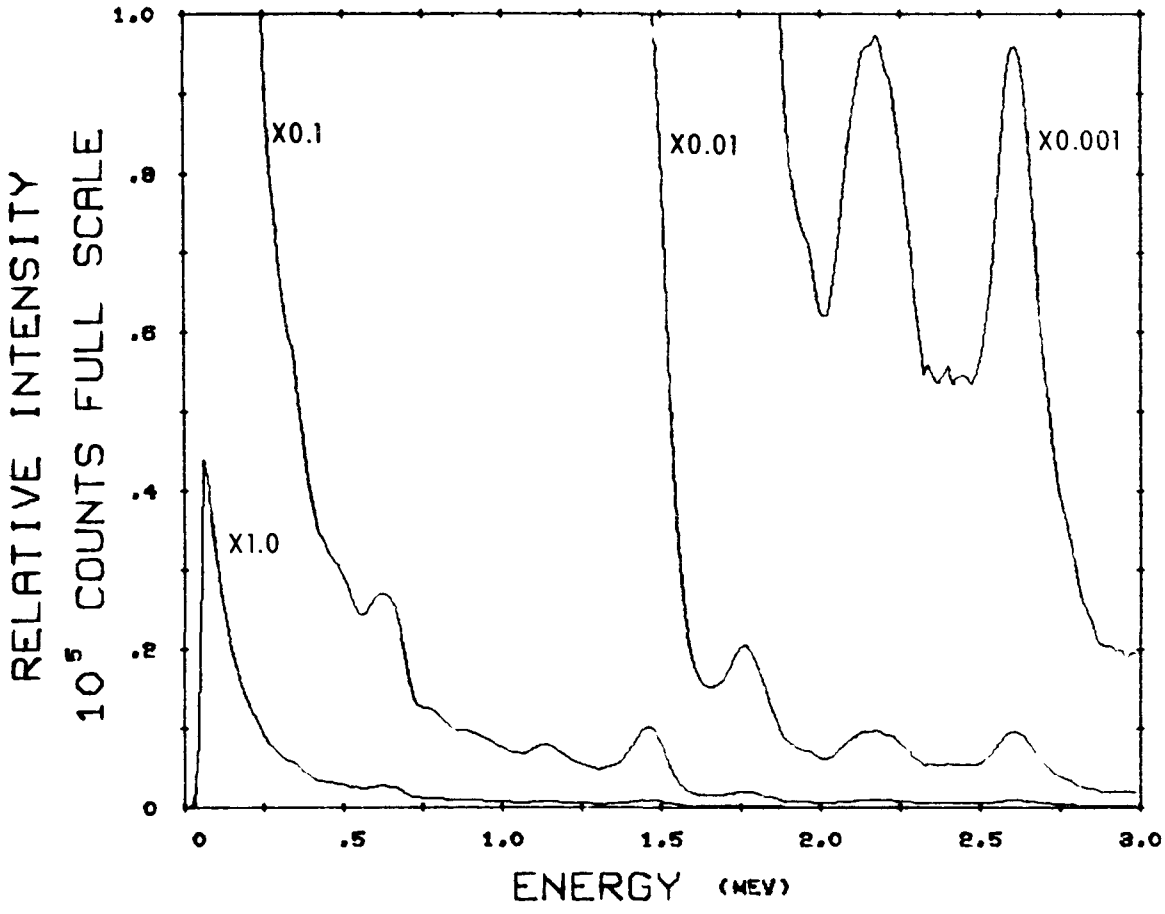
LOCATION: LINE 22 (WESTERN HALF)
LINE 20 (WESTERN HALF)

SPECTRUM NO. 703
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 529186
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



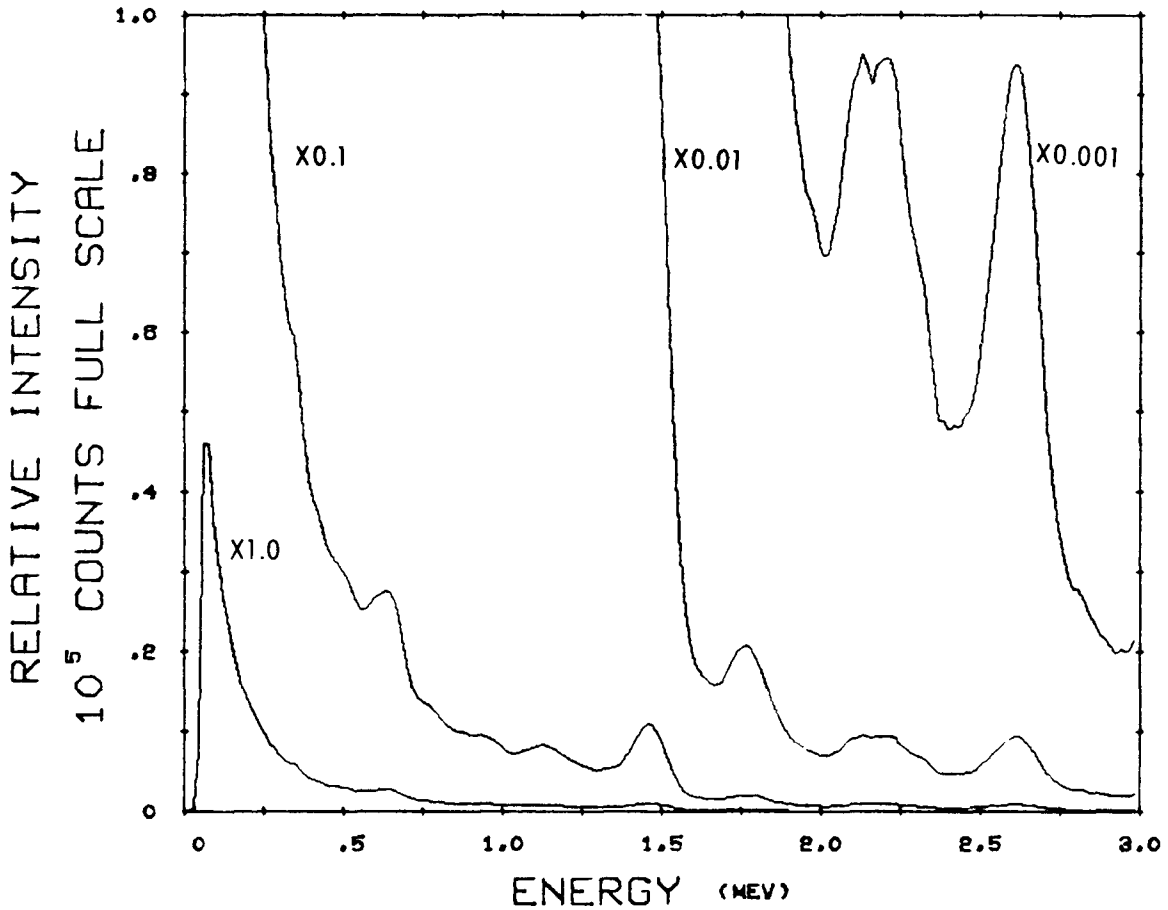
LOCATION: LINE 20 (EASTERN HALF)
LINE 18 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 704
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 477914
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



