RAI 03.09.01-1

QUESTION:

A follow-up to RAI 03.09.02-21

During a technical audit for Section 3.9.2, the staff reviewed the applicant's proprietary documents and found that ACSTIC2 computer code is being used to compute the forcing function due to the pump-induced acoustic pulsation. Since ACSTIC2 was not a listed program for use in the ABWR design, the staff requested that the applicant in RAI 03.09.02-21 address the ACSTIC2 program in the STP FSAR and that the V&V information for ACSTIC2 program be made available for review and approval by the staff. In its response to RAI 03.09.02-21, the applicant stated in Letter U7-C-NINA-NRC-110064 dated April 13, 2011, that the verification analysis is available in a WEC proprietary report for staff audit. In addition, the STP 3&4 COLA will be revised to include the ACSTIC2 computer code in STP FSAR where Subsection 3.9.1.2 states that the computer codes are addressed in Appendix 3D, and Appendix 3D references Subsection 4.1.4.1 for description of ACSTIC2. Therefore, the V&V of ACSTIC2 will be reviewed and evaluated by Section 3.9.1.2, "Applicable Computer Codes." Changes from Revision 5 of the COLA are shown in the markup attached to the response. However, the program shown in the markup is ACSTIC, not ACSTIC2. On June 22, 2011, the staff conducted an audit of ACSTIC2 computer code in the WES offices at Rockville, MD.

Based on the response to the RAI, the staff requests that the applicant clarify the difference between ACSTIC and ACSTIC2. Since the program ACSTIC2 was used for the analysis of STP 3&4 pump-induced pulsation, justify why ACSTIC was referenced in the STP FSAR. Based on the audit, the staff identified two open items. First, the program was developed for use on PWRs, not on BWRs, and the validation is based on the subcooled single phase water system and test data from PWR plants. The staff requests the applicant to provide justification, from K6 plant test data if appropriate, to show that the program is applicable to the ABWR design which is operating in a steam-water saturated condition. Second, the program was verified and validated for version 1.1 for use on PWRs. The applicant is requested to provide V&V package applicable to ACSTIC2 (version 1.3) which was used for the STP 3&4 analysis.

RESPONSE:

1. Difference between ACSTIC and ACSTIC 2

   As stated in the RAI question, ACSTIC2 is used to compute the forcing functions for pump-induced acoustic pulsations for the STP 3&4 ABWR reactor internals. ACSTIC2 is the current version of the computer code that was formerly referred to as ACSTIC. ACSTIC2 was the name given to the initial updated version. Subsequent versions retained the ACSTIC2 name and indicated the version as version 1.1, 1.2, etc. The changes made in the

FSAR as attached to NINA's revised response to RAI 03.09.02-21 should have incorporated ACSTIC2. As a result, the response to RAI 03.09.02-21 is being revised (Revision 2) to correct the FSAR changes to identify ACSTIC2 as the code used for the STP 3&4 analysis.

2. Justification to show ACSTIC2 is applicable to ABWR environment

As noted in this RAI, the ACSTIC2 program has been used primarily in PWR applications and received most of its verification and validation (V&V) in that environment. The following information provides details of the justification and evaluations that further support the applicability of ACSTIC2 to the analysis performed for the STP 3&4 ABWR.

a) STP-3 modeling and analysis: The analysis described in WCAP-17287-P considers only the regions where water is the dominant medium, that is, the fluid below the normal water level. In some parts of this region, some vapor will exist. However, it was decided to proceed with the analysis using properties (density and sound speed) of pure water rather than perform a two phase flow-induced vibration analysis with two phase properties that would be difficult to predict. Because of its higher density and sound speed, assuming water to be the working fluid will yield higher acoustic loads than a less stiff, less dense fluid like steam or a steam-water mixture. Since higher loads mean greater conservatism, this approach was adopted.

b) Boundary conditions: The STP-3 ACSTIC2 model uses a boundary condition at the steam-water interface that requires the pressure fluctuation to be zero. This is a commonly used boundary condition in acoustics and is valid as long as the acoustical fluid interfaces with a large volume of similar fluid. It is also valid for smaller volumes if the fluid in the volume is less stiff and/or less dense than the fluid in the analysis region. Westinghouse will prepare a formal confirmatory calculation providing a simple analytical solution to demonstrate the validity of this zero pressure boundary condition in a BWR environment. NINA will make the Westinghouse calculation of this analytical solution available for NRC review no later than September 15, 2011.

