U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

6.5.4 ICE CONDENSER AS A FISSION PRODUCT CLEANUP SYSTEM

REVIEW RESPONSIBILITIES

Primary - Materials and Chemical Engineering Branch (EMCB)[1]

Secondary - Plant Systems Branch (SPLB)[2]
Emergency Preparedness and Radiation Protection Branch (PERB)[3]

I. AREAS OF REVIEW

The ice condenser system is reviewed to determine the fission product removal effectiveness whenever the applicant claims a containment atmosphere fission product cleanup function for the system.[4]

The following areas of the applicant's safety analysis report (SAR) are reviewed:

1. Fission Product Removal Requirement for the Ice Condenser System

   Sections of the SAR related to accident analyses, dose calculations, and fission product removal and control are reviewed to establish whether or not fission product scrubbing of the containment atmosphere is required for mitigation of radiological consequences following a postulated accident. This review usually covers SAR Chapters 6 and 15.

2. Design Bases

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

The methodology used in this SRP section is not intended for containment venting evaluation. Containment venting will be considered in the evaluation of ice condensers as fission product cleanup systems when the Commission approves the final guidance on containment venting.

3. System Design

The information on the design of the ice condenser system important to its fission product removal function is reviewed to familiarize the reviewer with the design and post-accident functioning of the ice condenser. The information includes:

a. The basic design concept, the systems, subsystems, and support systems required to carry out the fission product cleanup function of the ice condenser.

b. Descriptions and figures from the SAR related to the time required to establish a steady flow of an air-steam-iodine mixture through the ice beds, and the time of meltout of the ice beds.

4. Testing and Inspections

The details of the applicant's proposed preoperational test to be performed for system verification and operational tests and inspections to verify the continued status of readiness of the iodine removal capacity of the ice condenser system are reviewed.

5. Technical Specifications

~~At the operating license stage, t~~The[5] applicant's proposed technical specifications are reviewed to establish surveillance requirements for the proposed chemical additive concentrations in the ice.

Review Interfaces:[6]

The EMCB also performs the following review under the SRP section indicated:

1. The upper compartment spray system for ice condenser plants is reviewed under SRP Section 6.5.2 Containment Spray Systems.[7]

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

1. The pressure suppression function of the system is reviewed by the Containment Systems and Severe Accident Branch (SCSB)[8] under SRP Sections 6.2.1 and 6.2.1.1.B.

2. The assumptions and methods for calculating the radiation environment for ice condenser containments following a design basis LOCA, to ensure environmental qualification, are reviewed by Plant Systems Branch (SPLB) under SRP Section 3.11.[9]

3. In addition, SRP Section 6.5.1 contains the review performed by the SPLB addressing the engineered safety feature atmosphere cleanup systems, applicable portions of which must be met by the ice condenser systems.[10]

For those areas of review identified above the acceptance criteria and their methods of application are contained in the referenced SRP sections of the corresponding primary branch.[11]

II. ACCEPTANCE CRITERIA

The acceptance criteria for the fission product cleanup function of the ice condenser system are based on the relevant requirements of the following regulations:

A. General Design Criterion 41~~ (Ref. 1)~~[12] as it relates to containment atmosphere cleanup systems being designed to control fission products that may be released to the reactor containment following postulated accidents.

B. General Design Criterion 42~~ (Ref. 2)~~[13] as it relates to containment atmosphere cleanup systems being designed to permit appropriate periodic inspections.

C. General Design Criterion 43~~ (Ref. 3)~~[14] as it relates to containment atmosphere cleanup systems being designed to permit appropriate periodic functional testing.

Specific criteria necessary to meet the relevant requirements of General Design Criteria 41, 42, and 43 include:

1. The ice condenser system is acceptable for elemental iodine removal if the ice contains a quantity of the proposed chemical additive sufficient to ensure that the pH of the post-accident recirculating solution is above 7 (Reference~~. 4~~ 7)[15].

2. The technical specifications are acceptable if they specify appropriate limiting conditions for operations, tests, and inspections to ensure that the system is capable of its design function whenever the reactor is critical. These specifications should include: the operability requirements for the system, and periodic sampling and testing requirements of the ice to confirm that the concentration of the chemical additive in the ice melt is within the limits established by the system design.

