September 11, 2003

Mr. R. S. Lytton
Chair, Ice Condenser Utility Group
Duke Power Company
P. O. Box 1006
Charlotte, NC 28201-1006

SUBJECT: SAFETY EVALUATION FOR ICE CONDENSER UTILITY GROUP TOPICAL REPORT NO. ICUG-001, REVISION 2 RE: APPLICATION OF THE ACTIVE ICE MASS MANAGEMENT CONCEPT TO THE ICE CONDENSER ICE MASS TECHNICAL SPECIFICATION (TAC NO. MB3379)

Dear Mr. Lytton:

The Nuclear Regulatory Commission staff has completed its review of the Ice Condenser Utility Group (ICUG) Topical Report No. ICUG-001, Revision 2, “Application of the Active Ice Mass Management Concept to the Ice Condenser Ice Mass Technical Specification,” submitted by Mr. R. S. Lytton’s letter dated June 19, 2003.

The NRC staff issued a Draft Safety Evaluation on Revision 0 of the ICUG-001 report on May 6, 2003. The ICUG provided additional information in Revision 2 of the Topical Report on June 19, 2003, and in Mr. D. R. Hoffman’s letter dated July 15, 2003, submitting Revision 2 to Technical Specification Task Force traveler no. 429, “Ice Mass Determination Surveillance Requirements.” The enclosed Safety Evaluation provides the results of the NRC staff’s review. Please note that the NRC staff finds two aspects of the topical report to not be acceptable, as discussed in Sections 2.3.2 and 2.5 of the enclosed Safety Evaluation.

Should you have questions or comments, please contact Mr. Robert Martin of my staff at (301) 415-1493.

Sincerely,

/RA/

John A. Nakoski, Chief, Section 1
Project Directorate II
Division of Licensing Project Management
Office of Nuclear Reactor Regulation

Docket Nos. 50-413, 50-414, 50-369, 50-370, 50-327, 50-328, 50-390, 50-315 and 50-316

Enclosure: As stated

cc w/encl: See next page

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATING TO TOPICAL REPORT ICUG-001, REVISION 2

APPLICATION OF THE ACTIVE ICE MASS MANAGEMENT CONCEPT TO THE ICE

CONDENSER ICE MASS TECHNICAL SPECIFICATIONS

ICE CONDENSER UTILITY GROUP

1.0 INTRODUCTION

By letter dated September 18, 2001, (Reference 1), as supplemented by letters dated June 12, October 10, October 22 and November 26, 2002 (References 2, 3, 4, and 5), the Ice Condenser Utility Group (ICUG), representing the Catawba and McGuire Nuclear Stations, the Sequoyah and Watts Bar Nuclear Plants and the Donald C. Cook Nuclear Plant, submitted for Nuclear Regulatory Commission (NRC) staff review and approval, the Topical Report: ICUG-001, Revision 0, “Application of the Active Ice Mass Management Concept to the Ice Condenser Ice Mass Technical Specification.” By letter dated June 19, 2003, the ICUG submitted Revision 2 to ICUG-001 (Reference 12).

The topical report describes the basis and methodology to support an industry-proposed revision to the generic ice condenser containment (ICC) Technical Specification (TS) for the ICC ice bed. The standard TS for the ICC ice bed is included in NUREG-1431, “Standard Technical Specifications for Westinghouse Plants.” Technical Specification Task Force (TSTF) traveler number 429, Revision 2, dated July 15, 2003, (Reference 6) proposes revisions to the standard TS surveillance requirement (SR) for determining the mass of the ICC ice baskets that are consistent with the methodology in the ICUG-001 topical report. Further references to TSTF-429 and to the ICUG-001 topical report in this safety evaluation refer to Revision 2 of each of these documents (References 6 and 12).

The ice bed consists of approximately two million pounds of ice stored in 1,944 perforated metal baskets within the ICC. Its primary purpose is to provide a large heat sink to absorb heat in the event of a design basis accident (DBA) in the containment. The TS limiting condition for operation for the ice bed requires that a sufficient amount of stored ice be provided to maintain the containment air temperature and pressure within the DBA design bases limits. The SR for the ice weighing program is intended to verify that the total weight of ice is adequate by taking a sample of the ice baskets to determine the weight of the entire ice bed. In addition, determining the weight of an appropriate sample of baskets ensures that no local zone of the ice bed is deficient in ice.

2.0 EVALUATION

The NRC staff’s review of the topical report and TSTF-429 included the following areas: (1) the concept of Active Ice Mass Management (AIMM) proposed by the ICUG and the total ice mass requirement, (2) the minimum ice mass requirement for individual ice baskets,

(3) methodologies for determining ice basket mass, (4) the concept of sampling from three radial zones in the ice bed and alternate basket sampling, and (5) the ice mass statistical sampling plan.

