U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

2.4.7 ICE EFFECTS

REVIEW RESPONSIBILITIES

Primary - ~~Hydrologic & Geotechnical Engineering Branch (HGEB)~~Civil Engineering and Geosciences Branch (ECGB)[1]

Secondary - None

I. AREAS OF REVIEW

The hydrometeorologic design basis is developed in this section of the safety analysis report (SAR) to ~~assure~~ ensure[2] that safety-related facilities and water supply are not affected by ice flooding or blockage. The areas of review include:

1. The regional history and types of historical ice accumulations (i.e., ice jams, wind-driven ice ridges, floes, etc.).

2. The potential for ice-produced forces on, or blockage of, safety-related facilities.

3. The potential effects of ice-induced high or low flow levels on safety-related facilities and water supplies.

If there is evidence of potential structural effects, ~~the Structural Engineering Branch (SEB) will be requested by HGEB to~~ ECGB will[3] ascertain whether these effects are properly considered in the structural design basis for the plant.

Review Interfaces[4]

~~similarly, i~~If[5] there is evidence of potential mechanical effects, the Mechanical Engineering Branch ~~(MEB)~~(EMEB)[6] and the ~~Auxiliary~~ Plant Systems Branch (~~ASB~~ SPLB)[7] will be requested by ~~HGEB~~ ECGB[8] to ascertain whether these effects are properly considered in the mechanical design basis for the plant.

The staff will develop a position based on the analysis; resolve, if possible, differences between the applicant's and staff's estimates of ice effects; and write the safety evaluation report (SER) input accordingly.

For those areas of review identified as part of the primary responsibility of other branches, the acceptance criteria and methods of application are contained in the referenced Standard Review Plan (SRP) section.[9]

II. ACCEPTANCE CRITERIA

Acceptance criteria for this SRP section are based on meeting the requirements of the following regulations:

1. 10 CFR Part 50, ~~50.55a~~ Appendix A, General Design Criterion 1 (GDC 1)[10] as it requires structures, systems, and components to be designed and constructed to quality standards commensurate with the importance of the safety function to be performed.

2. General Design Criterion 2 (GDC 2) as it requires structures, systems, and components important to safety to be designed to withstand the effects of natural phenomena.

3. 10 CFR Part 100 as it relates to identifying and evaluating hydrologic features of the site.

Appropriate sections of the following documents are used by the staff to ~~assure~~ ensure that the Commission regulations identified above are met:

Regulatory Guide 1.59[11] provides guidance for developing the hydrometeorologic design basis;

Regulatory Guide 1.29 identifies the safety-related structures, systems, and components;

Regulatory Guide 1.102 describes acceptable flood protection to prevent the safety-related facilities from being adversely affected; and

Regulatory Guide 1.27 describes the ultimate heat sink capabilities which apply.

To meet the requirements of ~~10 CFR Part 50, 50.55a~~GDC 1,[12] GDC 2, and 10 CFR Part 100 as they relate to ice effects the following specific criteria are used:

A. Publications of the National Oceanic and Atmospheric Administration (NOAA), the United States Geologic Survey (USGS), the Corps of Engineers, and other

sources are used to identify the history and potential for ice formation in the region. Historical maximum depths of icing should be noted, as well as mass and velocity of any large floating ice bodies. The phrase "historical low water ice affected" or similar phrases in stream flow records (USGS and State publications) will alert the reviewer to the potential for ice effects. The following items must be considered and evaluated, if found necessary, in the design of protection of safety-related facilities and water supplies.

(1) The regional ice and ice jam formation history must be described to enable an independent determination of the need for including ice effects in the design basis.

(2) If icing has not been severe, based on regional icing history, design considerations must be presented (e.g., return of a portion of low-grade heat to the intake) to ~~assure~~ ensure that icing or ice blockage of intake screens and pumps will not adversely affect safety-related facilities and water supplies.

(3) If the potential for icing is severe, based on regional icing history, it must be shown that water supplies capable of meeting safety-related requirements are available from under the ice formations postulated and that safety-related equipment is protected from icing as in item (2), above. If ~~not~~ this cannot be shown,[13] it must be demonstrated that alternate sources of water are available, that they are protected from freezing, and that the alternate source is capable of meeting safety-related requirements in such situations. Ice loading must have been included in the structural design basis, if severe icing is possible.

