**U.S. NUCLEAR REGULATORY COMMISSION**

# STANDARD REVIEW PLAN

**OFFICE OF NUCLEAR REACTOR REGULATION**

## 6.5.2 CONTAINMENT SPRAY AS A FISSION PRODUCT CLEANUP SYSTEM

REVIEW RESPONSIBILITIES

Primary - Organization responsible for review of chemical engineering issues.

Secondary - Organization responsible for review of containment systems.

## I. AREAS OF REVIEW

The containment spray and the spray additive or pH control systems are reviewed to determine the fission product removal effectiveness whenever the applicant claims a containment atmosphere fission product cleanup function for the systems. The following areas of the applicant's safety analysis report (SAR) relating to the fission product removal and control function of the containment spray system are reviewed.

1. Fission Product Removal Requirement for Containment Spray

   Sections of the SAR related to accident analyses, dose calculations, and fission product removal and control are reviewed to establish whether the applicant claims fission product scrubbing of the containment atmosphere for the mitigation of radiological consequences following a postulated accident. This review usually covers sections in SAR Chapters 6 and 15.

2. Design Bases

   The design bases for the fission product removal function of the containment spray system are reviewed to verify that they are consistent with the assumptions made in the accident evaluations in SAR Chapter 15.

3. System Design

The information on the design of the spray system, including any subsystems and supporting systems, is reviewed to familiarize the reviewer with the design and operation of the system. The information includes:

a. The description of the basic design concept; the systems, subsystems, and support systems required to carry out the fission product scrubbing function of the system; and the components and instrumentation employed in these systems.

b. The process and instrumentation diagrams.

c. Layout drawings (plans, elevations, isometrics) of the spray distribution headers.

d. Plan views and elevations of the containment building layout.

4. Testing and Inspections

The system description is reviewed to establish the details of the preoperational test to be performed for system verification and the postoperational tests and inspections to be performed for verification of the continued readiness of the spray system.

5. Technical Specifications

At the operating license stage, the applicant's proposed technical specifications are reviewed to establish permissible outage times and surveillance requirements.

6. Inspection, Test, Analysis, and Acceptance Criteria (ITAAC)

For design certification and combined license reviews, the applicant's proposed information on the ITAAC associated with the systems, structures, and components (SSCs) related to this SRP section is reviewed in accordance with SRP Section 14.3. It is recognized that the review of ITAAC is performed after review of the application against acceptance criteria contained in this SRP section. Furthermore, the ITAAC are reviewed to assure that all SSCs in this area of review are identified and addressed as appropriate in accordance with SRP 14.3.

Review Interfaces:

The primary reviewer also reviews any chemical additive storage requirements, materials compatibility of the long-term containment sump and recirculation spray solutions, and organic material decomposition including formation of organic iodides as part of SRP Sections 6.1.1 and 6.1.2.

In addition, the primary reviewer will coordinate other branches' evaluations that interface with the overall review of the system as follows:

- the heat removal and automatic initiation of the containment spray system and containment sump design (as part of SRP Section 6.2.2),

- the hydrogen mixing function of the containment spray system (as part of SRP Section 6.2.5), and

- the general guidance on the initial plant test program (as part of SRP Section 14.2).

The acceptance criteria and review procedures are given in the referenced SRP sections for the areas of review identified above.

## II. ACCEPTANCE CRITERIA

The acceptance criteria for the fission product cleanup function of the containment spray system are based on meeting the relevant requirements of the following regulations:

A. General Design Criterion (GDC) 41 as it relates to containment atmosphere cleanup systems designed to control fission product releases to the reactor containment following postulated accidents.

