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REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 1.21

MEASURING, EVALUATING, AND REPORTING RADIOACTIVITY IN SOLID WASTES AND RELEASES OF RADIOACTIVE MATERIALS IN LIQUID AND GASEOUS EFFLUENTS FROM LIGHT-WATER-COOLED NUCLEAR POWER PLANTS

A. INTRODUCTION

General Design Criterion 60, "Control of releases of radioactive materials to the environment," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Licensing of Production and Utilization Facilities," requires that the nuclear power plant design include means to control the release of radioactive materials in gaseous and liquid effluents and to handle radioactive solid wastes produced during normal reactor operation, including anticipated operational occurrences.

General Design Criterion 64, "Monitoring radioactivity releases," requires that nuclear power plant designs provide means for monitoring effluent discharge paths for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents.

Section 20.106, "Concentrations in effluents to unrestricted areas," of 10 CFR Part 20, "Standards for Protection Against Radiation," provides that a licensee shall not release to an unrestricted area, radioactive materials in concentrations which exceed limits specified in 10 CFR Part 20 or as otherwise authorized in a license issued by the Commission. Section 20.201, "Surveys," of 10 CFR Part 20 further requires that a licensee conduct surveys of concentrations of radioactive materials as necessary to demonstrate compliance with AEC regulations.

Paragraph (a)(2) of §50.36a, "Technical specifications on effluents from nuclear power reactors," of 10 CFR Part 50 provides that technical specifications for each license will 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 specifies the quantity of each of the principal radionuclides released to unrestricted areas in liquid and in gaseous effluents during the previous 6 months of operation, and such other information as may be required by the Commission to estimate maximum potential annual radiation doses to the public resulting from effluent releases.

Paragraph (c) of §20.1, "Purpose," of 10 CFR Part 20 states that every reasonable effort should be made by AEC licensees to maintain radiation exposure, and releases of radioactive materials in effluents to unrestricted areas, as far below the limits specified in Part 20 as practicable, i.e., as low as is practicably achievable, taking into account the state of technology, and the economics of improvements in relation to benefits to the public health and safety and in relation to the utilization of atomic energy in the public interest.

This guide describes programs acceptable to the Regulatory staff for measuring, reporting, and evaluating releases of radioactive materials in liquid and gaseous effluents and guidelines for classifying and reporting the categories and curie content of solid wastes. Other programs for the reporting of operating information, including abnormal occurrences, are presented in Regulatory Guide 1.16, "Reporting of Operating Information." In some cases, specific programs should be supplemented because of individual plant design features or other factors. The need for supplemental or modified programs will be determined on a case-by-case basis.

The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

B. DISCUSSION

Information on the identity and quantity of radionuclides in liquid and gaseous effluents and solid wastes from light-water-cooled nuclear power plants, together with meteorological data representative of principal release points, are needed:

1. For evaluation by the licensee and the Regulatory staff of the environmental impact of radioactive materials in effluents and solid wastes, including estimates of the potential annual radiation doses to the public;
2. To ascertain whether AEC regulatory requirements and limiting conditions of operation have been met and whether concentrations of radioactive materials in liquid and gaseous effluents have been kept as low as practicable;
3. For evaluation by the licensee and the Regulatory staff of the adequacy and performance of containment, waste treatment methods, and effluent controls.

It is essential to have a degree of uniformity in the methods used for measuring, evaluating, recording, and reporting data on radioactive material in effluents and solid wastes. The methods described in this guide provide a uniform basis for comparison of data from different sources and permit the preparation of consistent summaries of data for use by the Regulatory staff as bases for the assessment of a licensee's effluent controls and the potential environmental impact of radioactive materials in effluents and solid wastes.

This guide outlines general guidelines for monitoring and reporting programs. Detailed specifications for sampling and analysis of effluents are not included since they need to be tailored to the requirements of each specific plant. Standardized methods for monitoring, sampling, and analysis should be used to the extent practicable. The following is an example of a standard which is appropriate for these purposes.

The American National Standards Institute (ANSI) has developed a standard[1] which includes general principles and guidance for sampling airborne radioactive materials.

To assure uniformity of interpretation, the following definitions of terms used in this guide are provided:

Abnormal releases—unplanned or uncontrolled release of radioactive material from the site boundary.

Batch releases—discontinuous release of gaseous or liquid effluent which takes place over a finite period of time, usually hours or days.

Continuous release—release of gaseous or liquid effluent which is essentially uninterrupted for extended periods during normal operation of the facility.

Determined (or a determination)—a quantitative evaluation of the release or presence of radioactive material under a specific set of conditions. A determination may be made by direct or indirect measurements. In some cases it may not be practical to make direct measurements of specific radionuclides in effluent or waste; e.g., the concentrations may be too low for measurement in a reasonable or practical volume of sample, certain nuclides may be masked by other radionuclides in the sample, or as in the case of solid or concentrated wastes, it may be difficult to obtain a representative sample. Under these circumstances, it may be more appropriate to calculate releases using previously established ratios with those nuclides which are readily measurable. Such a procedure would constitute a determination.

Elevated release point—the point of release of gaseous waste for which credit was given as such in the determination of the technical specification limit for that release point.

Ground-level release point—the point of release for gaseous waste which is treated in the technical specifications as having zero height.

This guide, which is a revised and rewritten version of Regulatory Guide 1.21 (issued as Safety Guide 21 December 29, 1971), describes acceptable programs for measuring, evaluating, and reporting release of radioactive material in liquid and gaseous effluents and solid wastes from nuclear power plants. It also provides guidelines for calculating potential annual radiation doses to individuals and populations using appropriate models and parameters and pertinent recorded effluent and meteorological data. Significant changes from the previous version are identified below:

1. There has been a major change in the format of this guide. The more detailed recommendations concerning radionuclide measurements are presented in Appendix A and the reporting recommendations are indicated in Appendix B.
2. In many cases the criteria for sensitivity of effluent measurements have been modified to reflect as low as practicable dose considerations in the offsite environs; i.e., the sensitivity of effluent measurements should be sufficient to detect concentrations which, when dispersed in the offsite environs, would result in a dose to individuals of a small fraction of natural background radiation.
3. Some changes have been made in the frequency of analysis for certain radionuclides in several categories of effluents.

[1] ANSI N.13.1-1969, "Guide to Sampling Airborne Radioactive Materials in Nuclear Facilities." Copies may be obtained from the American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018.

