U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

BRANCH TECHNICAL POSITION 11-5

POSTULATED RADIOACTIVE RELEASES DUE TO A WASTE GAS SYSTEM LEAK OR FAILURE

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of effectiveness of radwaste systems.

Secondary - None

A. Background

During normal operation of a nuclear power plant, the reactor generates radioactive fission and activation gases and gases resulting from the radiolytic decomposition of water. These gases are continuously removed from the reactor coolant. After separation, the gases may be treated for volume reduction of the non-radioactive species before they are stored for radioactive decay and ultimately released to the environment. The waste gas system accomplishes this separation, reduction, and decay process.

The waste gas system at BWRs may include steam air ejectors, vacuum pumps, decay pipes, moisture separators, condensers, cryogenic distillation, tanks, ambient or chilled charcoal adsorber beds, filters, process sampling, instrumentation and radiation monitoring, and associated control features. The waste gas system at PWRs may include volume control tanks, letdown or shim bleed gas separation, gas stripping, cover gas collection, compressors, recombiners, surge and storage tanks, ambient or chilled charcoal adsorbers, moisture separators, condensers, filters, process sampling, instrumentation and radiation monitoring, and control features. In all cases, the waste gas system is part of the radioactive GWMS and information on the system is considered as part of the design information required by 10 CFR 50.34a. System operation is required to be in accordance with 10 CFR 50.36a. SRP Section 11.3 describes the design acceptance criteria for waste gas systems (as part of the GWMS).

The basic criterion for reactor accidents, including waste gas system failures, is that offsite doses shall not exceed 25 rem to the whole body (10 CFR Part 100). However, that criterion assumes that the probability of occurrence is very small. It is recognized that the probability of an accidental release from the waste gas system is relatively high and that lower dose criteria are appropriate.

Generally, the following two kinds of waste gas system failures have been designated as warranting evaluation:

1. Gross system failures, such as rupture of a decay tank (Regulatory Guide 1.24) or rupture of a line (Regulatory Guide 1.98);

2. Malfunctions, such as operator errors, valve misalignments, malfunction of attendant equipment, and active component failures;

Both the probabilities and the consequences of a waste gas system leak or failure depend on the kind of accident considered and the characteristics of the system (as defined in Tables 15-1 and 15-4 in Section 15.7.1 of Regulatory Guide 1.70).

Waste gas system design characteristics differ between plants, particularly between BWRs and PWRs, but the most important common characteristic among plants is that designs incorporate the guidance of Regulatory Guide 1.143 to withstand the effects of a hydrogen explosion and earthquakes for gaseous wastes produced during normal operation and anticipated operational occurrences. As a result, a gross failure of the waste gas system is considered highly unlikely, e.g., such as a failure involving the near total loss of the system's inventory of radioactive materials. However, for present purposes, the most important aspect is that they have been designed in accordance with Regulatory Guide 1.143, and therefore, the NRC considered a higher dose criterion for evaluating gross failures of such fortified systems. The goal of this position paper is to minimize potential radiation exposures to the public and to provide reasonable assurance that the radiological consequences of a single failure of an active component in the waste gas system will not result in a dose in excess of a small fraction (i.e., 10 percent) of the 10 CFR Part 100 limit for whole body dose to any offsite individual for a postulated event.

The dichotomy in having dose criteria for systems designed to withstand explosions and earthquakes that differ from those systems that are not designed to withstand such events has led to a problem. System malfunctions appear to be the controlling failure mode and resistance to explosions and earthquakes provides no protection against operator error and system malfunction. No specific types of system malfunction failures have been designated as being representative. However, it appears that an event, such as valve misalignment or over-pressure, could result in a release approximating that from the rupture of a tank or pipe. Therefore, it was considered that, for future safety evaluations of waste gas systems, the failures analyzed could be limited to tank or pipe ruptures, but the dose criterion in every case should not exceed 25 mSv (2.5 rem) at the exclusion area boundary, given that such systems are fortified to withstand the effects of a hydrogen explosion and earthquakes. However, for systems not designed to withstand explosions and earthquakes, the criterion is 1 mSv (0.1 rem) at the exclusion area boundary.

