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MEMORANDUM TO: File

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SUBJECT: STAFF AUDIT SUMMARY RELATED TO THE USE OF NARWHAL AND BADGER SOFTWARE IN SUPPORT OF A RISK-INFORMED APPROACH TO RESOLVE THE ISSUE OF POTENTIAL IMPACT OF DEBRIS BLOCKAGE ON EMERGENCY RECIRCULATION DURING DESIGN-BASIS ACCIDENTS AT PRESSURIZED-WATER REACTORS

The NRC staff conducted a regulatory audit at the ENERCON office in Albuquerque, New Mexico, from May 17-19, in order to gain a better understanding of the design and functionality of the Break Accident Debris Generation Evaluator (BADGER) and Nuclear Accident Risk Weighted Analysis (NARWHAL) software programs proposed to support a risk-informed approach to resolve Generic Letter 2004-02 (“Potential impact of debris blockage on emergency recirculation during design-basis accidents at pressurized-water reactors”, Agencywide Documents Access and Management System (ADAMS) Accession No. ML042360586). The audit was conducted in accordance with the NRC audit plan dated May 6, 2016 (ADAMS Accession No. ML16131A798)

The enclosure describes the audit activities and some of the key technical issues highlighted by the NRC staff during the audit.

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Enclosure:
Audit Summary

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STAFF AUDIT SUMMARY – MAY 17-19, 2016

REVIEW OF NARWHAL AND BADGER SOFTWARE PROGRAMS

ASSOCIATED WITH THE RISK-INFORMED APPROACH

TO RESOLVE OF GENERIC LETTER 2004-02

1.0 BACKGROUND, SCOPE, AND PURPOSE

In SECY-12-0093, dated July 9, 2012 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML121320270), a risk-informed option to resolve Generic Letter (GL) 2004-02, "Potential impact of debris blockage on emergency recirculation during design-basis accidents at pressurized-water reactors" (ADAMS Accession No. ML042360586) is discussed. Several pressurized-water reactor licensees indicated an intention to use the risk-informed option to resolve GL 2004-02 at their plant(s). The Break Accident Debris Generation Evaluator (BADGER) and Nuclear Accident Risk Weighted Analysis (NARWHAL) are software tools developed to perform calculations in support of the risk-informed GL 2004-02 closure approach. In order for the NRC staff to gain a better understanding of the architecture, documentation, validation and verification, and underlying algorithms and equations of BADGER and NARWHAL, an audit was conducted at the ENERCON office in Albuquerque, New Mexico, from May 17-19, 2016, consistent with the audit plan dated May 6, 2016 (ADAMS Accession No. ML16131A798). ENERCON and Southern Nuclear Operating Company (SNC) participated in the audit and site-specific application of BADGER and NARWHAL to Vogtle Electric Generating Plant, Units 1 and 2 (VEGP) was used for demonstration purposes.

2.0 AUDIT TEAM

The following NRC staff members participated in the audit:

- Christopher Fong – Team Leader, Risk-Informed Licensing Initiatives Team
- Candace Pfefferkorn – General Engineer, Risk-Informed Licensing Initiatives Team

- Victor Cusumano – Branch Chief, Safety Issues Resolutions Branch
- Steve Smith – Sr. Reactor Systems Engineer, Safety Issues Resolutions Branch
- Ashley Smith – Reactor Systems Engineer, Safety Issues Resolutions Branch

The following ENERCON staff participated in the audit:

- Tim Sande – Chief Mechanical Group Supervisor
- Kip Walker – Chief Mechanical Group Supervisor
- Diane Jones – Chief PRA Group Principal Engineer
- Austin Glover – NARWHAL Cognizant Engineer
- Tom McCarthy – NARWHAL Project Manager
- Nick Eggemeyer – Quality Assurance (QA) Manager
- Frank Kenny – Mechanical Engineering Chief
- Ron Lumia – NARWHAL Project Design Lead
- Alan Mertens – Sr. Mechanical Designer
- David Jurjevich – BADGER Cognizant Engineer
- Patrick Doherty – Mathematician and NARWHAL Developer

The following SNC staff participated in the audit:

- Phil Grissom – Corporate Generic Safety Issue (GSI)-191 Program Manager
- Tim Littleton – VEGP Site Project Engineer
- Franchelli Febo – VEGP Site Design Engineer
- Owen Scott – Risk-Informed Engineering Manager

3.0 AUDIT SUMMARY

A summary of specific audit activities including NRC staff questions and observations are described below.

