NINA

Nuclear Innovation
North America LLC
4000 Avenue F, Suite A
Bay City, Texas 77414

June 30, 2011
U7-C-NINA-NRC-110088

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville MD 20852-2738

South Texas Project
Units 3 and 4
Docket Nos. 52-012 and 52-013
Flow Induced Vibration - Closure of Actions

Following the October 2010 NRC Audit of the South Texas Project (STP) 3&4 Flow Induced Vibration (FIV) Program, the NRC Staff requested documentation of the closure of the future actions referenced in the responses to several Requests for Additional Information (RAIs) to support the review of the Combined License Application (COLA) Section 3.9. The attachment to this letter documents Nuclear Innovation North America LLC (NINA) closure of the future action associated with RAI 03.09.02-49. This letter and associated NINA letters U7-C-NINA-NRC-110089, U7-C-NINA-NRC-110090, U7-C-NINA-NRC-110091, and U7-C-NINA-NRC-110092 providing revised technical documents concludes all known actions required to support the NRC review associated with the FIV Program.

The attachment to this letter contains no proprietary information. There are no commitments in this letter.

If you have any questions regarding these responses, please contact me at (361) 972-7136 or Bill Mookhoek at (361) 972-7274.

D091
NRO

STI 32891513

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 6/30/11

Scott Head
Manager, Regulatory Affairs
South Texas Project Units 3 & 4

jep

Attachment:
RAI 03.09.02-49, Revision 1

cc: w/o attachment except*
(paper copy)

Director, Office of New Reactors
U. S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

Regional Administrator, Region IV
U. S. Nuclear Regulatory Commission
611 Ryan Plaza Drive, Suite 400
Arlington, Texas 76011-8064

Kathy C. Perkins, RN, MBA
Assistant Commissioner
Division for Regulatory Services
Texas Department of State Health Services
P. O. Box 149347
Austin, Texas 78714-9347

Alice Hamilton Rogers, P.E.
Inspection Unit Manager
Texas Department of State Health Services
P. O. Box 149347
Austin, Texas 78714-9347

*Steven P. Frantz, Esquire
A. H. Gutterman, Esquire
Morgan, Lewis & Bockius LLP
1111 Pennsylvania Ave. NW
Washington D.C. 20004

*Tom Tai
Two White Flint North
11545 Rockville Pike
Rockville, MD 20852

(electronic copy)

*George F. Wunder
*Tom Tai
Charles Casto
U. S. Nuclear Regulatory Commission

Jamey Seely
Nuclear Innovation North America

Peter G. Nemeth
Crain, Caton and James, P.C.

Richard Peña
Kevin Pollo
L. D. Blaylock
CPS Energy

RAI 03.09.02-49, Revision 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.

REVISED RESPONSE:

The original response to this RAI was provided in Nuclear Innovation North America LLC (NINA) Letter No. U7-C-NINA-NRC-110038 dated February 28, 2011. All changes from the original response are indicated with revision bars in the margin.

a) The referenced audit of the STP 3&4 flow-induced vibration (FIV) documentation was conducted by NRC on December 1-3, 2010. At a subsequent audit conducted on January 24-26, 2011 and a phone call with NRC staff on February16, 2011, additional discussions were held that resulted in a re-direction to the approach as outlined in this RAI. Therefore this response provides a modified approach from that described in the RAI to demonstrate steam dryer FIV qualification for the STP Unit 3 prototype.

Background:

Regulatory Guide (RG) 1.20 provides guidance for the comprehensive vibration assessment program (CVAP) for nuclear power plants including preoperational and initial startup testing. The program is intended to demonstrate that the reactor internals are adequately designed to withstand flow-induced vibration (FIV) forces at normal and transient plant operating conditions for the design life of the plant. The ABWR was designed and certified under RG 1.20 Revision 2. This same design is employed in multiple ABWR plants in Japan. One of those Japanese ABWRs, as described in Reference 1 and referred to as the reference Japanese ABWR (RJ-ABWR), commenced commercial operation in 1996 after going through extensive preoperational and start-up testing to confirm that the reactor internals are adequately designed to withstand FIV loads. The RJ-ABWR steam dryer has an excellent operating history as demonstrated by tests and inspections. The latest revision (Revision 3, March 2007) of RG 1.20 contains additional requirements based on recent BWR experiences on steam dryers. Based on the need to address the current guidance, STPNOC (now NINA) decided that STP Unit 3 reactor internals will be designated as the US ABWR prototype.