B. GDC 42 as it relates to containment atmosphere cleanup systems designed to permit appropriate periodic inspections.

C. GDC 43 as it relates to containment atmosphere cleanup systems designed for appropriate periodic functional testing.

D. 10 CFR 52.47(a)(1)(vi) provides the requirement for ITAAC for design certification reviews.

E. 10 CFR 52.97(b)(1) provides the requirement for ITAAC for combined license reviews.

The specific criteria necessary to meet the relevant requirements of GDC 41, 42, and 43 include:

1. Design Requirements for Fission Product Removal

   The containment spray system should be designed in accordance with the requirements of ANSI/ANS 56.5 (Reference 14), except that the requirements for any spray additive or other pH control system in this reference need not be followed.

   a. System Operation

      The containment spray system should be designed to be initiated automatically by an appropriate accident signal and transferred automatically from the injection mode to the recirculation mode to ensure continuous operation until the design objectives of the system have been achieved. In all cases, the operating period should not be less than 2 hours. Additives to the spray solution may be initiated manually or automatically or stored in the containment sump to be dissolved during the spray injection period.

b. Coverage of Containment Building Volume

To ensure full spray coverage of the containment building volume, the following should be observed:

(1) The spray nozzles should be located as high in the containment building as practicable to maximize the spray drop fall distance.

(2) The layout of the spray nozzles and distribution headers should be such that the cross-sectional area of the containment building covered by the spray is as large as practicable and the spray produced is a nearly homogeneous distribution in the containment building space. Unsprayed regions in the upper containment building and, in particular, an unsprayed annulus adjacent to the containment building liner should be avoided wherever possible.

(3) In designing the layout of the spray nozzle positions and orientations, the effects of the postaccident atmosphere should be considered, including the effects of postaccident conditions that result in the maximum possible density of the containment atmosphere.

c. Promotion of Containment Building Atmosphere Mixing

Because the effectiveness of the containment spray system depends on a well-mixed containment atmosphere, consideration should be given to all design features enhancing postaccident mixing.

d. Spray Nozzles

The nozzles used in the containment spray system should be designed to minimize the possibility of clogging while producing drop sizes effective for iodine absorption. The nozzles should not have internal moving parts such as swirl vanes and turbulence promoters. They should not have orifices or internal restrictions which narrow the flow passage to less than 0.64 cm (0.25 inch) in diameter.

e. Spray Solution

The partition of iodine between liquid and gas phases and retention of iodine in the liquid is enhanced by the alkalinity of the solution. The spray system should be designed so that the spray solution is within material compatibility constraints. Iodine-scrubbing credit is given for spray solutions whose chemistry, including any additives, has been demonstrated to be effective for iodine absorption and retention under postaccident conditions.

f. Containment Sump Solution Mixing

The containment sump should be designed to permit mixing of emergency core cooling system (ECCS) and spray solutions. Drains to the engineered safety features sump should be provided for all regions of the containment which would collect a significant quantity of the spray solution. Alternatively, allowance should be made for “dead” volumes in the determination of the pH of the sump solution and the quantities of additives injected.

g. Containment Sump and Recirculation Spray Solutions

The pH of the aqueous solution collected in the containment sump after completion of injection of containment spray and ECCS water and all additives for reactivity control, fission product removal, or other purposes should be maintained at a level sufficiently high to provide assurance that significant long-term iodine reevolution does not occur. The expected long-term partition coefficient is used to calculate the long-term iodine retention. Long-term iodine retention may be assumed only when the equilibrium sump solution pH, after mixing and dilution with the primary coolant and ECCS injection, is above 7 (Reference 17). This pH value should be achieved by the onset of the spray recirculation mode.

h. Storage of Additives

The design should provide facilities for the long-term storage of any spray additives. These facilities should be designed so that the additives required to achieve the design objectives of the system are stored in a state of continuous readiness whenever the reactor is critical for the design life of the plant. The storage facilities should be designed to prevent freezing, precipitation, chemical reaction, and decomposition of the additives. For sodium hydroxide storage tanks, heat tracing of tanks and piping is required whenever exposure to temperatures below 4.5 °C (40 °F) is predicted. An inert cover gas should be provided for solutions that may deteriorate when exposed to air.

i. Single Failure

The system should be able to function effectively and meet all the criteria in Subsection II with a single failure of an active component in the spray system, in any of its subsystems, or in any of its support systems.

2. Testing

Tests should be performed to demonstrate that the containment spray system, as installed, meets all design requirements for an effective fission-product-scrubbing function. Such tests should include preoperational verification of:

a. freedom of the containment spray piping and nozzles from obstructions,

b. the capability of the system to deliver the required spray flow, and

c. the capability of the system to deliver spray additives (if any are needed) and to achieve the sump solution pH specified in the SAR. For a system such as a gravity feed system, whose performance is sensitive to the as-built piping layout, the testing should be performed at full flow.