While granting credit for ice condenser scrubbing of fission products in the calculations of accident doses, the acceptance criteria of containment leakage in SRP Section 6.2.1.1.B and the acceptance criteria of the engineered safety feature atmosphere cleanup systems in SRP Section 6.5.1 should still be met.

Technical Rationale:[16]

The technical rationale for application of the above acceptance criteria to the ice condenser as a fission product cleanup system is discussed in the following paragraphs.

1. GDC 41 establishes requirements regarding the containment atmosphere cleanup systems being designed to control fission products released into the reactor containment to reduce the concentration and quality of fission products released to the environment following postulated accidents. The ice condenser systems are relied upon, in part, to provide an effective means for removal of fission product iodine released to the reactor containment during the design basis accident. Requiring the ice condenser system ice to contain a quantity of the proposed chemical additive sufficient to ensure that the pH of the post-accident recirculating solution is above 7 enhances the dissolution and retention of iodine in the ice melt. Tests have shown an alkaline additive in the ice, such as sodium tetraborate, improves the dissolution and retention of iodine in the ice melt through hydrolysis reactions (Reference 8). The deposition of volatile iodine on the surfaces of the ice provides a means of iodine removal that is highly efficient in a steam condensing environment. Ice without any additives has been shown to not function as well as ice containing an alkaline additive. In addition, ensuring the pH of the post-accident recirculating solution is above 7 ensures that the iodine remains fixed in the recirculation water. Under acid conditions (pH less than 7), the iodine is completely dissolved but will be available for stripping by air flow, resulting in a refluxing action that returns the iodine to the containment atmosphere. Enhancing dissolution and retention of radioactive iodine in the ice melt limits the quantity of radioactive iodine available in the containment atmosphere, thereby mitigating the potential release of fission products to the environment. Therefore, requiring compliance with GDC 41 for the ice condenser ensures that it will provide an effective method of controlling volatile fission products released to the containment atmosphere, mitigating the potential release of fission products and minimizing the potential dose to the general public during and following postulated accidents.

2. GDC 42 establishes requirements regarding the periodic inspection of containment atmosphere cleanup systems. The ice condenser systems are one of the containment atmosphere cleanup systems relied upon to entrain volatile fission products during and after the design basis accident. Inspection of important components for the ice condenser systems assures the integrity and capability of the system to perform its design function. Assuring the integrity and capability of the ice condenser systems through inspections of important components improves plant safety by ensuring that the system will perform as assumed in the design basis accident analysis during and after postulated accidents. Operability of the ice condenser systems during and after postulated accidents minimizes the potential release of volatile fission products, thereby minimizing the potential dose to the general public.

3. GDC 43 establishes requirements regarding the design of the containment atmosphere cleanup systems to permit appropriate periodic functional testing. The allowance in the design for periodic functional testing ensures the operability and performance of the ice condenser system can be verified. Ensuring Operability and performance of the ice

condenser system assures that the system will be capable of performing its design function within the limits of the safety analysis. The ice condenser functions to absorb and retain volatile fission products during and after a design basis accident. Therefore, ensuring operability and performance of the ice condenser systems through functional testing minimizes the potential release of volatile fission products, thereby minimizing the potential dose to the general public.

III. REVIEW PROCEDURES

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

The first step in the review of the fission product removal function of the ice condenser system is to determine whether the ice condenser system is used for mitigating radiological consequences. Based on the information in Chapter 15 of the SAR the reviewer determines whether a dose reduction credit was assumed for the ice condenser. If no fission product removal credit is assumed in the accident analysis, no further review is required under this SRP section.

If the ice condenser system is used for iodine removal, the iodine removal effectiveness of the ice condenser system is reviewed. The review includes the following:

1. System Design and Evaluation

   a. Chemical Additive

      To achieve long-term iodine retention, chemical compounds are usually added to the ice for adjusting the pH of the post-accident recirculating fluid when the ice melt is diluted and mixed with the containment sump solution, primary coolant, emergency core cooling system water, and containment spray solution, if any.

