



REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 1.112

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

A. INTRODUCTION

In Title 10, Part 20, of the *Code of Federal Regulations* (10 CFR Part 20), “Standards for Protection Against Radiation,” Section 20.1302, “Compliance with Dose Limits for Individual Members of the Public,” establishes limits on concentrations of radioactive material in effluents to unrestricted areas. In particular, 10 CFR 20.1301(e) states that, in addition to the requirements in 10 CFR Part 20, a licensee shall comply with the generally applicable environmental radiation standards that the U.S. Environmental Protection Agency (EPA) established in 40 CFR Part 190, “Environmental Radiation Protection Standards for Nuclear Power Operations,” if the licensee is subject to those standards.

In addition, in 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” Section 50.34a, “Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents — Nuclear Power Reactors,” sets forth the design objectives for equipment that is intended to control releases of radioactive effluents from nuclear power reactors. Moreover, 10 CFR 50.36a, “Technical Specifications on Effluents from Nuclear Power Reactors,” provides that, 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, installation and maintenance of effluent control equipment, and reporting of actual releases.

The U.S. Nuclear Regulatory Commission (NRC) issues regulatory guides to describe and make available to the public methods that the NRC staff considers acceptable for use in implementing specific parts of the agency's regulations, techniques that the staff uses in evaluating specific problems or postulated accidents, and data that the staff need in reviewing applications for permits and licenses. Regulatory guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions that differ from those set forth in regulatory guides will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

This guide was issued after consideration of comments received from the public. The NRC staff encourages and welcomes comments and suggestions in connection with improvements to published regulatory guides, as well as items for inclusion in regulatory guides that are currently being developed. The NRC staff will revise existing guides, as appropriate, to accommodate comments and to reflect new information or experience. Written comments may be submitted to the Rules and Directives Branch, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001.

Regulatory guides are issued in 10 broad divisions: 1, Power Reactors; 2, Research and Test Reactors; 3, Fuels and Materials Facilities; 4, Environmental and Siting; 5, Materials and Plant Protection; 6, Products; 7, Transportation; 8, Occupational Health; 9, Antitrust and Financial Review; and 10, General.

Requests for single copies of draft or active regulatory guides (which may be reproduced) should be made to the U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Reproduction and Distribution Services Section, or by fax to (301) 415-2289; or by email to Distribution@nrc.gov. Electronic copies of this guide and other recently issued guides are available through the NRC's public Web site under the Regulatory Guides document collection of the NRC's Electronic Reading Room at <http://www.nrc.gov/reading-rm/doc-collections/> and through the NRC's Agencywide Documents Access and Management System (ADAMS) at <http://www.nrc.gov/reading-rm/adams.html>, under Accession No. ML070320241.

To augment those requirements, 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 keep the releases as low as is reasonably achievable. To implement the design objectives of Appendix I, the staff of the U.S. Nuclear Regulatory Commission (NRC) has developed a series of regulatory guides that provide methods that the staff considers acceptable for use in calculating effluent releases, dispersion of the effluent in the atmosphere and various water bodies, and associated radiation doses to people.

This regulatory guide references NUREG-0016, “Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling-Water Reactors (BWR-GALE Code),” Revision 1, dated January 1979, and NUREG-0017, “Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized-Water Reactors (PWR-GALE Code),” Revision 1, dated April 1985.¹ These two reports provide acceptable methods for calculating annual average expected releases of radioactive material in gaseous and liquid effluents from light-water-cooled nuclear power reactors. The NRC staff will undertake a review the procedures and models provided in the referenced NUREG-series reports with the aim of updating the methodology for calculating release of radioactive materials.

As an alternative to the methods in NUREG-0016 or NUREG-0017, the methodology that the American National Standards Institute (ANSI) described in ANSI/ANS-18.1-1999, “Radioactive Source Term for Normal Operation for Light Water Reactors,”² may be used in calculating radioactive source terms in BWR reactor coolant and reactor steam, as well as PWR primary coolant and secondary water and steam.