3. Technical Specifications

The technical specifications should specify appropriate limiting conditions for operation, tests, and inspections to provide assurance that the system is capable of performing its design function whenever the reactor is critical. These specifications should include:

a. The operability requirements for the system, including all active and passive devices, as a limiting condition for operation (with acceptable outage times). The following items should be specifically included: containment spray pumps, additive pumps (if any), additive mixing devices (if any), valves and nozzles, additive quantity and concentration in additive storage tanks, and nitrogen (or other inert gas) pressure in additive storage tanks.

b. Requirements for periodic inspection and sampling of the contents of additive storage tanks to confirm that the additive quantity and concentrations are within the limits established by the system design.

c. Requirements for periodic testing and exercising of the active components of the system and verification that essential piping and passive devices are free of obstructions.

Acceptable methods for computing fission product removal rates by the spray system are given in Subsection III.4.c, “Fission Product Cleanup Models.”

Although credit is granted for containment spray removal of fission products in the calculations of accident doses, the acceptance criteria of containment leakage in SRP Section 6.2.1.1.A and the acceptance criteria of the engineered safety feature atmosphere cleanup systems in SRP Section 6.5.1 should still be met.

Technical Rationale:

The technical rationale for application of the above acceptance criteria to the containment spray system is discussed as follows.

A. GDC 41 establishes the design requirements for containment atmosphere cleanup systems which function to reduce the concentration and quality of fission products released to the environment following postulated accidents. The radiological consequences of accidents in Chapter 15 of the SAR depend on the quantity and quality of the fission products released from containment. The containment spray system may be relied upon to provide an effective means for removal of iodine and other fission products released to the containment atmosphere following a design-basis accident. Fission product iodine is removed and retained by the spray solution and is unavailable for release to the environment. Compliance with GDC 41 ensures that the containment spray system will accomplish the fission product removal function assumed in the Chapter 15 radiological consequence calculations.

B. GDC 42 establishes the requirements for the inspection of containment atmosphere cleanup systems. The inspection of important components such as pumps, valves, tanks, and flow paths ensures the integrity and capability of the system. The containment spray system may be credited with providing fission product removal and retention following design-basis accidents. Proper operation of the containment spray system depends on the integrity of system pumps, valves, spray nozzles, chemical additive systems, and flow paths. Periodic inspection ensures that these components are capable of performing their design function in the event of an accident.

C. GDC 43 establishes the requirement that the design of the containment atmosphere cleanup systems allow appropriate periodic functional testing. The capability of the containment spray system to perform the function of fission product removal depends on the operability of the pumps, valves, nozzles, chemical additive systems, actuation circuitry, and power supplies for the system. The periodic functional testing of the containment spray system and its components provides assurance of system operability and the capability to fulfill the design function of fission product removal in the event of a design-basis accident.

## III. <u>REVIEW PROCEDURES</u>

The reviewer selects and emphasizes aspects covered by this SRP section as appropriate for a particular plant. The judgment of which areas need to be given attention and emphasis in the review is based on whether the material presented is similar to material recently reviewed for other plants and whether items of special safety significance are involved.

The reviewer determines whether the containment spray system is used for fission product removal purposes. SAR Chapter 15 should be reviewed to establish whether the accident dose evaluations assume a fission product removal function for the containment spray system. If the containment spray system is not used for mitigating radiological dose, no further review is required under this SRP section. If the containment spray system is used for mitigation of radiological doses, then the review of the fission product removal function of the containment spray system follows the procedure and carries out the review responsibilities outlined below.

1. <u>System Design</u>

   Review of the system design includes an examination of the components and design features necessary to carry out the fission product scrubbing function, including:

   a. <u>Spray Solution Chemistry</u> (primary reviewer)

      The reviewer identifies the forms of iodine for which spray removal credit is claimed in the accident analyses (SAR Chapter 15). Containment spray systems may be designed for removal of iodine in the elemental form, in the form of organic compounds, and in the particulate form. The reviewer also determines whether spray removal credit is claimed for other particulate fission products.