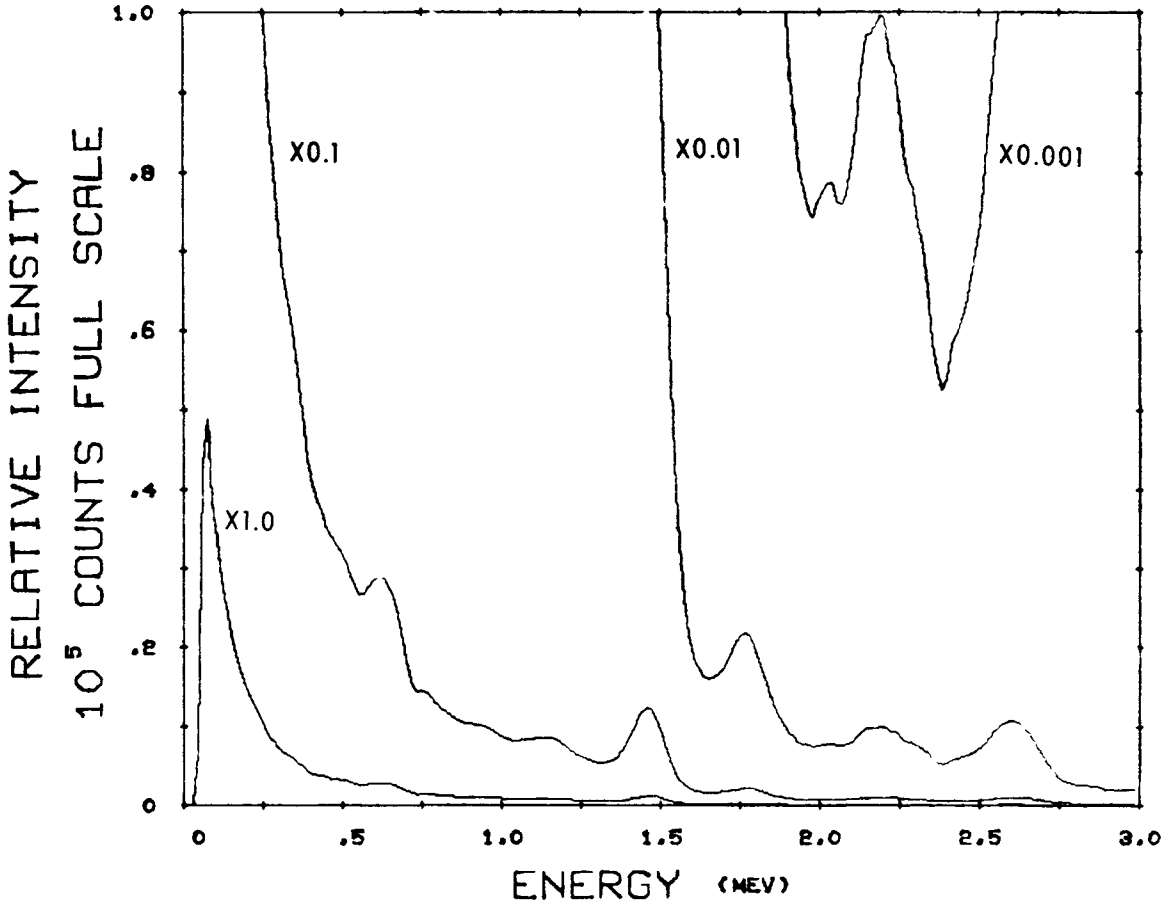
LOCATION: LINE 16 (ENTIRE FLIGHT LINE)
LINE 14 (EASTERN HALF)

SPECTRUM NO. 705
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 486481
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



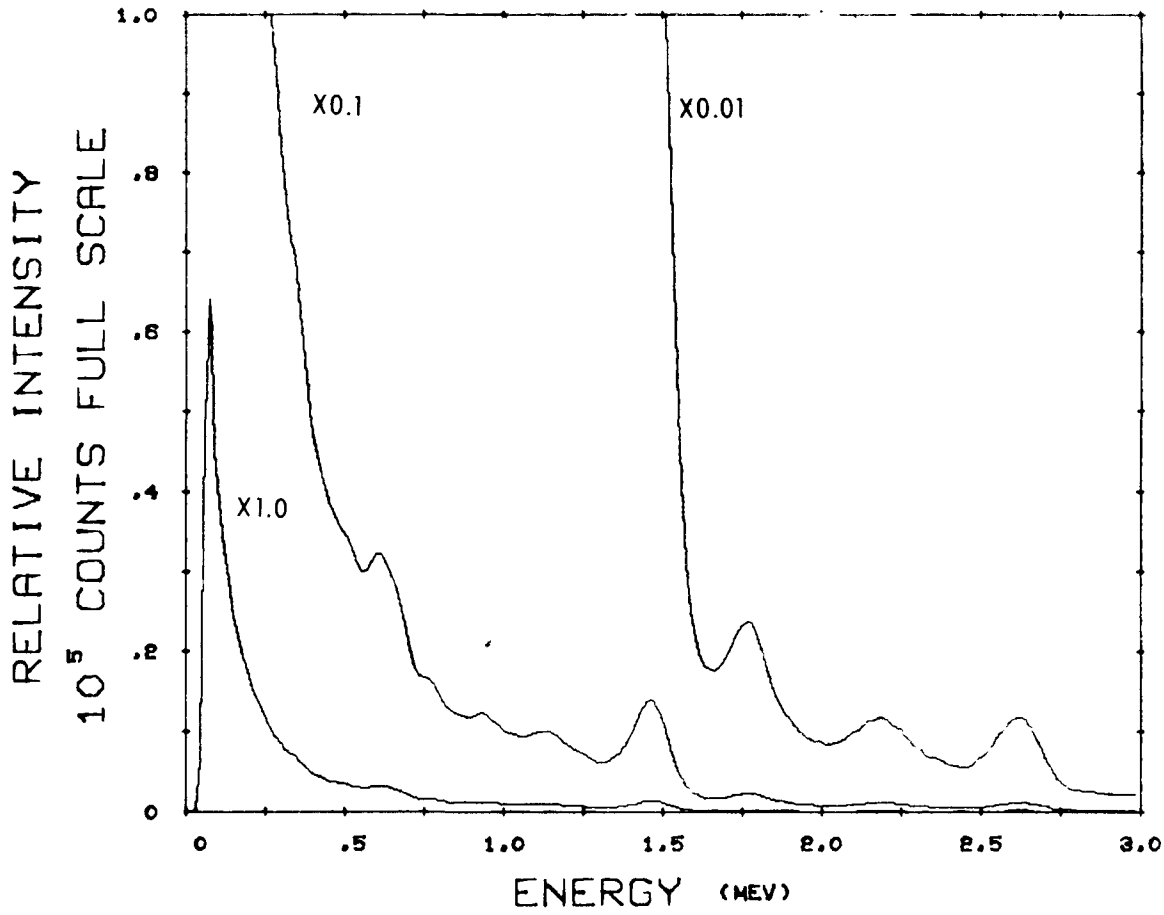
LOCATION: LINE 14 (WESTERN HALF)
LINE 12 (WESTERN HALF)

