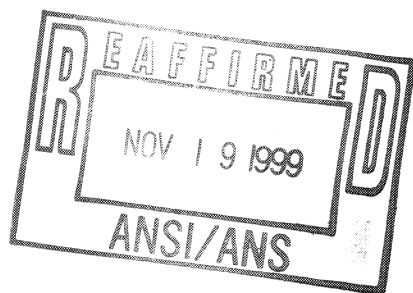


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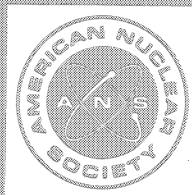
gaseous radioactive waste processing systems for light water reactor plants

an American National Standard



This standard has been reviewed and reaffirmed by the ANS Nuclear Facilities Standards Committee (NFSC) with the recognition that it may reference other standards and documents that may have been superceded or withdrawn. The requirements of this document will be met by using the version of the standards and documents referenced herein. It is the responsibility of the user to review each of the references and to determine whether the use of the original references or more recent versions is appropriate for the facility. Variations from the standards and documents referenced in this standard should be evaluated and documented.

This standard does not necessarily reflect recent industry initiatives for risk informed decision-making or a graded approach to quality assurance. Users should consider the use of these industry initiatives in the application of this standard.



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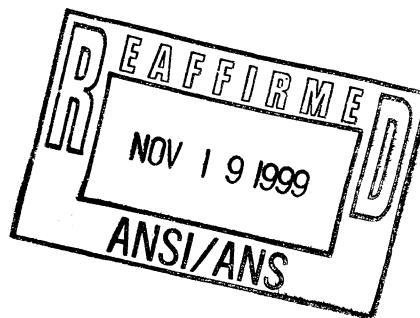
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American National Standard for Gaseous Radioactive Waste Processing Systems for Light Water Reactor Plants

Secretariat
American Nuclear Society

Prepared by the
**American Nuclear Society
Standards Committee
Working Group ANS-55.4**

Published by the
**American Nuclear Society
555 North Kensington Avenue
La Grange Park, Illinois 60525 USA**



Approved July 16, 1993
by the
American National Standards Institute, Inc.

American National Standard

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Printed in the United States of America

Foreword

(This foreword is not a part of American National Standard for Gaseous Radioactive Waste Processing Systems for Light Water Reactor Plants, ANSI/ANS-55.4-1993, but is included for information purposes only.)

Management of the gaseous radioactive waste generated as a by-product of nuclear power plant operation constitutes a major management responsibility. Quantities of gaseous radioactive waste generated during operation are dependent upon several factors including design conditions, type of equipment, equipment arrangements, and operating philosophy.

The purpose of this standard is to establish uniform practices and minimum requirements for design, construction, and performance, with due consideration for operation, of gaseous radioactive waste processing systems. The standard sets forth design, construction, and performance requirements for acceptable gaseous radioactive waste processing systems. Adherence by system designers to the criteria contained in the standard will enable the operator (a) to control to regulatory levels radiation exposures to operating personnel; (b) to assure a low probability of unplanned release of radioactivity from the system; and (c) to control system releases of radioactivity to levels as low as reasonably achievable.

In accordance with ANS policy to maintain standards on a five year basis, the standard was revised to update its contents and to reflect changes in industry practices. Members of Working Group 55.4, and their affiliations at the time of their approval of this standard, were as follows:

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D. H. DaCosta, *Ergenics, Incorporated*
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J. Lee, *U.S. Nuclear Regulatory Commission*
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Gaseous Radioactive Waste Processing Systems for Light Water Reactor Plants

1. Scope and System Description

1.1 Scope. This standard sets forth minimum design, construction, and performance requirements, with due consideration for operation, for gaseous radioactive waste processing systems (GRWPS) for light water reactor (LWR) plants. It is applicable for routine operation, design basis fuel leakage, and other design basis occurrences.

1.2 System Description. For the purpose of this standard, the boiling water reactor (BWR) GRWPS begins at the point of discharge from the main condenser air removal equipment, the main condenser mechanical vacuum pump, and the turbine steam packing exhaust. For pressurized water reactors (PWRs), the GRWPS begins at the point of discharge from the volume control tank, the reactor coolant drain tank, the reactor coolant gas stripper, the boron recycle holdup tank, the pressurizer relief tank, and the boron recycle evaporator. The systems terminate at the point of introduction into the plant exhaust.