      The systems or subsystems required to carry out the fission-product-scrubbing function of the containment spray are identified, for example, the spray system, recirculation system, spray additive system, and borated water source. The design of the systems involved is reviewed in order to:

(1) Ascertain the effectiveness of any chemical additive for iodine removal and retention.

(2) Ascertain that the amount of additive is sufficient to meet the acceptance criteria of Subsection II or that adequate justification is given for the iodine removal and retention effectiveness for the range of concentrations encountered. The concentrations in the storage facility, the chemical addition lines, the spray solution injection, the containment sump solution, and the recirculation spray solution should be examined. The extremes of the additive concentrations should be determined with the most adverse combination of ECCS, spray, and additive pumps (if any) assumed to be operating and considering a single failure of active components in the systems or subsystems.

The reviewer verifies that the stability of the containment spray and sump solutions and the corrosion, solidification, and precipitation behavior of the chemical additives have appropriately been considered for the range of concentrations encountered.

b. System Operation (secondary reviewer)

The time and method of system initiation, including chemical addition, is reviewed to confirm that the acceptance criteria of Subsection II are met. Automatic initiation of spray is reviewed under SRP Section 6.2.2. The system should operate continuously until the fission product removal objectives of the system are met. The reviewer should confirm that all requirements listed in the acceptance criteria, particularly the requirements for spray coverage and sump solution pH, are met during the recirculation phase. Switchover from the injection mode to the recirculation mode following initiation to the spray system operation must be automatic to prevent damage to the spray pumps through loss of suction.

c. Spray Distribution and Containment Mixing (secondary reviewer)

The number and layout of the spray headers used to distribute the spray flow in the containment space are reviewed. The reviewer verifies that the layout of the headers ensures that the spray covers essentially the entire horizontal cross section of the containment building under minimum spray flow conditions. The effect of the postaccident high-temperature and pressure conditions in the containment atmosphere on the spray droplet trajectories should be accounted for in determining the area covered by the spray.

The layout of the containment building is reviewed to determine if any areas of the containment free space are not sprayed. The mixing rate attributed to natural convection between the sprayed and unsprayed regions of the containment building is assumed to be two turnovers of the unsprayed region(s) per hour, provided that adequate flow exists between these regions. The applicant would have to justify other rates. The containment building atmosphere may be considered a single well-mixed space if the spray covers at least 90 percent of the containment building space and if a ventilation system is available for adequate mixing of any unsprayed compartments.

d. Spray Nozzles (secondary reviewer)

The design of the spray nozzles is reviewed to confirm that the spray nozzles are not subject to clogging from debris entering the recirculation system through the containment sump screens.

e. Containment Sump Mixing (primary reviewer)

The mixing of the spray water containing any chemical additive and water without additive (such as spilling ECCS coolant) in the containment sump is reviewed. The reviewer considers areas of the containment building that are exposed to the spray but are without direct drains to the recirculation sump (such as the refueling cavity). The reviewer confirms that the required sump solution concentrations are achieved within the appropriate time intervals. The pH of the sump solution should be reviewed in regard to iodine reevolution, using the criteria given in Subsection II.1.g and the procedure in Subsection III.4.c.(2).

f. Storage of Additives (primary reviewer)

The design of any additive storage tank is reviewed to establish whether heat tracing is required to prevent freezing or precipitation in the tank. The reviewer determines whether an inert cover gas is provided for the tank to prevent reactions of the additive with air such as the formation of sodium carbonate by the reaction of sodium hydroxide and carbon dioxide. Alternatively, the reviewer verifies by a conservative analysis that an inert cover gas is not required.

g. Single Failure (primary reviewer/secondary reviewer)

The system schematics are reviewed by inspection, postulating single failures of any active component in the system, including inadvertent operation of valves that are not locked open. The review is performed with respect to the fission product removal function, considering conditions that could result in fast as well as slow injection of the spray solution.

2. Testing (secondary reviewer)

At the construction permit stage, the containment spray concept and the proposed tests of the system are reviewed to confirm the feasibility of verifying the design functions by appropriate testing. At the operating license stage, the proposed tests of the system and its components are reviewed to verify that the tests will demonstrate that the system, as installed, is capable of performing—within the bounds established in the description and evaluation of the system—all functions essential for effective fission product removal following postulated accidents.