2.1 Active Ice Mass Management and Total Ice Mass Requirement

2.1.1 Technical Information in the Topical Report and TSTF-429

The ICUG-001 report contains a discussion of the AIMM methodology in Section I (page I-5), as follows:

> In order to perform appropriate replenishment activities of the ice bed each outage, the number of baskets needing to be serviced must be identified. Replenishment “triggers” vary from plant to plant due to variations in specific sublimation rates, but at all plants the as-found ice mass in each basket of the bed must be assessed prior to assigning replenishment scope. As shown in Figure 1-2, there are a significant number of baskets that will not need ice replenishment every outage (such as those in rows 1-6). However, the current mass of ice in these baskets must be determined in order to predict *when* they will need replenishment in the future. This process (assigning replenishment scope to the current and future outages based on current basket mass and known sublimation trends) is an active management process, requiring that plants know the specifics behind their ice bed’s behavior patterns. In most cases, each individual basket in the ice bed has a known sublimation behavior pattern associated with it, based on its specific location. Upon determining the as-found mass for a basket in the bed, plant personnel then compare that value to the required safety analysis mean value and apply that basket’s sublimation trend to project its mass forward through the coming cycle. Any individual basket’s ice mass that is projected to sublimate to or below the safety analysis mean mass value is serviced during the current outage. This is how AIMM practice maintains the ice mass in each individual basket above the required safety analysis mean.

The plant-specific ice basket sublimation data can be obtained from operating experience and is trended using software such as ICEMAN™ (an ICE condenser MANagement program). Table 1-1 of ICUG-001 shows a comparison of the mean sublimation rates for each row-group combination and for each radial row.

The current TS requires an “as-left” (post-maintenance) surveillance to determine the total ice mass and its distribution. With this approach, an operational cycle is completed and during the following outage the ice baskets are replenished to meet the SR to ensure that sufficient ice will be provided for the following operational cycle. This requires that an assumed uniform sublimation (and weighing error) allowance be added to the ice mass required for the DBA analysis to meet the SR. In the current standard TS, the total “as-left” ice mass of [2,721,600] lbms is required for the coming operational cycle. The bracket around this standard TS value indicates that it would be adjusted to reflect plant-specific requirements.

The proposed revision to the standard TS, as set forth in TSTF-429, Revision 2, uses an “as-found” (pre-maintenance) surveillance of the ice mass. The total ice mass of [2,200,000] lbs is specified in SR 3.6.15.2 of TSTF-429, Revision 2, and represents the value to be used in the DBA analysis. This value is the minimum requirement for ice bed operability. The SR is conducted at the end of an operational cycle and it verifies that the "as-found" ice mass at the end of a cycle was adequate for that cycle's requirements. With the "as-found" approach, the sublimation allowance and mass determination uncertainty is not included in the TS value for total ice mass but will be maintained in accordance with procedures at each site that are controlled pursuant to the requirements of the Commission's regulations in Title 10 *Code of the Federal Regulations* (10 CFR) Part 50, Appendix B (Reference 7), and 10 CFR 50.59, "Changes, Tests and Experiments."

The NRC staff requested additional information regarding how the AIMM methodology would monitor ICC conditions and the ICUG provided the following response in Reference 2.

> Domestic ice condenser plants have been amassing ice basket mass and sublimation data for many years, partly as a result of original and current technical specification requirements, but also as a result of augmented ice mass determination to facilitate maintenance program effectiveness. In this sense, the monitoring of ice mass depletion rates is periodic, occurring each time the plants perform periodic maintenance-related ice basket mass determination (weighing) procedures.
>
> Since ice mass depletion rates tend to be linear and consistent over time, with sufficient historical data the mass of ice in any basket can be predicted, as described in Chapter II of the topical report. If an anomaly occurs that could cause ice mass depletion rates to differ from those expected [...], discovery would come from either Control Room indicators, current ice bed temperature surveillance requirements or frequent procedurally-mandated online ice condenser inspections performed by plant staff, and resolution would come from a plant's Corrective Action Program.

2.1.2 Staff Evaluation

The NRC staff reviewed the proposed AIMM concept described in the topical report. This concept couples the plant-specific ice maintenance procedures to the TS SR for the total ice mass requirement. However, Revision 0 of the topical report did not describe the procedures in sufficient detail. In requests for additional information (RAI) nos. 1 and 2, the NRC staff requested that the ICUG provide a copy of typical plant-specific procedures to support an improved understanding of how the ice maintenance procedures (i.e., AIMM methodology) can be used with the TS surveillance to establish the total ice mass requirement. The ICUG responded in RAIs 1 and 2 in Reference 2, stating that the plant-specific procedures were not available. However, in Revision 2 of ICUG-001, the ICUG provided additional information about the plant-specific ice maintenance procedures.