3.1 Entrance Meeting

At the audit entrance meeting, NRC and ENERCON/SNC staff delivered introductions and reviewed the audit's scope and anticipated schedule.

3.2 NARWHAL Graphical User Interface (GUI) Description

NARWHAL is a computer program that evaluates the probability of GL 2004-02 failures by holistically analyzing break specific conditions in a time-dependent manner. The NRC staff observed a NARWHAL software demonstration that evaluated a simplified non plant-specific example case. NARWHAL inputs and assumptions such as debris characterization and transport as well as results output options were viewed and discussed. The NARWHAL methodology accounts for failures due to multiple variables such as strainer flashing and exceeded strainer debris, in-vessel, and net positive suction head (NPSH) loss limits. NARWHAL has the capability to evaluate all potential breaks for a specific input case. For the bulk case, where all potential breaks for a specific input case are evaluated, a relatively general result is obtained which can detail when acceptance criteria are exceeded.

Alternately, a single break can be evaluated and time dependent results of calculated variables can be obtained. Notably, NARWHAL does not terminate calculations once a failure is identified; the program continues calculations to determine if subsequent failures may occur, when they occur, and to gain other insights regarding the plant response.

With regards to transport of debris to the suction strainer, the NRC staff reviewed the ways in which transport calculations are executed by the NARWHAL software. The transport metrics can be changed based on several factors including break location, debris type/characteristics, flow rates, number of strainers in service, and whether containment sprays initiate.

Based on NRC staff questioning, the following specific information was ascertained:

- Multi-unit (2 or 3 unit) plants are evaluated using one, two, or three NARWHAL models depending on how similar the units are. For the VEGP example case, one model is used.
- NARWHAL relies on thermal-hydraulic analysis input calculated outside of the NARWHAL software. These inputs are used to determine values such as break sizes that would result in containment spray actuation and/or accumulator injection.
- NARWHAL can accommodate plants with spray additive tanks.
- A user defined latent debris penetration for transported fiber during pool fill is included in NARWHAL to account for effects such as increased latent debris causing reduced strainer penetration.
- ENERCON/SNC staff discussed an analysis showing that blowdown transport for small and large break LOCAs results in a relatively similar distribution of debris throughout the containment for an example plant. The analysis is based on work completed in support of NUREG/CR-6369, titled "Drywell Debris Transport Study" (ADAMS Accession Nos. ML003728226, ML003726871, and ML003728322).
- ENERCON/SNC staff stated that head loss test data is used in a straightforward manner. When a debris limit is exceeded it is assumed that the head loss increases to the head loss from the next higher debris load. Other extrapolations are based on approved guidance.

The following additional NRC staff observations were discussed:

- NRC noted that flow rates underlying the basis for calculation of NPSH required (NPSHR) should be based on pump runout flow unless calculations are available to show that the flow will be reduced from that value. Additionally, any operator actions credited for flow reductions should be demonstrated to be achievable. ENERCON/SNC staff stated that NPSHR is corrected for void fraction using approved methodology. For VEGP, NPSHR is based on the calculated flow though the pump, not the pump runout flow. No throttling is credited. The flow rates are based on hydraulic calculations.
- The NRC staff commented that use of parameter input values generally considered to be conservative on an individual basis may result in non-conservative results when considered holistically due to the many competing effects (e.g., temperature versus chemical effects). Therefore, the NRC staff affirmed that it will examine inputs, such as selected temperature profiles, in detail during its review of GL 2004-02 closure submittals.
- ENERCON/SNC staff discussed NARWHAL results based on inputs from both design basis and best estimate temperature/pressure curves. The NRC staff commented that specific thermal hydraulic inputs used for final analyses should be justified.