3. Technical Specifications (primary reviewer/secondary reviewer)

The technical specifications are reviewed to verify that the system, as designed, is capable of meeting the design requirements and that it remains in a state of readiness whenever the reactor is critical.

a. Limiting Conditions for Operation

The limiting conditions for operation should require the operability of the containment spray pumps, all associated valves and piping, the appropriate quantity of additives, and any metering pumps or mixing devices.

b. Tests

Preoperational testing of the system, including the additive storage tanks, pumps (if any), piping, and valves, is required. In particular, the preoperational testing should verify that the system, as installed, is capable of delivering a well-mixed solution containing all additives in concentrations that are within the design margins assumed in the dose analyses of SAR Chapter 15.

Periodic testing and exercising of all active components should include the spray pumps, metering pumps (if any), and valves. Confirmation should be made periodically that passive components, such as all essential spray and spray additive piping, and any passive mixing devices are free of obstructions. The contents of the spray additive storage tanks should be sampled and analyzed periodically to verify that the concentrations are within the established limits, that no concentration gradients exist, and that no precipitates have formed.

4. Fission Product Removal Effectiveness (primary reviewer)

The fission product removal effectiveness of the system is calculated to establish the degree of dose mitigation by the containment spray system following the postulated accident. The mathematical model used for this calculation should reflect the preceding steps of the review. The analysis and assumptions are as follows:

a. The amounts of fission products assumed to be released to the containment space are obtained from Regulatory Guide 1.3 (Reference 4), Regulatory Guide 1.4 (Reference 5), or Regulatory Guide 1.183 (Reference 6) as appropriate. The amounts of airborne fission product inside the containment building depend on plateout on interior surfaces, removal by the spray system and other engineered safety features present, radioactive decay, and outleakage from the containment building.

   If the value in Position C.1.a of Regulatory Guides 1.3 (Reference 4) and 1.4 (Reference 5) is used in the calculation of fission product removal, then deposition by plateout, as described in paragraph III.4.c of this SRP section, should not be considered as an additional removal mechanism. Deposition by plateout is already accounted for in the regulatory guide values.

b. The removal of fission products from the containment atmosphere by the spray is considered a first-order removal process. The removal coefficient **8** (lambda) for each of the sprayed regions of the containment is computed. Removal coefficients for time-dependent wall plateout are also calculated. The coefficients for spray removal and wall plateout are summed. The removal lambdas are the input parameters of a computer model for dose calculation.

c. Fission Product Cleanup Models

Based on the information in the SAR, the reviewer estimates how large an area of the interior surfaces of the containment building could be washed by the spray system, the volume flow rate of the system (assuming a single failure), the average spray drop fall height and the mass-mean diameter of the spray drops. The effectiveness of a containment spray system may be estimated by considering the chemical and physical processes that can occur during an accident during which the system operates. Models that consider such process are reviewed on a case-by-case basis.

In the absence of detailed models, reviewers should use the following simplifications. Experimental results (References 16, 18, and 15) and computer simulations of the chemical kinetics (Reference 10) show that an important factor in determining the effectiveness of sprays against elemental iodine vapor is the concentration of iodine in the spray solution. Experiments with fresh sprays with no dissolved iodine were found to be quite effective at scrubbing elemental iodine at a pH as low as 5 (References 18 and 15). Solutions with dissolved iodine such as the sump solutions that recirculate after an accident may revolatilize iodine if the solutions are acidic (References 17 and 10). Chemical additives in the spray solution have no significant effect on aerosol particle removal because this removal process is largely mechanical.

(1) <u>Elemental iodine removal during spraying of fresh solution</u>

During injection, the removal of elemental iodine by wall deposition can be estimated by the equation

$$\lambda_w = K_w A / V$$

Where, $\lambda_w$ is the first-order removal coefficient by wall deposition, A is the wetted-surface area, V is the containment building net free volume, and $K_w$ is a mass-transfer coefficient. All available experimental data are conservatively bounded if $K_w$ is taken to be 4.9 meters per hour (Reference 7, page 17).