This regulatory guide contains information collections that are covered by the requirements of 10 CFR Part 20, which the Office of Management and Budget (OMB) approved under OMB control number 3150-0014. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

¹ All NUREG-series reports listed herein were published by the U.S. Nuclear Regulatory Commission. Copies are available for inspection or copying for a fee from the NRC’s Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR’s mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; email PDR@nrc.gov. In addition, copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328, telephone (202) 512-1800; or from the National Technical Information Service (NTIS), at 5285 Port Royal Road, Springfield, Virginia 22161, online at <http://www.ntis.gov>, by telephone at (800) 553-NTIS (6847) or (703) 605-6000, or by fax to (703) 605-6900.

² Copies of ANSI/ANS-18.1-1999 may be obtained from the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, Illinois 60526; telephone (708) 352-6611; fax (708) 352-0499. Purchase information is available through the ANS Web-based store at <http://www.ans.org/store/vi-240238>.

B. DISCUSSION

Background

Each applicant for a permit to construct a light-water-cooled nuclear power reactor should evaluate the environmental impact of the proposed facility. This guide provides an acceptable method of calculating realistic radioactive source terms for use in evaluating radioactive waste treatment systems to determine whether the design objectives of Appendix I to 10 CFR Part 50 are met, and to assess the environmental impact of radioactive effluents. This guide applies to light-water-cooled nuclear power reactors that use zirconium alloy-clad fuel.

Use of parameters and models different from those given in the referenced NUREG reports (NUREG-0016, Revision 1, and NUREG-0017, Revision 1) may result in differences between applicant and NRC staff evaluations. 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-series reports.

Boiling-Water Reactors

Radioactive source term calculations for boiling-water reactors (BWRs) should be based on the BWR-GALE Code given in NUREG-0016, Revision 1. The calculations performed with this code are based on (1) standardized reactor coolant activities recommended by ANS-18.1, Source Term Specification N237, "Radioactive Materials in Principal Fluid Streams of Light-Water-Cooled Nuclear Power Plants," which ANSI issued in 1976;³ (2) the release and transport mechanisms that result in their appearance in gaseous and liquid waste streams; and (3) the effectiveness of design features employed to reduce the quantities of radioactive materials ultimately released to the environment.

Chapter 1 of NUREG-0016, Revision 1, provides instructions for using the BWR-GALE Code, and describes the parameters incorporated in the code, the input data required, and a step-by-step procedure for completing the data entry. Chapter 2 provides parameters for a realistic assessment of reactor and radioactive waste treatment system performance for normal operation, including anticipated operational occurrences. It also delineates and provides the bases for items such as expected leakage rates, equipment decontamination factors, iodine partition factors, and other parameters needed to realistically assess the capabilities of gaseous and liquid radioactive waste treatment systems for BWRs. These parameters are periodically reviewed and updated on the basis of actual operating data. In addition, 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 lists information to be submitted with the application, and summarizes the parameters the applicant should consider in performing BWR source term calculations. Applicants should extract the information listed in Appendix A from the contents of the safety analysis report (SAR) and environmental report (ER), and should include this information in a special section of the ER. Following each response, the applicant should reference the sections of the SAR and ER that contain a more detailed discussion of the relevant information.

³ ANSI updated ANS-18.1 in 1999 to issue ANSI/ANS-18.1-1999, "Radioactive Source Term for Operation of Light-Water Reactors." The source term data provided in this standard will be considered in future upgrades of the GALE computer code.

Pressurized-Water Reactors

Radioactive source term calculations for pressurized-water reactors (PWRs) are based on the PWR-GALE Code given in NUREG-0017, Revision 1. The calculations performed with this code are based on (1) standardized reactor coolant activities recommended by ANS-18.1, Source Term Specification N237, "Radioactive Materials in Principal Fluid Streams of Light-Water-Cooled Nuclear Power Plants," which ANSI issued in 1976; (2) the release and transport mechanisms that result in the appearance of radioactive materials in gaseous and liquid waste streams; and (3) the effectiveness of design features employed to reduce the quantities of radioactive materials ultimately released to the environment. NUREG-0017, Revision 1, is divided into chapters similar to those in NUREG-0016, Revision 1, as described above.