The components of the GRWPS are nonnuclear safety related and the system is classified as Nonnuclear Safety (NNS) as defined in Section 3.3 of American National Standards for Nuclear Safety Criteria for the Design of Stationary Boiling Water Reactor Plants, ANSI/ANS-52.1-1983 (R1988) [1],¹ and Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants, ANSI/ANS-51.1-1983 (R1988) [2].

2. Definitions

charcoal adsorption system. A processing system incorporating activated charcoal at ambient or reduced temperatures for adsorption and decay of radioactive gases.

clean steam. Steam generated by the vaporization of non-radioactive demineralized water.

cover gas. Gas in liquid storage tanks pressurized to prevent in-leakage of air.

¹ Numbers in brackets refer to corresponding numbers in Section 7, References.

cryogenic adsorption systems. Processing systems utilizing an adsorbent at cryogenic temperatures for separation or adsorption and decay of radioactive gases.

cryogenic distillation units. Equipment employing cryogenic temperature distillation for separation of noble gases from waste gas streams.

decontamination factor (DF). The ratio of the concentration of the radioactive material in the influent stream to its concentration in the effluent.

gas stripper. Degassing equipment to remove dissolved gases from liquids.

high efficiency particulate air filter (HEPA). A disposable dry-type filter having minimum efficiency of 99.97 percent for 0.3 micrometer particles.

pressurized gas storage tank system. A system using tanks, operating at pressures above 1.5 atmospheres absolute, for the hold-up of gaseous radioactive waste prior to release or reuse.

recombiner. Equipment designed to accomplish the controlled reaction of hydrogen and oxygen by catalytic or thermal means.

shall, should, and may. The word "shall" is used to denote a requirement; the word "should" to denote a recommendation; and the word "may" to denote permission, neither a requirement nor a recommendation.

standard cubic foot (SCF). As used in this standard, an amount of gas occupying one cubic foot at a temperature of 60°F and a pressure of one atmosphere (absolute).

3. Criteria

This standard establishes minimum requirements for the design and construction of the GRWPS to achieve the performance, safety, and operational objectives specified in this section.

3.1 Performance Criteria. The GRWPS shall be designed such that radioactive materials in gaseous effluents from the plant collectively meet the design objectives given in:

(a) Title 10, "Energy," Code of Federal Regulations, Part 50, "Domestic Licensing of Production and Utilization Facilities," (10 CFR 50) 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" [3].

(b) Title 10, "Energy," Code of Federal Regulations, Part 50, "Domestic Licensing of Production and Utilization Facilities," Section 50.34a [4].

(c) Title 10, "Energy," Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation" (10 CFR 20) [5].

(d) Title 10, "Energy," Code of Federal Regulations, Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," Criteria 60 and 64 [6].

3.2 Safety Criteria. The GRWPS shall be designed such that the release of radioactive material to the environment or exposure to the general public does not exceed the requirements of 10 CFR 20 [5], nor a small fraction of the guidelines contained in Title 10, "Energy," Code of Federal Regulations, Part 100, "Reactor Site Criteria" [7].

3.3 Operational Criteria. The design, construction, and operation of the GRWPS shall be such that radiation exposures to operating and maintenance personnel are maintained "as low as is reasonably achievable" (ALARA) in accordance with 10 CFR 50, Appendix I [3].

4. Design Requirements

4.1 Code Classification. Equipment and piping shall be designed, constructed, and tested in accordance with the requirements of the applicable codes as given in Table 1.

4.2 Seismic Design. Supports for equipment that by design are used for the storage of gaseous radioactive waste for decay, and portions of structures housing this equipment, shall be designed to withstand the effect of an operating basis earthquake (OBE). For the systems normally operating at pressures greater than 1.5 atmospheres (absolute), the requirement for OBE seismic design shall apply to isolation valves, equipment, inter-

connecting piping, and components located between the upstream and downstream valves used to isolate these components from the rest of the system (e.g., waste gas storage tanks in a PWR). For systems that operate essentially at atmospheric pressure and retain gases on charcoal adsorbers, only the equipment supports and portions of structures housing the tanks shall be designed to these seismic design criteria (e.g., charcoal delay tanks in a BWR).

4.3 Quality Assurance. The design, procurement, fabrication, and construction activities shall conform to the quality assurance provisions of the codes and standards specified in Table 1. In addition, or where not covered by the referenced codes and standards, the following quality assurance features shall be established as a minimum.