SPECTRUM NO. 706
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 504043
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



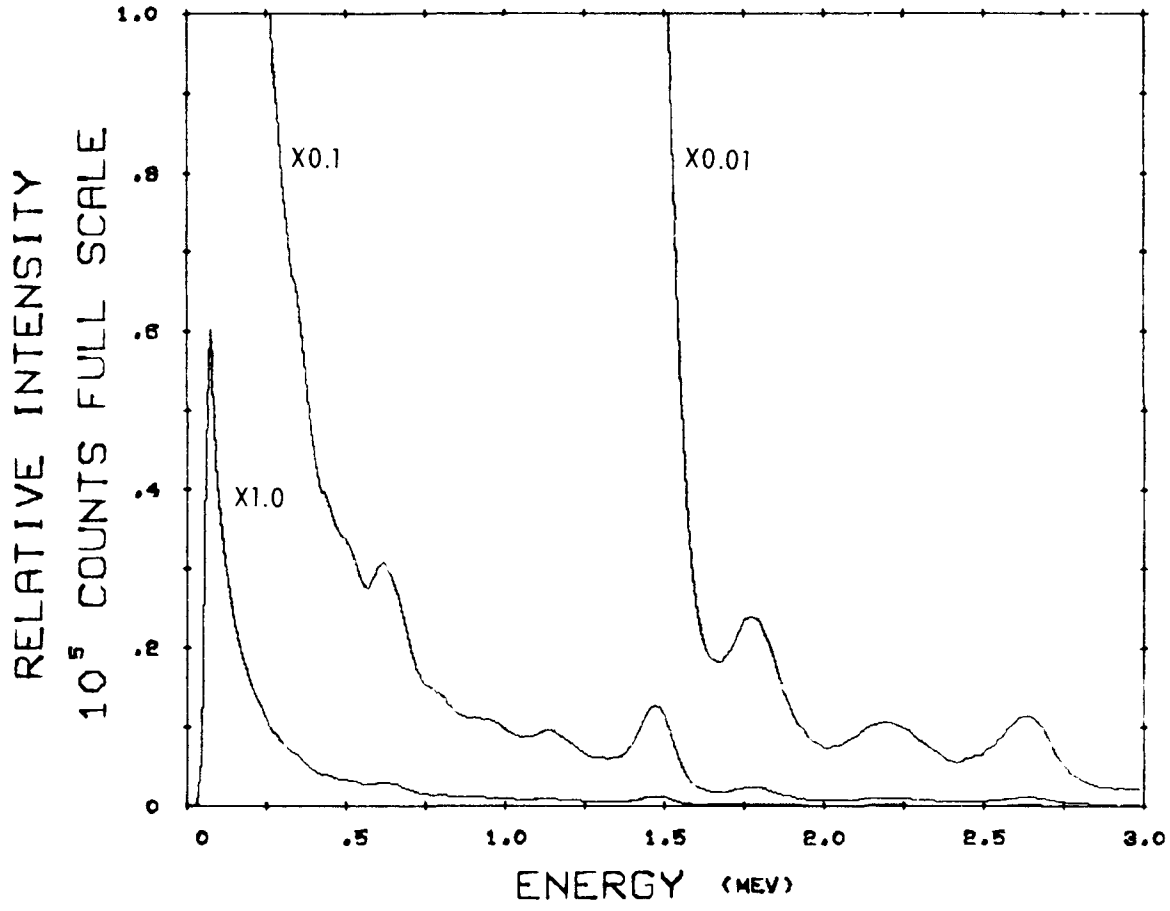
LOCATION: LINE 12 (EASTERN HALF)
LINE 10 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 707
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 526019
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



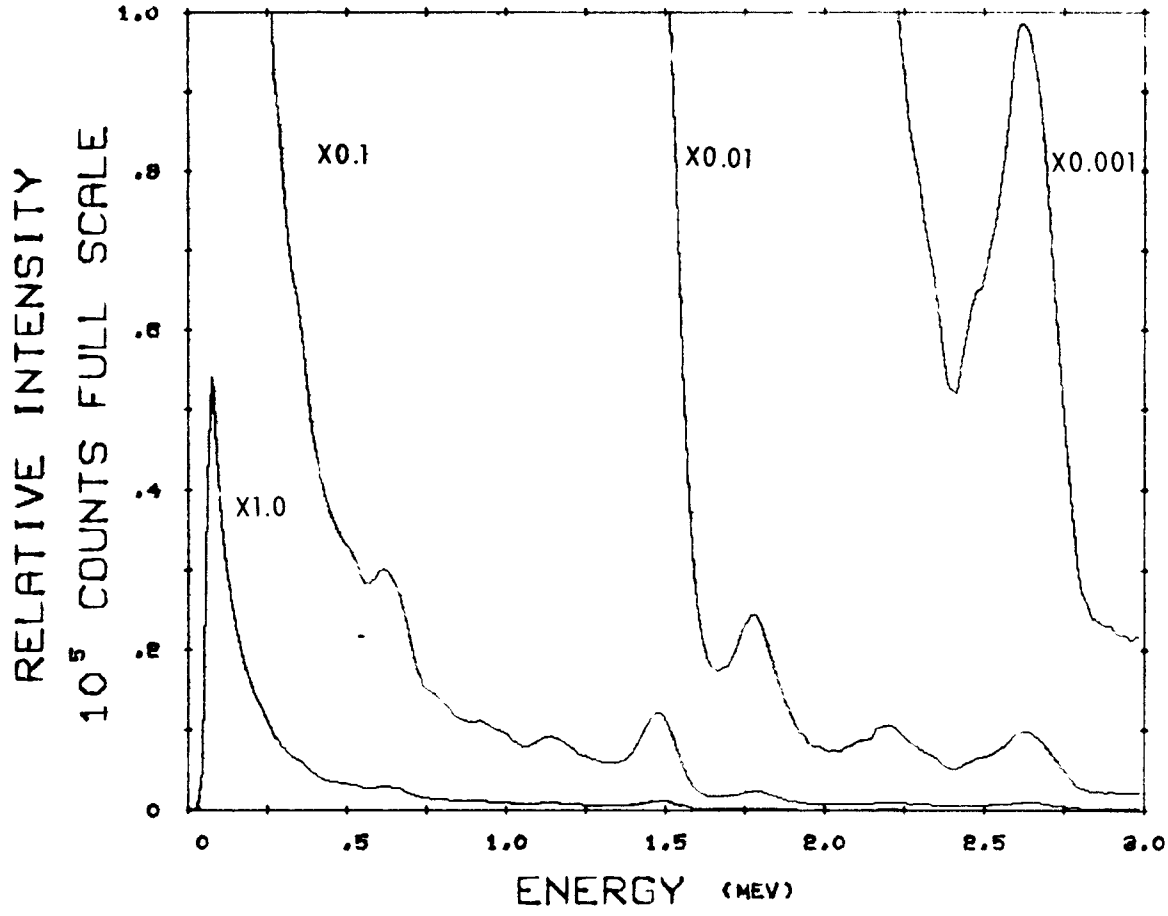
LOCATION: LINE 1 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 708
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 607455
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