Approach for Qualification of STP Unit 3 Steam Dryers:

As stated above, the steam dryer design in the ABWR certified design was developed to satisfy the guidance of RG 1.20 Revision 2. The Final Safety Evaluation Report (FSER) for the ABWR (Reference 2) states that the response of the dryer to FIV must be predicted before final design approval, discusses the analyses that were done by the DC applicant which were reviewed by the NRC staff, and concludes that the combination of predictive analysis, pre-test inspections, tests, and post-test inspections provides reasonable assurance that the reactor internals will perform without loss of structural integrity. The ABWR DCD specifies a peak stress amplitude limit that is significantly lower than the ASME Code allowable value (the ASME allowable is approximately 37% higher than the DCD allowable value). Thus the certified dryer design has a predictive analysis that is adequate for this lower allowable stress. This has been confirmed by pre-operational testing at the RJ-ABWR, which confirmed the peak and alternating stresses in the steam dryer meet the DCD allowable limit, and that the maximum stresses are less than this conservative allowable limit.

As discussed in Reference 2, it was anticipated that the data results from the RJ-ABWR, including the information specified in Regulatory Positions C.2.1, C.2.2, C.2.3, and C.2.4 of RG 1.20, would be provided in the response to COL License Information Item 3.9.7.1. However, it was determined in a meeting between STPNOC and the NRC staff in December 2009 that the predictive analyses that were available to STPNOC for submittal in the STP 3&4 COLA were not adequate to meet the guidance as described in Regulatory Position C.2.1 of RG 1.20. However, the FSER was written to anticipate the possibility of this, as it states that if the data from the RJ-ABWR proves insufficient, the COL applicant will develop a test plan to ensure that any additional data is obtained and submitted to the staff. The approach described herein includes an approach to obtain this additional data.

RG 1.20, Revision 3, Part D – Implementation, states, "Except in those cases in which a licensee proposes or has previously established an acceptable alternative method for complying with specified portions of the NRC's regulations, the NRC staff will use the methods described in this guide…" Because the certified ABWR steam dryer design was not designed specifically to meet the guidance of RG 1.20 Revision 3 (as portions of this guidance were not available at the time), but was designed to satisfy the earlier guidance of RG 1.20 Revision 2, NINA proposes to use a combination of the previously established qualification of the dryer along with a proposed alternative to provide a means to demonstrate that the reactor internals will perform without loss of structural integrity, as discussed in the FSER. The alternative approach consists of the activities as described in the following paragraphs:

- *Operating Experience:* As described in Reference 1, the ABWR dryer incorporates improvements in the dryer design that result in greater structural capability and better performance than earlier dryer designs. The ABWR dryers are in use at multiple ABWR reactors in Japan. The STP 3&4 dryers are essentially identical in both configuration and plant operating conditions to the RJ-ABWR and another Japanese ABWR (J-ABWR). The RJ-ABWR has operated for over twelve years and the J-ABWR has operated since 2005. The dryers for both operating plants have undergone inspections and no indications were found. The RJ-ABWR is inspected during each outage, and underwent an extensive examination following the July 2007 earthquake near the site. This successful operating experience, as documented in Reference 1, supports the conclusion of the predictive analysis as described in the DCD and the FSER that the ABWR steam dryer is adequate to meet the DCD stress limits.

- *Confirmatory Predictive Analysis using RJ-ABWR Data:* Reference 2 cites a letter that documents an audit of the reactor internals (Reference 3) by the NRC staff. Reference 3 summarizes that the predictive analyses performed in support of the design certification provided reasonable assurance that the ABWR reactor internals are adequately designed to withstand FIV. In Reference 3 it is also stated that the staff agreed that the analytically predicted values may be upgraded when future test data become available, such as data from preoperational and startup tests of the RJ-ABWR. For STP 3&4, confirmatory predictive analysis has been performed following this approach, using the recorded data from the RJ-ABWR applied to the STP 3&4 analytical model. Stresses in the dryer have been developed and used as a baseline for establishing the design margin. This analysis uses the same finite element model (FEM) that will be used for the power ascension as described below. This confirmatory predictive analysis has been completed and is incorporated in Reference 5, and summarized in Reference 4.

- *Design Modifications to Avoid Acoustic Resonance:* Testing of the RJ-ABWR indicated resonance at a power level less than 100%. As part of the detailed design effort for STP 3&4, subscale testing of the dryer and main steam lines was performed to identify the potential for acoustic resonance for power levels up to 100%. The initial subscale tests confirmed an acoustic resonance occurs below 100% power, similar to that noted for the RJ-ABWR. While the operating experience and inspection results prove that this acoustic resonance does not result in dryer cracking, the STP 3&4 safety relief valve (SRV) standpipe configuration has been redesigned to eliminate the possibility of acoustic resonance. Additional subscale testing was then performed to confirm that the modified standpipe configuration eliminates the acoustic resonance. This subscale testing, standpipe redesign, and confirmatory subscale testing is documented in Reference 4. This design improvement will enhance the overall ability of the STP 3&4 steam dryers to maintain structural integrity for FIV type loads.

