Aerial Radiological Measuring Surveys
of the Dresden Nuclear Power Station
July 1970

EG&G, Inc., Las Vegas, Nevada

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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.

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ABSTRACT

The Aerial Radiological Measuring System (ARMS) was used to perform an aerial radiological survey of the Dresden Nuclear Power Station and surrounding area during July 1970. The survey included terrestrial background gamma radiation and a plume track of the stack release gases.

A high-sensitivity detection system collected gamma-ray spectral and gross-count data. The data were then computer processed into an isoexposure contour map, 3 feet above the ground, of a 200 square mile area and a plume track map. Results indicated the presence of isotopes normally found in the background radiation throughout the United States. The plume track revealed fission product-related noble gases consistent with normal plant operations.

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CHAPTER 1 INTRODUCTION

1.1 ARMS PROGRAM

The Aerial Radiological Measuring System (ARMS)¹ operated by EG&G, Inc., Las Vegas, Nevada for the U. S. Atomic Energy Commission, was used to perform an aerial radiological survey of an extensive area surrounding the Dresden Nuclear Power Station during July 1970.

This survey was made as part of a continuing nationwide ARMS program started in 1958 to determine radiation levels surrounding facilities maintaining or utilizing radioactive materials. The present survey represents the second such performed in the Dresden Nuclear Power Station area since the station began operation in 1959. The previous ARMS survey was performed during September of 1968.²

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

1.2 DRESDEN NUCLEAR POWER STATION

The reactor is a boiling water type. The Dresden Reactor, Unit 1, has a thermal power output of 700 megawatts and an electrical power output of 200 megawatts. The principal nuclear contractor is the General Electric Company. It is operated by the Commonwealth Edison Company, and its startup date was in 1959. The reactor was in a normal operational mode at the time of the survey.

1.3 ARMS EQUIPMENT AND PROCEDURES

The ARMS aircraft and its on-board radiation detection equipment were used to measure the radiation from the Dresden facility and the surrounding area. The ARMS equipment and procedures have been discussed in detail¹ and, hence, 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 the ground level (AGL) at a ground speed of about 140 knots (235 ft/sec). A typical flight pattern consists of a grid of parallel paths 5 to 25 miles in length with a spacing of 1/4 to 2 miles. The ground position of the aircraft as well as its altitude AGL are measured and recorded every other second via a radar-navigation-computer system. The position and altitude measurements are accurate to ± 350 and ± 5 ft, respectively, although greater position accuracy can be inferred.

The aerial radiation measurements are of two distinct types and both are made simultaneously: gross gamma count (intensity) measurements and gamma spectral (identity) measurements. The detector system, common to both, consists of an integrated package of fourteen 4- by 4-in. NaI(Tl) scintillation crystals, each mounted on its own photo-multiplier assembly. The detector system output is directed both to the gross gamma count computing system and to the multichannel spectrum analyzer.

The gross gamma count system consists of an amplifier-discriminator-computer package which counts and records the total number of gamma-rays of energy greater than 50 keV that are detected during a precisely determined 1-second time interval. The gross gamma count rate (number of detected gamma-rays per second) is measured every other second and is simultaneously and automatically recorded along with the aircraft position and altitude. Gross gamma count rates, typical of background, are several thousand per second.

As a backup and complement to the digital readout of the gross gamma count data, a record is made on a continuous strip chart plot of both gross gamma count rate and altitude as a function of distance.

Whereas the gross gamma count data specify the intensity of radiation as a function of position, the gamma spectral data identify the sources of radiation. A pulse height analyzer (PHA) automatically sorts detected gamma-rays according to energy, thereby generating a number-per-unit-energy versus energy spectrum. While nuclear gamma-rays occur only at well known discrete energies, characteristic of the emitting species, air scatter phenomena tend to smear the detected distribution. Nonetheless, the discrete characteristic peaks that permit isotopic identification are readily observable. A typical spectrum with identified species is shown in Fig. 1.1. In wide area surveys, the typical acquisition time for a gamma-ray spectrum is several minutes, thereby characterizing the average radiological properties of a tract several miles in length. However, if an area of

SPECTRUM NO. 31
 DATE 07-11-70
 LIVE TIME 4.00
 INTEGRATED CT. 1061456
 TYPE ACFT TERRAIN BKG.-GND. DEPO.
 ALTITUDE 300
 AIRCRAFT (ARMS)

Figure 1.1. Typical ARMS γ -ray spectrum showing naturally occurring radionuclides.

interest is indicated by an increase of the gross gamma count data, spectral data acquisition times of only a few seconds are used to isolate the area spatially. If further investigation is warranted, a similarly equipped ground mobile unit with greater areal and energy resolution is available as part of the ARMS program.