The NRC staff finds that the ICUG has adequately described the relationship of AIMM maintenance-related practices to the requirement to maintain the total ice mass required by the TS. The proposed total ice mass requirement has two elements: (1) the TS SR to specify the "as-found" total ice mass, and (2) the plant-specific ice maintenance procedures to manage sublimation and weighing variations. The NRC staff finds that the combination of these two elements ensures that a sufficient total amount of ice will be provided in the ice condenser for removing heat during DBAs and for meeting sublimation requirements during operating cycles. The NRC staff also notes that the applicable plant-specific procedures are maintained in accordance with 10 CFR Part 50, Appendix B, and 10 CFR 50.59. The change from determining the total mass on an as-left basis to an as-found basis and the control of the sublimation and mass determination allowances is adequately described. The NRC staff notes the provisions that the ICUG has identified to detect anomalies and further notes that if a condition should develop during operation such that it could result in the TS SRs being violated, the TS action statements will continue to require that the plant be brought to a safe mode of operation. On these bases, the NRC staff finds the AIMM concept and its application for the total ice mass requirement in TSTF-429, SR 3.6.15.2, to be acceptable.

The NRC staff notes that the frequency for performing the current standard TS SR 3.6.15.2 is 9 months. TSTF-429, Revision 2, proposed changing this to 18 months. TSTF-429 states that the change to an 18-month frequency does not result in an overall reduction in the end-of-cycle ice mass. The TSTF states that ICUG historical operating experience has shown that the ice condenser can meet and even exceed its design function without performing these surveillances on a 9-month frequency. The NRC staff finds that the operating experience at ICUG plants demonstrates that the stored ice has been effectively maintained in this regard and that the sublimation rates are predictable. On these bases the NRC staff concludes that the proposed change to an 18-month surveillance interval for TSTF-429, Revision 2, SR 3.6.15.2 is acceptable. The NRC staff also concludes, for the same general reasons, that the similar change to an 18-month frequency for TSTF-429, Revision 2, SR 3.6.15.3 is acceptable.

2.2 Minimum Ice Mass Requirement for Individual Ice Baskets

2.2.1 Technical Information in the Topical Report, through Revision 2, and TSTF-429, through Revision 2

The current TS SR 3.6.15.3 described in TSTF-429, Revision 2, is deleted and is replaced by the SR for minimum individual ice basket mass. The current standard TS SR 3.6.15.3 ensures that the distribution of ice on an azimuthal basis, i.e., around the 300 degree arc of the ice bed, is reasonably uniform by verifying that the average ice weight in each of three azimuthal groups of ICC bays is within the limit. Azimuthal Group 1 includes bays 1 through 8; Group 2 includes bays 9 through 16, and Group 3 includes bays 17 through 24. The changes proposed by TSTF-429, Revision 2, SR 3.6.15.3, would remove the azimuthal row-group ice distribution verification. The TSTF indicates that the change in statistical sampling and the crediting of AIMM processes provides inherent verification of ice mass distribution making azimuthal row-group distribution verification redundant. The ICUG report states on page O-5, that: “Proper azimuthal distribution of ice in the ice bed is no longer assessed by a separate surveillance requirement; it is implemented through established industry-wide maintenance practices that manage each ice basket above the required safety analysis mean and confirmed through as-found random sampling techniques.” The report states on page III-7 that: “The azimuthal (as opposed to radial) distribution of ice [...] does not need to be verified via stratification if the overall azimuthal sublimation rate of the ice bed is not expected to vary significantly. As described in Section I [of the ICUG report], historical industry and plant-specific data show that azimuthal variances would not preclude a random sample from being representative of the ice bed.”

The SR number, 3.6.15.3, is re-assigned to the newly created minimum individual ice basket mass SR. Section I of the ICUG report indicates that the purpose of the SR for a minimum ice mass for individual ice baskets is to ensure that a significant localized degraded mass condition is avoided so that the containment pressure responses following a DBA will remain within design basis limits. The ICUG established the minimum ice mass for individual ice baskets of

≥ 600 lbms per basket based on a sensitivity study (Reference 4) using the GOTHIC computer code and the McGuire containment model. The ICUG added a new section, “Regions of Localized Degraded Mass,” to Section I of Topical Report ICUG-001, Revision 2, that provided information about the sensitivity study.

Revision 2 of TSTF-429, (Reference 12) also proposed revising SR 3.6.15.3 to include a value of ≥ 600 lbms for the minimum ice mass in any individual basket. The value of ≥ 600 lbms was proposed without a plant-specific variation in the TSTF (i.e., no bracket), meaning that the value of ≥ 600 lbms is intended to be applicable to all ICC plants. The ICUG Topical, Section I, also indicates that concurrent with the individual basket limit of ≥ 600 lbm further assurance that localized regions of gross degradation do not exist in the ice bed will be provided by the implementation of the AIMM methodology. The objective of the AIMM practices is to manage the ice basket masses such that the ice mass in each basket in the ice bed will be maintained above the required safety analysis mean, and to service the baskets prior to reaching this limit. The safety analysis mean is the average basket weight that must be maintained in each of the three radial zones to meet the total TSTF-429 SR 3.6.15.2 ice mass requirement. The safety analysis mean value is also included in the Bases for SR 3.6.15.2 of TSTF-429 as a bracketed value of 1132 lbs, meaning the value can be changed according to plant-specific safety analyses.