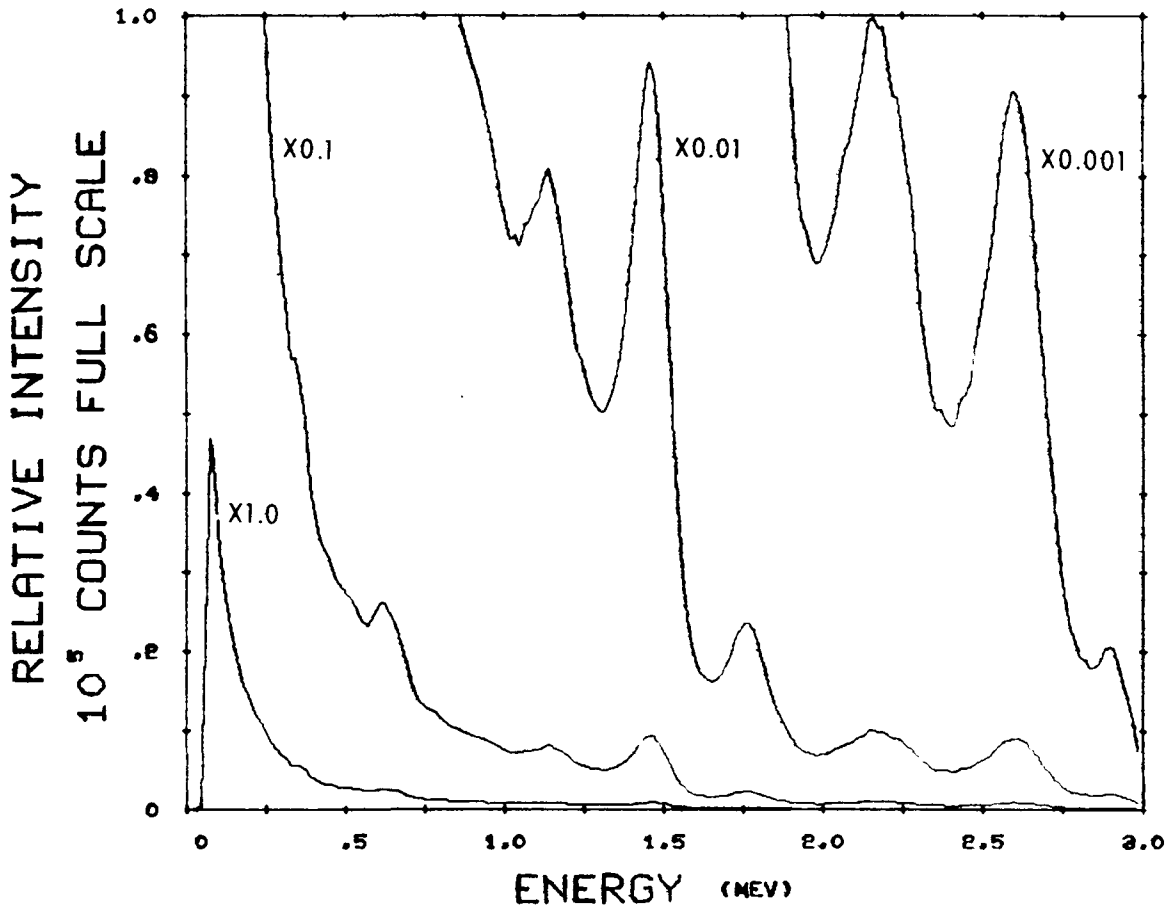
LOCATION: LINE 3 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 709
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 572338
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



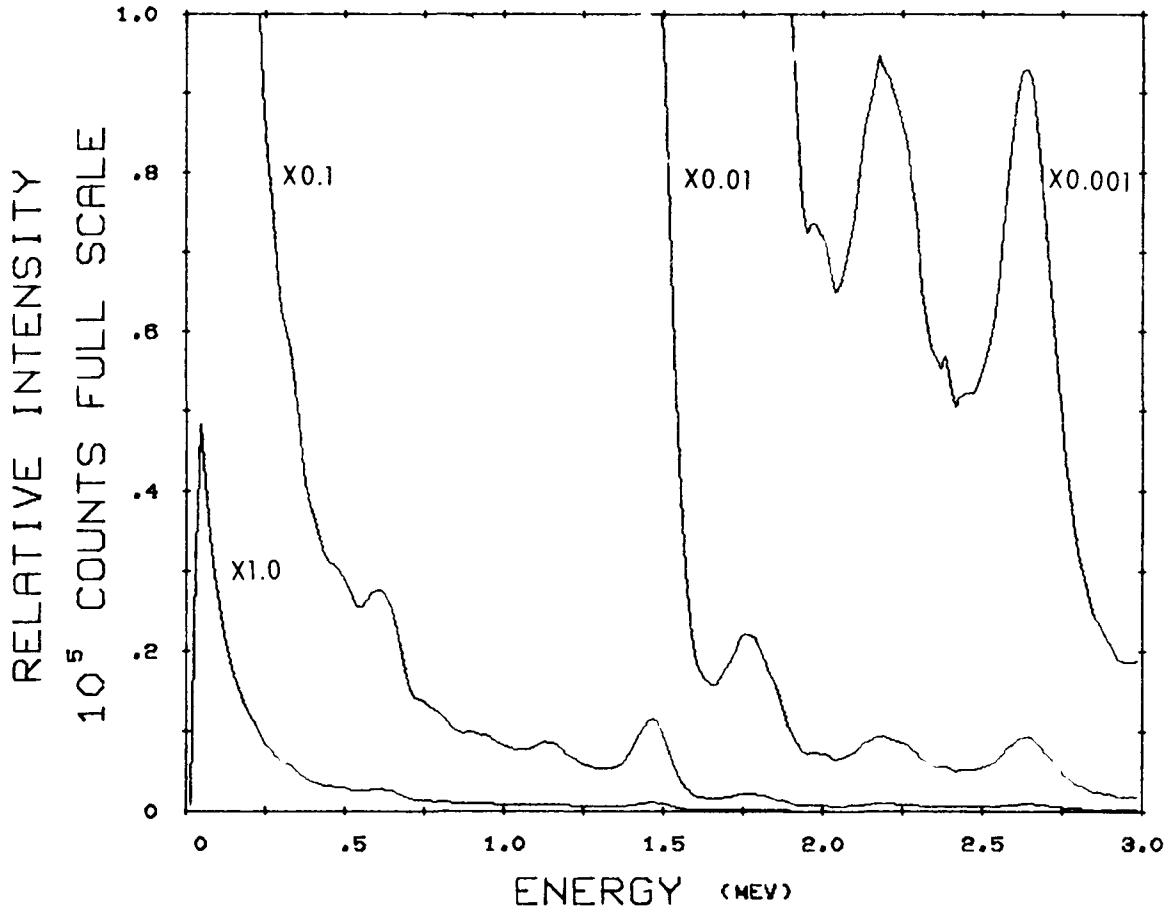
LOCATION: LINE 5 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 710
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 558246
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