Appendix B to this guide lists information to be submitted with the application, and summarizes the parameters the applicant should consider in performing PWR source term calculations. Applicants should extract the information listed in Appendix B from the contents of the SAR and the ER, and should include this information in a special section of the ER. Following each response, the applicant should reference the sections of the SAR and ER that contain a more detailed discussion of the information.

C. REGULATORY POSITION

1. Each application for a permit to construct a nuclear power reactor should include in-plant control measures to maintain environmental releases of radioactive materials in gaseous and liquid effluents as low as is reasonably achievable in accordance with the requirements of 10 CFR 20.1302, 10 CFR 50.34a, and Appendix I to 10 CFR Part 50. For gaseous effluents, such measures could include storage for decay of noble gases removed from the primary coolant, as well as charcoal adsorbers or high-efficiency particulate air 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. Applicants should use the calculation method described in NUREG-0016, Revision 1, and NUREG-0017, Revision 1, as well as the parameters presented in Chapter 2 of each report, 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 differ from those given in NUREG-0016, Revision 1, and NUREG-0017, Revision 1, the applicant should describe them in detail and provide in the ER the basis for the methods and parameters employed.
4. For new reactor applications filed under the provisions of 10 CFR Part 52, an applicant may use the methodology described in ANSI/ANS-18.1-1999, "Radioactive Source Term for Normal Operation for Light-Water Reactors." When using that standard, the applicant should describe and justify all adjustments made to the reference BWR or PWR plant parameters in developing radionuclide concentrations in BWR reactor coolant and reactor steam, as well as PWR primary coolant and secondary water and steam.
5. If none of the above guidance (NUREG-0016, NUREG-0017, or ANSI/ANS-18.1-1999) is followed, the applicant should describe the specific alternative method used, and provide justifications for all supporting parameters and assumptions.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide. No backfitting is intended or approved in connection with its issuance.

Except in those cases in which an applicant or licensee proposes or has previously established an acceptable alternative method for complying with specified portions of the NRC's regulations, the NRC staff will use the methods described in this guide to evaluate (1) submittals in connection with applications for construction permits, standard plant design certifications, operating licenses, early site permits, and combined licenses; and (2) submittals from operating reactor licensees who voluntarily propose to initiate system modifications if there is a clear nexus between the proposed modifications and the subject for which guidance is provided herein.

REGULATORY ANALYSIS / BACKFIT ANALYSIS

The regulatory analysis and backfit analysis for this regulatory guide are available in Draft Regulatory Guide DG-1160, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Nuclear Power Plants."⁴ The NRC issued DG-1160 in October 2006 to solicit public comment on the draft of this Revision 1 of Regulatory Guide 1.112.

⁴ Draft Regulatory Guide DG-1160 is available electronically under Accession #ML062680253 in the NRC's Agencywide Documents Access and Management System (ADAMS) at <http://www.nrc.gov/reading-rm/adams.html>. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR), which is located at 11555 Rockville Pike, Rockville, Maryland; the PDR's mailing address is USNRC PDR, Washington, DC 20555-0001. The PDR can also be reached by telephone at (301) 415-4737 or (800) 397-4209, by fax at (301) 415-3548, and by email to PDR@nrc.gov.

APPENDIX A

DATA NEEDED FOR RADIOACTIVE SOURCE TERM CALCULATIONS FOR BOILING-WATER REACTORS

The applicant should provide the information listed in this appendix, using information drawn from the safety analysis report (SAR) and environmental report (ER) for the proposed boiling-water reactor (BWR), and should include this information in a special section of the ER. Following each response, the applicant should reference the appropriate sections of the SAR and ER containing more detailed discussions or supporting data for the required information. However, each response should be independent of both the SAR and the ER.⁵

The information listed in this appendix constitutes the basic data necessary to calculate the releases of radioactive material in gaseous and liquid effluents (the source terms). Applicants should provide responses for each reactor, and indicate systems that are shared between reactors.