2.2.2 Staff Evaluation

The NRC staff reviewed the above reason for deleting the azimuthal sampling of ice baskets from SR 3.6.15.3 and finds this to be acceptable because the azimuthal sampling is redundant to the random sampling of ice baskets over three radial zones of the ice bed. The concept of radial-zone sampling is reviewed in Section 2.4 of this report. SR 3.6.15.6 requires a physical inspection of two ice baskets from each azimuthal group and relies on the definition of azimuthal group that was previously included in SR 3.6.15.3. Since the definition of “azimuthal groups” is deleted from SR 3.6.15.3 of TSTF-429, Revision 2, it has been relocated to the revised SR 3.6.15.6. The NRC staff finds the relocation of the definition of “azimuthal groups” to the revised SR 3.6.15.6 to be an administrative change, and therefore, it is acceptable.

The NRC staff reviewed the minimum ice basket mass study of the sensitivity of peak containment pressures to the number of baskets at the minimum mass, as documented in Reference 4. The McGuire plant was the representative plant chosen for the study and it has a containment design pressure of 15 psig. The results of the ICUG analysis are shown below:

	ice mass lbs/basket	peak containment pressure P, psig	ΔP, psi, increase from base case	margin (psi), from 15 psig	margin reduction, ΔP/1.56,%
Base Case	973 (all baskets)	13.44	0	1.56	0
Case 1	600 (75 baskets)	13.5	0.06	1.50	3.8
Case 2	400 (75 baskets)	13.73	0.29	1.27	19
Case 3	400 (225 baskets)	13.79	0.35	1.21	22

The ICUG results show that for a range of reduced mass (973, 600, and 400 lbms/basket) in a group of about 75 ice baskets the peak containment pressure increases when the ice mass is decreased. The base case of 973 lbms per basket corresponds to the current design basis accident analysis requirement for all 1,944 baskets for the McGuire plant. The ICUG sensitivity analysis shows that, for a reduction from 973 lbms to 600 lbms per basket for 75 baskets (Case 1), the amount of localized ice melt-through would have a relatively insignificant impact on the peak containment pressure. For Cases 2 and 3, the pressure increases are 0.29 psi and 0.35 psi, respectively, corresponding to a margin reduction of 19 percent and 22 percent, respectively. The design margins are plant-specific values. The NRC staff reviewed the comparable design margins for the other ICC plants, based on information currently in their Updated Final Safety Analysis Report as follows:

Plant	Total Ice Mass	Containment Design Pressure	Maximum Calculated Containment Pressure
Catawba	2,132,000	15	13.30
McGuire	1,890,000	15	13.44
Sequoyah	1,790,000	12	11.45
Watts Bar	2,029,375	15	10.64
D. C. Cook	2,200,000	12	11.50

However, the design margins are plant-specific values, as shown in the above table. The other ice condenser plants have lower containment design pressures and smaller design margins compared to McGuire. The value of 0.06 psi for Case 1 may not be bounding for all ICC plants. In the absence of a bounding analysis, the additional AIMM practices of managing ice basket mass to greater than the safety analysis mean values will address the above uncertainty concern. Actively managing the ice mass of individual baskets to the safety analysis mean will prevent premature local ice melt-through during a DBA. Allowing licensees to manage individual ice baskets masses is consistent with the AIMM concept, as discussed in Section 2.1 above. The NRC staff finds that an individual ice basket lower limit of $\geq$ 600 lbms in the SR, in conjunction with implementation of the AIMM practices of actively managing the ice mass of individual baskets to above a safety analysis mean value of [1132] lbm for each of the three radial zones, provides reasonable assurance that the impact of local ice melt-through will not be significant. Therefore, the NRC staff concludes that the combination of the two elements of the proposed methodology for controlling the required ice mass per basket: (1) the plant-specific active ice management to the “safety analysis mean” for individual baskets, and (2) the SR of $\geq$ 600 lbms per basket, as specified in TSTF-429, SR 3.6.15.3,and in ICUG-001, is acceptable.

2.3 Ice Basket Mass Determination Methodology

2.3.1 Technical Information in the Topical Report

The NRC staff reviewed Revision 0 of the ICUG-001 report and supplemental submittals (References 1 through 5), and indicated in its draft safety evaluation that was issued on May 6, 2003, (Reference 11), that additional information would be needed for the mass determination methodologies. Subsequently, the ICUG submitted Revision 2 to the report on June 19, 2003, (Reference 12).

The ICUG notes in Section II of the topical report that, historically, the method to determine ice basket mass has been to manually lift the basket with a lifting rig and weigh the basket with an attached scale or load cell. Although other methods, discussed below, have been used to predict the number of ice baskets that would require replenishment during outages to meet the TS SR, the specific determination of ice basket mass to meet the SR has been by manual lifting and weighing of ice baskets. The topical report (Section II) states that this method provides the most accurate determination of ice mass.

