U.S. ATOMIC ENERGY COMMISSION

1/18/73

REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 4.1

MEASURING AND REPORTING OF RADIOACTIVITY IN THE ENVIRONS OF NUCLEAR POWER PLANTS

A. INTRODUCTION

General Design Criterion 64, "Monitoring Radioactivity Releases," of Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," requires that licensees provide for monitoring the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents.

Subparagraph (a)(2) of §50.36a of 10 CFR Part 50 requires that technical specifications for each license include a requirement that the licensee submit a report to the Commission within 60 days after January 1 and July 1 of each year which, in addition to specifying the quantity of each of the principal radionuclides released to unrestricted areas in liquid and airborne effluents during the last six months of operation,[1] provides sufficient information to estimate annual radiation doses to the public resulting from effluent releases.

Paragraph (e) of § 20.106 of 10 CFR Part 20 states that the Commission may limit the quantities of radioactive materials released in air or water during a specified period of time to assure that the daily intake of radioactive materials from air, water, or food by a suitable sample of an exposed population group, averaged over a time period not exceeding one year, would not exceed specified quantities. Section 20.201 of 10 CFR Part 20 further requires that a licensee conduct surveys of levels of radiation or concentrations of radioactive material as necessary to show compliance with AEC regulations.

This guide describes an acceptable basis for designing a program to measure and report levels of radiation and radioactivity in the plant environs. The provisions and principles in International Commission on Radiological Protection (ICRP) Publication 7[2] pertaining to the releases of radioactivity during normal plant operation should be used as additional guidance in developing a program of this nature.

B. DISCUSSION

Present requirements to keep levels of radioactive material in effluents as low as practicable should assure that radiation doses to the public resulting from effluent releases will continue to remain minimal. The type of program described in this guide is considered adequate to provide information needed to determine whether exposures in the environment are within prescribed or expected limits and to assure that long-term buildup of specific radionuclides in the environment will not become hazardous.

A preoperational program should be conducted in the environs of each proposed nuclear power plant site to: (1) identify probable critical[3] pathways to be monitored after the plant is in operation; (2) measure background levels and their variations along the anticipated critical pathways in the area surrounding the plant; (3) train personnel; and (4) evaluate procedures, equipment, and techniques.

Years of experience at various Commission facilities have demonstrated that specific radionuclides behave in known ways under given environmental conditions. Therefore, comprehensive and detailed environmental studies may not be needed at sites with well known

[1] An acceptable program is presented in Safety Guide 21 (to be reissued as a Regulatory Guide), "Measuring and Reporting of Effluents from Nuclear Power Plants."

[2] ICRP Publication 7, *Principles of Environmental Monitoring Related to the Handling of Radioactive Materials*, September 13, 1965 (hereinafter ICRP Publication 7).

[3] For the purpose of this guide, the term "critical" has the same meaning as in ICRP Publication 7, Supra note 2.

bioenvironmental transport processes. Once adequate studies have been done to assure that the transport processes are understood, analyses of "indicator organisms" may adequately define radionuclide levels in the environment. The "indicator organism" concept of environmental sampling involves the practice of examining food chains for selected organisms or materials which provide a sensitive and reliable measure of the quantities of each radionuclide cycling through each food chain. For example, in the case where the plant-cow-milk-man food chain is determined to be a critical pathway, it may not be necessary to extensively sample and measure grazing plants and fodder to keep track of iodine-131 cycling in the food chain, since sampling and measuring the milk produced by dairy cows in surrounding areas may be adequate.

After the plant is in operation, a program for measuring radiation levels and radioactivity in the plant environs must be maintained on a continuing basis to assist in verifying projected or anticipated radioactivity concentrations and related public exposures. An environmental monitoring program should be flexible, and, as results are obtained, the program should be reviewed to identify any necessary changes. The program should then be appropriately modified. The initial program should be designed in accordance with the following criteria:

1. It should be based on the analysis of critical pathways for the types and quantities of radionuclides released from the plant into the surrounding environment;

2. It should consider the possibility of buildup of long half-lived radionuclides in the environment and identify physical and biological sites of accumulation that may contribute to human exposures;

3. It should be designed to facilitate use of reported levels of radiation and radioactivity in estimating annual radiation doses to the public resulting from effluents;

4. It should consider the potential damage to important plants and animals;[4]

5. It should be designed to establish correlations between levels of radiation and radioactivity in the environment and radioactive releases from plant operation. (A variety of techniques, including measurements at control locations, preoperational surveys, correlations with effluent data, and comparisons of operating versus shutdown levels of radioactivity in the environs may all be useful for this purpose.) Information of this nature will be of considerable help in modifying the initial environmental measurements program.