c) The STP-3 ACSTIC2 model employs pump forcing function models that essentially act as a body force in a pump flow path momentum equation. In the past, these forcing functions have been determined by test. In the case of STP-3, no independent tests are available to determine these forcing functions. Instead, the plant test data taken from the Reference Japanese ABWR (RJ-ABWR) were [

]^{a,c} The approach used unit forcing functions magnitudes in the analysis and compared analysis and test results at the transducer location to determine

actual forcing function magnitudes. For this purpose, RJ-ABWR plant test [ ]a,c This is in keeping with the desire to perform a conservative analysis.

d) Comparisons with RJ-ABWR test data: The relevant RJ-ABWR test data [ ]a,c Obviously, a comparison of analysis amplitude results with test data would agree at this location. [ ]a,c Secondly, the nature of the 10 pumps in the RJ-ABWR plant is that they will operate at slightly different rotational speeds. This means that their pulsations will sometimes reinforce each other and sometimes will interfere with each other. This random phasing behavior will influence what the transducers measure at any point in time as pressure amplitudes. Since there is no way of determining relative pump phases at any moment, there is no way to adjust the analysis to properly represent these phases, making comparisons of calculations and transducer amplitude data difficult.

The ACSTIC2 results are used in the structural analysis of the reactor internals components. The structural response of these components is dependent primarily on the frequency and amplitude of the ACSTIC2 results. Thus, it is necessary that the fluid behavior of the system as modeled by the ACSTIC2 code appropriately predict the pressure response of the ABWR plant. Since STP-3 is essentially identical to the RJ-ABWR plant, the test data obtained from RJ-ABWR is used to assure that the ACSTIC2 predictions are representative of an ABWR plant. Thus, the two important characteristics of the analysis model are that 1) the predicted pressure amplitudes are representative of the pressure amplitudes measured at RJ-ABWR, and 2) the acoustic modal response is the same as the measured frequency response in the RJ-ABWR plant. As noted in item c, [ ]a,c to establish a conservative value. The frequency behavior of the ACSTIC2 results is a consequence of the ACSTIC2 model, and thus it is important that these results exhibit [ ]a,c Therefore, Westinghouse will perform [ ]a,c in a formal calculation. Much of the RJ-ABWR data [ ]a,c It is expected that this confirmatory calculation will demonstrate that the ACSTIC2 model [ ]a,c NINA will make the Westinghouse calculation of this analytical solution available for NRC review no later than September 15, 2011.

3. ACSTIC2 Version 1.1 vs. Version 1.3

   Westinghouse procedures for computer software development include a process that is applicable for single application computer programs (Westinghouse Procedure NSNP 3.6.6, "Single Application Computer Programs"). This process can be applied to a specially created version of an existing configured program used on a one-time basis for a specific project. The verification and validation (V&V) of ACSTIC2 version 1.3 utilized this approach.

   ACSTIC2 version 1.1 is configuration controlled in accordance with Westinghouse procedures (RAEA-94-008, Validation Package for ACSTIC2 Version 1.1; MSE-RAEA-106, ACSTIC2 Version 1.1 Release Letter). ACSTIC2 version 1.1 was used as the baseline for version 1.3. Appendix A.4 of CN-A&SA-10-30, Revision 2, "South Texas Project Units 3 and 4 Advanced Boiling Water Reactor Pump-Induced Pulsation Analysis," describes the application of this process to the V&V of ACSTIC2 version 1.3, including the test case comparison files. The above-mentioned documents were among those provided to the NRC for review during the June 22, 2011 audit.

No COLA change is required as a result of this RAI response.

RAI 03.09.02-26, Supplement 1

QUESTION:

In Toshiba Document Number 7B11-D001-3809-01, Revision 0, "CFD Analysis Report for Lower Plenum," the flow within the lower plenum is simulated by means of CFD. The applicant is requested to address the procedure used to validate the CFD model on a system reflecting the degree of complexity of the STP lower plenum.

SUPPLEMENTAL RESPONSE:

This supplemental response is being provided as a result of several discussions with the NRC staff reviewers after submittal of the initial response in STPNOC Letter Number U7-C-STP-NRC-100246 dated November 4, 2010, and the closure of actions in NINA Letter Number U7-C-NINA-NRC-110069 dated May 16, 2011. In those discussions, the NRC requested additional explanation regarding the non-dryer components evaluation. Two (2) specific questions were identified.

