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CALCULATION OF RELEASES OF RADIOACTIVE MATERIALS IN GASEOUS AND LIQUID EFFLUENTS FROM LIGHT-WATER-COOLED POWER REACTORS

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A. INTRODUCTION

Section 20.106 of the Commission's regulations in 10 CFR Part 20, "Standards for Protection Against Radiation," establishes limits on concentrations of radioactive material in effluents to unrestricted areas. Paragraph 20.1(c) of 10 CFR Part 20 states that licensees should, in addition to complying with the limits set forth in that part, make every reasonable effort to maintain radiation exposures, and releases of radioactive materials in effluents to unrestricted areas, as far below the limits specified in that part as is reasonably achievable.

Section 50.34a of 10 CFR Part 50, "Licensing of Production and Utilization Facilities," sets forth design objectives for equipment in nuclear power reactors to control releases of radioactive effluents. Section 50.36a of 10 CFR Part 50 further provides that, in order to keep power reactor effluent releases as low as is reasonably achievable, each license authorizing operation of such a facility will include technical specifications on establishing operating procedures for the control of effluents, the installation and maintenance of effluent control equipment, and the reporting of actual releases.

Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," to 10 CFR Part 50 provides numerical guidance for design objectives and technical specification requirements for limiting conditions for operation to meet the criterion "as low as is reasonably achievable" for radioactive material in light-water-cooled nuclear power reactor effluents.

To implement the design objectives of Appendix I, the NRC staff has developed a series of regulatory guides that provide methods acceptable to the staff for the calculation of effluent releases, dispersion of the effluent in the atmosphere and different water bodies, and associated radiation doses to man.

This regulatory guide references two NUREG reports that provide acceptable methods for calculating annual average expected releases of radioactive material in liquid and gaseous effluents from light-water-cooled nuclear power reactors. The procedures and models provided in the referenced NUREG reports will be subject to continuing review by the NRC staff with the aim of employing the best available experimental data and calculational models in order to achieve increased accuracy and realism. As a result of such reviews, it is expected that alternative acceptable methods for calculation will be made available to applicants and that calculational procedures found to be unnecessary will be eliminated. The guide supersedes portions of Regulatory Guide 1.42, Revision 1, "Interim Licensing Policy on as Low as Practicable for Gaseous Radioiodine Releases from Light-Water-Cooled Nuclear Power Reactors," which has been withdrawn.

B. DISCUSSION

Each applicant for a permit to construct a light-water-cooled nuclear power reactor should evaluate the environmental impact of the proposed facility. The objective of this guide is to provide an acceptable method of calculating realistic radioactive source terms for the evaluation of radioactive waste treatment systems in determining whether the design objectives of Appendix I to 10 CFR Part 50 are met and in determining the impact of radioactive effluents on the environment. This guide is intended for use with light-water-cooled nuclear power reactors in which zircaloy-clad fuels are used.

Use of parameters and models different from those given in the referenced NUREG reports may result in differences between the evaluations by applicants and those by the NRC staff. To reconcile any such differences, the applicant should provide the bases for all parameters used in the evaluation that differ from or are not contained in the referenced NUREG reports.

1. Boiling Water Reactors (BWRs)

Radioactive source term calculations for BWRs should be based on the BWR-GALE Code given in NUREG-0016, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors (BWR-GALE Code)."* The calculations performed by this Code are based

*Copies of NUREG-0016 may be purchased from the National Technical Information Service, Springfield, Virginia 22161.

on (1) standardized reactor coolant activities recommended by the ANS 18.1 Working Group,* (2) the release and transport mechanisms that result in their appearance in liquid and gaseous waste streams, and (3) the effectiveness of design features employed to reduce the quantities of radioactive materials ultimately released to the environs.

Chapter 1 of NUREG-0016 provides instructions for using the BWR-GALE Code. It describes the parameters incorporated in the Code, the input data required, and a step-by-step procedure for completing the input data cards. Chapter 2 provides parameters for a realistic assessment of reactor and radwaste treatment system performance for normal operation, including anticipated operational occurrences. Items such as the expected leakage rates, equipment decontamination factors, iodine partition factors, and other parameters necessary to make a realistic assessment of the capabilities of the liquid and gaseous radwaste treatment systems for BWRs are delineated along with their bases. These parameters are periodically reviewed and updated on the basis of actual operating data. Chapter 3 contains a Fortran IV listing of the BWR-GALE Code and a sample calculation, and Chapter 4 lists the data needed to generate source terms.