4.3.1 System Designer and Procurer.

4.3.1.1 Design and Procurement Document Control. Design and procurement documents shall be verified for conformance to the requirements of this standard by individual(s) within the design organization who are not the originators of the document. Changes to these documents shall be verified or controlled to maintain conformance to this standard.

4.3.1.2 Control of Purchased Material, Equipment, and Services. Measures shall be established to ensure that suppliers of material, equipment, and construction services are capable of supplying these items to the quality specified in the procurement documents. This may be done by an evaluation of a survey of the supplier's products and facilities.

4.3.1.3 Handling, Storage, and Shipping. Instructions shall be provided in procurement documents to control the handling, storage, shipping, and preservation of material and equipment to prevent damage, deterioration, and reduction of cleanliness.

4.3.2 System Fabricator and Constructor.

4.3.2.1 Inspection. In addition to required code instructions, a program for inspection of construction and installation quality related activities shall be established and executed by, or for, the organization performing the activity to verify conformance with the documented instructions, procedures, and drawings. This shall include the visual inspection of components prior to installation for conformance with procurement documents, and visual inspection of items and systems following installation, cleaning, and passivation (where applied).

4.3.2.2 Inspection, Test, and Operating Status. Measures shall be established to provide

for the identification of items which have satisfactorily passed the required inspections and tests.

4.3.2.3 Identification and Corrective Action for Items of Nonconformance. Measures shall be established to identify items of nonconformance with regard to the requirements of the procurement documents or applicable codes and standards and to identify the remedial action taken to correct such items.

4.4 Materials. Materials for pressure retaining components of process systems shall be selected from those covered by the material specifications listed in Table 1, except that malleable, wrought, or cast iron materials shall not be used. The components shall meet all of the mandatory requirements and the material specifications with regard to manufacture, examination, repair, testing, identification, and certification.

(a) For equipment, other than piping and valves, with operating temperatures less than 32°F, material shall meet the test requirements of Paragraph UG-84, American National Standard ANSI/ASME Boiler and Pressure Vessel Code (B&PVC), Section VIII, Division 1, except that code exemptions shall not be permitted and the minimum tensile strength requirement of Section VIII, Division 1, UG-84(c)(4)(b) shall be deleted [8].

(b) For piping and valves with operating temperatures less than 32°F, materials shall meet the test requirements of ANSI/ASME B&PVC, Section VIII, Division 1, UG-84, with code exemptions permitted [8].

4.5 Welding. All pressure boundary welding of pressure retaining components and piping shall be performed employing welding procedures per Table 1. Pressure retaining components and piping of the GRWPS shall utilize welded construction to the maximum practical extent. For lines 2.5 in. and larger, pipe welds shall be of the butt type. To eliminate a possible source of leakage, flanged manways on pressurized gas storage tanks should be seal welded or provided with an underlying seal welded diaphragm. Butt weld or socket weld joints shall be used on all piping with the following exceptions:

(a) Flanged joints or suitable rapid disconnect fittings may be used only where maintenance or operational requirements clearly indicate such construction to be preferable.

(b) For instrument line connections, a screwed connection backed up by seal welding may be used where maintenance requirements clearly indicate such construction to be preferable.

4.6 Sampling. Provisions shall be made to allow representative grab sampling and analysis of gaseous radioactive waste during release. Provisions should also be included so that process gases can be sampled at appropriate points in the system to determine component performance.

Depending upon the radioactivity concentration of the gas being sampled, particulate and halogen analysis might require the passing of waste gas through filtration or adsorption sample cartridges, or both. The sample gas should be returned to the GRWPS. For processed gases, such as those at the charcoal adsorber outlet, the sample gas may be routed to a monitored plant ventilation exhaust.

Grab-sampling connections in high activity portions of a pressurized system shall be all-welded, double-valved, and capped to minimize the potential for leakage. Sample valves shall be shielded from adjacent equipment. Sample tubing should be a minimum of 0.065 in. wall thickness; refer to American National Standard for Sampling Line Piping and Tubing Standards for Use in Nuclear Power Plants, ANSI/ISA-S67.10-1986 [9].

4.7 Design for Explosive Conditions. If the potential for an explosive mixture of hydrogen and oxygen exists, the gaseous waste handling and treatment system shall be designed either to withstand the effects of a hydrogen explosion or be provided with two independent gas analyzers to detect the presence of flammable mixtures and to annunciate both locally and in the main control room.