(4) If floating ice is prevalent, based on regional icing history, ~~consideration of~~ potential[14] impact forces on the safety-related intakes must be a consideration in the design basis. The dynamic loading caused by floating ice must be included in the structural design basis.

(5) If ice blockage of the river or estuary is possible, it must be demonstrated that the resulting water level in the vicinity of the site has been considered in establishing the flood and water supply design bases. If this water level would adversely affect the intake structure, or other safety-related facilities, it must be demonstrated that an alternate safety-related water supply will not also be adversely affected.

B. The applicant's estimates of potential ice flooding or low flows are acceptable if the estimates are no more than 5% less conservative than the staff's estimates. If the applicant's estimates are more than 5% less conservative than the staff's,[1] the applicant should fully document and justify its estimates or accept the staff's

[1] Based on the difference between normal water levels and the flood event or low water.

estimates and redesign applicable flood protection. The suggested criteria of Regulatory Guide 1.27 apply when the water supply comprises part of the ultimate heat sink.

Technical Rationale[15]

The technical rationale for application of these acceptance criteria to reviewing ice effects on a nuclear power plant site is discussed in the following paragraphs:[16]

1. Compliance with GDC 1 requires that structures, systems, and components be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed.

   GDC 1 applies to this SRP section because the reviewer verifies that structures, systems, and components important to safety (e.g., the ultimate heat sink or cooling water intake structure) are not adversely affected by floating ice, ice jams, and ice blockage to the extent that they might be unable to perform their intended safety function. SRP Section 2.4.7 addresses the potential effects of ice on the hydrologic characteristics of the plant site. In general terms, it also specifies the amount of conservatism that must be used to determine the severity of icing phenomena for the purpose of assessing the adequacy of the codes and quality standards used to design, fabricate, erect, and test structures, systems, and components important to safety.

   Meeting the requirements of GDC 1 provides assurance that plant structures, systems, and components will perform their intended safety functions under the most severe icing conditions likely to occur.[17]

2. Compliance with GDC 2 requires that nuclear power plant structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as earthquake, tornado, hurricane, flood, tsunami, and seiche without loss of capability to perform their safety functions. The criterion further specifies that the design bases for these structures, systems, and components shall reflect the following:

   a. Appropriate consideration of the most severe natural phenomena historically reported for the site and its surrounding area, with sufficient margin for the limited accuracy, quantity, and time period in which the historical data have been accumulated;

   b. Appropriate combinations of the effects of normal and accident conditions with those of the natural phenomena; and

   c. The importance of the safety functions to be performed.

   GDC 2 applies to this SRP section because the reviewer verifies that structures, systems, and components important to safety (e.g., the cooling water intake structure) are not adversely affected by floating ice, ice jams, and ice blockage to the extent that they might be unable to perform their intended safety function. SRP Section 2.4.7 addresses the

potential effects of ice on the hydrologic characteristics of the plant site. In general terms, it also specifies the amount of conservatism that must be used to determine the severity of icing phenomena for the purpose of assessing the adequacy of the design bases used for structures, systems, and components important to safety.

Meeting the requirements of GDC 2 provides assurance that structures, systems, and components important to safety have been designed to withstand the most severe icing phenomena likely to occur.[18]

3. Compliance with 10 CFR Part 100.10(c) requires that the site's physical characteristics (including seismology, meteorology, geology, and hydrology) be taken into account when determining its acceptability for a nuclear power reactor.

To satisfy the hydrologic requirements of 10 CFR Part 100, the applicant's SAR must contain a description of any icing phenomena with the potential to result in adverse effects to the intake structure or other safety-related facilities. Ice-related characteristics historically associated with the site and region must be described, and an analysis must be performed to determine the potential for flooding, low water, or ice damage to safety-related structures, systems, or components. The analysis must be sufficient to evaluate the site's acceptability and to assess the potential for those characteristics to influence the design of the plant structures, systems, or components important to safety.