3. The reviewers noted that in WCAP-17371-P, Rev. 2, Section 5.1.2 the applicant stated that Analysis Case 4 is bounding because the [ ]^{a,c} flow rate is the maximum achievable at the 100% power level. The analyses of the internal components, except for the CRDH/CRGTs, ICGT/ICMHs, and stabilizers were done at a more conservative flow rate of [ ]^{a,c}. However, the staff noted that only large components in the downcomer (i.e., core shroud, shroud support, and shroud head) were analyzed with [ ]^{a,c} flow rate in Analysis Case 4 as stated in WCAP-17371-P, Rev. 0, Section 6.2.1. The staff went on to state that the small components in the downcomer (FW and LPCF sparger, RIP Guide Rails) and components above the core (steam separators and lifting rods, HPCP sparger and coupling) and components in lower plenum (CP and RIP DP lines) were not analyzed with a more conservative flow rate [ ]^{a,c}.

   In response to this question, NINA and Westinghouse reviewed WCAP-17371-P and the supporting calculations. This review has reconfirmed that all of the components discussed above have been analyzed with the [ ]^{a,c} flow rate for Analysis Case 4, with the exception of the CRDH/CRGTs, ICGT/ICMHs, and stabilizers as stated in Section 5.1.2.

4. In response to RAI 03.09.02-26 dated November 4, 2010, the applicant listed 4 tests which were performed to validate the CFD approach. These tests include cases of separated flow, rotating flow, branched flow, and turbulent flow. The validation tests results have been compared with theoretical or measured results, and it was concluded that the CFD results were sufficiently accurate for these test cases. [

][a,c] We need confirmation that this additional margin is included in the lower plenum component (i.e., CRGT/CRDH assemblies, ICGT/ICMH assemblies, stabilizers, CP DP lines, and RIP DP lines)

In response to this question, NINA, Westinghouse, and Toshiba have reviewed the supporting calculations and confirmed that the [ ][a,c] additional safety margin has been included in the analyses of the CRGT/CRDH assemblies, ICGT/ICMH assemblies, and stabilizers. The forcing functions for the CP and RIP DP lines are based on velocities developed for [ ][a,c] flow rate, as described in the above response to question 1. The resulting velocities were then [

][a,c]

There is no COLA change required as a result of this supplemental response.

RAI 03.09.02-49, Supplement 1

QUESTION:

During the audit, STP presented sample pressure spectra measured on the sub-scale steam dryer. STP suggested that these pressure measurements can be scaled up to the full scale reactor size and operating conditions and then used to estimate the design dynamic loading on the dryer. After reviewing these sample pressure spectra, the NRC staff concluded that most of the pressure spectra measured on the sub-scale dryer do not exemplify the spectral characteristics of the pressure fluctuations measured on the Japanese dryer. Therefore, the staff advised STP that the use of pressure measurements from the sub-scale tests to estimate the STP dryer design load at full power level cannot be approved by the staff. STP was further advised to propose an alternative approach to demonstrate that the steam dryer can be operated safely at the planned maximum power level. In response, STP suggested the following alternative approach:

1. Comprehensive industrial experiences on ABWR dryers will be collected and submitted to NRC for review. The industrial experiences will be compiled for the reactors in Japan because these reactors are "identical" to the STP dryer and have been in operation for several years at conditions similar to those of the STP dryer.

2. A "best estimate" design load for the STP dryer will be developed from compilation of the results obtained from:
   - 15 pressure transducers on the sub-scale dryer
   - 3 pressure transducers on the Japanese dryer
   - 7 strain gages on the Japanese dryer
   - 4 accelerometers on the Japanese dryer.

3. The "best estimate" design load will be used to design the dryer, but the dryer will be instrumented with pressure transducers, strain gages and accelerometers to monitor the alternating stresses during the start-up measuring program.

4. During the start-up measurement program, the reactor load will not be increased beyond an approved power level (around 60% CLTP) until pressure measurements on the actual dryer are obtained and used to update the dryer load, stress margins and limit curves. Further power increases would proceed only if the updated stress margins allow.

5. STP will provide a comprehensive report explaining the methodology which will be used to estimate the dynamic dryer load from pressure measurements on the dryer during the start-up test program. The report will include validation tests together with expected bias errors and uncertainties. The SMT will be used to validate the methodology of load definition.

6. STP will also submit a comprehensive report documenting the FE dynamic model of the

dryer and the method which will be used to estimate the minimum alternating stress ratio of the dryer at CLTP operating conditions. The report will include expected bias errors and uncertainties. In this report, the best estimate design load will be used to estimate the stress level of the dryer.