Appendix A to this guide contains a list of information items to be submitted with the application; it is a summary of the parameters to be considered by the applicant in performing BWR source term calculations. The information listed in Appendix A should be extracted from the contents of the Safety Analysis Report (SAR) and the Environmental Report (ER) and should be included in a special section of the ER. The sections of the SAR and ER that contain a more detailed discussion of the information should be referenced following each response.

2. Pressurized Water Reactors (PWRs)

Radioactive source term calculations for PWRs are based on the PWR-GALE Code given in NUREG-0017, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors (PWR-GALE Code)."** The calculations performed by this Code are based on (1) standardized reactor coolant activities recommended by the ANS 18.1 Working Group, (2) the release and transport mechanisms that result in their appearance in liquid and gaseous waste streams, and (3) the effectiveness of design features employed to reduce the quantities of radioactive materials ultimately released to the environs. NUREG-0017 is divided into chapters similar to those in NUREG-0016 (see Section B.1 of this guide).

Appendix B to this guide contains a list of information items to be submitted with the application; it is a summary of the parameters to be considered by the applicant in performing PWR source term calculations. The information listed in Appendix B should be extracted from the contents of the Safety Analysis Report (SAR) and the Environmental Report (ER) and should be included in a special section of the ER. The sections of the SAR and ER that contain a more detailed discussion of the information should be referenced following each response.

C. REGULATORY POSITION

1. Each application for a permit to construct a nuclear power reactor should include in-plant control measures to maintain releases of radioactive materials in liquid and gaseous effluents to the environment as low as is reasonably achievable in accordance with the requirements of paragraph 20.1(c) of 10 CFR Part 20 and of § 50.34a, § 50.36a, and Appendix I of 10 CFR Part 50. For gaseous effluents, such measures could include storage for decay of noble gases removed from the primary coolant and charcoal adsorbers or HEPA filters to remove radioiodine and radioactive particulates released from building ventilation exhaust systems. For liquid effluents, such measures could include storage for decay, demineralization, reverse osmosis, and evaporation.

2. The method of calculation described in NUREG-0016 and NUREG-0017 and the parameters presented in Chapter 2 of each report should be used to calculate the quantities of radioactive materials in gaseous and liquid effluents from light-water-cooled nuclear power reactors.

3. If methods and parameters used in calculating source terms are different from those given in NUREG-0016 and NUREG-0017, they should be described in detail and in the Environmental Report the basis for the methods and parameters used should be provided.

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*American National Standards Source Term Specification N237, ANS 18.1 Working Group, "Radioactive Materials in Principal Fluid Streams of Light-Water-Cooled Nuclear Power Plants," Draft, July 7, 1975.

**Copies of NUREG-0017 may be purchased from the National Technical Information Service, Springfield, Virginia 22161.

D. IMPLEMENTATION

The purpose of this section is to provide information to license applicants and licensees regarding the NRC staff's plans for this regulatory guide.

This guide reflects current Nuclear Regulatory Commission practice. Therefore, except in those cases in which the license applicant or licensee proposes an acceptable alternative method, the method described herein for complying with specified portions of the Commission's regulations is being and will continue to be used in the evaluation of submittals for operating license or construction permit applications until this guide is revised as a result of suggestions from the public or additional staff review.

APPENDIX A

DATA NEEDED FOR RADIOACTIVE SOURCE TERM CALCULATIONS FOR BOILING WATER REACTORS

The applicant should provide the information listed in this appendix. The information should be taken from the contents of the Safety Analysis Report (SAR) and the Environmental Report (ER) of the proposed boiling water reactor and included in a special section of the ER. The appropriate sections of the SAR and ER containing more detailed discussions or backup data for the required information should be referenced following each response. Each response, however, should be independent of the ER and SAR.*

The information listed in this appendix constitutes the basic data required in calculating the releases of radioactive material in liquid and gaseous effluents (the source terms). All responses should be on a per-reactor basis. Indicate systems shared between reactors.

1. General

   a. The maximum core thermal power (MWt) evaluated for safety considerations in the SAR. (Note: All of the following responses should be adjusted to this power level.)

   b. The quantity of tritium released in liquid and gaseous effluents (Ci/yr per reactor).

2. Nuclear Steam Supply System

   a. Total steam flow rate (lb/hr).

   b. Mass of reactor coolant (lb) in the reactor vessel at full power.

3. Reactor Coolant Cleanup System

   a. Average flow rate (lb/hr).

   b. Demineralizer type (deep bed or powdered resin) and size (ft^3).

   c. Regeneration or replacement frequency.

   d. Regenerant (backwash) volume (gal/event) and activity (if applicable).