4. Provisions for monitoring and reporting of solid wastes and for reporting of meteorological measurements, categories not considered in the earlier guide, have been included.

5. Provisions for applying the measured meteorological and effluent data to acceptable dose models [2] [3] in calculating potential doses to individuals and populations, and for reporting of these dose estimates have been included.

C. REGULATORY POSITION

1. Meteorology

A knowledge of meteorological conditions in the vicinity of the nuclear plant is essential to make valid estimates of maximum potential annual radiation doses resulting from radioactive materials released in gaseous effluents. Meteorological measurements should be made in accordance with the guidance set forth in Regulatory Guide 1.23 (Safety Guide 23), "Onsite Meteorological Programs." A summary report of the meteorological measurements taken during each calendar quarter in the 6-month period should be submitted with the semiannual Effluent and Waste Disposal Report as joint frequency distributions of wind direction and wind speed by atmospheric stability class in the format presented in Table 4A of Appendix B to this guide.

Hourly meteorological data for batch releases should be recorded for the periods of actual release, and quarterly summaries should be reported separately from the summaries of all observations taken during each quarter. The batch release data and the quarterly summaries of all observations should each be given in the format presented in Table 4A of Appendix B.

For abnormal releases, hourly meteorological data should be recorded for the periods of actual release and should be included in the quarterly summaries of batch releases.

2. Location of Monitoring

All major and potentially significant paths for release of radioactive material during normal reactor operation, including anticipated operational occurrences, should be monitored. Measurements of effluent volume, rates of release, and specific radionuclides should be made, insofar as practicable, at the point(s) which would provide data that are the most representative of effluent releases to the plant environs. For those effluent discharge points which have input from two or more contributing sources within the plant, monitoring of the major contributing sources should also be considered from the standpoint of more effective process and effluent control. In many cases, monitoring of each of the major contributing sources may be a preferable or more sensitive alternative to monitoring the total effluent release when dilution with other less concentrated effluent streams makes the resultant effluent concentrations too low for accurate measurements.

3. Type of Monitoring

The type of monitoring selected, including the frequency, duration, and methods of measurement, depends to a large degree on the objectives of the monitoring program. Effluent monitoring is required to (a) demonstrate compliance with technical specification and/or 10 CFR Part 20 effluent limits, (b) allow evaluation of the performance of containment, waste treatment, and effluent controls, and (c) permit evaluation of environmental impact and estimation of the potential annual radiation doses to the public. Because radiation dose is dependent on the radionuclide(s) to which the individual is exposed, monitoring programs should provide accurate information on the identity and quantity of specific radionuclides in effluents and wastes.

4. Gross Radioactivity Measurements

Gross radioactivity measurements alone are generally not acceptable for showing compliance with effluent release limits. However, gross radioactivity measurements are often the only practicable means of continuously monitoring effluents and therefore are acceptable under certain specified conditions. Gross radioactivity measurements are acceptable for the purpose of quantifying radioactivity (a) when gross total radioactivity concentrations are a small fraction of the maximum permissible concentrations (MPCs) for "unidentified mixtures" as specified in the notes of Appendix B to 10 CFR Part 20 or (b) when gross radioactivity measurements are shown to be truly indicative of the actual quantity and/or concentration of radionuclides released.

5. Measurements of Specific Radionuclides

Measurements should be made to identify specific radionuclides in batch releases prior to their release to the environment. In those cases where analysis of specific radionuclides such as strontium-89 and strontium-90 cannot be made prior to release, representative samples should be collected from each

[2] Draft Regulatory Guide 1.AA, "Calculation of Annual Average Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Implementing Appendix I," Draft Regulatory Guide 1.DD, "Methods for Estimating Atmospheric Dispersion of Gaseous Effluents from Routine Releases," and Draft Regulatory Guide 1.EE, "Analytical Models for Estimating Radioisotope Concentration in Different Water Bodies", in Attachment to Concluding Statement, Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low as Practicable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactors, Docket RM-50-2, USAEC, February 20, 1974.

[3] "Final Environmental Statement–Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low as Practicable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," WASH-1258, Vol. 1, Directorate of Regulatory Standards, USAEC, July 1973.

batch of effluents for the purpose of analysis at some later time. The use of composite samples is acceptable, and analyses of such samples should be performed at scheduled frequencies.

Measurements should be made to quantify specific radionuclides in continuous releases by analyses of grab samples collected at scheduled frequencies. The frequency of radionuclide analyses should be based on the degree of variance of the concentrations and mixture compositions from an established norm. Continuous monitoring data as well as grab sample data should be the bases for identifying this variance.

Frequent comparisons should be made between gross radioactivity measurements of continuous monitors and analyses of specific radionuclides. These comparisons should be the bases for calibrating continuous monitors to establish relationships between monitor readings and concentrations or release rates of radionuclides in continuous effluent releases.

6. Representative Samples

A sample should be representative of the bulk stream or volume of effluent from which it is taken. Provisions should be made to assure that representative samples are obtained from well-mixed streams or volumes of effluent by the selection of proper sampling equipment, the proper location of sampling points, and the development and use of proper sampling procedures.

Prior to sampling, large volumes of liquid waste should be mixed in as short a time interval as practicable to assure that any sediments or particulate solids are distributed uniformly in the waste mixture. Sample points should be located where there is a minimum of disturbance of flow due to fittings and other physical characteristics of the equipment and components. Sample nozzles should be inserted into the flow or liquid volume to ensure sampling the bulk volume of pipes and tanks. Sample lines should be flushed for a sufficient period of time prior to sample extraction in order to remove sediment deposits and air and gas pockets. Periodically, a series of samples should be taken during the interval of discharge to determine whether any differences exist as a function of time and to assure that individual samples are indeed representative of the effluent mixture.

The general principles for obtaining valid samples of airborne radioactive material, the methods and materials for gas and particle sampling, and the guides for sampling from ducts and stacks contained in ANSI N13.1-1969 [1] are generally acceptable and provide adequate bases for the design and conduct of monitoring programs for airborne effluents.

7. Composite Samples

To be representative of the average quantities and concentrations of radioactive materials released in liquid and in particulate form in gaseous effluents, samples for compositing should be collected in proportion to the rate of flow of the effluent stream or in proportion to the volume of each batch of effluent releases. Prior to analysis, the composite should be thoroughly mixed so that the sample is representative of the average effluent release.

Periods of collection for composites should be as short as practicable to preclude the loss of radioactive material by deposition on walls of the sample container or volatilization of potentially volatile material. Periodic checks should be performed to identify any such changes in composite samples.