      Long-term retention of iodine may be assumed only when the recirculating fluid meets the pH range specified in the acceptance criteria of this SRP section. For ice condenser systems similar to those of the D. C. Cook and Sequoyah plants (with a steady-state flow rate of approximately 18.9 m^3/s (40,000 cfm~~,~~[17]), an efficiency of 30% per pass for elemental iodine is assigned. The system is considered ineffective for organic iodide and particulate iodine removal. For designs different from those of D. C. Cook and Sequoyah plants, reconsideration of the system efficiency is required. The reviewer should consult References 5, 6, and ~~7~~8[18] when evaluating the iodine removal efficiency of the ice condenser. Reference ~~6~~5[19], in particular, should be considered if time-dependent removal efficiencies are used. Reference ~~8~~4[20] provides useful background information. Removal efficiencies of time-varying air-steam mixtures or flow rates should conservatively account for factors that affect their time dependencies (e.g., fan capacity, fan activation time, natural circulation rates).

b. Iodine Scrubbing Function

It is not feasible to specify the exact time of the fission product release following a postulated loss-of-coolant accident. In addition, the flow rates and air-steam fractions of the flow through the ice condenser vary significantly during and immediately following the accident. For radiological dose calculations, therefore, the following conservative assumptions are made:

(1) If a 30% iodine removal efficiency is used, the iodine removal effectiveness of the ice condenser commences with the establishment of a steady-state air-steam flow. Steady flow is assumed to start with the operation of the postaccident mixing fans. A single failure of one of the fans is assumed.

(2) The initial concentration of iodine is assumed uniform throughout the entire containment.

(3) The effectiveness of the ice condenser as an iodine removal system is assumed to cease with the meltout of the first ice bed.

c. Upper Compartment Spray Credit

Plants designed with an upper compartment spray system may claim credit for such. Containment spray systems are reviewed under SRP Section 6.5.2.

d. Evaluation

The iodine removal effectiveness and the degree of iodine dose mitigation by the ice condenser for the loss-of-coolant accident are determined using the air-steam fan flow rate and the assumptions in Subsections III.1.a and III.1.b.

2. Technical Specifications

The technical specifications are reviewed to assure that they require periodic inspections and sampling of the ice in order to confirm the continued state of readiness of the system, i.e., the system meets the chemistry requirements specified in the acceptance criteria of this SRP section.

For standard design certification reviews under 10 CFR Part 52, the procedures above should be followed, as modified by the procedures in SRP Section 14.3 (proposed), to verify that the design set forth in the standard safety analysis report, including inspections, tests, analysis, and acceptance criteria (ITAAC), site interface requirements and combined license action items, meet the acceptance criteria given in subsection II. SRP Section 14.3 (proposed) contains procedures for the review of certified design material (CDM) for the standard design, including the site parameters, interface criteria, and ITAAC.[21]

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided by the applicant and that the review and calculations support conclusions of the following type, to be included in the staff's safety evaluation report:

> The staff has reviewed the fission product scrubbing function of the ice condenser and finds that the ice will reduce the elemental iodine concentration of the steam-air mixture flowing through the ice beds following a loss-of-coolant accident. The staff estimates an elemental iodine removal efficiency of ___ % per pass during the time period starting at ___ minutes after the accident and ending at ___ minutes. The concept upon which the proposed system is based has been demonstrated to be effective for iodine sorption and retention under post-accident conditions. The system is largely passive in nature, but the active components are suitably redundant so that its safety function can be accomplished assuming a single failure. The applicant's proposed program for preoperational and periodic surveillance tests will ensure a continued state of readiness for the iodine removal function of the ice condenser system.
>
> The staff concludes that the ice condenser as a fission product cleanup system is acceptable and meets the requirements of General Design Criterion 41 with respect to the iodine removal function following a postulated loss-of-coolant accident, General Design Criterion 42 with respect to the capability for periodic inspection of the system, and General Design Criterion 43 with respect to the capability for periodic testing of the system.

For design certification 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 inspections, test, analyses, and acceptance criteria (ITAAC), including design acceptance criteria (DAC), site interface requirements and combined license action items that are relevant to this SRP section.[22]

V. IMPLEMENTATION

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

This SRP section will be used by the staff when performing safety evaluations of license applications submitted by applicants pursuant to 10 CFR 50 or 10 CFR 52.[23] Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

The provisions of this SRP section apply to reviews of applications docketed six months or more after the date of issuance of this SRP section.[24]

~~Implementation of the acceptance criteria in subsection II and the review procedures in subsection III is as follows:~~

~~1. Operating plants and applicants for operating licenses pending at the date of issue of this revision need not comply with the provisions of this revision, but may do so voluntarily.~~

~~2. Future applicants will be reviewed according to the provisions of this revision.~~[25]

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."