4. Condensate Demineralizers

   a. Average flow rate (lb/hr).

   b. Demineralizer type (deep bed or powdered resin).

   c. Number and size (ft^3) of demineralizers.

   d. Regeneration or replacement frequency.

   e. Indicate whether ultrasonic resin cleaning is used and the waste liquid volume associated with its use.

   f. Regenerant (backwash) volume (gal/event) and activity.

5. Liquid Waste Processing Systems

   a. For each liquid waste processing system, provide, in tabular form, the following information in tabular form:

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*The ER or SAR may be referenced for bases for parameters used; however, parameters should be given with responses to this questionnaire.

(1) Sources, flow rates (gal/day), and expected activities (fraction of primary coolant activity (PCA) for all inputs to each system).

(2) Holdup times associated with the collection, processing, and discharge of all liquid streams.

(3) Capacities of all tanks (gal) and processing equipment (gal/day) considered in calculating holdup times.

(4) Decontamination factors for each processing step.

(5) The fraction of each processing stream expected to be discharged over the life of the plant.

(6) For waste demineralizer regeneration, the time between regenerations, regenerant volumes and activities, treatment of regenerants, and fractions of regenerant discharged. Include parameters used in making these determinations.

(7) Liquid source term by radionuclide (in Ci/yr) for normal operation, including anticipated operational occurrences.

b. Provide piping and instrumentation diagrams and process flow diagrams for the liquid radwaste systems and for all other systems influencing the source term calculations.

6. Main Condenser and Turbine Gland Seal Air Removal Systems

a. The holdup time (hr) for offgases from the main condenser air ejector prior to processing by the offgas treatment system.

b. A description and the expected performance of the gaseous waste treatment systems for the offgases from the condenser air ejector and mechanical vacuum pump. Include the expected air inleakage per condenser shell, the number of condenser shells, and the iodine source term from the condenser.

c. The mass of charcoal (tons) in the charcoal delay system used to treat the offgases from the main condenser air ejector, the operating and dew point temperatures of the delay system, and the dynamic adsorption coefficients for Xe and Kr.

d. A description of the cryogenic distillation system, the fraction of gases partitioned during distillation, the holdup in the system, storage following distillation, and the expected system leakage rate.

e. The steam flow (lb/hr) to the turbine gland seal and the source of the steam (primary or auxiliary).

f. The design holdup time (hr) for gas vented from the gland seal condenser, the iodine partition factor for the condenser, and the fraction of radioiodine released through the system vent. Describe the treatment system used to reduce radioiodine and particulate releases from the gland seal system.

g. Piping and instrumentation diagrams and process flow diagrams for the gaseous waste treatment system and for all other systems influencing the source term calculations.

7. Ventilation and Exhaust Systems

For each plant building that houses a main condenser evacuation system, a mechanical vacuum pump, a turbine gland seal system exhaust, or a system that contains radioactive materials, provide the following:

a. Provisions incorporated to reduce radioactivity releases through the ventilation or exhaust systems.

b. Decontamination factors assumed and the bases (include charcoal adsorbers, HEPA filters, and mechanical devices).

c. Release rates for radioiodines, noble gases, and radioactive particulates and their bases.

d. Description of the release points, including height above grade, height above and location relative to adjacent structures, expected average temperature difference between gaseous effluents and ambient air, flow rate, exit velocity, and size and shape of flow orifice.

e. For the containment building, the expected purge and venting frequencies and duration and the continuous purge rate (if used).

APPENDIX B

DATA NEEDED FOR RADIOACTIVE SOURCE TERM CALCULATIONS FOR PRESSURIZED WATER REACTORS

The applicant should provide the information listed in this appendix. The information should be taken from the contents of the Safety Analysis Report (SAR) and the Environmental Report (ER) of the proposed pressurized water reactor and included in a special section of the ER. The appropriate sections of the SAR and ER containing more detailed discussions or backup data for the required information should be referenced following each response. Each response, however, should be independent of the ER and SAR.* The information listed in this appendix constitutes the basic data required in calculating the releases of radioactive material in liquid and gaseous effluents (the source terms). All responses should be on a per-reactor basis. Indicate systems shared between reactors.

1. General

   a. The maximum core thermal power (MWt) evaluated for safety considerations in the SAR. (Note: All of the following responses should be adjusted to this power level.)

   b. The quantity of tritium released in liquid and gaseous effluents (Ci/yr per reactor).