Meeting this requirement provides assurance that structures, systems or components important to safety are designed to withstand the effects of potentially severe icing conditions.[19]

III. REVIEW PROCEDURES

Applicable literature describing historical occurrences of icing in the region is reviewed to determine if icing protection should be considered in the design of safety-related facilities. If considered necessary, the most likely types of icing conditions (floating ice, river blockage by ice buildup, frazil, etc.) are listed, and the potential impact on plant design of each type is identified. Criteria of the Corps of Engineers and others provide a means of assessing icing impact and methods of mitigating adverse effects. For each type of icing condition, preliminary independent estimates of the "worst case" will be made by either conservative statistical or deterministic techniques.

If the applicant's estimates of ice effects are comparable to the staff's preliminary analysis, the staff will concur with the applicant's estimates. If the preliminary analysis indicates the applicant's estimates of ice effects are not comparable to the staff's estimates, the staff's analysis will be repeated using more realistic techniques.

The above reviews are performed only when applicable to the site or site regions. Some items of review may be done on a generic basis.

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.[20]

IV. EVALUATION FINDINGS

For construction permit (CP) and early site permit[21] reviews, the findings will summarize the applicant's and staff's estimates of the potential for ice flooding, ice blockage of water intakes, ice forces on structures, and the minimum low water levels (from upstream ice blockage). If the applicant's estimates are within acceptable margins (described in Acceptance Criteria), staff concurrence with the applicant's estimate will be stated. If the applicant's estimates are not within acceptable margins, if the staff predicts potential blockage of the intake, or if the proposed plant may be adversely affected, a statement of the staff bases will be made. If the icing conditions do not constitute a design basis, the findings will so indicate.

For operating license (OL) or COL[22] reviews of plants for which detailed icing reviews were made at the CP stage, the CP conclusions will be referenced. However, a review will be made to ~~assure~~ ensure that the design basis established in the CP review has been implemented properly. In addition, a review of icing records since the CP review will be made. If no CP review was undertaken (of the scope indicated), this fact will be noted in the OL findings.

A sample CP statement follows:

> The staff concludes that with respect to ice flooding the plant design is acceptable and meets the requirements of General Design Criteri~~on~~a 1 and[23] 2 and 10 CFR Part 100. This conclusion is based upon the following analysis which shows that safety-related structures identified in Regulatory Guide 1.29, are designed to withstand the effects of ice floods in accordance with position 1 of Regulatory Guide 1.59. This position is met in accordance with position 1.a of Regulatory Guide 1.102 which discusses dry sites.
>
> Ice flooding, which is common on the A River at the makeup intake structure, could only affect the river intake structure which would not result in any adverse effects to the plant's safety-related facilities. The applicant states that ice flooding may possibly raise the water surface near the A River intake to a maximum elevation of about ~~555 feet~~ 170 m (555 ft)[24] MSL. The applicant further states that ice and ice flooding on the A River tributaries outside the cooling lake will not affect the plant facilities. The major tributary nearest the plant is the B Creek with the closest point located about ~~one mile~~ 1.6 km (1 mi)[25] to the southeast of the site. The applicant concludes that, because of the distance from the proposed site and the wide floodplain of the river, there will be no adverse effects at the plant site due to ice in the river and consequent flooding. We concur with this conclusion.
>
> The staff concludes that with respect to ice blockage of water intakes the plant design is acceptable and meets the requirements of ~~10 CFR Part 50, 50.55a~~ GDC 1[26] and General Design Criterion 2. This conclusion is based upon the following analysis, which shows

that position 2 of Regulatory Guide 1.27 is met with respect to ice blockage of essential water intakes.

The safety-related pumps from the cooling lake are to be protected from ice blockage by means of traveling screens, stop logs, and trash racks located at the front of the lake screenhouse. In addition, the applicant proposes a warmup line from the circulating water discharge which will keep the inlet water temperature 4.5 °C (40 °F)[27] during winter operation. An essential cooling water screen bypass pipe is also available.

We concur with the applicant that icing or ice flooding should not adversely affect the plant's safety-related facilities.

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, tests, 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.[28]

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC 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.[29] 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.[30]

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides.

VI. REFERENCES

1. 10 CFR Part 50, ~~50.55a, "Codes and Standards."~~Appendix A, General Design Criterion 1, "Quality Standards and Records."[31]

2. 10 CFR Part 50, Appendix A, General Design Criterion 2, "Design Bases for Protection Against Natural Phenomena."

3. 10 CFR Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants."[32]

4. 10 CFR Part 100, "Reactor Site Criteria."