~~8~~4.[26] R. A. Soldano, "Basic Properties of Ice as Related to the Performance of Ice Condensers", U.S. Atomic Energy Commission Report, WASH-1232, September 1972.

~~6~~5. Ice Condenser Containment Model; memo from R. Zavadoski to files, U.S. Atomic Energy Commission, June 19, 1972.[27]

~~7~~6. Review of Topical Report WCAP-7426; memo from H. R. Denton to R. C. DeYoung, U.S. Atomic Energy Commission, November 24, 1972.[28]

~~4~~7. C. C. Lin, "Chemical Effects of Gamma Radiation on Iodine in Aqueous Solutions," Journal of Inorganic and Nuclear Chemistry, 42, pages 1101-1107 (1980).

~~5~~8. D. D. Malinowski and L. F. Picone, "Iodine Removal in the Ice Condenser System," Nuclear Technology, 10(4), pages 428-435 (1971).

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Attachment A - Proposed Changes in Order of Occurrence

Item numbers in the following table correspond to superscript numbers in the redline/strikeout copy of the draft SRP section.

Item	Source	Description
1.	Current PRB names and abbreviations.	Editorial change made to reflect current PRB names and responsibilities for this SRP section.
2.	Current PRB names and abbreviations.	Editorial change made to reflect current PRBs assigned secondary review responsibility for this section.
3.	Current PRB names and abbreviations.	Editorial change made to reflect current PRBs assigned secondary review responsibility for this section.

Item	Source	Description
4.	NOTE to reviewers regarding source term implications and the disposition of PI-24250.	In the SRM for SECY 93-087, the Commission directed the NRC staff to modify regulations, regulatory practices and the review process, as appropriate, to reflect the information resulting from source term research. Section 15A.3.1 of the Final SER for the CE80+ documents a staff review of the form of iodine released from the core during an accident as predicted in recent source term research. In Regulatory Guide 1.4, the chemical form of iodine is specified to be predominantly elemental iodine (91 percent), with 5 percent assumed to be particulate iodine. However, in draft NUREG-1465, "Accident Source Terms for Light-Water Nuclear Power Plants," the staff concluded that iodine entering the containment from the reactor core is composed of at least 95 percent cesium iodide in particulate form with no more than 5 percent as iodine (I) and hydrogen iodide (HI). Once within the containment, highly soluble cesium iodide will readily dissolve in water pools forming iodide in solution and will deposit onto the interior surfaces. The staff also indicated that without pH control, large fractions of iodine dissolved in water pools in ionic form will be converted to elemental iodine and will be released into the containment atmosphere if the pH is less than 7. On the other hand, if the pH is maintained at 7 or above, very little (less than 1 percent) of the dissolved iodine will be converted to elemental iodine. The SRP review procedures (step III.1.a) indicate that the ice condenser system is considered ineffective for organic iodide and particulate iodine removal. No changes were initiated to this SRP Section based upon the information provided in the Final SER for the CE 80+ because the information was from a draft NUREG-1465 and no final staff position or guidance is presented. However, the staff should consider the implications of the new source term research on the effectiveness of the ice condenser as a fission product removal system. The evaluation should consider the change in fraction of particulate iodine released to the containment atmosphere and the fact that highly soluble cesium iodide (particulate) will readily dissolve and only a small fraction will be converted to elemental iodine if the pH is maintained at 7 or above. The acceptance criteria for the SRP already states that the ice condenser system is acceptable for elemental iodine removal if the ice contains a quantity of the proposed chemical additive sufficient to ensure that the pH of the post-accident recirculating solution is above 7. The review conclusions documented in the CE80+ FSER are consistent with this acceptance criteria.