The ICUG reports (page II-5) that, for the manual weighing technique, a load cell is used that has a typical range of 0 to 5000 lbms, and an expected uncertainty is in the range of 0.3 percent, about ± 15 lbms. The report (page II-1) also states that these load cells are calibrated in accordance with plant procedures that conform to the quality assurance requirements of 10 CFR Part 50, Appendix B (Reference 7).

However, some baskets may become stuck, as a result of baskets freezing to the supporting lattice framework, thus, preventing them from being physically lifted and weighed. The ICUG proposed several alternate mass determination methods to address the issue of stuck baskets. These methods include: (a) estimating the basket weight based on previous measurements of basket weight and then trending that data using the ICEMAN™ software program and, (b) estimating basket weight based on visual examinations. Concepts for several other methods were mentioned in the topical report but they were not extensively described, and accordingly, were not reviewed by the NRC staff.

The ICUG states that ICEMAN™ is a software program that trends ice basket mass histories and can be used to project future ice basket mass based on valid individual sublimation rates and previous ice basket mass data. This alternate mass determination technique requires a significant amount of accurate ice mass data to generate projections. The technique requires a data validity criterion (described below) that limits the use of the most historically distant data in projecting a current basket's mass and also limits the number of times a given basket's mass can be projected successively before a lifted mass on the basket is required. The data validity criteria are provided in Table 2-1 of the ICUG report and are as follows:

Mass data used for uncertainty calculations must derive from:

- ≥ 3 of the last 6 operating cycles, or
- 2 out of the last 3 operating cycles

The ICUG report acknowledges that an important aspect of data validity involves the qualification of personnel trained to perform the mass determination technique. The report states that the mass sublimation projection process is much less subjective than the proposed visually based process (page II-7), and states that the training and equipment qualification processes will be included in procedures in accordance with 10 CFR Part 50, Appendix B (page II-13).

The ICUG provided a section on quantifying measurement uncertainty in Revision 2 of the ICUG report and provided an example of determining mass sublimation using historical data. This example accounted for the statistical parameters of systematic bias, random error and the degrees of freedom in the sample of data (page II-10).

The visual inspection method uses a camera to inspect over the length of the ice basket to estimate the amount of mass missing from the column in the form of linear gaps, shaped voids, and annular shrink-back from the ice basket mesh. The total amount of missing mass is subtracted from the known mean mass of a full basket to obtain an estimate of the mass of that basket. The ICUG report acknowledges that this technique is the most subjective of the three ice mass determination methods. The ICUG also proposed to apply the same validity criterion discussed above to the visual method.

With respect to the information identified in Reference 11 as being needed for the NRC staff to complete its review, the ICUG report briefly notes that the visual technique would be expected to require a rigorous training and testing protocol to ensure that accumulated data used to identify and ultimately refine process uncertainty has the highest practical quality. However, the report provides only a broad conceptual description of that information. The report acknowledges multiple sources of potential error in this technique (page II-10), and states that this technique will yield uncertainties that are larger than the other two methods. The report provides information on a set of 238 comparative individual mass data points. This data set shows a range of about ± 500 lbms and is biased non-conservatively in that it tends to show more ice mass than is actually present. The resulting uncertainty in the example provided, from bias plus random error, was minus 349 lbms. The comparable uncertainty from the mass projection and basket weighing techniques was minus 56 lbms and 15 lbms, respectively. The report noted that the relative uncertainty of the three techniques and outlined a four-point plan that a licensee could pursue to reduce uncertainty in the methods.

2.3.2 Staff Evaluation

The NRC staff discussed the relative degree of uncertainty of the three mass determination methods in its draft safety evaluation (Reference 11). The NRC staff found, at that time, that the direct weighing of baskets by scale or load cell is the most mature of the three methods and, would require the least additional information. The NRC staff concludes, on the basis of the above discussions of the uncertainty of this method provided by the ICUG, that this is an acceptable method. This conclusion is conditioned on the provision that the technique is implemented by licensees on a plant-specific basis consistent with the methodology in the ICUG-001, Revision 2, report.

The NRC staff also found that ICEMAN™ has been used extensively by at least one utility for maintenance purposes. The NRC staff concludes, on the basis of the discussions in section 2.3.1 of this report of the information provided by the ICUG on the uncertainty of this method, that this is an acceptable method. This conclusion is conditioned on the provision that the technique is implemented by licensees on a plant-specific basis consistent with the methodology in the ICUG-001, Revision 2, report.

The NRC staff found in its draft safety evaluation report that the visual inspection method was the least mature method and would require proportionately more information to justify it on a plant-specific basis. The NRC staff finds that, based on the consideration of the subjectivity of the technique, the multiple potential sources of error, the relatively small data base developed to date, the large uncertainty and the lack of information previously identified as being required by the NRC staff, that this technique is not, at present, an acceptable technique. Therefore, the approvals contained in this safety evaluation do not extend to this technique. Additional information justifying use of this technique may be submitted to the NRC staff, either by the ICUG or plant-specific licensees.