- The NRC questioned the ENERCON/SNC staff with regards to how transport is treated in cases where sprays do not actuate. The NRC staff concern is that the NRC-approved Nuclear Energy Institute (NEI) guidance on blowdown transport, NEI 04-07, Volumes 1 and 2, titled "Pressurized Water Reactor Sump Performance Evaluation Methodology" and "Safety Evaluation by the Office of Nuclear Reactor Regulation Related to NRC Generic Letter 2004-02, Revision 0" (ADAMS Accession Nos. ML050550138 and ML050550156, respectively), are based on scenarios where it was assumed that containment sprays initiate resulting in washdown of most fine and small debris. For VEGP, in a majority of cases, the sprays may not initiate resulting in significantly reduced washdown transport. NRC staff noted that the blowdown transport methodology applied should account for phenomena that may result in reduced blowdown out of the lower containment or transport to the pool from causes other than spray washdown. The NRC staff noted that there is a precedent transport analysis that assumes that sprays do not initiate (see request for additional information-7, ADAMS Accession No. ML100150072).
- The NRC and ENERCON/SNC staff discussed the filtering of particulate by a fiber bed. The NRC's understanding is that filtering of particulate was not accounted for until the fiber bed reached a 1/16 inch theoretical thickness. The NRC staff stated that filtering could occur due to impaction before a full fiber bed forms on the strainer. The NRC staff further noted that the formation of a full filtering fibrous bed has been considered in the past to determine whether the filtration of problematic debris types, like chemical precipitates, should be considered for strainer head loss. The NRC staff stated that modeling of the filtration of particulates should be performed realistically.
- The NRC questioned how the debris characteristics are handled by NARWHAL. The NRC stated that it appears that all fiber is added together and treated as a single size; if strainer head loss testing is performed with all fines this may be acceptable. ENERCON/SNC staff stated that NARWHAL can track all different debris types and sizes, both those tested and those predicted to transport. NARWAL can also perform a comparison to see if any of the tested quantities are exceeded by the calculated transport values. The VEGP implementation compares fiber fines only even though smalls were included in the pertinent test. ENERCON/SNC staff identified six cases that predict transport of more fine fibers than were included in the test. However, these six cases transport significantly less total small and fine fibers than the amounts included in the test. The ENERCON/SNC staff believe that these cases would not have resulted in failures because the total predicted fiber (small plus fine) is much less than the tested amount, and small fibers added to the test would also include some fine fiber. Also, the test head losses result in margin to failure. The NRC staff considered this methodology reasonable, but noted that cases that result in debris amounts beyond those tested, and considered not to result in failure, need to be justified on a case by case basis.

3.3 Summary of NARWHAL Verification and Validation (V&V) Tests

ENERCON/SNC staff presented specific single run test examples used to verify and validate NARWHAL.

Based on NRC staff questioning, the following specific information was ascertained:

- Though the V&V relied on simplified model cases, the process did account for all features required for more complex models.
- Small bulk runs, in addition to single cases, were included in the NARWHAL V&V.
- ENERCON/SNC staff stated that the ENERCON Quality Assurance (QA) program is compliant with Appendix B to Title 10 of the *Code of Federal Regulations* and The American Society of Mechanical Engineers Nuclear Quality Assurance-1 Certification Program.

The NRC staff noted that, in general, it is expected that pertinent plant-specific procedures for accepting QA software will be followed.

3.4 VEGP Computer Aided Design (CAD) Model Description

During this portion of the audit, the NRC staff observed the CAD model for VEGP and examples of its validation and implementation. BADGER (see below) relies on input information from CAD software to perform an interference analysis based on break size and Zone of Influence (ZOI) size to determine where spherical ZOIs intersect with targets (resulting in the generation of debris). Initially, all breaks are double ended guillotine breaks (DEGB) by default; refinements to smaller (partial) breaks are made thereafter.

Laser scans taken onsite are used to correct any significant deviations between the CAD model (developed based on plant drawings) and the as-built plant conditions. Slight deviations, judged to have insignificant effects on debris amounts, are not corrected in the CAD model.

The NRC questioned how non-pipe loss-of-coolant accidents (LOCAs) are assessed. ENERCON/SNC staff stated that non-pipe LOCAs are not specifically evaluated; however, supplemental analysis per NRC-approved guidance (NEI 04-07) demonstrates non-pipe break scenarios are bounded by analyzed breaks for debris generation and transport. It was noted that for frequency, the total plant LOCA frequency is used as a multiplier to correct the total risk. Plant frequencies from approved guidance NUREG-1829, “Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process” (ADAMS Accession No. ML080630013) include non-piping components.