8. Time between Collection and Analysis

Measurements should be made as soon as practicable after collection to minimize loss of short-lived radionuclides by decay. Measurement of longer-lived radionuclides sometimes can be simplified by allowing sufficient time before their analysis for the decay of short-lived radionuclides.

Procedures should be instituted for handling, packaging, and storing samples to assure that loss of radioactive materials or other factors causing sample deterioration do not invalidate the analysis.

9. Corrections for Decay

Decay corrections should be made as though the effluent were released uniformly throughout the sampling period unless it is shown that most of the effluent was released during a particularly short interval. The exact time or time intervals of sample collection should be recorded. To estimate radioactive decay in composite or pooled samples, weighting should be applied to the delay time of each portion and to the quantity of each portion in relation to the total quantity of the sample.

10. Sensitivity

The sensitivity limits given for radioactivity analyses in Appendix A of this guide are based on the potential significance in the environment of the quantities of radioactive materials released. For some radionuclides, lower detection limits than those given herein may be readily achievable and when measurements below the stated sensitivity limits are attained, the results should be recorded and reported.

For certain mixtures of gamma-emitting nuclides, it may not be possible to measure certain radionuclides at the stated sensitivity limits when other radionuclides are present in the sample in much greater concentrations. Also, it may not be possible to measure certain radionuclides whose gamma ray yields are low (e.g., Kr-85, Cr-51, etc.) at the stated sensitivity limits. Under these circumstances, and in the case of radionuclides which have no gamma rays and weak beta radiation (e.g., Fe-55, Ni-63, etc.), it may be more appropriate to calculate releases of such radionuclides using measured ratios of these radionuclides to those radionuclides which are routinely identified and measured. Measurements should be made periodically to establish and assure the continued validity of the ratios used. Any reported data determined by this method should be clearly identified.

11. Accuracy of Measurements

a. Errors in Measurements

An estimate should be made of the error associated with measurement of radioactive materials in effluents and solid wastes. Counting statistics can provide an estimate of the minimum error involved in radioactivity analyses. Counting statistics (e.g., one-sigma counting error) should be included in the records of measurements, since they provide a readily calculable estimate of the statistical uncertainty due to counting.

The total or maximum error associated with the effluent measurement will include the cumulative errors resulting from the total operation of sampling and measurement. Because it may be very difficult to assign error terms for each parameter affecting the final measurement, detailed statistical evaluations of error are not suggested. The objective should be to obtain an overall estimate of the error associated with measurements of radioactive materials released in liquid and gaseous effluents and solid waste.

b. Quality Controls

Control checks and tests should be applied to the analytical process by the use of blind duplicate analyses of selected effluent samples and by cross-check analysis of selected samples with an independent laboratory. Quality controls should also be applied to the entire sample-collection procedure to assure that representative samples are obtained and that samples are not changed or affected prior to their analysis because of handling or because of their storage environment.

c. Calibrations

Individual written procedures should be prepared and utilized for specific methods of calibrating radiological monitoring systems and measuring equipment. Calibration practices for ancillary equipment and systems are described in Regulatory Guide 1.23, "Onsite Meteorological Programs," and elsewhere,[1] and where appropriate, they should be utilized and included as a part of the written procedures. Calibration procedures may be compilations of published standard practices or manufacturers' instructions that accompany purchased equipment or they may be specially written in-house to include special methods or items of equipment not covered elsewhere. Calibration procedures should identify the specific equipment or group of instruments to which the procedures apply.

Calibrations of measuring equipment should be performed using reference standards certified by the National Bureau of Standards or standards that have been calibrated against standards certified by the National Bureau of Standards. Calibration standards should have the necessary accuracy, stability, and range required for their intended use.

Calibrations should generally be performed at regular intervals. Frequency of calibration should be based on the reproducibility and time stability of the system. An instrument system that gives a relatively wide range of readings when calibrated against a given standard should be recalibrated at more frequent intervals than one which gives measurements within a more narrow range. In many cases, it would be more appropriate to calibrate measuring equipment before and after use in addition to or instead of calibration at arbitrarily scheduled intervals. Calibration of measuring equipment before and after use permits detection of any erroneous readings or malfunctions that may have occurred during use. Any monitoring system or individual measuring equipment should be recalibrated or replaced whenever it is suspected of being out of adjustment, excessively worn, or otherwise damaged and not operating properly. Functional checks, i.e., routine checks performed to demonstrate that a given instrument is in working condition and functioning properly, may be performed using radioactive sources that are not standards.

Continuous radioactivity monitoring systems should be calibrated against appropriate standards and the relationship established between concentration and monitor readings over the full range of the readout device. Adequacy of the system should be judged on the basis of reproducibility, time stability, and sensitivity. Periodic inservice calibrations should also be performed to relate monitor "readings" to the concentrations and/or release rates of radioactive material in the monitored release path. These calibrations should be based on the results of analyses for specific radionuclides in grab samples from the release path.

12. Expression of Results of Measurements

a. Units

The information and data on effluent releases included in reports to the Commission should be expressed in the units given in Appendix B of this guide and reported in the form given in paragraphs b and c below.

b. Significant Figures

To avoid ambiguity, significant figures should be used in recording the results of effluent measurements. When several numbers are multiplied or divided together, the result should be rounded off to as few significant figures as are present in the factor with the fewest significant figures. When numbers are added or subtracted, the number with the fewest decimal places, not necessarily the fewest significant figures, puts the limit on the number of places that may justifiably be carried in the sum or difference.

For the purpose of reporting in the format of Appendix B of this guide, numerical values should be rounded off to three figures.

c. **Numerical Values**

Results of measurements, including percentages, should be reported in external floating point form, using the letter "E" to denote the exponent to the base 10. For example: 2% should appear as 2.00E+00; 0.00032 should appear as 3.20E-04; 157.6 should appear as 1.58E+02; 2.67 should appear as 2.67E+00.

The term "not detected" should not be used. If radioactivity in the sample(s) is less than the maximum sensitivity of measurement, the value should be reported as less than the maximum sensitivity. For example, if the maximum sensitivity is 3×10^{-9} μCi/ml, the values should be reported as <3.00E-09.

13. Radiological Impact on Man

Estimations of doses to individuals and populations are necessary for the assessment of the radiological impact on man from the operation of nuclear power plants. Dose calculations should be made using the measured effluent and meteorological data and acceptable dose models such as those provided in draft regulatory guides for implementation of numerical guides.[2] To the extent that they are not inconsistent with the models provided in these draft guides, other dose models such as those given in WASH-1258[3] or those used for calculating the estimated dose values given in the licensee's Environmental Report are also acceptable as bases for making dose calculations.