During injection, the effectiveness of the spray against elemental iodine vapor is chiefly determined by the rate at which fresh-solution surface area is introduced into the containment building atmosphere. The rate of solution surface created per unit gas volume in the containment atmosphere can be estimated as 6F/VD, where F is the volume flow rate of the spray pump, V is the containment building net free volume, and D is the mass-mean diameter of the spray drops. The first-order removal coefficient by spray, $\lambda_s$, may be taken to be

$$\lambda_s = \frac{6 K_g T F}{V D}$$

where $K_g$ is the gas-phase mass-transfer coefficient and T is the time of fall of the drops, which may be estimated by the ratio of the average fall height to the terminal velocity of the mass-mean drop (Reference 20). This equation represents a first-order approximation if a well-mixed droplet model is used for the spray efficiency. The equation is valid for $\mathbf{8}_s$ values equal to or greater than 10 per hour. $\mathbf{8}_s$ must be limited to 20 per hour to prevent extrapolation beyond the existing data for boric acid solutions with a pH of 5 (References 16 and 15). For $\mathbf{8}_s$ values less than 10 per hour, analyses using a more sophisticated expression are recommended.

(2) Elemental iodine removal during recirculation of sump solution

The sump solution at the end of injection is assumed to contain fission products washed from the reactor core and removed from the containment atmosphere. If the solution is acidic, the radiation absorbed by the sump solution generates enough hydrogen peroxide (Reference 19) to react with both iodide and iodate ions and make elemental iodine reevolution possible (Reference 17). For sump solutions having pH values less than 7, molecular iodine vapor should be conservatively assumed to evolve into the containment atmosphere (Reference 12).

Information on the partition coefficients for molecular iodine is given in References 12, 9, and 8. The equilibrium partitioning of iodine between the sump liquid and the containment atmosphere is examined for the extreme additive concentrations reviewed in Section III.1.a.(2), combined with the range of possible temperatures in the containment atmosphere and the sump solution. The reviewer should consider all known sources and sinks of acids and bases in a postaccident containment environment (e.g., alkaline earth and alkali metal oxides, nitric acid generated by radiolysis of nitrogen and water, alkaline salts or lye additives). The minimum iodine partition coefficient determined for these conditions forms the basis of the ultimate iodine decontamination factor in the staff's analysis (described in Subsection III.4.d).

(3) Organic iodides

It is conservative to assume that organic iodides are not removed by either spray or wall deposition. Radiolytic destruction of iodomethane may be modeled, but the model must also consider radiolytic production (Reference 11). Engineered safety features designed to remove organic iodides are reviewed on a case-by-case basis.

(4) Particulates

The first-order removal coefficient for particulates, **8**$_p$, can be determined by the method described in Reference 13, or estimated by:

$$\lambda_p = \frac{3hFE}{2VD}$$

where h is the spray drop fall height, V is the containment building net free volume, F is the spray flow, and E/D is the ratio of a dimensionless collection efficiency E to the average spray drop diameter D. Since the removal of particulate material chiefly depends on the relative sizes of the particles and the spray drops, it is convenient to combine parameters that cannot be known (Reference 7). It is conservative to assume E/D to be 10 per meter initially (i.e., 1% efficiency for spray drops of 1 millimeter in diameter), changing abruptly to 1 spray drop per meter after the aerosol mass has been depleted by a factor of 50 (i.e., 98% of the suspended mass is 10 times more readily removed than the remaining 2%).

d. The iodine decontamination factor, DF, is defined as the maximum iodine concentration in the containment atmosphere divided by the concentration of iodine in the containment atmosphere at some time after decontamination. The DF for the containment atmosphere achieved by the containment spray system is determined by the following equation (Reference 14):

$$DF = 1 + \frac{V_s H}{V_c}$$

where H is the effective iodine partition coefficient, $V_s$ is the volume of liquid in containment sump and sump overflow, and $V_c$ is the containment building net free volume less $V_s$.

The effectiveness of the spray in removing elemental iodine is presumed to end when the maximum elemental iodine DF is reached. This value cannot exceed 200. Because the removal mechanisms for organic iodides and particulate iodines are significantly different from and slower than the mechanisms for elemental iodine, there is no need to limit the DF for organic iodides and particulate iodines.