In order to confirm mutual understanding of the new approach being pursued by STP, the applicant is requested to:

(a) confirm that the above detailed approach will be followed, or update the NRC staff if any deviations from this approach are expected.

(b) submit comprehensive reports on: the industrial experiences of ABWRs; determination of the best estimate dryer load; validation of the procedure of load definition from pressure measurements on the dryer during start up tests; and FE stress analysis of the dryer based on the best estimate design load.

SUPPLEMENTAL RESPONSE:

This supplemental response is being provided as a result of several discussions with the NRC staff reviewers after submittal of the revised response to document closure of NINA actions in STPNOC Letter Number U7-C-STP-NRC-110088 dated June 30, 2011. In those discussions, the NRC requested additional explanation of the following:

e) WCAP-17385, Section 5.5.3.6: The NRC reviewers noted that this section of the WCAP indicates that [

]^{a,c} Validation of these assumptions was requested.

[

]^{a,c}

f) WCAP-17385, Section 5.5.3.4: The NRC reviewers noted that the report states that dead-weight stress is included in the load combination [

]a,c Justification that thermal stresses under these boundary conditions [
]a,c was requested.

[

]a,c

g) WCAP-17385, Section 5.5.5.2: The NRC reviewers noted that the stress ratio of the dryer is calculated as:

Stress ratio = [

]a,c The staff requested justification for not considering any end-to-end uncertainty and bias for [
]a,c

[

]a,c These assumptions assure that the stress evaluation provides conservative results.

h) WCAP-17370-P, Rev. 2, Section 6: NRC staff requested a clarification of the following statement, [

][a,c]

The intent of this statement can be summarized as follows:

- The measurement plus an uncertainty factor must be less than the acceptance criteria.
- The uncertainty factor is defined as [

][a,c]

The supplemental information provided in COLA Part 2, Tier 2, Subsection 3.9.2.4 will be revised to make the description consistent with the current approach as described in this RAI response and the associated WCAPs.

The changes to the STP 3&4 COLA are provided below. Changes to COLA Revision 5 are highlighted in gray shading.

3.9.2.4 Preoperational Flow-Induced Vibration Testing of Reactor Internals

The following standard supplement addresses Regulatory Guide (R.G.) 1.206, Rev. 0:

As discussed in Subsection 3.9.2.3, STP 3 reactor internals are classified as Prototype, and the STP 4 reactor internals are classified as non-prototype, Category I. In accordance with the requirement of Regulatory Guide 1.206 Section C.I.3.9.2.4 for prototype, Section 3.9.2.3 identifies the assessment program for STP 3 that addresses the flow modes, vibration monitoring and sensor types and locations, procedures and methods to be used to process and interpret the measured data, planned visual inspections, and planned comparisons of test results with analytical predictions. ~~In addition, scale model tests will also be used for the development of the analyses of the steam dryers for acoustic loads.~~ The approach for qualification of the STP 3 reactor internals, including the steam dryer, is as described in Reference 3.9-13.

For STP 4 reactor internals components, an inspection program will be implemented in lieu of a vibration measurement program as discussed in paragraph C.3.1.3 of Regulatory Guide 1.20. Subsection 3.9.2.3 identifies the assessment program for the STP 4 non-prototype.

~~Also, as discussed in Regulatory Guide 1.20, Rev. 3, the main steam lines in STP 3 and 4 will be instrumented with strain gages to provide measurements of pressure fluctuations due to flow-induced vibrations. The measurements will be used by the Acoustic Circuit Methodology to analytically predict the steam dryer flow-induced vibration loads. The predicted loads will then be used with a finite-element model of the dryer to confirm the acceptability of the flow-induced vibration loads.~~

RAI 03.09.02-21, Revision 2

QUESTION:

In WCAP-17287-P, Revision 0, "South Texas Project 3, ABWR Pump-Induced Pulsation Analysis", the ACSTIC2 computer code is used to compute the forcing functions generated by the pump acoustic pulsation. The validation process of this computer code is not addressed. The applicant is requested to explain how this code was validated on a system reflecting the degree of complexity of the STP reactor. The applicant is also requested to verify whether this computer code should be listed in Section 3.9.1.2 of the FSAR.