Information obtained from this program will be used, in conjunction with data on radioactive effluents, to evaluate measures taken by the licensee to assure that plant releases to the environment and radiation doses to the public are maintained within the numerical dose limits determined by the Commission to be as low as practicable. Also, licensees' data will be compiled and compared, and a comprehensive summary of radioactivity in the environs of nuclear power plants will be prepared by the Commission.

The Commission's Regulatory staff has evaluated the types of information needed to provide supporting evidence for assessing the performance of the plant with respect to keeping population exposures as low as practicable and to verify predictions of concentrations of specific radionuclides in the environment based on effluent measurements at the plant. Based on this evaluation and on a review and assessment of existing licensees' monitoring and reporting programs, the staff has developed the regulatory position set forth below.

C. REGULATORY POSITION

The program for measuring and reporting of radioactivity in the environs of nuclear power plants must provide suitable information from which levels of radiation and radioactivity in the environs of each plant can be estimated. This information also may provide supporting evidence in evaluating the performance of systems and equipment installed to control releases of radioactive material to the environment.

The basic principles set forth in this guide constitute an acceptable basis for use in establishing an environmental monitoring program. These same principles will also be used as bases in developing the licensee's corresponding technical specifications.

1. Preoperational Program

Potential critical pathways should be identified prior to plant operation. The provisions in ICRP Publication 7 related to operational releases of radioactivity to the environment should be used as a guide in determining critical radionuclides and pathways. Other pathways not directly related to humans should also be identified (see regulatory position 2.a. below). Wherever possible, suitable indicator organisms or media should be identified in each pathway.

2. Operational Program

a. Sample Media

Where practical, a suitable indicator organism or medium in each critical pathway should be sampled

[4] A species, whether animal or plant is "important" (1) if it is commercially or recreationally valuable, (2) if it is rare or endangered, or (3) if it affects the well-being of some important species within criteria (1) and (2) above or (4) if it is critical to the structure and function of the ecological system. A "rare or endangered" species is any species officially designated as such by the U.S. Fish and Wildlife Service.

and analyzed for the critical radionuclide(s) released from the plant. An abundant, readily available form with known habits should be selected.

Careful attention should be given to avoid inducing serious stress on an important species of organism by a sampling program. Heavy sampling pressure added to natural predation and other environmental stresses could result in temporary obliteration of desirable populations. In such cases, other indigenous but abundant species such as rodents, rabbits or scrap fish, may be substituted as indicator organisms that will provide an estimate of the radionuclides available to man through natural food chains. In some instances, properly selected and sampled vegetation may also provide a good measure of the radionuclides in a critical pathway.

Where use of a single indicator medium is impractical, samples of several media from each pathway should be collected and analyzed. The Commission recognizes that some pathways do not have more than one environmental medium, e.g., external radiation exposures from clouds of gamma-ray-emitting radionuclides involve only one pathway – the atmosphere. The actual number of media to be sampled in each pathway will be determined on a case-by-case basis for each site. In some cases field measurements may be preferable to collecting samples for laboratory analysis.

The program should include sampling of environmental media to estimate average radionuclide concentrations in important biota (see B.4. above). Radiation exposures (external) and internal doses from short half-lived nuclides may be estimated by calculations (using effluent measurements and appropriate dispersion and concentration factors) rather than by routine collection of samples of environmental media. In some cases field measurements at certain locations to establish concentrations of specific radionuclides may be necessary, initially, to confirm predictions.

b. Sampling Frequency

When a critical radionuclide has a short half-life (minutes to days), it may be necessary to evaluate radiation exposure by making measurements in the field (e.g., by use of thermoluminescent dosimeters or portable multichannel gamma spectrometers).

When a critical radionuclide with an intermediate half-life (weeks to months) is released continuously or frequently, sampling and analysis of environmental media in the critical pathway should generally be carried out at intervals no greater than two or three half-lives of the nuclide. For long half-life radionuclides (years), measurements should be made at least once per year. Where seasonal effects may be important, sampling should be on a quarterly or at least semiannual basis.

In some cases, sampling on a continuous basis may be necessary (e.g., air sampling and continuous measurement of cumulative external radiation exposure). Composites of some selected sample types, such as air filters, may be appropriate for measurement of long-lived radionuclides.