3.5 BADGER Overview

BADGER uses containment building CAD models to automate calculation of insulation debris quantities for a range of breaks (*e.g*. DEGB, Single Ended Guillotine Breaks (SEGBs), partial breaks, and longitudinal breaks). SEGBs are assumed for lines that are isolated within 10 pipe diameters (D) of the break. For longitudinal breaks, the maximum break size is the square-root of 2 times D, or the DEGB value. BADGER postulates breaks along length of the longitudinal weld between the circumferential welds.

These breaks are placed a maximum of 1/2 D along the weld. ENERCON/SNC staff stated that this value is less than the 5 feet (ft.) metric provided in approved guidance for break selection (NEI 04-07). The methodology assumes that a longitudinal weld can occur on either side of a pipe. The NRC staff observed graphics of the methodology which appeared to show that the method is reasonable for longitudinal breaks.

The following additional NRC observations were discussed:

- BADGER assumes that there is a one inch layer of coating on the surface and then multiplies by the dry film thickness for calculations of coating debris amount.
- For fibrous debris sizing, BADGER calculates a centroid of mass of the insulation and determines the size distribution based on the centroid.

3.6 Insulation Size Distribution Methodology

ENERCON/SNC staff presented a methodology for determining fibrous debris characteristics. The method is based on the distance of the centroid of the mass of fiber from the break. ENERCON/SNC staff provided example studies comparing scenarios where insulation is located at varied coordinates within sub-ZOIs around the break. The studies confirm that the centroid method is a good approximation for a 4 sub-zone model that has been accepted by the NRC for previous deterministic evaluations, but shows less fragmentation when the insulation is distant from the break. ENERCON/SNC staff stated that the centroid model is more representative of available test data, and that, in cases where the fragmentation is reduced, the result is justified because the insulation is located far from the break where testing shows that debris is mostly intact blankets.

ENERCON/SNC staff further stated that the approved sub-zone method assumes that the debris is evenly distributed throughout each zone. If the targets in the plant are uniformly distributed, the sub-zone model is accurate. The centroid method better accounts for where the insulation actually resides with respect to the break. The NRC staff was concerned that the centroid model did not predict that if the majority of insulation is very close to the break that more fragmentation would occur. For the case of a centroid close to the break the sub-zone method would predict the same debris characterization as the centroid method because of the assumption that insulation is spaced relatively uniformly within the sub-zones. The NRC staff expressed concern that if it is known that the insulation is closer to the break that the characterization should reflect the understanding that as jet impact pressure increases additional fragmentation occurs. However, the staff acknowledged that the centroid method would provide results similar to other approved methods because the assumption of uniform distribution of insulation around break locations is generally a good one. In addition, the NRC staff understands that the volume of a sphere with a small radius is much smaller than a sphere with a larger radius so that it is less likely for a majority of targets to reside close to the break. Most of the discussion regarding the centroid method was with respect to Nukon and low density fiber glass insulation. ENERCON/SNC stated it has also performed a similar analysis for Cal-Sil and Temp-Mat insulation types.

The NRC and ENERCON/SNC staff agreed that additional discussion of the centroid methodology as part of subsequent correspondence would be beneficial.

3.7 Additional Debris Generation Topics

ENERCON/SNC staff stated that BADGER uses 2, 1, and 0.5 inch increments for 2-14, 15-27, and greater than 27 inch break sizes, respectively. This approach allows for additional refinement (smaller increments) for breaks that are more likely to result in equipment failures (bigger breaks). Sensitivity analyses were presented to demonstrate how break size and orientation affect debris generation for partial breaks. The cases included partial breaks at 8 and 10 inch welds and used a 10 degree change in orientation and a 0.1 inch size increment. These results were compared to the 2 inch break increment and 45 degree orientation increment used in NARWHAL. The sensitivity studies showed that the NARWHAL methodology of using 45 degree increments for break orientation closely reflects the maximum possible debris amount. Data for 0.1 inch size increments were located between the 2 inch increments in a linear fashion. ENERCON/SNC staff also illustrated that conditional failure probability (CFP) is relatively insensitive to changes in size increments because both the total break number and total number of breaks general increases or decreases proportionally.