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Attachment A - Proposed Changes in Order of Occurrence

Item	Source	Description
5.	10 CFR 52 applicability related change.	The Area of Review specifying at what stage the technical specifications are reviewed was deleted. This was done because the sequence of application review is not what is being reviewed, but rather, that the requirements for the proposed chemical additive concentrations in the ice is contained in the technical specifications. The proper time for this review is controlled by other methods and eliminating the reference to a specific stage in the review ensures that all reviewers, including those performing evolutionary reactor reviews, include this in their areas of review.
6.	SRP-UDP format item.	Revised the review interface section of the Areas of Review to be consistent with the SRP-UDP required format which uses a number/paragraph format to distinguish individual reviews performed by this and other PRBs.
7.	Editorial change to make the areas of review reflect the existing review procedures.	Added an Areas of Review (review interface) to SRP section 6.5.2 to address the upper compartment spray system for ice condenser containments to be consistent with the Review Procedures.
8.	PRB names and Abbreviations.	Added the PRB name and abbreviation for SRP sections 6.2.1 and 6.2.1.1.B contained in the existing review interface.
9.	Editorial change to make the Areas of Review reflect the limitations of the Review Procedures.	Added an Areas of Review (review interface) to SRP section 3.11 to address the radiation environment for ice condenser containments to be consistent with the review interfaces documented in the Review Procedures.
10.	Editorial change to make the Areas of Review reflect the existing Acceptance Criteria.	Added an Areas of Review (review interface) to SRP Section 6.5.1 to address ESF atmosphere cleanup aspects for ice condenser containments to be consistent with the review interface documented in the Acceptance Criteria.
11.	Editorial.	Added a standard review interface closing paragraph referencing the reviewer to the identified SRP sections for the acceptance criteria and their methods of application. This paragraph is consistent with the SRP-UDP standard format.
12.	SRP-UDP format item.	Format change to make the citation of references consistent with the SRP-UDP format requirements. The citation of reference for the GDCs in the acceptance criteria subsection is not required.
13.	SRP-UDP format item.	Format change to make the citation of references consistent with the SRP-UDP format requirements. The citation of reference for the GDCs in the acceptance criteria subsection is not required.

Item	Source	Description
14.	SRP-UDP format item.	Format change to make the citation of references consistent with the SRP-UDP format requirements. The citation of reference for the GDCs in the acceptance criteria subsection is not required.
15.	SRP-UDP format item.	Format change to make the citation of references consistent with the SRP-UDP format requirements. Revised the reference number to reflect the reordering of the references in the Reference subsection.
16.	SRP-UDP format item.	Technical Rationale were developed and added for the following Acceptance Criteria: GDCs 41, 42 and 43. The technical rationale for specific criteria necessary to meet the relevant requirements of the above GDCs was incorporated in the discussion for the GDCs. The SRP-UDP requires that technical rationale be developed for the Acceptance Criteria.
17.	NRC Metrication Policy.	Converted 40,000 cfm to 18.9 m^3/sec (the metric equivalent) and reformatted to be consistent with NRC metrication policy.
18.	Editorial	Renumbered the reference citation to be consistent with the reordered references in Subsection VI. "REFERENCES."
19.	Editorial	Renumbered the reference citation to be consistent with the reordered references in Subsection VI. "REFERENCES."
20.	Editorial	Renumbered the reference citation to be consistent with the reordered references in Subsection VI. "REFERENCES."
21.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
22.	10 CFR 52 applicability related change.	A paragraph was added to the Evaluation Findings to address design certification review findings in accordance with 10 CFR 52. This paragraph is consistent with the format required by the SRP-UDP and with the review process described in 10 CFR 52.
23.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard sentence to address application of the SRP section to reviews of applications filed under 10 CFR Part 52, as well as Part 50.
24.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
25.	SRP-UDP Guidance, Editorial	Removed paragraph that is redundant to new standard implementation paragraph.
26.	SRP-UDP format item, Reformat References	Reordered and renumbered References 4-8 in accordance with SRP-UDP format guidance.

Item	Source	Description
27.	Reference Verification.	A copy of this reference could not be obtained and no other regulatory citation of this document could be located. Therefore, PNL was unable to complete verification for this reference.
28.	Reference Verification.	A copy of this reference could not be obtained and no other regulatory citation of this document could be located. Therefore, PNL was unable to complete verification for this reference.

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Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
	No Integrated Impacts were incorporated in this SRP Section.	