- *Instrumentation and Detailed Analysis during Startup:* The STP Unit 3 steam dryer will be instrumented and monitored during initial plant startup with pressure transducers, strain gages, and accelerometers as discussed in Reference 5. To determine the instrument locations for the STP Unit 3 dryer measurement program, a unit loads analysis approach is used to calculate the high stress locations, important acceleration / displacement locations, and important pressure locations that are used to best locate the instrumentation.

  At approximately 60% power, pressure, strain, and accelerometer data will be collected. A methodology has been submitted as part of Reference 4, which is based on preceding approaches presented to and/or approved by the NRC, describes in detail how the STP Unit 3 pressure loading will be developed from the full scale pressure transducer data, which includes application of bias and uncertainties, and frequency shifting for significant modes as applicable. This methodology will be used to perform a stress analysis for the dryer. Limit curves (Level 1 corresponding to 100% of the allowable stress fatigue limit and Level 2 corresponding to 80% of the allowable stress fatigue limit) will be generated. Power will be increased in increments of about 10% power, from approximately 60% power up to 100% power. At each new power level increment, data will be obtained and compared to the limit curves to ensure that the loads and resulting dryer stresses are below the fatigue limit. The limit curves will be redone using the actual pressure data at each new power level before ascending power to the next level. Actions are defined to address the circumstance of a limit curve being exceeded, as described in Reference 5.

  NINA will agree to a COL license condition stating this approach. The proposed license condition is included at the end of this RAI response.

Summary:

The structural adequacy of the STP 3&4 steam dryer for FIV loads is demonstrated by the predictive analysis reviewed by the NRC as part of initial design certification and the successful operating experience verified by inspections. In addition, the FEM used for the steam dryer analysis was used to perform a confirmatory analysis of the original predictive analysis, using the actual strain data obtained from the RJ-ABWR tests. To further assure minimization of acoustic excitation for STP 3&4, design modifications have been made to eliminate acoustic resonance, thereby improving the dryer margin for peak and alternating stresses, and the power ascension plan during initial startup with a hold at 60% power to generate limit curves, further ensure the structural adequacy of the STP 3&4 steam dryer for FIV loads.

The STP 3&4 COLA is to be revised to be consistent with this revised approach for steam dryer qualification. Proposed changes to COLA Revision 5 are provided below. Changes are highlighted by gray shading.

b) Comprehensive reports that provide the necessary information for qualification of the STP 3&4 steam dryers, including the industrial experiences of ABWRs (Reference 1), and the minimization of acoustic excitation and the use of startup test data for stress analyses and development of limit curves (Reference 5) have been submitted to the Staff for review.

References for RAI 03.09.02-49 Response:

1. Westinghouse Report, WCAP-17369-P, "ABWR Dryer Operating Experience for STP Units 3 and 4," February 2011.
2. NUREG-1503, "Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design," US Nuclear Regulatory Commission, July 1994.
3. NRC Document, "Audit Summary - Advanced Boiling Water Reactor (ABWR) Inspections, Tests, Analyses, and Acceptance Criteria (ITAAC) on Reactor Vessel Internals," May 10, 1992.
4. Westinghouse Report, WCAP-17256-P, Revision 2, "STP 3 ABWR Prototype Reactor Internals Flow-Induced Vibrations Assessment Program," June 2011.
5. Westinghouse Report, WCAP-17385-P, Revision 2, "STP Unit 3 Steam Dryer Flow-Induced Vibration Assessment," June 2011.

Proposed License Condition

During power ascension of STP Unit 3, power will be held at approximately 60% of licensed thermal power and data collected from instrumentation on the steam dryer. That data shall be used to predict the pressure loading definition on the steam dryer, and this loading will be used to perform dynamic finite element analysis of the dryer to predict stresses. Limit curves will be generated for the power ascension from the hold power up to 100% power, based on the methodology in report WCAP-17385-P. During power ascension from the hold power, data from the dryer instrumentation will be taken and compared to the limit curves at approximately 70%, 80%, 90%, and 100% licensed thermal power. At each power level, if the measured values are within the limit curves, then power may be increased to the next power level without prior NRC approval. If the Level 1 limit curve is exceeded, then the power will be reduced to a previous power level where the Level 1 limit curve was not exceeded. Evaluations will be performed to resolve the uncertainties in the steam dryer analysis and evaluate the continued structural integrity of the steam dryer, including evaluation of the steam dryer strain data at the power level at which the Level 1 limit curve was exceeded, and that evaluation will be submitted to the NRC staff.

Proposed COLA Changes

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.~~

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.~~

No later than ~~After~~ the first refueling outage ~~operating cycle~~ of STP 3 and STP 4, detailed inspections of the steam dryer will be performed to confirm the structural adequacy of the dryer for flow-induced vibration loads.