The NRC staff acknowledged the ENERCON/SNC staff rationale, but noted that plant-specific sensitivity analysis and/or additional justification may be required to justify specific break increment and orientation selections. The NRC and ENERCON/SNC staff agreed that additional discussion of the basis for specific break increment and orientation selections as part of subsequent correspondence would be beneficial.

3.8 Example Calculation for a Specific Break at Vogtle

ENERCON/SNC presented an example of a single-break analysis done for VEGP. Specific topics discussed during this presentation included break-specific input selection, time-dependent results, comparison of results to various failure criteria, and potential effects from GL 2004-02 phenomena evaluated outside of NARWHAL. The example was for a break of a 29 inch hot-leg pipe with sprays initiating and then secured at 24 hours. A summary of inputs and assumptions for this break was provided to the NRC staff. ENERCON/SNC staff stated that step changes in inputs for pool and atmospheric temperatures resulted in step changes in pool level due to increases in water density and liquid dropping out of the atmosphere due to lower temperatures. It was observed that sump level slowly decreases due to slow filling of the reactor cavity. The example assumed all pumps were operating. Extrapolation of the head loss test results to 30 days was applied at hot-leg switchover. The example case failed due to exceeding the tested amount of fiber even though the NPSH margin was never calculated to be less than zero.

The following NRC questions and observations were discussed:

- The timing associated with extrapolation of the head loss test results may be further examined. For example, the ENERCON/SNC staff choice to apply the 30 day head loss value at the time of hot leg switchover may be overly conservative.
- Forthcoming closure submittals should include explanation of the fraction of fines versus small pieces of debris based on testing and that used in the analysis.
- Documentation of the operating point of the pump is important when using NPSHR corresponding to flow rate.

3.9 Example Calculation for Bulk Simulation of Several Thousand Breaks

ENERCON/SNC staff discussed break-dependent inputs, summary of results, sensitivity calculations for equipment configurations and inputs, and a summary of bounding analyses for an example bulk simulation at VEGP.

The following NRC staff questions and observations were discussed:

- ENERCON/SNC staff noted that design basis calculations for time/temperature are used in the analysis; however, it was not clear to the NRC staff how uncertainties were captured and how, considering competing effects, it is ensured that conservative values are being used. In response, ENERCON/SNC staff described that sensitivities have been completed to ensure conservative inputs and that a description of the bases for use of time/temperature curves will be included in the forthcoming submittal.
- The NRC staff stated that forthcoming submittals should include an explanation of the fraction of fines verses small pieces of debris based on differences between head loss testing and values calculated in the analysis.
- The NRC staff noted how issues like downstream effects, that were satisfactorily addressed using deterministic methods, should be treated. The concern was that some very small potential could exist for undesirable effects to occur even though the evaluations were performed using conservative methods. Licensees should address these issues and demonstrate that they are insignificant. For example by demonstrating that the deterministic methodologies used are adequate to ensure that there would be no effect to plant operation post-LOCA.
- The NRC staff questioned how failure modes caused by conditions such as increased peak clad temperature and/or erosion of components, would be impacted and/or reflected in the analysis.

3.10 Overview of Simplified vs. Detailed Risk Quantification

During this portion of the audit, ENERCON/SNC staff compared its risk quantification approach to that employed by the South Texas Project Nuclear Operating Company (STPNOC), as described in letter dated August 20, 2015 (ADAMS Package Accession No. ML15246A125) for South Texas Project, Units 1 and 2. Specific topics included LOCA frequency allocation methodology, treatment of head loss correlation and chemical effects, and interpretations of the terms “simplified” and “detailed” used in draft Regulatory Guide (RG) 1.229, “Risk-Informed Approach for Addressing the Effects of Debris on Post-Accident Long-Term Core Cooling” (ADAMS Accession No. ML15023A025).

ENERCON/SNC staff stated that for VEGP flashing at the mid-point of the strainer was assumed. The NRC staff noted that this assumption could be non-conservative and/or non-physical given that flashing will occur where submergence is minimized (assuming other variables are held constant). The NRC staff considered the ENERCON/SNC staff justification for its mid-point assumption and also stated that using the mid-point should be verified to result in a good approximation of voids from degasification. Conservative application of crediting containment overpressure to prevent flashing was also discussed.