For reviews under 10 CFR Part 52, the reviewer should follow the above procedures to verify that the design set forth in the safety analysis report, and as applicable, site interface requirements, and combined license action items, meet the acceptance criteria. Following this review, SRP Section 14.3 should be followed for the review of Tier I information for the design, including the site parameters, interface criteria, and ITAAC.

## IV. EVALUATION FINDINGS

The reviewer verifies that the applicant has provided sufficient information and that the review and calculations support conclusions of the following type to be included in the staff's safety evaluation report. The reviewer also states the bases for those conclusions.

> The concept on which the proposed system is based has been demonstrated to be effective for fission product removal and retention under postaccident conditions. The proposed system design is an acceptable application of this concept. The system provides suitable redundancy in components and features so that its safety function can be accomplished assuming a single failure.
>
> The proposed preoperational tests, postoperational testing and surveillance, and proposed limiting conditions for operation of the spray system provide adequate assurance that the fission product scrubbing function of the containment spray system will meet or exceed the effectiveness assumed in the accident evaluation.
>
> The staff concludes that the containment spray system is acceptable as a fission product cleanup system and meets the requirements of GDC 41 with respect to the iodine removal function following a postulated loss-of-coolant accident, GDC 42 with respect to the periodic inspection of the system, and GDC 43 with respect to the periodic testing of the system.

For design certification and combined license reviews, the findings will also summarize (to the extent that the review is not discussed in other safety evaluation report sections) the staff's evaluation of the ITAAC, and as applicable, design acceptance criteria (DAC), interface requirements, and combined license action items relevant to this SRP section.

## V. IMPLEMENTATION

The following guidance is for applicants and licensees concerning the staff's plans for using this SRP section.

The staff will use this SRP section in performing safety evaluations of design certifications and license applications submitted by applicants pursuant to 10 CFR Parts 50 or 52. Except when the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the staff will use the method described herein to evaluate conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed 6 months or more after the date of issuance of this SRP section.

## VI. REFERENCES


1. 10 CFR Part 50, Appendix A, General Design Criterion 41, "Containment Atmosphere Cleanup."

2. 10 CFR Part 50, Appendix A, General Design Criterion 42, "Inspection of Containment Atmosphere Cleanup Systems."

3. 10 CFR Part 50, Appendix A, General Design Criterion 43, "Testing of Containment Atmosphere Cleanup Systems."

4. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.3, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss-of-Coolant Accident for Boiling Water Reactors."

5. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.4, "Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss-of-Coolant Accident for Pressurized Water Reactors."

6. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.183, "Alternate Radiological Source Terms for Design Basis Accidents at Nuclear Power Reactors."

7. A.K. Postma, R.R. Sherry, and P.S. Tam, "Technological Bases for Models of Spray Washout of Airborne Contaminants in Containment Vessel," NUREG/CR-0009, October 1978.

8. J.T. Bell, D.O. Campbell, M.H. Lietzke, D.A. Palmer, and L.M. Toth, "Aqueous Iodine Chemistry in LWR Accidents:  Review and Assessment," NUREG/CR-2493, April 1982.

9. J.T. Bell, M.H. Lietzke, and D.A. Palmer, "Predicted Rates of Formation of Iodine Hydrolysis Species at pH Levels, Concentrations, and Temperatures Anticipated in LWR Accidents," NUREG/CR-2900, October 1982.

10. M.F. Albert, "The Absorption of Gaseous Iodine by Water Droplets," NUREG/CR-4081, July 1985.

11. E.C. Beahm, W.E. Shockley, and O.L. Culberson, "Organic Iodide Formation Following Nuclear Reactor Accidents," NUREG/CR-4327, December 1985.

12. E.C. Beahm, W.E. Shockley, C.F. Weber, S.J. Wisbey, and Y-M. Wang, "Chemistry and Transport of Iodine in Containment," NUREG/CR-4697, October 1986.

13. D.A. Powers, S.B. Burson, "A Simplified Model of Aerosol Removal by Containment Sprays," NUREG/CR-5966, June 1993.

14. ANSI/ANS 56.5-1979 (reaffirmed 1987), "PWR and BWR Containment Spray System Design Criteria," American National Standards Institute.