1. General

- (a) maximum core thermal power in joules per second (J/s) [megawatts thermal (MWt)] evaluated for safety considerations in the SAR (adjust all of the following responses to this power level)
- (b) quantity of tritium released in gaseous and liquid effluents in becquerel per year per reactor (Bq/yr/reactor) [curies per year per reactor (Ci/yr/reactor)]

2. Nuclear Steam Supply System

- (a) total steam flow rate in kilograms per hour (kg/h) [pounds per hour (lb/h)]
- (b) mass of reactor coolant in kg/h (lb/h) in the reactor vessel at full power

3. Reactor Coolant Cleanup System

- (a) average flow rate in kg/h (lb/h)
- (b) demineralizer type (deep bed or powdered resin) and size in cubic centimeters (cm³) [cubic feet (ft³)]
- (c) regeneration or replacement frequency
- (d) regenerant (backwash) volume in cubic meters per event (m³/event) [gallons per event (gal/event)] and activity (if applicable)

⁵ The SAR or ER may be referenced for the bases of the parameters used in developing the radioactive source term; however, parameters should be provided for each item listed in this appendix.

4. Condensate Demineralizers

- (a) average flow rate in kg/h (lb/h)
- (b) demineralizer type (deep bed or powdered resin)
- (c) number and size in cm^3 (ft^3) of demineralizers
- (d) regeneration or replacement frequency
- (e) use of ultrasonic resin cleaning and the associated waste liquid volume
- (f) regenerant (backwash) volume in m^3/event (gal/event) and activity

5. Liquid Waste Processing Systems

- (a) For each liquid waste processing system, provide the following information in tabular form:
 - i. sources, flow rates in m^3 per day (m^3/d) (gal/d), and expected activities (fraction of primary coolant activity for all inputs to each system)
 - ii. holdup times associated with the collection, processing, and discharge of all liquid streams
 - iii. capacities of all tanks in m^3 (gal) and processing equipment in m^3/d (gal/d) considered in calculating holdup times
 - iv. decontamination factors for each processing step
 - v. the fraction of each processing stream expected to be discharged over the life of the plant
 - vi. for waste demineralizer regeneration, the time between regenerations, regenerant volumes and activities, treatment of regenerants, and fractions of regenerant discharged, including parameters used to make these determinations
 - vii. liquid source term by radionuclide in Bq/yr (Ci/yr) for normal operation, including anticipated operational occurrences
- (b) Provide piping and instrumentation diagrams and process flow diagrams for the liquid radioactive waste systems and all other systems influencing the source term calculations

6. Main Condenser and Turbine Gland Seal Air Removal Systems

- (a) holdup time (h) for offgases from the main condenser air ejector before processing by the offgas treatment system
- (b) description and expected performance of the gaseous waste treatment systems for the offgases from the condenser air ejector and mechanical vacuum pump, including the expected air in-leakage per condenser shell, number of condenser shells, and iodine source term from the condenser

- (c) mass of charcoal in kg (tons) in the charcoal delay system used to treat the offgases from the main condenser air ejector, operating and dew point temperatures of the delay system, and dynamic adsorption coefficients for xenon and krypton
- (d) description of the cryogenic distillation system, fraction of gases partitioned during distillation, holdup in the system, storage following distillation, and expected system leakage rate
- (e) steam flow in kg/h (lb/h) to the turbine gland seal, and the source of the steam (primary or auxiliary)
- (f) design holdup time (h) for gas vented from the gland seal condenser, iodine partition factor for the condenser, and fraction of radioiodine released through the system vent, and a description of 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 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 radioactive releases through the ventilation or exhaust systems
- (b) decontamination factors assumed and their bases, including charcoal adsorbers, high-efficiency particulate air 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, using information drawn from the safety analysis report (SAR) and environmental report (ER) for the proposed pressurized-water reactor (PWR), and should include this information in a special section of the ER. Following each response, the applicant should reference the appropriate sections of the SAR and ER containing more detailed discussions or supporting data for the required information. However, each response should be independent of both the SAR and the ER.⁶

The information listed in this appendix constitutes the basic data necessary to calculate the releases of radioactive material in gaseous and liquid effluents (the source terms). Applicants should provide responses for each reactor, and indicate systems that are shared between reactors.