5. E. Brown and G. C. Clark, "Ice Thrust in Connection with Hydro-Electric Design," Engineering Journal, pp. 18-25, 1932.

6. V. T. Chow (ed.), "Handbook of Applied Hydrology," McGraw-Hill Book Company, New York (1964).

7. O. Devik, "Freezing Water and Supercooling," Jour. of Glaciology, Vol. 1, No. 6, pp. 307-309 (1949).

8. N. E. Dorsey, "Properties of Ordinary Water Substances," Reinhold Publishing Company, New York (1940).

9. H. T. Mautis (ed.), "Review of Properties of Snow and Ice," Report 4, Corps of Engineers, Snow, Ice and Permafrost Research Establishment (1951).

10. E. Rose, "Thrust Exerted by Expanding Ice Sheet," Trans. Am. Soc. Civil Engineers, Vol. 112, pp. 871-900 (1947).

11. J. T. Wilson, "Coupling Between Moving Loads and Flexural Waves in Floating Ice Sheets," Report No. 34, Corps of Engineers, Snow, Ice, and Permafrost Research Establishment (1955).

12. J. T. Wilson, J. H. Zumberge, and E. W. Marshall, "A Study of Ice on an Inland Lake," Report No. 5, Corps of Engineers, Snow, Ice, and Permafrost Research Establishment (1954).

13. "River Ice Jams - A Literature Review," Engineer Technical Letter No. 1110-2-58, Corps of Engineers (1969).

14. "Design of Small Dams," Bureau of Reclamation, U.S. Department of the Interior (1973).

15. J. H. Zumberge and J. T. Wilson, "Quantitative Studies of Thermal Expansion and Contraction of Lake Ice," Jour. of Geophysical Research, Vol. 61, pp. 374-383 (1953).

16. "Surface Water Supply of the United States," U.S. Geological Survey, surface water supply papers as applicable to the plant region.

17. Regulatory Guide 1.27, "Ultimate Heat Sink for Nuclear Power Plants."

18. Regulatory Guide 1.29, "Seismic Design Classification."

19. Regulatory Guide 1.59, "Flood Design Basis for Nuclear Power Plants."

20. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants."

21. Regulatory Guide 1.102, "Flood Protection for Nuclear Power Plants."

22. ANSI N170,[33] "Standards for Determining Design Basis Flooding at Power Reactor Sites" (1976).

23. G. D. Ashton, et al., "Icebreaking by Tow on the Mississippi River," SR 192, CRREL, Hanover, New Hampshire, August 1973.

24. Roscoe E. Perham, "Forces Generated in Ice Boom Structures," SR 200, CRREL, Hanover, New Hampshire, January 1974.

25. George D. Ashton, "Air Bubbler Systems to Suppress Ice," SR 210, CRREL, Hanover, New Hampshire, September 1974.

26. Darryl J. Calkins and George D. Ashton, "Arching of Fragmented Ice Covers," SR 222, CRREL, Hanover, New Hampshire, April 1975.

27. W. H. Brierley, et al., "Lock Wall Deicing with Water Jets: Field Tests at Ship Locks in Montreal, Canada, and Sault Sainte Marie, Michigan," SR 239, CRREL, Hanover, New Hampshire, December 1975.

28. Bernard Michel, "Ice Pressure on Engineering Structures," CRREL, Hanover, New Hampshire, June 1970.

29. F. D. Haynes, et al., "Ice Force Measurements on the Pembina River, Alberta, Canada," SR 269, CRREL, Hanover, New Hampshire, October 1975.