14. Other Provisions

The provisions and principles presented in Appendices A and B of this guide are acceptable to the Regulatory staff as bases for measuring and reporting of radioactive materials in liquid and gaseous effluents and solid wastes from nuclear power plants, as well as for estimating doses to individuals and populations in the offsite environs.

APPENDIX A

MEASURING RADIOACTIVE MATERIALS IN LIQUID AND GASEOUS EFFLUENTS AND SOLID WASTE

This appendix describes a monitoring program that is acceptable to the Regulatory staff. The frequencies of sampling and analysis and the types of measurements described are considered to be the minimum acceptable. In some cases, this program should be supplemented with additional measurements because of individual plant design features or other factors. The need for supplemental or modified programs is determined on a case-by-case basis.

A. GASEOUS EFFLUENTS

Continuous monitoring should be conducted along principal gaseous effluent discharge paths. The radionuclide composition and quantities and concentrations of radioactive material in gaseous effluents should be determined and recorded. For the periods of release, the records should also show, on an hourly basis, the existing meteorological conditions of wind direction, wind speed, and atmospheric stability which are representative of conditions at the principal points of release (see Regulatory Guide 1.23, "Onsite Meteorological Programs").

The single Poisson (one sigma) error for discrete measurements should be less than 50 percent for release rates at the design objective level, less than 30 percent at twice the design objective release rate, and less than 20 percent at eight times the design objective release rate.

1. Fission and Activation Gases

During the release of gaseous wastes from the primary system waste gas holdup system, the effluent monitor should be operating and set to alarm and to initiate the automatic closure of the waste gas discharge valve before the limits specified in the technical specifications are exceeded.

a. Continuous Releases

For reactors which release gases continuously, a sample of the gaseous effluent should be analyzed within one month after the date of initial criticality of the reactor and at least weekly thereafter to determine the identity and quantity of the principal radionuclides being released. A similar analysis of samples should be performed following each refueling, process change, or other occurrence that could alter the mixture of radionuclides. For those processes or other conditions that change significantly (e.g., when the average daily gross radioactivity release rate equals or exceeds that given in the technical specifications or when the steady-state gross radioactivity release rate increases by 50% over the previous steady-state release rate at the same power level), an analysis should be done following each change until it is shown that a pattern exists that can be used to predict the isotopic composition of the effluent. In addition, radionuclide analyses should be performed when continuous monitoring shows an unexplained variance from an established norm which may be indicative of a change in the concentration and composition. The norm should be established as a range of readings that may be expected due to normal operating conditions including anticipated operational occurrences.

The calibration of continuous gross radioactivity monitoring systems should be performed by normalizing against the results of specific radionuclide analyses using established ratios of the respective radionuclides to total activity. When calibrated in this fashion, the gross radioactivity measurements obtained from continuous monitors may be used to determine the total quantity of radioactivity released.

b. Batch Releases

For reactors which release gases intermittently, an analysis should be made of a representative sample of each planned release prior to discharge to determine the identity and quantity of the principal radionuclides released. Continuous monitoring should also be conducted at appropriate points to obtain information on the quantity and pattern of abnormal releases.

c. Sensitivity

For those discharge points which have input from two or more contributing sources within the plant, separate monitoring of the major sources should be performed as a more sensitive alternative to monitoring the composite effluent stream when bulk dilution results in concentrations too low for accurate measurements.

The sensitivity of gross radioactivity measurements of fission and activation gases, as a minimum, should be sufficient to permit measurement of a small fraction of the activity which would result in (1) an annual air dose of 10 millirads due to gamma radiation at any location near ground level at or beyond the site boundary and (2) an annual air dose of 20 millirads due to beta radiation at any location near ground level at or beyond the site boundary.

The sensitivity of analysis for each of the principal radioactive gases in representative samples of gaseous effluents should be such that concentrations of 10^{-4} μCi/cc are measurable.

2. Iodines

a. Monitoring

A representative sample from the principal discharge paths should be drawn continuously through an iodine sampling device. The sample collected in the device should be analyzed at least weekly for iodine-131. An analysis should also be made monthly or more often for iodine-133 and iodine-135.

The results of these analyses should be used as the basis for recording, evaluating, and reporting the quantities of radioiodines released during the sampling period. In estimating releases for periods when analyses were not performed, the average of the two adjacent data points spanning this period should be used. These estimates should be included in the effluent records and reports; however, they should be clearly identified as estimates, and the method used to obtain these data should be described.

b. Sensitivity

The sensitivity of the analysis of radioiodines should be sufficient to permit measurement of a small fraction of the activity which would result in annual exposures of 15 millirems to the thyroid of individuals in unrestricted areas.

3. Particulates

a. Monitoring

A representative sample from the discharge paths should be drawn continuously through a particulate filter. Measurements should be made on these filters to determine the quantities of radionuclides with half-lives greater than 8 days that are released in particulate form to the environment.

(1) The particulate filters should be changed and analyzed at least weekly for the principal gamma-emitting nuclides (at least for the radionuclides barium-lanthanum-140 and iodine-131). When quantities of released radioactive materials are at low levels, precluding accurate measurement of principal radionuclides, gross beta radioactivity measurements should be made as a basis for estimating the quantity of radioactive material released in the week.

(2) A quarterly analysis for strontium-89 and strontium-90 should be made on a composite of all filters from each sampling location collected during the quarter.

(3) A monthly analysis for gross alpha radioactivity should be made on a composite of all filters collected during the month from each sampling location.

The results of these analyses should be used as the basis for recording and reporting the quantities of radioactive material in particulate form released during the sampling period. In estimating releases for periods when analyses were not performed, the average of the two adjacent data points spanning this period should be used. These estimates should be included in the effluent records and reports; however, they should be clearly identified as estimates, and the method used to obtain these data should be described.

b. Sensitivity

The sensitivity of analysis for radioactive material in particulate form should be sufficient to permit measurement of a small fraction of the activity which would result in annual exposures of 15 millirems to any organ of an individual in an unrestricted area.

4. Tritium

a. Monitoring

The release of tritium to the atmosphere should be determined for each batch released on an intermittent basis, and at least monthly for continuous releases.

b. Sensitivity

The sensitivity of analysis of tritium released to the atmosphere should be such that a concentration of 10^{-6} μCi/cc (of air) is measurable.