In its draft safety evaluation, the NRC staff discussed data in the topical report showing that ICEMAN™, on the average, underestimated the true weight (measured by lifting) by 13 lbs. This was statistically obtained from 9,470 projections by ICEMAN™. The NRC staff found that because underestimates are conservative in ice weighing surveillance, they are acceptable.

The ICUG-001 report, pages II-8, 9, 10 and Table 3-5, illustrates the process for determining and applying the value of the bias, or uncertainty in each proposed mass determination technique. In cases where the value of the projected mass minus lifted mass is a negative value, the corresponding component of the uncertainty equation is set equal to zero. This is conservative and is acceptable. The example information shown in Table 3-5 shows that the resulting bias value is subtracted from the weighed value or from the projected value prior to comparison with the $\geq$ 600 lbm limit. The NRC staff finds this to be acceptable because it appropriately considers the bias associated with the mass determination method when determining compliance with SR 3.6.15.3.

2.4 Radial Zones in the Ice Bed and Alternate Basket Sampling

2.4.1 Technical Information in the Topical Report and TSTF-429

A top-down view of an ice bed is shown in Figure A-1 of the topical report. The ice bed consists of 1,944 ice baskets in 24 bay sections arranged in approximately a 300 degree arc inside the containment. Each bay has 81 baskets in a 9 x 9 row-column arrangement.

Three radial zones are defined in ICUG-001, Revision 2, as follows: Zone A contains Rows 7, 8, and 9 (innermost rows next to the crane wall); Zone B contains Rows 4, 5, and 6, and Zone C contains Rows 1, 2, and 3. For statistical purposes, each zone has a similar expected as-found mean mass and a reasonable standard deviation. Taking random samples in each radial zone to estimate the total mass of that zone to be [733,400] lbms, as described in the topical report and TSTF-429, Revision 2, is a change from the current TS that requires taking an azimuthal row-group sample. The random sample will include at least 30 baskets from each of these defined radial zones. The value of [733,400] lbms is one-third of the total ice mass in the ice bed.

The ICUG states that an alternate sample basket from the vicinity of the initial sample will need to be selected in cases where a physical obstruction or surface ice accumulation is encountered. The alternate selection criteria have been designed using the radial zone concept, in which baskets in the same radial zone generally have similar mass. Alternate selections are representative of initial selections as long as they have the same probability of being selected as an initial selection and can be expected to have similar characteristics as an initial selection. The representative alternate must be from the same bay and same radial zone as the original selection. In addition, the use of alternate selections is restricted to preventing repeated use of the same alternate basket from affecting statistical confidence.

2.4.2 Staff Evaluation

With respect to the three radial zone concept, the NRC staff asked for a more refined error analysis in RAI no. 8 to demonstrate the adequacy of representing the ice bed with three radial zones. All of the nine radial rows in the ice bed may have different means and different standard deviations through the application of alternate mass determination methods. The ICUG's response to RAI no. 8 in Reference no. 2 re-analyzed the mean difference and standard deviation between ICEMAN™ and manual lifting data. Based on the analysis, the ICUG concluded that the mean difference between ICEMAN™ and manual lifting remains conservative over all the radial rows in the ice bed. The mean difference is less conservative in rows 2-6, because in these rows the ICEMAN™ prediction is closer to the actual mass. The mean difference is larger toward the containment and crane wall (rows 1 and 9, respectively). The standard deviation evaluated by rows shows a similar distribution; i.e., the standard deviation is closer to zero in the middle rows of the ice bed (rows 2-6) because ICEMAN™ predicts the actual masses better, and the standard deviation increases as the rows move outward toward the containment and crane wall. Based on the above analysis, the NRC staff concludes that the use of three radial zones is statistically adequate to represent the nine rows of the ice bed.

With respect to alternate basket sampling, the NRC staff's review of ICUG-001, Table 1-1, Figure 1-2, Table 1-2, and Table A-1 found, as stated by the ICUG report, that the greatest degree of sublimation occurs in radial zone A (inner rows 9, 8, and 7). The NRC staff noted, in RAI no. 3 that significant differences in sublimation rates appeared among Rows 9, 8, and 7, and that more frozen ice baskets exist in Row 9 than in Rows 7 or 8. The assumptions for the criteria for the selection of alternate baskets within a zone are that they are likely to have similar masses and to have similar probabilities of being selected. In RAI No. 3, the NRC staff asked the ICUG to explain how these two apparent deviations from the alternate selection criteria assumptions would affect the accuracy of the mass determination.