30. K. L. Carey, et al., "Ice Engineering for Civil Works, Baseline Study," CRREL, Hanover, New Hampshire, August 1973.

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SRP Draft Section 2.4.7
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 name and abbreviation	Changed PRB to Civil Engineering Branch (ECGB).
2.	Editorial	Changed "assure" to "ensure" (global change for this section).
3.	Current PRB abbreviation	Changed PRB to ECGB.
4.	SRP-UDP format item	Added "Review Interfaces" to AREAS OF REVIEW to describe how ECGB coordinates the review of ice effects with those of other branches.
5.	SRP-UDP format item	Modified to accommodate lead-in for "Review Interfaces."
6.	Current PRB name and abbreviation	Changed PRB to Mechanical Engineering Branch (EMEB) and described responsibility for reviewing the potential mechanical effect of ice.
7.	Current PRB name and abbreviation	Changed review branch to Plant Systems Branch (SPLB).
8.	Current PRB abbreviation	Changed PRB to ECGB.
9.	Editorial	Added boilerplate paragraph concerning the interrelationship of reviews conducted by various branches.
10.	Integrated Impact No. 1393	10 CFR 50.55a is not regarded as applicable to Section 2.4.7. Replacement with GDC 1 is recommended.
11.	Integrated Impact No. 643	ANSI N170-1976 is referenced in Regulatory Guide 1.59. This standard was revised in 1981 to ANSI/ANS-2.8, which in turn was revised in 1992. This reference in RG 1.59 should be updated to ANSI/ANS-2.8-1992 if a detailed comparison of the two versions supports the adoption of the more recent standard.
12.	Integrated Impact No. 1393	10 CFR 50.55a is not regarded as applicable to Section 2.4.7. Replacement with GDC 1 is recommended.
13.	Editorial change	Provided clarification: replaced the ambiguous "If not" with "If this cannot be shown."
14.	Editorial change	Eliminated the first use of the word "consideration" in the sentence and modified to provide clarification.
15.	SRP-UDP format item	Added "Technical Rationale" to ACCEPTANCE CRITERIA and put in paragraph form to describe the bases for referencing specific NRC regulations.
16.	SRP-UDP format item	Added lead-in sentence for "Technical Rationale."

Item	Source	Description
17.	SRP-UDP format item	Added technical rationale for GDC 1.
18.	SRP-UDP format item	Added technical rationale for GDC 2.
19.	SRP-UDP format item	Added technical rationale for 10 CFR Part 100.
20.	SRP-UDP Guidance, Implementation of 10 CFR 52	Added standard paragraph to address application of Review Procedures in design certification reviews.
21.	SRP-UDP format item	Added reference to early site permit reviews.
22.	SRP-UDP format item	Added reference to combined license reviews.
23.	SRP-UDP format item	Added reference to GDC 1.
24.	Conversion to SI units	Convert 555 ft to 170 m.
25.	Conversion to SI units	Convert one mi to 1.6 km.
26.	Integrated Impact No. 1393	10 CFR 50.55a is not regarded as applicable to Section 2.4.7. Replacement with GDC 1 is recommended.
27.	Conversion to SI units	Converted 40 °F to 4.5 °C.
28.	SRP-UDP Format Item, Implement 10 CFR 52 Related Changes	To address design certification reviews a new paragraph was added to the end of the Evaluation Findings. This paragraph addresses design certification specific items including ITAAC, DAC, site interface requirements, and combined license action items.
29.	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.
30.	SRP-UDP Guidance	Added standard paragraph to indicate applicability of this section to reviews of future applications.
31.	Integrated Impact No. 1393	10 CFR 50.55a is not regarded as applicable to Section 2.4.7. Replacement with GDC 1 is recommended.
32.	SRP-UDP format item	Added reference to 10 CFR Part 52.
33.	Integrated Impact No. 643	ANSI N170-1976 was revised in 1981 to ANSI/ANS-2.8, which in turn was revised in 1992. This reference should be updated to ANSI/ANS-2.8-1992 if a detailed comparison of the two versions supports the adoption of the more recent standard.

SRP Draft Section 2.4.7
Attachment B - Cross Reference of Integrated Impacts

Integrated Impact No.	Issue	SRP Subsections Affected
643	Regulatory Guide 1.59 references ANSI N170-1976 that was revised in 1981 to ANSI/ANS-2.8, which was further revised in 1992. In addition, ANSI N170 is referenced in this and several other sections of the SRP. Such references should be updated to ANSI/ANS-2.8-1992 in RG 1.59 and the SRP if a detailed comparison of the two versions supports the adoption of the more recent standard.	Section II, second paragraph Section VI, Ref
1393	SRP Section 2.4.7 inappropriately specifies 10 CFR 50.55a as an acceptance criterion for this section. Section 55.55a applies to quality standards and inservice inspection of vessels and other components subject to the ASME Boiler and Pressure Vessel Code. General Design Criterion 1 is a more appropriate quality standards criterion for structures, systems and components important to safety.	Section II, first and third paragraphs Section IV, third paragraph Section VI, Reference 1