1. General

- (a) maximum core thermal power in joules per second (J/s) [megawatts thermal (MWt)] evaluated for safety considerations in the SAR (adjust all of the following responses to this power level)
- (b) quantity of tritium released in gaseous and liquid effluents in becquerel per year per reactor (Bq/yr/reactor) [curies per year per reactor (Ci/yr/reactor)]

2. Primary System

- (a) total mass in kilograms (kg) [pounds (lb)] of coolant in the primary system, excluding the pressurizer and primary coolant purification system, at full power
- (b) average primary system letdown rate in cubic meters per minute (m^3/min) [gallons per minute (gal/min)] to the primary coolant purification system
- (c) average flow rate in m^3/min (gal/min) through the primary coolant purification system cation demineralizers (letdown rate should include the fraction of time the cation demineralizers are in service)
- (d) average shim bleed flow in m^3/min (gal/min)

⁶ The SAR or ER may be referenced for the bases of the parameters used in developing the radioactive source term; however, parameters should be provided for each item listed in this appendix.

3. Secondary System

- (a) number and type of steam generators, type of chemistry used, and carryover factor used in the evaluation for iodine and nonvolatiles
- (b) total steam flow in kilograms per hour (kg/h) [pounds per hour (lb/h)] in the secondary system
- (c) mass of liquid in each steam generator in kg (lb) at full power
- (d) primary-to-secondary leakage rate in kg/d (lb/d) used in the evaluation
- (e) description of the steam generator blowdown and blowdown purification systems, and the average steam generator blowdown rate in kg/h (lb/h) used in the evaluation
- (f) 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, as follows:
 - i. average flow rate in kg/h (lb/h)
 - ii. demineralizer type (deep bed or powdered resin)
 - iii. number and size in cubic centimeters (cm³) [cubic feet (ft³)] of demineralizers
 - iv. regeneration or replacement frequency
 - v. use of ultrasonic resin cleaning and the associated waste liquid volume
 - vi. regenerant (backwash) volume in m³/event (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:
 - i. sources, flow rates in m³/d (gal/d), and expected activities (fraction of primary coolant activity for all inputs to each system)
 - ii. holdup times associated with the collection, processing, and discharge of all liquid streams
 - iii. capacities of all tanks in m³ (gal) and processing equipment in m³/d (gal/d) considered in calculating holdup times
 - iv. decontamination factors for each processing step
 - v. fraction of each processing stream expected to be discharged over the life of the plant
 - vi. for demineralizer regeneration, the time between regenerations, regenerant volumes and activities, treatment of regenerants, and fraction of regenerant discharged, including parameters used to make these determinations
 - vii. liquid source term by radionuclide in Bq/yr (Ci/yr) for normal operation, including anticipated operational occurrences
- (b) Provide piping and instrumentation diagrams and process flow diagrams for the liquid radioactive waste systems and for all other systems influencing the source term calculations.

5. Gaseous Waste Processing System

- (a) volume in m^3/yr (ft^3/yr) of gases stripped from the primary coolant
- (b) description of the process used to hold up gases stripped from the primary system during normal operations and reactor shutdown; if using pressurized storage tanks, include a process flow diagram of the system indicating the capacities in cm^3 (ft^3), number, and design and operating storage pressures of the storage tanks
- (c) 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), including the minimum holdup time used in the evaluation and the basis for this value
- (d) if high-efficiency particulate air (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, and a list of all parameters, including mass of charcoal in kg (lb), flow rate in cm^3 per minute (cm^3/min) [ft^3 per minute (ft^3/min)], operating and dew point temperatures, and dynamic adsorption coefficients for xenon and krypton used in calculating holdup times
- (f) piping and instrumentation diagrams and process flow diagrams for the gaseous radioactive waste systems and 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 radioactive releases through the ventilation or exhaust systems
- (b) decontamination factors assumed and their 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 in cm^3 (ft^3) and a thorough description of the internal recirculation system (if provided), including recirculation rate, charcoal bed depth, operating time assumed, and mixing efficiency, as well as the expected purge and venting frequencies, their duration, and the continuous purge rate (if used)