The equipment and procedures discussed, while sophisticated, offer great flexibility even during in-flight operation. Equipment may be tested and calibrated, detector sensitivities may be easily modified to accommodate large dynamic ranges of gamma radiation intensity, local areas of interest may be repeatedly scanned from different directions to get a detailed areal radiological profile, and the techniques can be applied equally well to the detection and identification of both diffusely dispersed or highly localized quantities of radioactive materials. Lastly, there exist no terrestrial or aquatic survey techniques capable of monitoring such large areas in such short times.

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, and they must undergo reduction and analysis to characterize the radiological properties of the surveyed area.

Calibration measurements, which give the altitude dependence of the gross gamma count rate over a field of uniformly dispersed radioactivity, are utilized to convert the raw gross gamma count rate data (cps) plus the recorded altitude information to the biologically more significant exposure rate ($\mu\text{R/hr}$) at 3 feet above-ground, which is referred to here as "ground exposure rate." When 14 gamma-ray detectors are used at an altitude of 300 feet, 460 cps corresponds to 1 $\mu\text{R/hr}$.

This exposure rate conversion factor was obtained by repeated flights, from 200 to 1000 feet above terrain containing known distributions of natural isotopes. Average gross counts from repeated surveys indicate a precision of 2%, or better, (assuming similar meteorological conditions). These 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.

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

REFERENCES

1. "Aerial Radiological Measuring Systems (ARMS) - Systems and Procedures Employed Through FY71," AEC Report No. ARMS-71.6, in preparation.
2. "Aerial Radiological Measuring Survey (ARMS) Dresden September 1968," AEC Report No. ARMS-68.6.8, in preparation.

CHAPTER 2 PLANNED SURVEY AREA

2.1 SURVEY AREA

The planned survey area for the Dresden Reactor consisted of 10 flight lines approximately 20 nautical miles long and spaced 1 nautical mile apart. The flight lines were oriented in a north-south direction. The gamma-ray spectral, gross-count, aircraft position, and meteorological information were collected along the flight lines.

2.2 SURVEY PREPLANNING

Preplanning for the surveys consisted of locating the reactor site on appropriate topographic maps used for visual navigation, and making a real-time analysis of local meteorological conditions.

Prior to all survey missions flown over each site by the ARMS aircraft, a test line was flown over a strip of terrain in the area whose radiation signature was determined by previous flights. This procedure ensures that the survey equipment operates as it did on previous flights.

CHAPTER 3 DRESDEN REACTOR AND SITE CHARACTERISTICS

3.1 SITE AREA CHARACTERISTICS

The Dresden Nuclear Power Station is located in northeast Illinois, approximately 10 miles east of the community of Morris. Currently operating at the site is Dresden I, a boiling water reactor with a capacity of 200 MW(e), owned and operated by the Commonwealth Edison Company. In addition, construction has begun at the same site for Dresden II and III, each to have an 800 MW(e) capability. Table 3-1 presents a breakdown of the population of the region in terms of radial distance and direction from the reactor site. The terrain within the survey area is comprised mainly of flat farmland areas, covered with crops, interrupted occasionally by the strip mines and their associated gravel pits. Major water bodies lying within the survey boundaries are the Illinois River, which divides into the Des Plaines and Kankakee Rivers near the power station. These rivers run through the center of the survey area. Numerous smaller streams are also in evidence.

Table 3-1. Population distribution within the Dresden Nuclear Power Station area. (Preliminary Data 1970 Census)¹

Town	Direction From Power Station	Radial Distance From Station (miles)		
		0-5	5-10	10-15
		Population		
Braidwood	SSE		2, 323	
Central City	S		1, 377	
Coal City	S		3, 040	
Crest Hill	NE			7, 460
E. Brooklyn	S			72
Fairmont	NE			2, 000
Forest Park	NE			15, 472
Gardner	S			1, 212
Ingalls Park	ENE			5, 000
Joliet	NE			80, 378
Lockport	NE			9, 985
Mazon	SW			727
Morris	W		8, 194	
New Lenox	NE			2, 855
Plainfield	NNE			2, 928
Platville	NNW		125	
Ridgewood	NE			5, 500
Rockdale	NE			2, 085
Wilmington	SE		4, 335	
Totals			19, 394	135, 674
Area Population Total: 155, 068				

REFERENCE

1. 1970 Census of Population, Advance Report, PC (VI)-15,
U. S. Department of Commerce, Bureau of Census, January 1971.