It was reiterated that NRC guidance regarding LOCA frequency methodology is still under development; however, a publically available draft guidance document is available (ADAMS Accession No. ML16075A340). Specific methodologies described in the draft regulatory guidance were discussed.

The NRC and ENERCON/SNC staff agreed that additional discussion on LOCA frequency allocation as part of subsequent correspondence would be beneficial.

3.11 Overview of Uncertainty Quantification and Input Parameter Distributions

This portion of the audit included ENERCON/SNC staff presentations on quantitative and qualitative methods for assessing uncertainties, use of consensus inputs, and models, and example methodology for determining ranges/probability distributions on specific input parameters. Specifically, the ENERCON/SNC staff described the regulatory basis for inclusion of uncertainty quantification and discussed two different approaches that could be used to quantify uncertainty: a simplified approach using sensitivity analysis and statistical sampling of input parameter distributions with propagation.

ENERCON/SNC staff noted that several inputs can be varied at the same time using the sensitivity analysis method potentially leading to large variations in results. The ENERCON/SNC staff were concerned that the sensitivity method could produce results in unacceptable regions which would appear non-conservative, but actually be a result of compounding uncertainties in the conservative direction. Vice versa, this approach could also potentially produce very low risk results when all uncertainties are set in the non-conservative direction. The statistical approach was envisioned to provide more realistic results. The ENERCON/SNC staff noted uncertainty would need to be addressed for several values including LOCA frequency, fiber penetration, and spray activation and duration.

ENERCON/SNC staff also stated that consensus inputs/models would be used as provided (no additional uncertainty analysis) while site-specific input parameters would be subjected to uncertainty quantification.

The following additional NRC staff questions and observations were discussed:

- NRC staff agreed with the ENERCON/SNC staff assessment that it is important to closely examine parameter values typically considered conservative given that results may not be intuitive when evaluating sensitivities for more than one variable at a time.
- Following-up on previous discussion on mid-point flashing assumptions, NRC staff reiterated that if a plant has overpressure in its design basis, credit for it with regards to GL 2004-02 phenomena could be considered.

3.12 LOCA Frequency Methodology

During this portion of the audit, ENERCON/SNC staff presented potential approaches to allocate LOCA frequency to specific breaks in the VEGP case analysis. Methods based on the use of expert elicitation results as outlined in NUREG-1829, the use of plant-specific data and PRA results for each break/weld, and the use of both size-based frequency information and weighting factors based damage mechanisms, were discussed. ENERCON/SNC staff also discussed the selection of size based bin intervals and analysis based on use of continuum versus DEGB only break sizes.

The following NRC staff questions and observations were discussed:

- NRC staff noted that NARWHAL includes the ability to interpolate frequency values between break sizes using a logarithmic (log)-log and linear-linear approach. NRC staff communicated that a log-linear interpolation scheme is considered by the NRC staff as an adequate approach, as stated in draft RG 1.229.
- NRC staff reiterated that extrapolation of break size exceedance frequencies beyond 31 inches was not included in NUREG-1829.
- Regarding the use of a continuum versus DEGB-only break size model, the NRC staff noted the potential benefit of providing sensitivity analysis to evaluate both cases.
- Although not directly applicable to GL 2004-02 closeout, the NRC staff summarized an NRC-endorsed approach (ADAMS Accession No. ML013470102) associated with risk-informed inservice inspection in which certain weld degradation mechanisms are classified.

The NRC and ENERCON/SNC staff agreed that additional discussion on LOCA frequency methodology and DEGB-only versus continuum break models would be beneficial.

3.13 Example CFP and Probabilistic Ricks Analysis (PRA) Calculation

ENERCON/SNC staff described how LOCA categories, PRA success criteria, LOCA frequencies, and NARWHAL results are used to calculate CFPs. Specifically, each term contributing to CFP was discussed (*e.g*. the probability of a LOCA occurring in each size range for every PRA category, the probability of a LOCA occurring at each weld within each size range, and the probability estimate for success criteria failure at each weld in each size range). NRC staff achieved a general understanding of the ENERCON/SNC CFP calculation and identified areas where additional evaluation may be needed to confirm consistency with pertinent NUREG-1829 guidance.