B. LIQUID EFFLUENTS

During the release of radioactive wastes, the effluent control monitor should be set to alarm and to initiate automatic closure of the waste discharge valve prior to exceeding the limits specified in the technical specifications.

Continuous monitoring should be provided for liquid effluent releases. The radionuclide mixture of liquid effluents should be determined and recorded. For the period(s) of release, the records should also show the volume of water used to dilute the liquid effluent and the resultant concentrations at the point(s) of release to unrestricted areas. If the effluent passes into a flowing stream, data on the average flow of the stream during periods of effluent release should be collected and reported in the Supplemental Information section of the report. (See Effluent and Waste Disposal Semiannual Report, Appendix B.)

The single Poisson (one sigma) error for discrete measurements should be less than 50 percent for release rates at the design objective level, less than 30 percent at twice the design objective release rate, and less than 20 percent at eight times the design objective release rate.

1. Batch Releases

a. A representative sample of each batch of liquid effluent released should be analyzed for the principal gamma-emitting radionuclides.

When operational or other limitations preclude specific gamma radionuclide analysis of each batch, gross radioactivity measurements should be made to estimate the quantity and concentrations of radioactive material released in the batch, and a weekly sample composited from proportional aliquots from each batch released during the week should be analyzed for the principal gamma-emitting radionuclides.

b. A monthly sample composited from proportional aliquots from each batch released during the month should be analyzed for tritium and gross alpha radioactivity.

c. A representative sample from at least one representative batch per month should be analyzed for dissolved and entrained fission and activation gases.

d. A quarterly sample composited from proportional aliquots from each batch released during the three-month period should be analyzed for strontium-89 and strontium-90.

The results of these analyses should be used as the basis for recording and reporting the quantities of radioactive material released in liquid effluents during the sampling period. In estimating releases for a period when analyses were not performed, the average of the two adjacent data points spanning this period should be used. Such estimates should be included in the effluent records and reports; however, they should be clearly identified as estimates, and the method used to obtain these data should be described.

2. Continuous Releases

For continuous releases (e.g., secondary plant leakage), in addition to continuous monitoring, a representative sample of the liquid effluent should be analyzed at least weekly to determine the identity and quantity of the principal gamma-emitting radionuclides being released. Analysis for other specific radionuclides should be conducted in accordance with 1 above.

3. Sensitivity

The sensitivities of analyses of radioactive materials in liquid effluents should be sufficient to permit the measurement of concentrations of 10^{-7} μCi/ml by gross radioactivity measurements, 5×10^{-7} μCi/ml of each gamma-emitting radionuclide, 10^{-5} μCi/ml of each of the dissolved and entrained gaseous radionuclides, 10^{-7} μCi/ml of gross alpha radioactivity, 10^{-5} μCi/ml of tritium, and 5×10^{-8} μCi/ml of strontium-89 and strontium-90.

C. SOLID WASTE

The total curie quantity and radionuclide composition of the solid waste shipped offsite should be determined. Provisions should be made to monitor and to limit the curie quantity of material and the maximum radiation level of each package of solid waste in order to reduce radiation exposure to personnel and to meet the regulatory requirements of 10 CFR Part 71, "Packaging of Radioactive Material for Transport and Transportation of Radioactive Material under Certain Conditions," and of the Department of Transportation. Monitoring of solid wastes in storage and preparatory to shipment should be performed to provide assurance that the radiation levels from waste in storage and in transport do not exceed regulatory limits.

APPENDIX B

EFFLUENT AND WASTE DISPOSAL REPORT

This appendix describes the data and information that should be included in effluent and waste disposal reports. The data and information should be reported in a format similar to that given in Tables 1 through 4 and the Supplemental Information sheet. Except as noted, effluent and solid waste data should be summarized on a quarterly basis, although in some cases more detailed data may be needed. The need for reporting of additional data to the Commission will be determined on a case-by-case basis.

The reporting method includes the use of uniform notation for numerical values and generally defined guidance for reporting certain supplemental information. Data from licensee's effluent and waste disposal reports are compiled, and summary reports of nuclear power plant effluents are prepared by the Commission. The supplemental information reduces errors in processing and compiling of report data.

In the report, a separate section should contain a discussion of the radiological impact of facility operation on man. Calculations and estimates of potential doses to individuals and population doses should be summarized for the report (6-month) period, although in some cases more detailed data may be needed. The need for these additional data to be reported to the Commission is determined on a case-by-case basis.

Meteorological data during continuous releases should be submitted in the format presented in Table 4A. (Also see Regulatory Guide 1.23.) Data on meteorological conditions during batch releases should be reported separately in the same format. For the purpose of this guide, abnormal releases should be treated as batch releases, and the meteorological data obtained during abnormal releases should be included in the batch release report.

A. SUPPLEMENTAL INFORMATION

1. Regulatory Limits

The technical specification limits for radioactive materials released in liquid and gaseous effluents should be included in each report. If changes are made in limiting conditions of operation during the report period, the appropriate limits and dates should be included.

2. Maximum Permissible Concentrations

The maximum permissible concentrations (MPC) used to calculate permissible release rates and concentrations for air and water should be included in each report (if appropriate), i.e., the MPC used in accordance with technical specifications and/or derived from the use of Notes to Appendix B, 10 CFR Part 20.

3. Average Energy

The release rate limits for fission and activation gases in gaseous effluents are usually based on the average energy ($\bar{E}$) of the radionuclide mixture in the effluent. The $\bar{E}$ value for the gamma and beta energies per disintegration that is used should be included in the report.

4. Measurements and Approximations of Total Radioactivity

A summary description should be provided of the method(s) used to determine or measure total radioactivity in effluent releases (total here means the overall gross curie quantity). For example, gross radioactivity measurements (gross beta and/or gross gamma) may be used to approximate total radioactivity in effluents, and/or analyses of specific radionuclides in selected or composited samples may be used to determine the radionuclide composition of the effluent. A summary description of the methods used for estimating overall errors associated with radioactivity measurements should also be provided.

5. Batch Releases

The report should provide information relating to batch releases of liquid and gaseous effluents which are discharged to the environment. This information should include the number of releases, total time period for batch releases, and the maximum, mean, and minimum time period of release.

6. Abnormal Releases

The number of abnormal releases of radioactive material to the environment should be reported. The total curies of radioactive materials released as a result of abnormal releases should be included.