CHAPTER 4 RADIOLOGICAL SURVEY

4.1 SURVEY MISSIONS

The aerial survey to collect radiological data of the Dresden Reactor area was conducted on 11 and 12 July 1970. This survey required a total flying time of 5.6 hours. A plume track mission was flown on 17 July 1970. The base of operations for this survey was Rockford, Illinois.

Gross count and spectral data were simultaneously collected at an altitude of 300 feet. Spectral collections were accumulated over a 4 minute live-time during which the aircraft traveled approximately 12 miles; consequently, 2 spectra per line were collected.

4.2 GROSS-COUNT DATA

The typical nonterrestrial background encountered during a survey consists of cosmic ray, aircraft and airborne radioactivity contributors. A terrestrial radiation level from natural radiation of 10 $\mu\text{R/hr}$ (at 3 ft) produces 5500 cps in the detector array at 300 feet. An additional 500 cps is contributed by aircraft background and cosmic radiation. The contribution from airborne radioactivity (primarily from radon daughters) is variable and can be as high as 1500 cps. The gamma-ray gross-count data and aircraft position information collected on the flight lines are processed by the computer to make an overlay on U.S.G.S. topographical maps. After accounting for the nonterrestrial background contributors¹, the resultant net count data are computer processed to give an exposure rate in microroentgens per hour ($\mu\text{R/hr}$) at the 3 foot level above terrain. The various exposure rates are processed into an isoexposure contour map, which is superimposed upon a map of the area.

An isoexposure map for the Dresden Nuclear Power Station is enclosed. A cosmic radiation contribution of 2 to 4 $\mu\text{R/hr}$ is included in the data shown on the map.

4.3 SPECTRAL DATA

Prior to takeoff on the survey mission, the system was calibrated with a Y-88 source. Yttrium-88 has two prominent gammas:

0.898 and 1.836 MeV. The calibration source is used to set the gain of each crystal of the 14-crystal array. Each gamma-ray detector is a 4 x 4 inch sodium iodide, thallium-activated, crystal. Spectral data are recorded from 0.0 to 3.0 MeV.

Spectra typical of the spectral data collected along the flight lines are included in Appendix A. The table preceding the spectral plots lists the energies and isotopes identified from the data. Only the more prominent photopeaks have been included in the tabulation A-1. Only isotopes consistent with normal background radiation were observed in the spectral data.

4.4 PLUME TRACK

On the day of the plume track, 17 July 1970, the reactor was operating with a thermal power level of 675 megawatts and an electrical output of 200 megawatts*. The stack release rate was 30,000 to 40,000 $\mu\text{Ci}/\text{second}$.

The wind was blowing from 220 degrees at 10 to 20 knots. The plume was tracked approximately 17 miles from the reactor site. The plume boundaries are superimposed on a topographical map of the area in Figure 4.1. After the periphery of the plume had been outlined, the aircraft flew in the centerline of the plume, at an altitude of 1000 to 1200 feet, and collected gamma ray spectral data from the crystal array and air filters (Figure 4.2, Table 4.1). The air filters were analyzed on board the aircraft after leaving the vicinity of the plume (Figure 4.3, Table 4.2).

REFERENCE

1. "Aerial Radiological Measuring Systems (ARMS) - Systems and Procedures Employed Through FY71," AEC Report No. ARMS-71.6, in preparation.

* Information provided by R. Pavlick, Assistant Plant Supervisor.

BASE FROM USGS TOPOGRAPHIC MAP
SCALE 1 250,000

SCALE
0 5 10 MILES

DRESDEN PLUME TRACK 17 JULY 1970

Figure 4.1

SPECTRUM NO. 80
 DATE 07-17-70
 LIVE TIME 10.00
 INTEGRATED CT. 3608318
 TYPE CLOUD TRACK
 ALTITUDE 1200
 AIRCRAFT (ARMS)

Figure 4.2 Spectral data from the crystal array while on center line of plume.