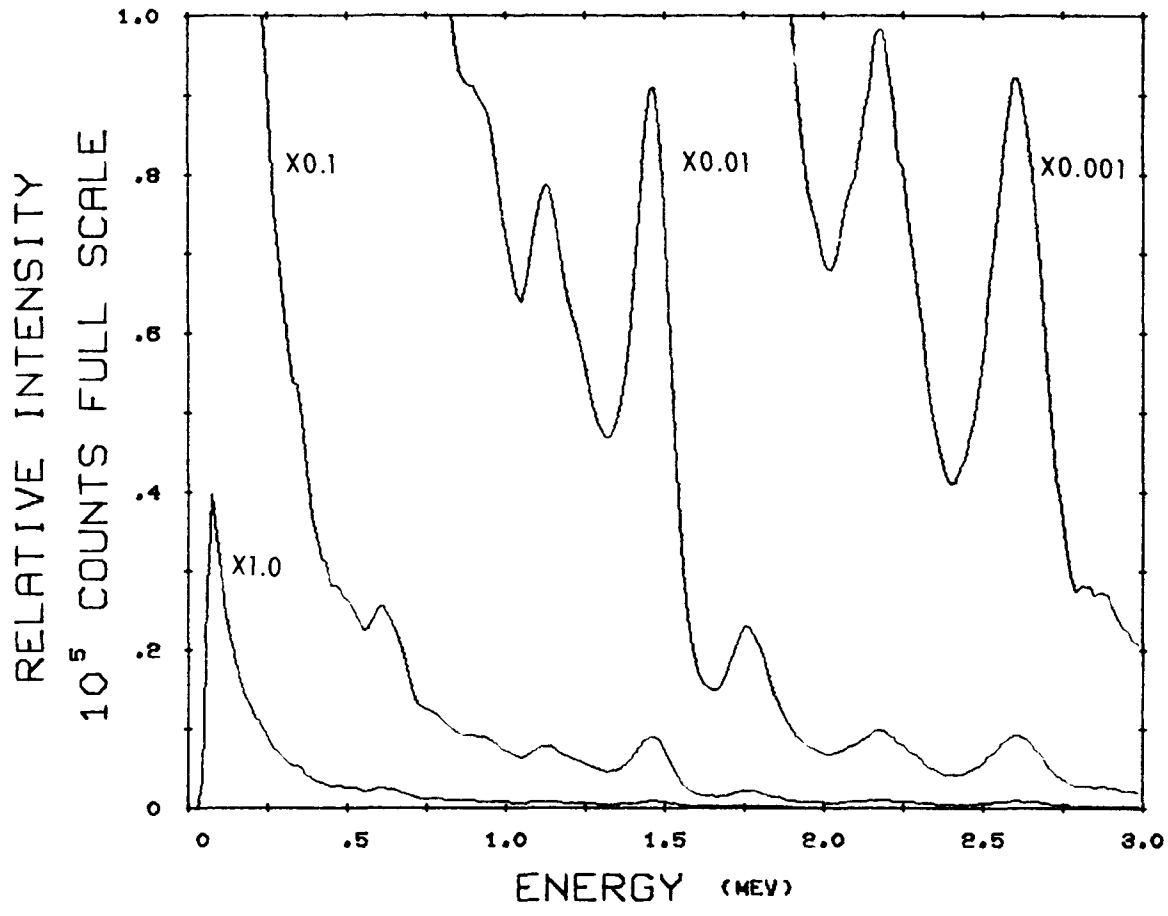
LOCATION: LINE 7 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 711
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 473664
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



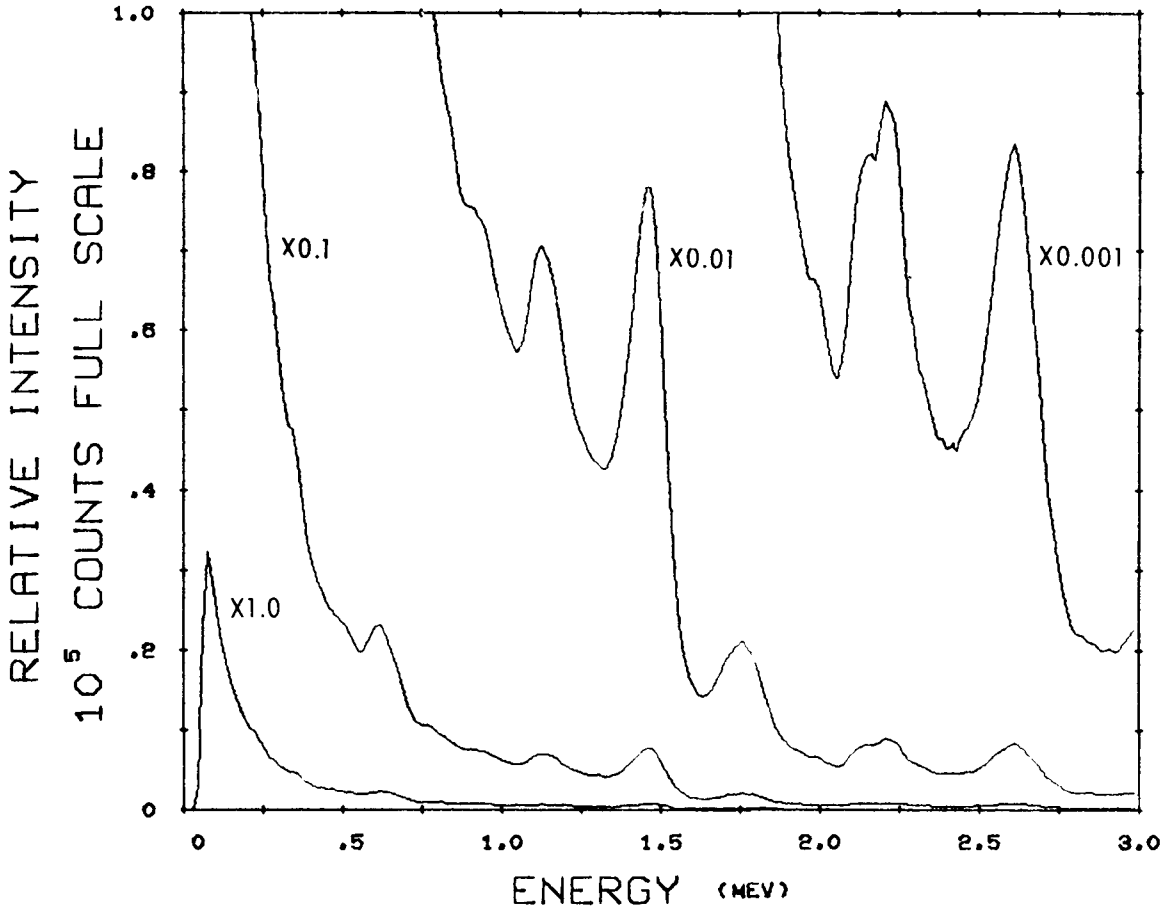
LOCATION: LINE 9 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 712
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 516567
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