When critical pathways become firmly identified and correlations are developed between concentrations of radionuclides in environmental media and plant releases, or levels have been found too low to detect, it is probable that sampling frequencies of certain media may be appropriately increased or decreased. Such changes should only be made on individual power plants after considerable operational experience has accrued.

c. Program Scope

During the initial three years of commercial power operation (or other period corresponding to maximum fuel burnup in the initial core cycle), the measurement program should be relatively comprehensive in an attempt to verify any projected correlations between radioactive effluents and levels in environmental media. The extent of measurement of environmental media should be flexible and should depend on the type, quantity, and concentration of radionuclides from the plant as well as the results obtained from previous measurements.

If, after this period, the licensee is able to demonstrate from levels in environmental media or calculations (using measured effluents and appropriate dispersion and bioaccumulation factors) that the doses from a particular pathway are sufficiently small, the number of media sampled in the pathway and the frequency of sampling may be reduced. An adequate program with emphasis on indicator organisms and selected media should still be continued in order to confirm that the levels of radioactivity in environmental media remain small.

d. Analyses

Samples should be analyzed for the critical radionuclide(s) released from the plant. Gross beta and gamma analyses of samples such as air and fresh water may be useful to indicate that the concentration of a critical radionuclide is not greater than the detection capability for that nuclide.

3. Detection Capabilities

The detection capabilities associated with measuring and analyzing radioactivity levels should be established primarily on the basis of potential human dose. The least detectable dose will vary from facility to facility depending on the critical pathways identified and the state-of-the-art of sampling and analysis in these pathways. Because of the need for a preoperational monitoring program, detection capabilities for a

particular program should be determined during an early stage of licensing. The staff recognizes that direct measurements of environmental media cannot always detect levels corresponding to Commission design objectives. Nevertheless, every reasonable effort should be made to achieve detection capabilities which will detect radiation levels or radioactivity concentrations in critical pathways that could result in radiation doses corresponding to a few percent of the Federal Radiation Council's radiation protection guides (e.g., a few percent of 170 mrem/year[5] for whole body dose to a suitable sample of the exposed population).

4. Reporting of Results

Data should be reported to the Commission in the report submitted within 60 days after January 1 and July 1 of each year.[6] In the event that an unexpected increase in radioactivity or radiation levels is measured in a particular critical pathway, the Commission should be notified promptly. Appropriate levels and reporting intervals will be determined on an individual plant basis and included in the technical specifications for each license.

The Commission utilizes the data from these reports to provide assurance that man and his environment are not being subjected to unacceptable radiation exposures. Consequently, all assumptions, parameters and methods used to measure and report radioactivity concentrations and radiation levels should be specified in the licensee's initial report and updated in subsequent reports as appropriate. The licensee should demonstrate that all assumptions, parameters and methods used are adequate and complete to allow (where data permit) a comparison with predicted concentrations and doses based on effluents from each nuclear power plant under license. (See Safety Guide 21).

To permit comparison of significant environmental monitoring data with predicted concentrations and doses (based on requirements of 10 CFR Part 50), the report should include the following items for each environmental medium:

a. Sample Type

1. Biological (to the extent practicable, list species, life stage, age, weight or size, biological condition, tissue or material sampled, sample weight, etc.).

2. Non-Biological (identify type - soil, air, etc.; list actual area, depth and weight or volume sampled as appropriate, whether grab or continuous sample, number of samples, etc.).

b. Sample Location (also supply map showing locations)

c. Collection Period (continuous samples) or Date of Collection

d. Critical Pathway

e. Radionuclide

f. Concentration (μCi/ml or g, specifying wet or standard dry weight) and/or Deposition (μCi/m^2 or other appropriate units of measure). (List conversion factors relating sample activity and volume - depth X cross section - to total area deposition; average and maximum values for each medium, etc.)

g. Background Value

h. Analytical Method[7]

i. Comparison of Observed Concentrations, Depositions and Estimated Doses with Predicted Values (based on effluent measurements)

j. Remarks (be sure to explain any unusual measurements or deviations).

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[5] Federal Radiation Council Report No. 1, *Background Material for the Development of Radiation Protection Standards*, May 13, 1960.

[6] Subparagraph (a)(2) of §50.36a of 10 CFR Part 50 requires the submission of a report within 60 days after January 1 and July 1 of each year specifying the quantity of each of the principal radionuclides released to unrestricted areas in liquid and in gaseous effluents. The data taken in support of the licensee's environmental monitoring program should also be submitted semiannually. If additional time is needed, the report should so indicate and the data should be carried over into the next semiannual report. It would greatly facilitate comparisons and correlations of data if the environmental and effluent monitoring data were combined into single reports.

[7] Estimates of the error associated with the measurement of each environmental medium should be reported.