REVISED RESPONSE:

The original response to this RAI was provided in STPNOC Letter Number U7-C-STP-NRC-100236 dated October 25, 2010. In that response, it was stated that the ACSTIC code was not one of the major computer codes that needed to be included in COLA Part 2, Tier 2, Subsection 3.9.1.2. Following the review of this response, the NRC required that the code be included in Subsection 3.9.1.2. Revision 1 to the response to this RAI was provided in NINA Letter Number U7-C-NINA-NRC-110064 dated April 13, 2011 to incorporate the requested information. This revised response (Revision 2) updates the information provided in the Revision 1 response to clarify the correct name of the code (ACSTIC2) that is used for STP 3. These changes are provided in the COLA markup below. All changes from the response Revision 1 are indicated with bars in the margin.

The code was verified by comparisons with two analytical solutions and a comparison of predictions with test loop data. The analytical solutions involved a closed-open pipe resonator and a two-dimensional square of fluid. The two-dimensional square of fluid model is similar in complexity to the downcomer simulation in the STP-3 ACSTIC2 model. Both analyses were performed by first calculating acoustic mode frequencies by hand, exciting the ACSTIC2 models at these frequencies with a unit forcing function, and comparing the ACSTIC2 calculated mode shapes with theoretical values. Figures 10 and 12 of the reference (PVP-Vol. 63 - below) indicate that the ACSTIC2 and theoretical mode shapes are, for any given point, no more than 2% off and, on the average, no more than 0.5-1% different.

The test mentioned above was run with the intention of providing forcing functions for several pump frequencies and accomplished this objective for the first and second blade-passing frequencies. The comparisons also showed that the calculated waveforms in the test loop for each of these frequencies agreed within an average of 10% with the pressure transducer data collected at various locations around the test loop.

The verification analyses were published in PVP-Vol. 63 (ASME) as "A Method for Predicting Pump-Induced Acoustic Pressures in Fluid Handling Systems," R. E. Schwirian et al., pp. 167-184. This publication is identified as Reference 2 in WCAP-17287-P.

Also, verification was performed against plant data in 1983 and involved a comparison of analytically predicted (using ACSTIC, the predecessor of the current ACSTIC2 code) pressure gradient amplitudes with those inferred from guide tube and support column vibration measurements. The results were in reasonably good agreement, one case giving 0.180 psi/inch for the strain-inferred measurement compared to 0.190 psi/inch for the ACSTIC calculation, a difference of 5.6%. This analysis is available for audit in a WEC proprietary report.

The ACSTIC2 code is controlled under WEC's quality assurance program.

The STP 3&4 COLA will be revised to include the ACSTIC2 computer code in the list of computer codes used for evaluation of reactor internals. COLA Part 2, Tier 2, Subsection 3.9.1.2 states that the computer codes are described in Appendix 3D, and Appendix 3D references Subsection 4.1.4.1 for the description of computer codes used for evaluating reactor internals. Therefore the revision to incorporate the ACSTIC2 computer into the COLA will be made to Appendix 3D and Subsection 4.1.4.1. Changes from Revision 5 of the COLA are highlighted with gray shading.

3D Computer Programs Used in the Design of Components, Equipment and Structures

The information in this appendix of the reference ABWR DCD, including all subsections, is incorporated by reference with ~~no departures or~~ the following supplements. A computer code that is used for analysis of reactor internal components is added to Section 3D.3.

3D.3 Reactor Pressure Vessel and Internals

The following computer programs are used in the analysis of the reactor pressure vessel, core support structures, and other safety class reactor internals: NASTR04V, SAP4G07, HEATER, FATIGUE, ANSYS, CLAPS, ASSIST, SEISM03, AND SASSI and ACSTIC2*. These programs are described in Subsection 4.1.4.*

4.0 Reactor

4.1 Summary Description

The information in this section of the reference ABWR DCD, including all subsections and figures, is incorporated by reference with ~~no departures or~~ the following supplements. A computer code that is used for analysis of reactor internal components is added to Section 4.1.4.1.

4.1.4.1 Reactor Internal Components

Computer codes used for the analysis of the internal components are as follows:

(10) ACSTIC2

4.1.4.1.10 ACSTIC2

ACSTIC2 is a Westinghouse computer code which is used for predicting the amplitudes of pump-induced acoustic pressures in fluid-handling systems using a node-flow path discretization methodology and a harmonic analysis algorithm. The pump is represented as what has been referred to in the literature as a "volumetric forcing function." With this program, the fluid system is broken into nodes(pressure) and flow paths (mass flow), the latter connecting the former in multi-dimensional arrays or networks. The computer code is used to calculate pump-induced pressure pulsation loads on reactor internals.