This information should be reported separately for liquid and gaseous releases. The activity values should also be included, as appropriate, in Tables 1 and 2. Hourly meteorological data should be recorded for the periods of actual release and included in the quarterly summaries for batch releases in the format given in Table 4A.

B. GASEOUS EFFLUENTS

Summary information should be reported in the formats of Tables 1A through 1C. Table 1A values should include the sums of all sources of release, i.e., routine and abnormal releases, continuous and batch, elevated and ground level. The reported percent of technical specification limits should be based on the combined releases from multiple sources as given in the technical specifications. This also applies to the releases from multireactor sites.

For reactors that have technical specification limits for more than one principal point of release, separate radionuclide data should be reported for each of these release points. Data should be separated by release height, i.e., elevated or ground level, and these data should be further subdivided by release mode, i.e., continuous or batch mode. (See Tables 1B and 1C.)

Estimates of the total error associated with certain total values should be provided in each report. (See Table 1A.) These error values should be the best effort at an overall estimate of the errors associated with the totals in the report.

Report the following information as indicated by Tables 1A through 1C.

1. Gases

a. Quarterly sums of total curies of fission and activation gases released.

b. Average release rates (μCi/sec) of fission and activation gases for the quarterly periods covered by the report.

c. Percent of technical specification limit for releases of fission and activation gases. This should be calculated in accordance with technical specification limits.

d. Quarterly sums of total curies for each of the radionuclides determined to be released, based on analyses of fission and activation gases. The data should be categorized by (1) elevated releases, batch and continuous modes, and (2) ground-level releases, batch and continuous modes. (See Tables 1B and 1C.)

2. Iodines

a. Quarterly sums of total curies of iodine-131 released.

b. Average release rate (μCi/sec) of iodine-131.

c. Percent of technical specification limit for iodine-131.

d. Quarterly sums of total curies of each of the isotopes, iodine-131, iodine-133, and iodine-135 determined to be released. (See B.1.d above and Tables 1B and 1C.)

3. Particulates

a. Quarterly sums of total curies of radioactive material in particulate form with half-lives greater than 8 days determined to be released.

b. Average release rate (μCi/sec) of radioactive material in particulate form with half-lives greater than 8 days.

c. Percent of technical specification limit for radioactive material in particulate form with half-lives greater than 8 days.

d. Quarterly sums of total curies for each of the radionuclides in particulate form determined to be released based on analyses performed. (See B.1.d above and Tables 1B and 1C.)

e. Quarterly sums of total curies of gross alpha radioactivity determined to be released.

4. Tritium

a. Quarterly sums of total curies of tritium determined to be released in gaseous effluents.

b. Average release rate (μCi/sec) of tritium.

c. Percent of appropriate technical specification or MPC limits for tritium.

C. LIQUID EFFLUENTS

Summary information should be reported in the formats of Tables 2A and 2B. Table 2A values should include the quarterly sums of all releases of radioactive materials in liquid effluents, i.e., routine and abnormal occurrences, continuous and batch. The reported percent of technical specification limits should be based on the combined releases from multiple sources as given in the technical specifications. This also applies to the releases from multireactor sites.

Estimates of the total error associated with certain total values should be provided in each report. (See Table 2A.) These error values should be the best effort at an overall estimate of the errors associated with the totals in the report.

Report the following information, as indicated by Tables 2A and 2B.

1. Mixed Fission and Activation Products

a. Quarterly sums of total curies of radioactive material determined to be released in liquid effluents (not including tritium, dissolved and entrained gases, and alpha-emitting material). (See Table 2A.)

b. Average concentrations (μCi/ml) of mixed fission and activation products (C.1.a above) released to unrestricted areas, averaged over the quarterly periods covered by the report.

c. Percent of applicable limit of average concentrations released to unrestricted areas (C.1.b above). Include the limit used and the bases in the supplemental report information.

d. Quarterly sums of total curies for each of the radionuclides determined to be released in liquid effluents, based on analyses performed. Data should be separated by type of release mode, i.e., continuous or batch. (See Table 2B.)

2. **Tritium**

a. Quarterly sums of total curies of tritium determined to be released in liquid effluents.

b. Average concentrations (μCi/ml) of tritium released in liquid effluents to unrestricted areas, averaged over the quarterly periods covered by the report.

c. Percent of applicable limit of average concentrations released to unrestricted areas (C.2.b above), i.e., percent of 3 x 10^{-3} μCi/ml. Include the limit and the bases in the supplemental report information.

3. **Dissolved and Entrained Gases**

a. Quarterly sums of total curies of gaseous radioactive material determined to be released in liquid effluents.

b. Average concentrations (μCi/ml) of dissolved and entrained gaseous radioactive material released to unrestricted areas, averaged over the quarterly periods covered by the report.

c. Percent of technical specification limit of average concentrations released to unrestricted areas (C.3.b above). Include the limit used and the bases in the supplemental report information.

d. Quarterly sums of total curies for each of the radionuclides determined to be released as dissolved and entrained gases in liquid effluents.

4. **Alpha Radioactivity**

Quarterly sums of total curies of gross alpha-emitting material determined to be released in liquid effluents.

5. **Volumes**

a. Quarterly sums, in liters, of total measured volume, prior to dilution, of liquid effluent released.

b. Quarterly sums of total determined volume, in liters, of dilution water used during the period of the report.

6. **Stream Flow**

Where the effluent passes into a flowing stream, data on the average flow of the stream during periods of effluent release should be collected and reported in the Supplemental Information section of the report.

D. SOLID WASTE

The following information should be reported for shipments of solid waste and irradiated fuel transported from the site during the report period:

1. The semiannual total quantity in cubic meters and the semiannual total radioactivity in curies for the categories or types of waste. (See Table 3.)

   a. Spent resins, filter sludges, evaporator bottoms;
   b. Dry compressible waste, contaminated equipment, etc.;
   c. Irradiated components, control rods, etc.;
   d. Other (furnish description).

2. An estimate of the major nuclide composition in the categories of waste in D.1 above.

3. The disposition of solid waste shipments. (Identify the number of shipments, the mode of transport, and the destination.)

4. The disposition of irradiated fuel shipments. (Identify the number of shipments, the mode of transport, and the destination.)

Estimates of the total error associated with certain total values should be provided in each report. (See Table 3.) These error values should be the best effort of an overall estimate of the errors associated with the totals in the report.