Table 4.1 Radionuclides consistent with spectral photopeaks shown in Figure 4.2

Obs. Energy (MeV)	Radionuclides Consistent with Spectral Photopeaks		
	Fission Products	Activation Products	Background
0.25	Xe-135		
0.35-0.45	Xe-138 + Cs-138 + Kr-87		Pb-214
0.50-0.52	Xe-138 + Annihilation		
0.60-0.75	Xe-135 + Sr-91		Bi-214
0.85-0.93	Rb-88 + Kr-87 + Sr-91		
1.01	Cs-138		
1.12			Bi-214
1.43-1.46	Cs-138 + Sr-91		K-40
1.78	Xe-138		Bi-214
1.86	Rb-88		
2.01	Xe-138		
2.21	Cs-138		Bi-214
2.40	Kr-88		
2.55-2.70	Kr-87 + Cs-138 + Rb-88

SPECTRUM NO. 4
 DATE 07-17-70
 LIVE TIME 40.00
 INTEGRATED CT. 254191
 TYPE FILTER SAMPLE-IPC 1478
 ALTITUDE 1000
 AIRCRAFT (ARMS)

Figure 4.3 Spectral plot of plume track air filter analysis.

Table 4.2 Radionuclides consistent with spectral photopeaks shown in Figure 4.3

Obs. Energy (MeV)	Radionuclides Consistent with Spectral Photopeaks		
	Fission Products	Activation Products	Background
0.35			Pb-214
0.46	Cs-138		
0.61-0.65	Sr-91		Bi-214
0.75	Sr-91		Bi-214
0.90-0.93	Rb-88 + Sr-91		
1.01	Cs-138		
1.12			Bi-214
1.41-1.43	Cs-138 + Sr-91		K-40
1.76			Bi-214
1.86	Rb-88		Bi-214
2.21	Cs-138		Bi-214
2.63-2.68	Rb-88 + Cs-138		Tl-208

CHAPTER 5 SUMMARY

5.1 REACTOR AREA

The 200 square mile aerial survey of the Dresden Nuclear Power Station and surrounding area revealed that both the concentration and relative abundance of isotopes are consistent with normal background radiation throughout the United States. No apparent anomalies were detected that could be attributed to Dresden Reactor operations.

5.2 PLUME TRACK

The plume track data revealed the presence of only fission product-related noble gases, and their daughters, consistent with normal reactor operations (Tables 4.1 & 4.2).

5.3 CONCLUSION

The exposure rates mapped during the aerial radiation survey were predominantly in the 6 to 10 $\mu\text{R/hr}$ range, 3 feet above the ground.

A comparison of our previous survey data indicates no significant changes in the terrestrial radiation signature of the area.

APPENDIX A GAMMA -RAY SPECTRAL CHARTS

This section contains typical spectral data from the crystal array that were taken along the flight lines flown over the Dresden Reactor area.

The tabulation preceding the spectra shows the energies present in all the charts and the isotopic contributor associated with the photo-peaks observed.

Table A-1 Gamma-ray energies and isotopes consistent with spectral data collected along the flight lines

Obs. Energy (MeV)	Radionuclides Consistent with Spectral Photopeaks		
	Fission Products	Activation Products	Background
0.35			Pb-214
0.61			Bi-214
0.94			Bi-214
1.12			Bi-214
1.46			K-40
1.76			Bi-214
2.20			Bi-214
2.62			Tl-208

SPECTRUM NO. 26
 DATE 07-11-70
 LIVE TIME 3.61
 INTEGRATED CT. 946229
 TYPE ACFT TERRAIN BKG.-GND. DEPO.
 ALTITUDE 300
 AIRCRAFT (ARMS)

Figure A-1

SPECTRUM NO. 28
 DATE 07-11-70
 LIVE TIME 4.00
 INTEGRATED CT. 1093250
 TYPE ACFT TERRAIN BKG.-GND. DEPO.
 ALTITUDE 300
 AIRCRAFT (ARMS)

Figure A-2

**EXPOSURE RATE CONTOURS
DRESDEN NUCLEAR POWER PLANT
ILLINOIS, JULY 1970**

**GAMMA RADIATION
CONTOUR INTERVALS SHOWN
ARE IN μR/hr AT THE 3-FOOT LEVEL
(INCLUDES TERRESTRIAL AND COSMIC
RAY CONTRIBUTIONS)**

GAMMA RADIATION PULSE HEIGHT DISTRIBUTION

**THIS SURVEY WAS MADE FOR THE USAEC
WITH THE AERIAL RADIOLOGICAL
MEASURING SYSTEM (ARMS).***

**THE MEASUREMENTS WERE MADE USING
AN ARRAY OF 14 4X4 NaI SCINTILLATION
DETECTORS, MOUNTED IN AN AIRCRAFT,
FLOWN IN A CAREFULLY CONTROLLED
PATTERN AT A 300-FOOT ALTITUDE.**

SURVEY REPORT: ARMS 70.6.3 (DRESDEN)

***(SEE REPORT: ARMS 71.6, ARMS SYSTEMS
AND PROCEDURES THROUGH FY71.)**