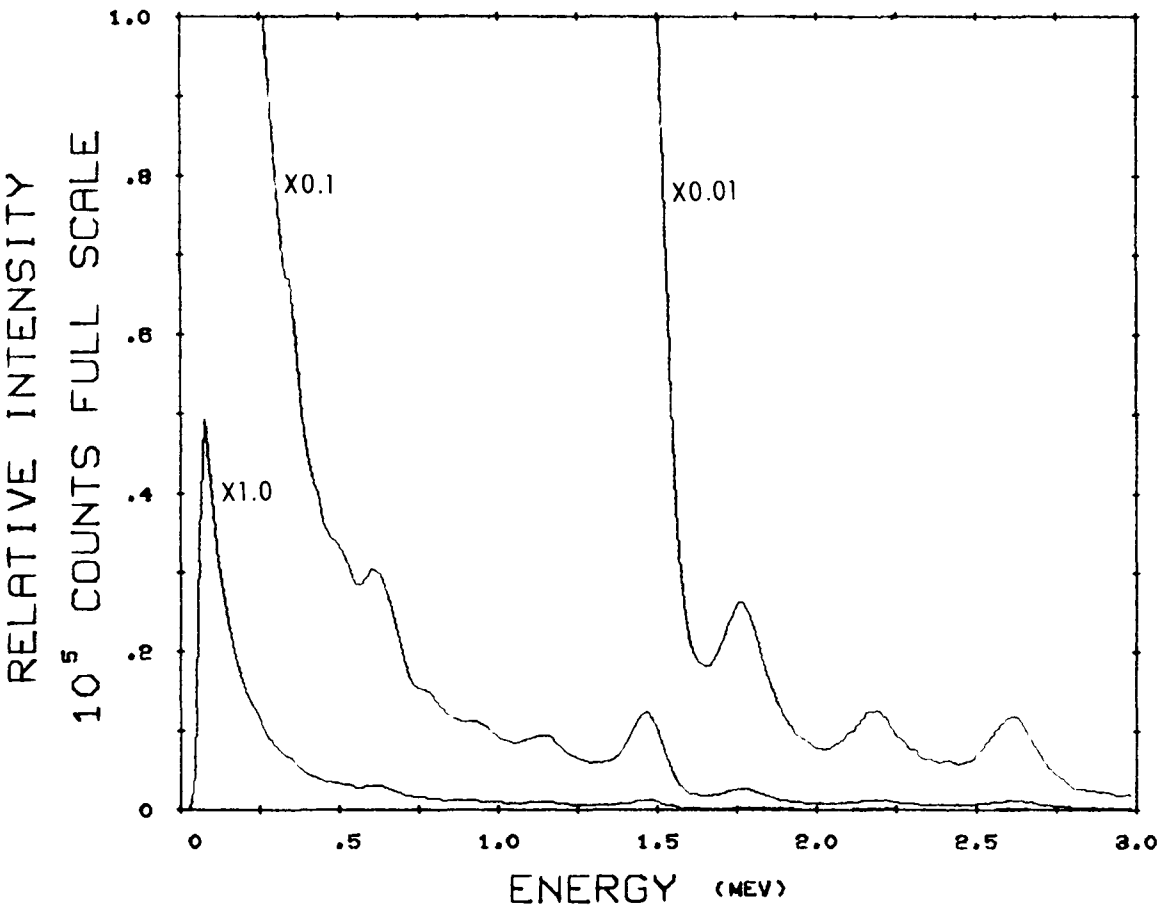
LOCATION: LINE 11 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 713
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 439503
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



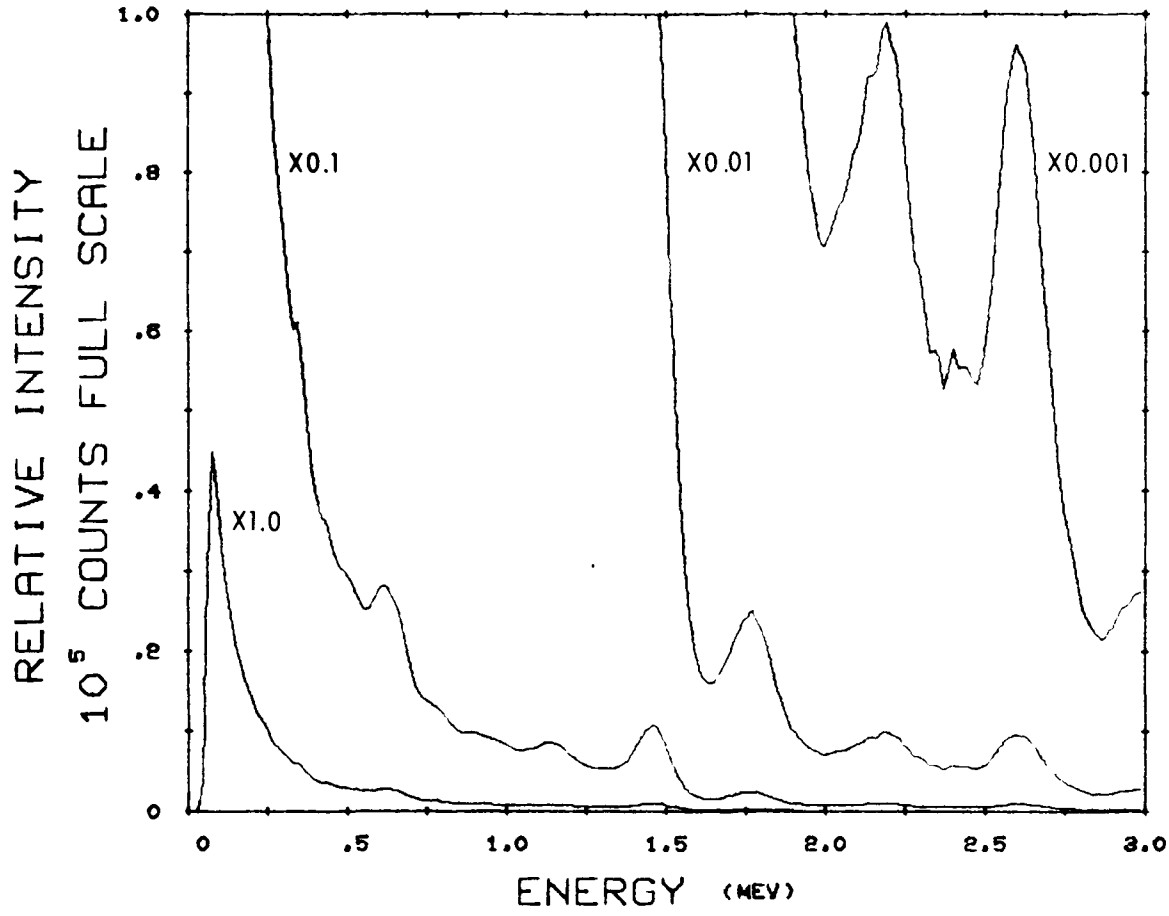
LOCATION: LINE 13 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 714
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 378177
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