Catalytic recombiner outlet piping shall not be interconnected with those piping regions which, by design, contain explosive mixtures. Additionally, the following are examples of features which should be used to reduce the probability of explosion:

- (a) Maintenance of non-explosive mixture.
- (b) Minimization of potential ignition sources.
- (c) System and component purging to assure non-explosive mixtures prior to inspection and maintenance.
- (d) Purging of standby equipment.
- (e) Adequate room ventilation for areas containing gaseous radwaste equipment.
- (f) No backflow of off-gas through the recombiner during idle periods (catalyst migration).
- (g) No branching of shared gaseous auxiliary supply lines to points both upstream and

downstream of recombiner.

- (h) Recombination of H_2 with O_2 to limit hydrogen to <1% by volume.
- (i) Administrative controls and procedures to assure that features such as those above are enforced.

4.8 Provisions for Calibration and Testing.

The GRWPS shall be designed to allow for the periodic calibration of instrumentation. For those systems which are not in continuous operation, testing provisions shall be incorporated into the system design to enable periodic re-evaluation of the operability and functional performance of all active components in the systems.

4.9 Leak Tightness. Equipment purchased for the GRWPS shall have leak rates within the limits specified in Table 2. The sum of the maximum leak rates from all individual components located within a ventilation zone shall not exceed the ventilation zone totals tabulated in Table 2. Completed BWR process systems shall be tested to verify that the ventilation zone totals tabulated in Table 2 are not exceeded.

4.10 Charcoal Adsorption Parameters. The delay time required for gas in the charcoal adsorbers shall be determined by the decontamination factor that meets the design criteria of 3.1. The following equation shall then be used to describe the adsorption process:

$$T = K_d M / F$$

Where

- T = average delay time, sec
- K_d = dynamic adsorption coefficient, cm^3/g
- M = mass of adsorbent, g
- F = flow rate of carrier gas, cm^3/sec

All values are those at operating conditions.

Dynamic adsorption coefficient for xenon and krypton should be based on the charcoal type, relative humidity, temperature, pressure, and other effects. The mass and type of charcoal and the system operating parameters shall be selected by the designer to achieve the required holdup time with the expected curie quantities shown in Tables 3 and 4 and the design basis input (flow rates) in Tables 5 and 6 as a minimum.²

² A discussion of charcoal adsorption characteristics appears in Section 2.2.1.1 of both *Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors* (NUREG-0017, Revision 1), and *Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors* (NUREG-0016, Revision 1).

5. Process and Equipment Requirements

5.1 Process Requirements. The minimum processing requirements for the various waste sources are stated in 5.1.1 through 5.1.2.3. The requirements included in these sections are considered the minimum necessary to meet the performance criteria of the standard.

5.1.1 BWR Process Requirements. Three distinct BWR GRWPSs are included in this standard. They are the main condenser off-gas system, the steam seal off-gas system, and the mechanical vacuum pump off-gas system. Figure 1 shows a typical BWR waste gas processing system arrangement. This section encompasses the considerations that are necessary to establish the overall process design for each of these systems so that the systems can meet the objectives of Section 3, "Criteria."

5.1.1.1 Main Condenser Off-Gas System. The main condenser off-gas system shall have the following process features:

- (a) Maintenance of the hydrogen concentration at the discharge of the main condenser air removal equipment to less than 4% by volume under all operating conditions.
- (b) No condensate in the recombiner during operation.
- (c) Recombination of hydrogen and oxygen.
- (d) Removal of water vapor during normal operation and during transient conditions (e.g., during recovery from loss or decrease of main condenser vacuum) by drying or cooling, or both, to achieve the required performance of the adsorbent consistent with the adsorption coefficients selected by the designer (see 4.10).
- (e) Hold-up of radioactive gases for decay.
- (f) Filtration of gases to remove radioactive particulate daughters prior to release if charcoal adsorbers can be bypassed.
- (g) Provision of a dry air purge to the standby recombiner.
- (h) Provision of superheated steam at the recombiner entrance at all times (including standby at zero power).
- (i) Provision of a means to extinguish a fire in charcoal adsorption media.
- (j) For designs using hydrogen water chemistry, the concentration of hydrogen and oxygen shall be monitored in the off-gas flow downstream of the recombiner.

5.1.1.2 Mechanical Vacuum Pump Off-Gas System. The mechanical vacuum pump off-gas system connects the mechanical vacuum