The ICUG explained in its response to RAI no. 3 in Reference 2, that the probability of an ice basket being initially selected for the sample analysis is based on a blind, random sampling strategy that includes all rows of the ice bed. Therefore, regardless of the sublimation rates, each basket in the radial zone has the same probability of being initially selected as any other basket in the zone. The ICUG report states that the radial zone grouping concept considers that baskets in the same radial zone will sublimate through their operating "lives" to approximately the same mean mass. Because of the noted sublimation differences between rows, baskets in radial Zone A are actively managed to the design basis limit such that every basket in the zone inherently contains a similar mass at the end of the operating cycle. Because the baskets in Row 9 are characteristically the most likely to be frozen and have higher sublimation than baskets in other rows, the beginning-of-cycle mass of stored ice in Row 9 is typically higher than in Row 7 or Row 8. Therefore, the ICUG concluded that it is likely that an alternate selection of another sample basket from Row 7 or Row 8 would contain the same, or conservatively less, stored ice than that of a Row 9 basket in the as-found condition. Further, the ICUG provided information on the alternate selection criteria as follows:

> In addition to the above, frequency restrictions were established in the alternate selection criteria so that the statistical validity of the 95% confidence sample would be further protected. The criterion established in the topical report prohibits the repeat use of an ice basket which was analyzed as an alternate in any of the three most recent

> surveillances that included the Bay-Zone involved. This restriction, coupled with the potential of multiple statistical sample selections from a single Bay-Zone, ultimately requires that the plants have access to as many baskets as possible for the determination of mass. The combination of this alternate selection criteria and active management of the ice bed ensures a 95 percent confidence level in the total mass of ice in any radial zone.

The clarification provided by the ICUG, as discussed above, resolved the NRC staff's concern that was identified in the RAI. The concern about having to select alternates for frozen row 9 baskets is likely to be offset by the likelihood that an alternate selection from rows 8 or 7 will be of lower weight, which would be conservative. The alternate selection criteria are incorporated into the TSTF-429, Revision 2, Bases and, therefore, will be controlled pursuant to the requirements of 10 CFR 50.59. On these basis, the NRC staff finds the proposed radial zone concept and the alternate basket sampling method to be acceptable.

2.5 <u>Ice Mass Statistical Sampling Plan</u>

The surveillance to determine the mass of ice in the ice bed consists of three activities: (a) the random selection of the sample group of 30 or more ice baskets for each radial zone, (b) selection of the mass determination method, whether by direct weighing or estimation, and (c) for weighing attempts that encounter stuck baskets, either selection of an alternate basket or use of an estimation technique to determine the weight.

The ice mass statistical sampling plan is discussed in Chapter III of the topical report. As stated in the topical report, the sampling plan calls for a stratification of the population by radial zones, where Zone A comprises the first three rows next to the crane wall, Zone B includes the three middle rows of the ice bed, and Zone C includes the three outer rows next to the containment wall. A random sample of at least 30 baskets from each stratum (zone) is selected for a total of at least 90 baskets for the entire ice bed. The distinct advantage of the stratified sampling is that it minimizes the risk that the sample will contain a disproportionate number of a minority group.

The selection of the sample size (at least 30 baskets per zone for a total of at least 90 baskets) is explained in Chapter III of the topical report and is consistent with statistical methodology in Reference 8 that is acceptable to the NRC staff, with one area of exception. This area relates to expansion of the initial sample of 30 or more baskets as discussed in the following paragraph on page III-4 of the topical report:

> The initial sample group can be expanded as necessary (such as when the calculated total mean mass of the ice bed is below the minimum required total mean ice mass), however, the initial sample population must be retained and the additional samples added to build the sample group as follows: [...]
>
> Note that the initial sample group is not discarded; rather, it becomes an element of the expanded sample group. This concept is based on Stein's Procedure in Chapter 8 of Reference 12 [NUREG-1475, "Applying Statistics"].

Further, the ICUG states in item 14 of its letter dated June 12, 2002, that: "The topical report did not specify an exact procedure for expanding the sample, focusing instead on the statistical validity of the concept of expansion as necessary to achieve the intent of the proposed surveillance requirements; i.e., ensuring that adequate ice mass is present for the ice bed to perform its safety function." This issue was also addressed in the ICUG's letter dated October 10, 2002.

The NRC staff finds that the processes described by the topical report and these two ICUG letters would allow a continuously expanding sample to be taken, beyond the initial sample of 30 baskets, until such time that the surveillance limits are either met or the licensee determines that the limit is not met. The NRC staff finds this approach to be unacceptable because if the first sample has been analyzed and determined to be deficient, some doubt has been cast on operability, and by continuously expanding the sample the licensee would be simply increasing the chance of an acceptable result.

The NRC staff also does not agree that the reference to Stein's Procedure in the manner mentioned above is correct. Stein's procedure includes two stages designed to determine the required sample size when the standard deviation is not known. It is not applicable to an expansion of the sample size if the test failed in the first stage, since the claimed confidence (typically 95%) deteriorates with every attempt to retest the assurance.

The NRC staff concludes that the concerns expressed above regarding the expansion of the initial sample may be readily addressed by the proposal of a specific size for the expanded sample. The NRC staff concludes that, with the exception of the process for expanding the initial sample as discussed above, the sampling plan is acceptable to the NRC staff.