2. Primary System

   a. The total mass (lb) of coolant in the primary system, excluding the pressurizer and primary coolant purification system, at full power.

   b. The average primary system letdown rate (gal/min) to the primary coolant purification system.

   c. The average flow rate (gal/min) through the primary coolant purification system cation demineralizers. (Note: The letdown rate should include the fraction of time the cation demineralizers are in service.)

   d. The average shim bleed flow (gal/min).

3. Secondary System

   a. The number and type of steam generators, the type of chemistry used, and the carryover factor used in the evaluation for iodine and nonvolatiles.

   b. The total steam flow (lb/hr) in the secondary system.

   c. The mass of liquid in each steam generator (lb) at full power.

   d. The primary-to-secondary leakage rate (lb/day) used in the evaluation.

   e. Description of the steam generator blowdown and blowdown purification systems. The average steam generator blowdown rate (lb/hr) used in the evaluation.

   f. The fraction of the steam generator feedwater processed through the condensate demineralizers and the decontamination factors used in the evaluation for the condensate demineralizer system.

   g. Condensate demineralizers:

      (1) Average flow rate (lb/hr).

      (2) Demineralizer type (deep bed or powdered resin).

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*ER or SAR may be referenced for bases for parameters used; however, parameters should be given with responses to this questionnaire.

(3) Number and size (ft^3) of demineralizers.

(4) Regeneration or replacement frequency.

(5) Indicate whether ultrasonic resin cleaning is used and the waste liquid volume associated with its use.

(6) Regenerant (backwash) volume (gal/event) and activity.

4. Liquid Waste Processing Systems

a. For each liquid waste processing system (including the shim bleed, steam generator blowdown, and detergent waste processing systems), provide the following information in tabular form:

(1) Sources, flow rates (gal/day), and expected activities (fraction of primary coolant activity (PCA) for all inputs to each system).

(2) Holdup times associated with the collection, processing, and discharge of all liquid streams.

(3) Capacities of all tanks (gal) and processing equipment (gal/day) considered in calculating holdup times.

(4) Decontamination factors for each processing step.

(5) The fraction of each processing stream expected to be discharged over the life of the plant.

(6) For demineralizer regeneration, the time between regenerations, regenerant volumes and activities, treatment of regenerants, and the fraction of regenerant discharged. Include parameters used in making these determinations.

(7) Liquid source term by radionuclide (in Ci/yr) for normal operation, including anticipated operational occurrences.

b. Provide piping and instrumentation diagrams and process flow diagrams for the liquid radwaste systems and for all other systems influencing the source term calculations.

5. Gaseous Waste Processing System

a. The volume (ft^3/yr) of gases stripped from the primary coolant.

b. A description of the process used to hold up gases stripped from the primary system during normal operations and reactor shutdown. If pressurized storage tanks are used, include a process flow diagram of the system indicating the capacities (ft^3), number, and design and operating storage pressures of the storage tanks.

c. A description of the normal operation of the system, e.g., the number of tanks held in reserve for back-to-back shutdown, fill time for tanks. Indicate the minimum holdup time used in the evaluation and the basis for this number.

d. If HEPA filters are used downstream of the pressurized storage tanks, the decontamination factor used in the evaluation.

e. If a charcoal delay system is used, a description of this system indicating the minimum holdup times for each radionuclide considered in the evaluation. List all parameters including mass of charcoal (lb), flow rate (ft^3/min), operating and dew point temperatures, and dynamic adsorption coefficients for Xe and Kr used in calculating holdup times.

f. Piping and instrumentation diagrams and process flow diagrams for the gaseous radwaste systems and for other systems influencing the source term calculations.

6. Ventilation and Exhaust Systems

For each building that houses a steam generator blowdown system vent exhaust, a gaseous waste processing system vent, a main condenser air removal system, or a system that contains radioactive materials, provide the following:

a. Provisions incorporated to reduce radioactivity releases through the ventilation or exhaust systems.

b. Decontamination factors assumed and the bases (include charcoal adsorbers, HEPA filters, and mechanical devices).

c. Release rates for radioiodine, noble gases, and radioactive particulates and their bases.

d. Description of the release points, including height above grade, height above and location relative to adjacent structures, expected average temperature difference between gaseous effluents and ambient air, flow rate, exit velocity, and size and shape of flow orifice.

e. For the containment building, the building free volume (ft^3) and a thorough description of the internal recirculation system (if provided), including the recirculation rate, charcoal bed depth, operating time assumed, and mixing efficiency. Indicate the expected purge and venting frequencies and duration and the continuous purge rate (if used).