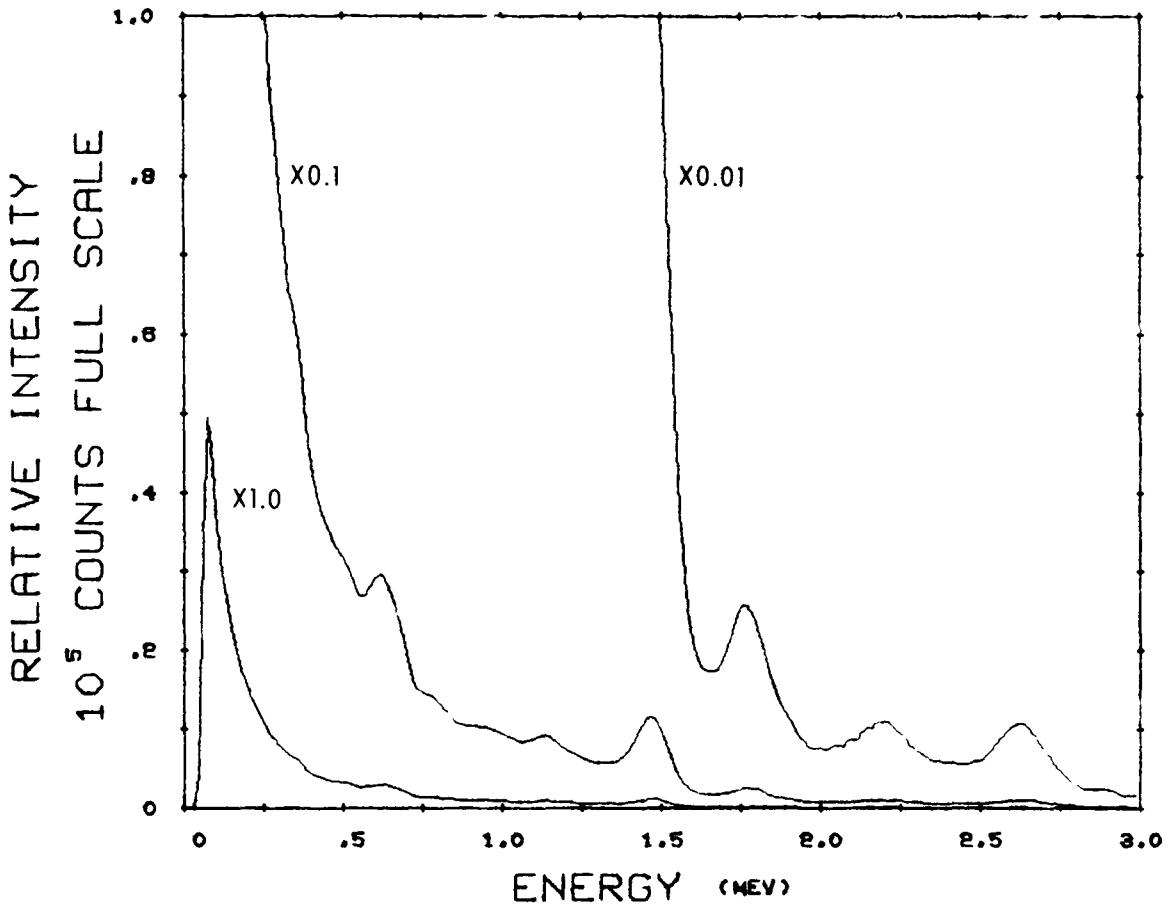
LOCATION: LINE 15 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 715
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 552308
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



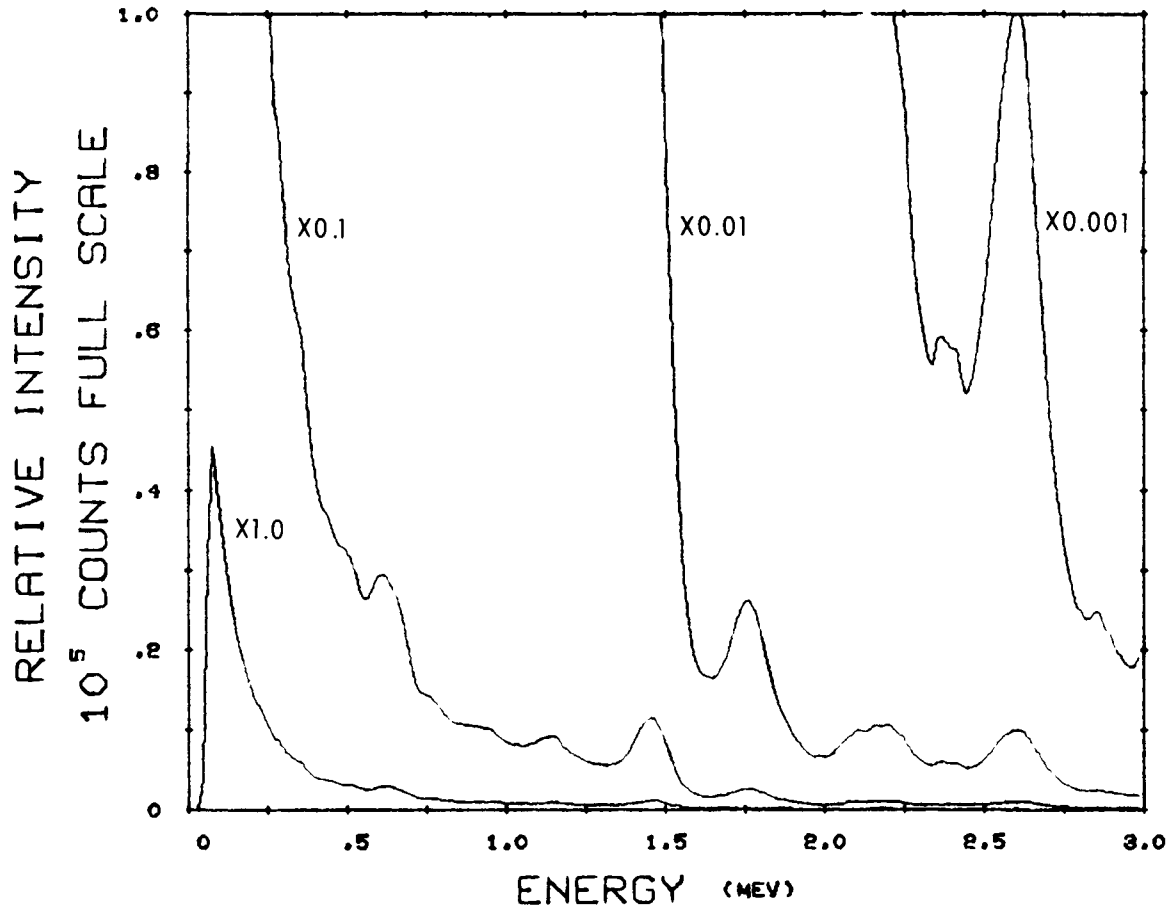
LOCATION: LINE 17 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 716
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 492931
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