The ICUG has recognized that the statistical calculations must account for the use of multiple estimation methods that have different measurement uncertainties. The topical report's method for accomplishing this is derived from the statistical methodology described in Section 8.3.1.1 of Reference 8 and is described by equation 3.2 of the report. The topical report states that its equation 3.2 will be used to calculate the lower bound of the mean for individual ice basket masses. The NRC staff has reviewed the formulation of equation 3.2 and has determined that it is consistent with the NRC approved statistical methodology in Reference 8 and, therefore, finds equation 3.2 to be acceptable. In summary, the principal statistics involved in the total ice mass determination are the average and the standard deviation from which a 95-percent lower confidence limit (LCL) is constructed. Thus, there would be 95-percent assurance that the total ice weight is not below the calculated LCL. The calculations of the main statistics (including the finite population correction for the standard deviation) and the LCL are acceptable to the NRC staff.

In addition to the requirement for an acceptable estimate of the total ice mass, a minimum weight criterion of $\geq$ 600 lbms is set for each of the baskets selected for the sample. The measured minimum weight, accounting for bias and measurement uncertainty, must not fall short of the minimum weight criterion. The topical report indicates (pages III-2, III-3) that all mass determination values are first corrected for the bias of the determination process. Table 3-5 illustrates that the ICUG methodology then calls for subtraction of the uncertainty followed by comparison of the resulting values to the $\geq$ 600 lbm limit. The NRC staff finds that the subtraction of the uncertainty is conservative. The NRC staff concludes that this methodology for determining compliance with the $\geq$ 600 lbm limit is acceptable. The NRC staff may request information on a plant-specific basis for each license amendment application referencing the topical report to confirm that this methodology is being used and to confirm the values of the bias and uncertainty for the mass determination methods being used by the licensee.

3.0 CONCLUSION

The NRC staff has reviewed Topical Report ICUG-001, Revision 2. The NRC staff finds, based on the evaluation provided in the above sections of this report, that the following concepts and methodology are acceptable: (1) the concept of AIMM proposed by the ICUG and the total ice mass requirement, as discussed in Section 2.1, (2) the minimum ice mass requirement for individual ice baskets of $\geq$ 600 lbms, as discussed in Section 2.2, (3) the two methodologies for determining ice basket mass by direct weighing and projection by ICEMAN, as discussed in Section 2.3, (4) the concept of sampling from three radial zones in the ice bed and alternate basket sampling, as discussed in Section 2.4, and (5) the ice mass statistical sampling plan, with the exception of the process for expanding the initial sample as discussed in Section 2.5 above. The NRC staff also finds, as stated in Section 2.3.2, that the visual inspection technique is not, at present, an acceptable technique. The NRC staff finds that TSTF-429, Revision 2, is consistent with these findings, and accordingly, the NRC staff finds TSTF-429, Revision 2, to be acceptable, subject to the two exceptions noted above. Also, the full title and revision number of the ICUG report should be included in the references for the Bases, since this identifies the version of the report that has been approved, with exceptions, by the NRC staff.

4.0 REFERENCES

1. Letter from R. S. Lytton, Chair, ICUG, to NRC, transmitting ICUG-001: “Application of the Active Ice Mass Management Concept to the Ice Condenser Ice Mass Technical Specification,” September 18, 2001.

2. Letter from R. S. Lytton, Chair, ICUG, to NRC, responding to questions on ICUG-001, Rev. 0 and TSTF-429, Rev. 0, June 12, 2002.

3. Letter from R. S. Lytton, Chair, ICUG, to NRC, responding to followup questions on ICUG-001, Rev. 0 and TSTF-429, Rev. 0, October 10, 2002.

4. Letter from R. S. Lytton, Chair, ICUG, to NRC, responding to followup questions on ICUG-001, Rev. 0, and TSTF-429, Rev. 0, October 22, 2002.

5. Letter from R. S. Lytton, Chair, ICUG, to NRC, responding to followup questions on ICUG-001, Rev. 0 and TSTF-429, Rev. 0, November 26, 2002.

6. Letter, D. R. Hoffman, Excel Services Corporation, to Dr. W. D. Beckner, NRC, “TSTF-447, TSTF-429, TSTF-450 for NRC Review,” dated July 15, 2003, transmitting TSTF-429, Revision 2, “Ice Mass Determination Surveillance Requirements” ADAMS # ML032020067.

7. Appendix B to Part 50 - Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants.

8. NUREG/CR-4604, Statistical Methods for Nuclear Material Management, December 1988.

9. Letter, M. S. Tuckman, Duke Power Company to NRC, “Nuclear Quality Assurance Program, Amendment 32,” dated December 18, 2002.

10. Letter, B. B. Desai, NRC, to Duke Energy Corporation, “Catawba Nuclear Station - NRC Inspection Report 50-413/02-02, 50-414/02-02,” dated July 17, 2002.

11. Letter, J. A. Nakoski, NRC, to R. S. Lytton, Duke Power Company, Draft Safety Evaluation for Ice Condenser Utility Group Topical Report no. ICUG-001, Revision 0, dated May 6, 2003, ADAMS # ML031260010.

12. Letter, R. S. Lytton, Duke Power Company, to NRC, transmitting Revision 2 to ICUG-001, dated June 19, 2003, ADAMS # ML031920647.

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