This BTP provides guidelines on postulated radioactive releases from a radioactive waste gas system leak or failure associated with normal operation and anticipated operational occurrences. The criteria in Section II, below, provide adequate and acceptable design solutions for the concerns outlined above. This position paper sets forth minimum requirements and does not prohibit the implementation of more rigorous design codes, standards, or quality assurance measures than those indicated. It also does not require a reevaluation of waste gas systems with limiting conditions for operation based on more conservative analysis and calculational assumptions.

B. BRANCH TECHNICAL POSITION

1. Waste Gas System Leak or Failure Analysis

   A. Criteria

      The SAR (Section 11.3) should provide an analysis of the radiological consequences of a single failure of an active component in the waste gas system. The analysis should provide reasonable assurance that, in the event of a postulated failure or leak of the waste gas system, the resulting total body exposure to an individual at the nearest exclusion area boundary will not exceed 25 mSv (2.5 rem) for systems designed to withstand explosions and earthquakes, or 1 mSv (0.1 rem) for systems not designed to withstand explosions and earthquakes. The bases for the analysis should include the assumption that the waste gas system fails to meet its design intent as required by 10 CFR 50.34a(c) and GDC 60 of Appendix A to 10 CFR Part 50.

   B. Source Term

      The safety analysis on the radiological consequences of a single failure of an active component in the waste gas system should use a system design-basis source term for light-water-cooled nuclear power plants. The NRC staff method of calculation for this analysis is based on conservative assumptions to maximize the design capacity source term (sustained power operation). These assumptions are given below:

      i. For a PWR: 1 percent of the operating fission product inventory in the core being released to the primary coolant

      ii. For a BWR: A fission product release rate consistent with the noble gas release to the reactor coolant of 100 μCi/s per MWt (after 30-minute decay)

      The analysis should assume principal parameters and conditions typical of the equipment designed to remove radioactive gases from the coolant and to process and treat these gases during normal operation, including anticipated operational occurrences, by the waste gas system. The NRC staff believes that no major alteration would occur in the use or performance of gas separation, reduction, and decay equipment before and immediately following this unique unplanned release affected by the waste gas system maximum design capacity source term. The source terms and releases may be developed using the BWR-GALE Code (NUREG-0016) or PWR-GALE Code (NUREG-0017) with appropriately justified adjustments made in modeling a specific type of event.

C. Release

The NRC staff considers that the release to the environment resulting from the postulated event will occur via a pathway not normally used for planned releases, and the release will require a reasonable time to detect and take remedial action to terminate the release. The NRC staff considers that the release of a compressed gas storage tank of a batch-type waste gas system or the inadvertent bypass of the main decay portion of a continuous-type waste gas system (such as charcoal delay beds in a BWR-augmented offgas system) will provide a conservative assumption for the release, while the input to the waste gas system is at the system design-basis source term. Only the radioactive noble gases (xenon and krypton) are to be considered since the assumed transit time is long enough to permit major radioactive decay of oxygen and nitrogen isotopes. Particulates and radioiodines are assumed to be removed by pretreatment, gas separation, and intermediate radwaste treatment equipment. The release should be assumed to occur within the building structure housing the waste gas system storage tank or the main decay position of the system. It should further be assumed that the effluent resulting from the postulated event will be released to the environs without continuous effluent radiation monitoring to automatically isolate and/or terminate the effluent release. In addition, ground-level release without credit for a building wake factor should be assumed, and a conservative (5 percent) short-term diffusion estimate (X/Q), as determined by a method outlined in the acceptance criteria in SRP Section 2.3.4, should be assumed. No deposition is assumed to occur during downwind transport.

2. <u>Staff Method for Analysis</u>

A. Pressurized Storage Tanks: The safety analysis for the radiological consequences of a single failure of an active component in a waste gas system with compressed gas storage (holdup or decay) tanks or cover gas tanks assumes that the tank being filled has a major leak to the environs. The following general procedural steps should be used for this analysis:

i. The radioactive noble gas inventory in the tank, at 100-percent capacity, should be determined based on the maximum expected radioactive source term and the system design capacity using the parameters and principal components considered for pretreatment and collection of waste gas to the waste gas system tanks during normal operation, including anticipated operational occurrences. The assumptions and parameters used in the analysis should be described and justified to include among others: a description of the event leading to the release, release path from the affected system and building to the environment, type of release, duration of the release, basis for the noble gas source term, assumed receptor location, atmospheric dispersion parameters, and any modifying factor specific to the event.