E. RADIOLOGICAL IMPACT ON MAN

Potential doses to individuals and populations should be calculated using measured effluent and meteorological data. A semiannual summary report should be submitted containing the following information:

1. Total body and significant organ doses to individuals in unrestricted areas from receiving-water-related exposure pathways.
2. Total body and skin doses to individuals exposed at the point of maximum offsite ground-level concentrations of radioactive materials in gaseous effluents.
3. Organ doses to individuals in unrestricted areas from radioactive iodine and radioactive material in particulate form from all pathways of exposure.
4. Total body doses to individuals and populations in unrestricted areas from direct radiation from the facility.
5. Total body doses to the population and average doses to individuals in the population from all receiving-water-related pathways.
6. Total body doses to the population and average doses to individuals in the population from gaseous effluents to a distance of 50 miles from the site. If a significantly large population area is located just beyond 50 miles from the site, the dose to this population group should be considered.

F. METEOROLOGICAL DATA

The report should include the cumulative joint frequency distribution of wind speed, wind direction, and atmospheric stability for the quarterly periods. Similar data should be reported separately for the meteorological conditions during batch releases. (See Regulatory Guide 1.23 and Tables 4A and 4B in this appendix.)

EFFLUENT AND WASTE DISPOSAL SEMIANNUAL REPORT

Supplemental Information

Facility________________________________ **Licensee**________________________________

1. **Regulatory Limits**

   a. Fission and activation gases:
   b. Iodines:
   c. Particulates, half-lives >8 days:
   d. Liquid effluents:

2. **Maximum Permissible Concentrations**

   Provide the MPCs used in determining allowable release rates or concentrations.
   a. Fission and activation gases:
   b. Iodines:
   c. Particulates, half-lives >8 days:
   d. Liquid effluents:

3. **Average Energy**

   Provide the average energy $(\bar{E})$ of the radionuclide mixture in releases of fission and activation gases, if applicable.

4. **Measurements and Approximations of Total Radioactivity**

   Provide the methods used to measure or approximate the total radioactivity in effluents and the methods used to determine radionuclide composition.
   a. Fission and activation gases:
   b. Iodines:
   c. Particulates:
   d. Liquid effluents:

5. **Batch Releases**

   Provide the following information relating to batch releases of radioactive materials in liquid and gaseous effluents.

   a. **Liquid**

      1. Number of batch releases:
      2. Total time period for batch releases:
      3. Maximum time period for a batch release:
      4. Average time period for batch releases:
      5. Minimum time period for a batch release:
      6. Average stream flow during periods of release of effluent into a flowing stream:

   b. **Gaseous**

      1. Number of batch releases:
      2. Total time period for batch releases:
      3. Maximum time period for a batch release:
      4. Average time period for batch releases:
      5. Minimum time period for a batch release:

6. **Abnormal Releases**

   a. **Liquid**

      1. Number of releases:
      2. Total activity released:

   b. **Gaseous**

      1. Number of releases:
      2. Total activity released:

TABLE 1A

EFFLUENT AND WASTE DISPOSAL SEMIANNUAL REPORT (YEAR)

GASEOUS EFFLUENTS—SUMMATION OF ALL RELEASES

	Unit	Quarter	Quarter	Est. Total Error, %
A. Fission & activation gases				
1. Total release	Ci	. E	. E	. E
2. Average release rate for period	μCi/sec	. E	. E	
3. Percent of Technical specification limit	%	. E	. E	
B. Iodines				
1. Total iodine-131	Ci	. E	. E	. E
2. Average release rate for period	μCi/sec	. E	. E	
3. Percent of technical specification limit	%	. E	. E	
C. Particulates				
1. Particulates with half-lives >8 days	Ci	. E	. E	. E
2. Average release rate for period	μCi/sec	. E	. E	
3. Percent of technical specification limit	%	. E	. E	
4. Gross alpha radioactivity	Ci	. E	. E	
D. Tritium				
1. Total release	Ci	. E	. E	. E
2. Average release rate for period	μCi/sec	. E	. E	
3. Percent of technical specification limit	%	. E	. E	

TABLE 1B

EFFLUENT AND WASTE DISPOSAL SEMIANNUAL REPORT (YEAR)

GASEOUS EFFLUENTS—ELEVATED RELEASE

Nuclides Released	Unit	CONTINUOUS MODE Quarter	CONTINUOUS MODE Quarter	BATCH MODE Quarter	BATCH MODE Quarter
1. Fission gases					
krypton-85	Ci	. E	. E	. E	. E
krypton-85m	Ci	. E	. E	. E	. E
krypton-87	Ci	. E	. E	. E	. E
krypton-88	Ci	. E	. E	. E	. E
xenon-133	Ci	. E	. E	. E	. E
xenon-135	Ci	. E	. E	. E	. E
xenon-135m	Ci	. E	. E	. E	. E
xenon-138	Ci	. E	. E	. E	. E
Others (specify)	Ci	. E	. E	. E	. E
	Ci	. E	. E	. E	. E
	Ci	. E	. E	. E	. E
unidentified	Ci	. E	. E	. E	. E
Total for period	Ci	. E	. E	. E	. E
2. Iodines					
iodine-131	Ci	. E	. E	. E	. E
iodine-133	Ci	. E	. E	. E	. E
iodine-135	Ci	. E	. E	. E	. E
Total for period	Ci	. E	. E	. E	. E
3. Particulates					
strontium-89	Ci	. E	. E	. E	. E
strontium-90	Ci	. E	. E	. E	. E
cesium-134	Ci	. E	. E	. E	. E
cesium-137	Ci	. E	. E	. E	. E
barium-lanthanum-140	Ci	. E	. E	. E	. E
Others (specify)	Ci	. E	. E	. E	. E
	Ci	. E	. E	. E	. E
	Ci	. E	. E	. E	. E
unidentified	Ci	. E	. E	. E	. E

TABLE 1C

EFFLUENT AND WASTE DISPOSAL SEMIANNUAL REPORT (YEAR)

GASEOUS EFFLUENTS–GROUND-LEVEL RELEASES

		CONTINUOUS MODE		BATCH MODE	
Nuclides Released	Unit	Quarter	Quarter	Quarter	Quarter

1. Fission gases

krypton-85	Ci	. E	. E	. E	. E
krypton-85m	Ci	. E	. E	. E	. E
krypton-87	Ci	. E	. E	. E	. E
krypton-88	Ci	. E	. E	. E	. E
xenon-133	Ci	. E	. E	. E	. E
xenon-135	Ci	. E	. E	. E	. E
xenon-135m	Ci	. E	. E	. E	. E
xenon-138	Ci	. E	. E	. E	. E
Others (specify)	Ci	. E	. E	. E	. E
	Ci	. E	. E	. E	. E
	Ci	. E	. E	. E	. E
unidentified	Ci	. E	. E	. E	. E
Total for period	Ci	. E	. E	. E	. E