15. A.K. Postma, L.F. Coleman, and R.K. Hilliard, "Iodine Removal from Containment Atmospheres by Boric Acid Spray," Pacific Northwest Laboratories report, BNP-100, July 1970.

16. R.K. Hilliard, A.K. Postma, J.D. McCormack, L.F. Coleman, and C.E. Lunderman, "Removal of Iodine and Particles From Containment Atmospheres - Containment Systems Experiments," Pacific Northwest Laboratories report, BNWL-1244, February 1970.

17. C.C. Lin, “Chemical Effects of Gamma Radiation on Iodine in Aqueous Solutions,” *Journal of Inorganic and Nuclear Chemistry*, 42, pp. 1101-1107.

18. S. Barsali, F. Bosalini, F. Fineschi, B. Guerrini, S. Lanza, M. Mazzini, and R. Mirandola, “Removal of Iodine by Sprays in the PSICO 10 Model Containment Vessel,” *Nuclear Technology*, 23, pps. 146-156 (August 1974).

19. A.O. Allen, “The Radiation Chemistry of Water and Aqueous Solutions,” Van Nostrand, New York (1961).

20. G.B. Wallis, “The Terminal Speed of Single Drops or Bubbles in an Infinite Medium,” *International Journal of Multiphase Flow*, 1, pps. 491-511 (1974).

21. NUREG-1465, “Accident Source Terms for Light-Water Nuclear Power Plants,” June 1992.

## Appendix: Description of Changes

The following summarizes the changes in Revision 3, dated December 2005. Minor editorial changes and formatting changes are not identified by side bars.

1. Review Responsibilities:
   a. Editorial changes made to reflect the review responsibilities as functions. The cognizant organization is maintained separately from the SRP. Similarly, references to other SRP sections no longer identify the specific branch.

2. Areas of Review:
   a. Added ITAAC as an area of review

   b. Added "automatic initiation of spray" under SRP Section 6.2.2. as a review interface.

   c. Added initial plant test program (as part of SRP 14.2) as a review interface.

   d. Editorial change to revise the review interface section to identify SRP sections and functions and not individual organizations.

3. Acceptance Criteria:
   a. Added citations for ITAAC

   b. Editorial change to make the citation of references consistent with the SRP-UDP specified format.

   c. Editorial change to add reference to ANSI/ANS 56.5

   d. Editorial change to add clarity to "retention of iodine in the liquid"

   e. Technical rationale associated with GDC 41, 42, and 43 was formulated and added to this section in accordance with the specified SPR-UDP format.

4. Review Procedures:
   a. A new reference was added to the current Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors."

   b. A new paragraph was added to the Review Procedures to address NRC staff concerns regarding double counting of fission product removal by plateout when using Regulatory Guides 1.3 or 1.4 in conjunction with the procedures in the SRP.

   c. Draft NUREG-1465 was introduced in the 1996 draft SRP to specifically address the CE System 80+ and the GE ABWR. This reference is being removed because the model, which is now applicable to other designs, is captured in RG 1.183. Note: There was a comment received on the 1996 draft SRP section related to this reference, specifically on the use of "draft" NUREG and its applicability to other designs. Regulatory Guide 1.183 encompasses this reference; therefore the reference was deleted.

d. NUREG/CR-5966 was introduced in the1996 draft SRP. This reference was in draft SRP and it was moved to section III.4.c.(4), “Particulates” as an acceptable method for determining first-order iodine removal coefficient, $\mathbf{8}_{p.}$”

e. Provide administrative limit for the maximum allowable decontamination factor in the post-LOCA containment environment.

f. Added paragraph on implementing of 10 CFR 52. A standard paragraph was added to address Review Procedures in design certification reviews.

5. Evaluation Findings:
   Added paragraph on Applicability of 10 CFR 52 for design certification reviews.

6. Implementation:
   Editorial changes capturing applicability to Part 52 and time-frame in which SRP update goes into effect.

7. References:
   a. Renumbered per SRP update format.

   b. Added 3 new references as described above.

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11. ABSTRACT *(200 words or less)*

This is a revision to the Standard Review Plan that includes guidance related to 10 CFR Part 52 applicability, general formatting and editorial changes, and updated references.

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