ii. The radiological impact should be determined using the noble gas radionuclide inventory determined step 1 above, total-body dose factor listed as DFB_i in Table B-1 of Regulatory Guide 1.109, in mrem-m^3/pCi-yr, any modifying factor specific to the event, and the relative concentration (X/Q, in s/m^3) at the nearest exclusion area boundary given in Figure 1 of Regulatory Guide 1.24 for ground-level releases.

iii. The dose, summed over all radionuclides, shall not exceed 25 mSv (2.5 rem) for systems designed to withstand explosions and earthquakes, or 1 mSv (0.1 rem) for systems not designed to withstand explosions and earthquakes. Using the same parameters, a corresponding TS can be defined to set a curie limit on a tank, based on the maximum of 25 mSv (2.5 rem) or 1 mSv (0.1 rem) at the nearest exclusion area boundary and same noble gas mixture to assure that the BTP criteria are met at the exclusion area boundary.

B. Charcoal Delay Units: The safety analysis for the radiological consequences of a single failure of an active component in a waste gas system with charcoal delay or decay beds assumes that the charcoal unit is bypassed with a 1-hour release to the environs. The staff considers that either a line bypass valve malfunction, control error, or a charcoal bed bypass will require a remedial action by isolation and that starting an alternate charcoal unit, if available, or reducing reactor power could take up to 2 hours. The following general procedural steps should be used for this analysis:

i. The radioactive noble gas inventory should be determined based on the maximum expected radioactive source term and the system design capacity using the parameters and principal components considered for pretreatment and collection of waste gas to the waste gas charcoal delay or decay beds during normal operation, including anticipated operational occurrences. The assumptions and parameters used in the analysis should be described and justified to include among others: a description of the event leading to the release, release pathway from the affected system and building to the environment, type of release, duration of the release, basis for the noble gas source term after 30-minute decay, assumed receptor location, atmospheric dispersion parameters, and any modifying factor specific to the event.

ii. The radiological impact should be determined using the noble gas radionuclide inventory determined step 1 above, total-body dose factor listed as DFB_i in Table B-1 of Regulatory Guide 1.109, in mrem-m^3/pCi-yr, any modifying factor specific to the event, and the relative concentration (X/Q, in s/m^3) at the nearest exclusion area boundary given in Figure 1 of Regulatory Guide 1.24 for ground-level releases.

iii. The dose, summed over all radionuclides, shall not exceed 1 mSv (0.1 rem). Using the same parameters, a corresponding TS can be defined to set a maximum release rate to the waste gas system of 100 µCi/s per MWt (after 30-minute decay) or use the value of Q_i (in µCi/s) as determined above. Using the lowest of these two values will assure that the BTP criteria are met for an exposure duration of 2 hours at the exclusion area boundary.

C. REFERENCES

1. 10 CFR Part 50.34a, “Design Objective for Equipment to Control Releases of Radioactive Materials in Effluents—Nuclear Power Reactors.”

2. 10 CFR 50.36a, “Technical Specifications on Effluents from Nuclear Power Reactors.”

3. 10 CFR Part 50, Appendix A, General Design Criterion 60, “Control of Releases of Radioactive Materials to the Environment.”

4. 10 CFR Part 100, “Reactor Site Criteria.”

5. Regulatory Guide 1.24 (Safety Guide 24), “Assumptions Used for Evaluating the Potential Radiological Consequences of a Pressurized Water Reactor Radioactive Gas Storage Tank Failure.”

6. Regulatory Guide 1.70, “Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition.”

7. Regulatory Guide 1.98, “Assumptions Used for Evaluating the Potential Radiological Consequences of a Radioactive Offgas System Failure in a Boiling Water Reactor.”

8. Regulatory Guide 1.109, “Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I.”

9. Regulatory Guide 1.143, “Design Guidance for Radioactive Waste Management Systems, Structures and Components Installed in Light-Water-Cooled Nuclear Reactor Power Plants.”

10. NUREG-0016, “Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors (BWRs) (BWR GALE-Code).”

11. NUREG-0017, “Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors (PWRs) (PWR GALE Code).”

12. NUREG-0800, Standard Review Plan, Section 2.3.4, “Short-term Dispersion Estimates for Accidental Atmospheric Releases.”