ENERCON/SNC staff presented an example PRA calculation which included a description of VEGP plant modifications and ∆CDF and ∆LERF [large early release frequency] calculations. The NRC staff observed the ENERCON/SNC staff use of standard methods to modify PRA model logic and specific input values to evaluate risk associated with GL 2004-02 phenomena.

3.14 Uncertainty Quantification Methodology using NARWHAL Statistics Package

ENERCON/SNC staff discussed the current (version 1) and forthcoming (version 2) uncertainty quantification capabilities of NARWHAL during this portion of the audit. While NARWHAL version 1 has the capability to perform sensitivity analyses, version 2 will include a statistics package with the capability to accept probability distributions for pertinent uncertain input parameters and propagate them through the model (also discussed in section 4.10 of this audit summary). The NRC staff acknowledged the potential for enhanced risk-insights afforded by a statistical uncertainty package; however, the NRC staff also noted that the basis for specific input probability distributions would need to be thoroughly justified.

3.15 Perspectives Regarding the Use of Draft RG 1.229

Draft RG 1.229 provides proposed guidance for applying a risk-informed approach for addressing the effects of debris on post-accident long-term core cooling. During this portion of the audit, ENERCON/SNC staff described its experience with draft RG 1.229 for evaluating GL 2004-02 associated risk at VEGP.

The following draft RG 1.229-related topics were noted for additional consideration:

- The use of the arithmetic mean as an aggregation method for LOCA frequencies.
- The inferred definition of "deterministic."
- The reporting requirements as they apply to defense in depth and safety margins.

3.16 GL 2004-02 Closure Documentation

ENERCON/SNC provided an overview of proposed GL 2004-02 closure submittal documentation including a summary of technical justification sections, exemption requests (as necessary), and potential pertinent commitments. ENERCON/SNC staff noted its intention to take into consideration the information and format of the submittal provided by STPNOC in its letter dated August 20, 2015 (ADAMS Package Accession No. ML15246A125). Specific discussion of technical sections such as PRA identification of high-likelihood configurations, base case PRA/configurations, LOCA frequency calculation, CDF/LERF and ΔCDF/ΔLERF results, and compliance with RG 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," dated May 2011 (ADAMS Accession No. ML100910006) was included.

The following NRC staff questions and observations were discussed:

- The approach to ensuring that periodic updates (*e.g*. every 48 months) to the risk-informed analysis are completed should be clearly documented. This documentation should include reporting requirements such as notification to the NRC if debris exceeds the NRC acceptance criteria or in the event that defense in depth or safety margins have decreased from the previously NRC-approved analysis.
- It was reiterated that GL 2004-02 responses should be a complete as possible.

3.17 Exit Meeting

During the exit meeting on May 19, 2016, the NRC staff stated that the audit was very successful in that it provided a comprehensive overview of the capabilities and proposed uses of the NARWHAL and BADGER software in support of a forthcoming GL 2004-02 closeout submittals. It was noted that the audit was conducted in accordance with the audit plan and that the outcome of the audit would be documented according to this audit summary.

The NRC and ENERCON/SNC staff summarized the following open issues that would benefit from additional discussion as part of continued correspondence:

- Strainer flashing failures
- Fiber quantity required to filter particulate
- Insulation size distribution (centroid) methodology
- Break size and orientation increments
- LOCA frequency allocation methodology
- DEGB-only versus continuum break model
- Analysis of breaks past the first isolation valve
- Random pump failure timing
- Risk-contribution from secondary side breaks

5.0 CONCLUSION

The NRC staff found that the audit provided a better understanding of the functionality and proposed use of NARWHAL and BADGER. The NRC staff noted that it was advantageous to discuss the proposed software tools and associated methods so that licensees understand NRC expectations regarding their use in forthcoming site-specific GL 2004-02 closure submittals. There was open communication throughout the audit and items warranting additional discussion were identified.

SUBJECT: STAFF AUDIT SUMMARY RELATED TO THE USE OF NARWHAL AND BADGER SOFTWARE IN SUPPORT OF A RISK-INFORMED

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