2. Iodines

iodine-131	Ci	. E	. E	. E	. E
iodine-133	Ci	. E	. E	. E	. E
iodine-135	Ci	. E	. E	. E	. E
Total for period	Ci	. E	. E	. E	. E

3. Particulates

strontium-89	Ci	. E	. E	. E	. E
strontium-90	Ci	. E	. E	. E	. E
cesium-134	Ci	. E	. E	. E	. E
cesium-137	Ci	. E	. E	. E	. E
barium-lanthanum-140	Ci	. E	. E	. E	. E
Others (specify)	Ci	. E	. E	. E	. E
	Ci	. E	. E	. E	. E
	Ci	. E	. E	. E	. E
unidentified	Ci	. E	. E	. E	. E

TABLE 2A

EFFLUENT AND WASTE DISPOSAL SEMIANNUAL REPORT (YEAR)

LIQUID EFFLUENTS–SUMMATION OF ALL RELEASES

	Unit	Quarter	Quarter	Est. Total Error, %
A. Fission and activation products				
1. Total release (not including tritium, gases, alpha)	Ci	. E	. E	. E
2. Average diluted concentration during period	μCi/ml	. E	. E	
3. Percent of applicable limit	%	. E	. E	
B. Tritium				
1. Total release	Ci	. E	. E	. E
2. Average diluted concentration during period	μCi/ml	. E	. E	
3. Percent of applicable limit	%	. E	. E	
C. Dissolved and entrained gases				
1. Total release	Ci	. E	. E	. E
2. Average diluted concentration during period	μCi/ml	. E	. E	
3. Percent of applicable limit	%	. E	. E	
D. Gross alpha radioactivity				
1. Total release	Ci	. E	. E	. E
E. Volume of waste released (prior to dilution)	liters	. E	. E	. E
F. Volume of dilution water used during period	liters	. E	. E	. E

TABLE 2B

EFFLUENT AND WASTE DISPOSAL SEMIANNUAL REPORT (YEAR)

LIQUID EFFLUENTS

		CONTINUOUS MODE		BATCH MODE	
Nuclides Released	Unit	Quarter	Quarter	Quarter	Quarter
strontium-89	Ci	. E	. E	. E	. E
strontium-90	Ci	. E	. E	. E	. E
cesium-134	Ci	. E	. E	. E	. E
cesium-137	Ci	. E	. E	. E	. E
iodine-131	Ci	. E	. E	. E	. E
cobalt-58	Ci	. E	. E	. E	. E
cobalt-60	Ci	. E	. E	. E	. E
iron-59	Ci	. E	. E	. E	. E
zinc-65	Ci	. E	. E	. E	. E
manganese-54	Ci	. E	. E	. E	. E
chromium-51	Ci	. E	. E	. E	. E
zirconium-niobium-95	Ci	. E	. E	. E	. E
molybdenum-99	Ci	. E	. E	. E	. E
technetium-99m	Ci	. E	. E	. E	. E
barium-lanthanum-140	Ci	. E	. E	. E	. E
cerium-141	Ci	. E	. E	. E	. E
Other (specify)	Ci	. E	. E	. E	. E
	Ci	. E	. E	. E	. E
	Ci	. E	. E	. E	. E
	Ci	. E	. E	. E	. E
	Ci	. E	. E	. E	. E
unidentified	Ci	. E	. E	. E	. E
Total for period (above)	Ci	. E	. E	. E	. E
xenon-133	Ci	. E	. E	. E	. E
xenon-135	Ci	. E	. E	. E	. E

TABLE 3

EFFLUENT AND WASTE DISPOSAL SEMIANNUAL REPORT (YEAR)

SOLID WASTE AND IRRADIATED FUEL SHIPMENTS

A. SOLID WASTE SHIPPED OFFSITE FOR BURIAL OR DISPOSAL (Not irradiated fuel)

1. Type of waste	Unit	6-month Period	Est. Total Error, %
a. Spent resins, filter sludges, evaporator bottoms, etc.	m^3 Ci	. E . E	. E
b. Dry compressible waste, contaminated equip, etc.	m^3 Ci	. E . E	. E
c. Irradiated components, control rods, etc.	m^3 Ci	. E . E	. E
d. Other (describe)	m^3 Ci	. E . E	. E

2. Estimate of major nuclide composition (by type of waste)

a. ______	%	. E
______	%	. E
______	%	. E
b. ______	%	. E
______	%	. E
______	%	. E
c. ______	%	. E
______	%	. E
______	%	. E
d. ______	%	. E
______	%	. E
______	%	. E

3. Solid Waste Disposition

Number of Shipments	Mode of Transportation	Destination

B. IRRADIATED FUEL SHIPMENTS (Disposition)

Number of Shipments	Mode of Transportation	Destination

TABLE 4A

HOURS AT EACH WIND SPEED AND DIRECTION [a]

PERIOD OF RECORD:

STABILITY CLASS:

ELEVATION:

Wind Direction	Wind Speed (mph) at 10m Level 1-3	4-7	8-12	13-18	19-24	≥ 24	TOTAL
N							
NNE							
NE							
ENE							
E							
ESE							
SE							
SSE							
S							
SSW							
SW							
WSW							
W							
WNW							
NW							
NNW							
VARIABLE							

Total
Periods of calm (hours):
Hours of missing data:

[a] In the table, record the total number of hours of each category of wind direction for each calendar quarter. Provide similar tables separately for each atmospheric stability class and elevation.

TABLE 4B

CLASSIFICATION OF ATMOSPHERIC STABILITY

Stability Classification	Pasquill Categories	$\sigma\theta$[a] (degrees)	Temperature change with height (°C/100m)
Extremely unstable	A	25.0	<-1.9
Moderately unstable	B	20.0	-1.9 to -1.7
Slightly unstable	C	15.0	-1.7 to -1.5
Neutral	D	10.0	-1.5 to -0.5
Slightly stable	E	5.0	-0.5 to 1.5
Moderately stable	F	2.5	1.5 to 4.0
Extremely stable	G	1.7	>4.0

[a] Standard deviation of horizontal wind direction fluctuation over a period of 15 minutes to 1 hour. The values shown are average for each stability classification.

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