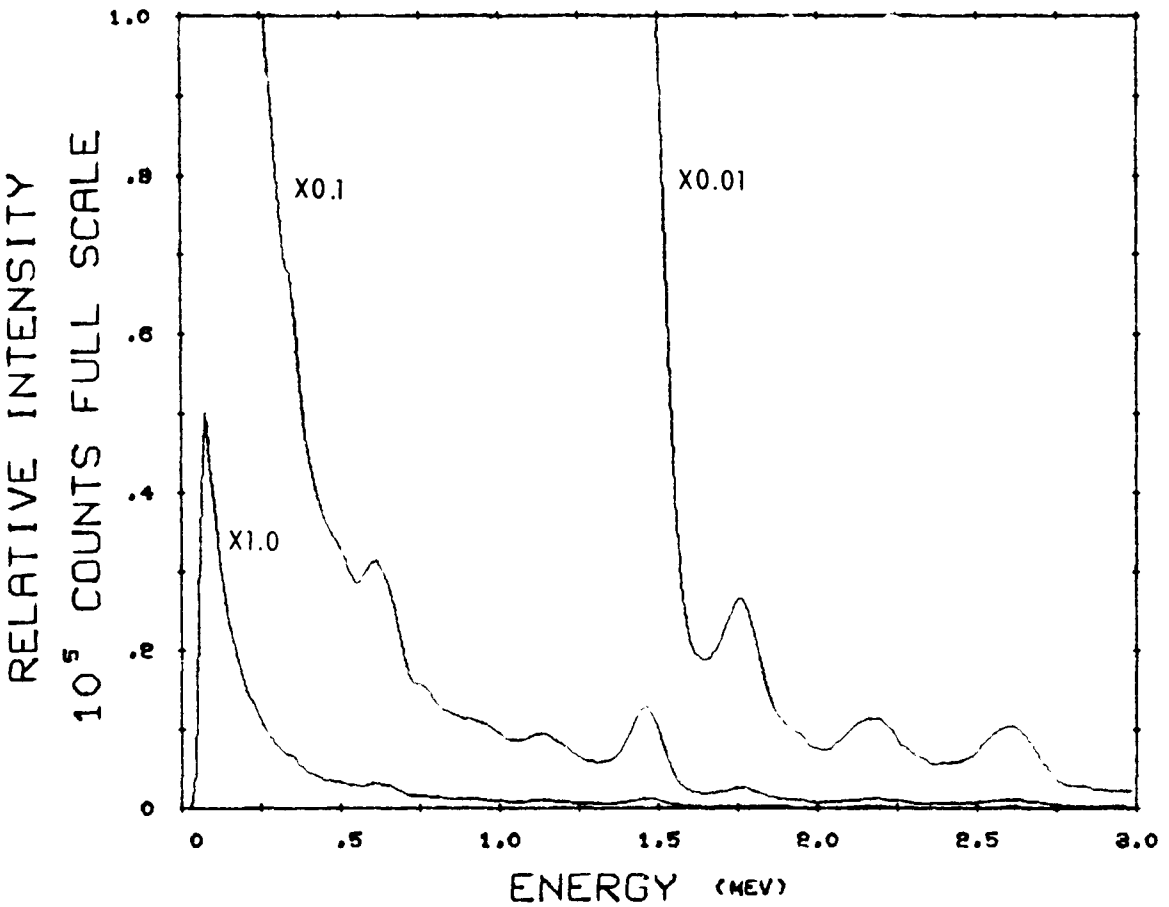
LOCATION: LINE 19 (ENTIRE FLGHT LINE)

SPECTRUM NO. 717
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 534470
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



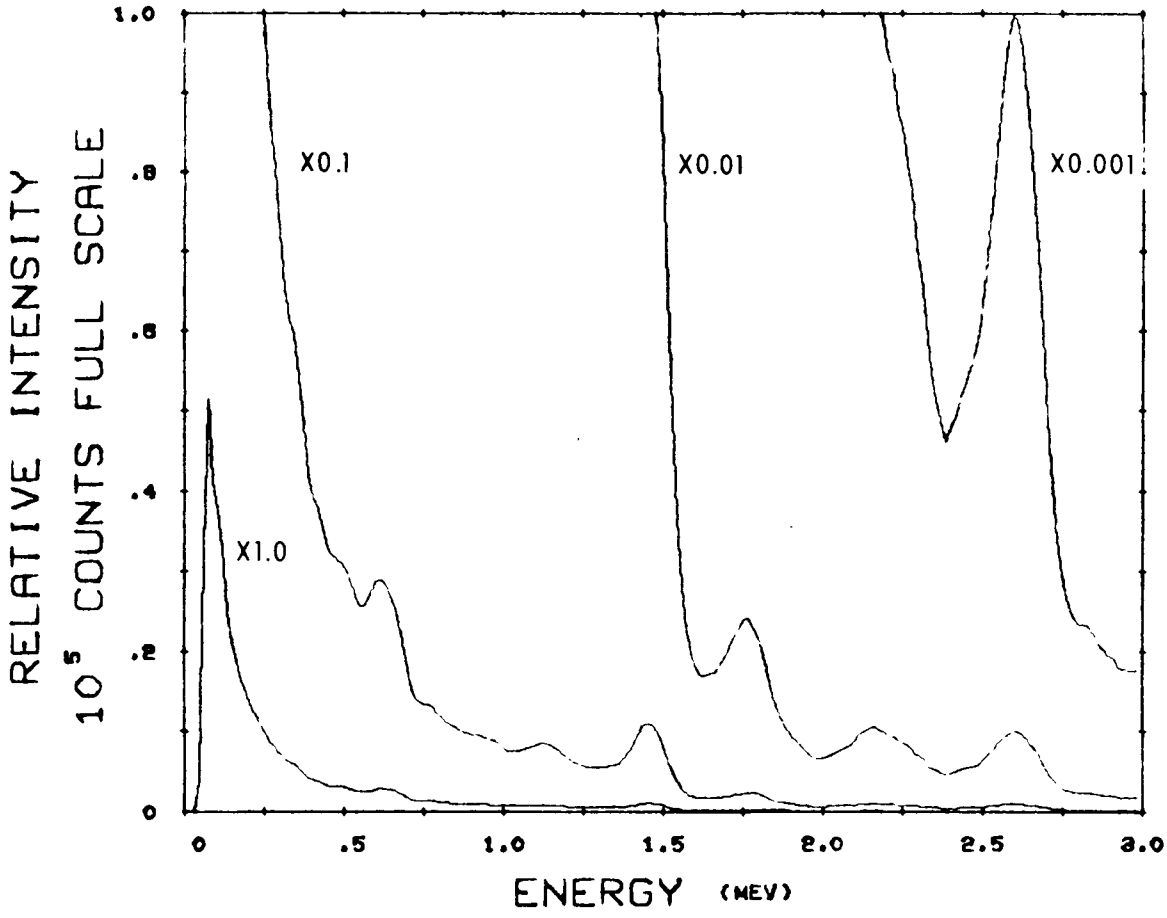
LOCATION: LINE 21 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 718
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 519978
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



LOCATION: LINE 23 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 719
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 555050
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)



LOCATION: LINE 25 (ENTIRE FLIGHT LINE)

SPECTRUM NO. 720
DATE 07-15-68
LIVE TIME 4.00
INTEGRATED CT. 515339
TYPE ACFT TERRAIN BKG.-GND. DEPO.
ALTITUDE 300
AIRCRAFT (ARMS)