Tennessee Valley Authority, Post Office Box 2000, Decatur, Alabama 35609-2000

July 26, 2006

TVA-BFN-TS-431
TVA-BFN-TS-418

10 CFR 50.90

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Mail Stop OWFN, P1-35
Washington, D. C. 20555-0001

Gentlemen:

In the Matter of	)	Docket Nos. 50-259
Tennessee Valley Authority	)	50-260
	)	50-296

BROWNS FERRY NUCLEAR PLANT (BFN) - UNITS 1, 2, AND 3 - TECHNICAL SPECIFICATIONS (TS) CHANGES TS-431 AND TS-418 - EXTENDED POWER UPRATE (EPU) - RESPONSE TO ROUND 7 REQUESTS FOR ADDITIONAL INFORMATION (TAC NOS. MC3812, MC3743, AND MC3744)

By letters dated June 28, 2004 (ADAMS Accession No. ML041840109) and June 25, 2004 (ML041840301), TVA submitted applications to the NRC for EPU of BFN Unit 1 and BFN Units 2 and 3, respectively. On July 19, 2006, the NRC staff issued the Round 7 requests for additional information (RAIs) for BFN Unit 1 and BFN Units 2 and 3, respectively). In addition, by email transmission on July 12, 2006, the NRC staff proposed a supplemental Round 7 set of questions regarding steam dryer analyses.

Enclosure 1 to this letter provides responses to the Round 7 RAI questions, as supplemented. In support of this effort,

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and to provide additional conservatism, TVA is providing in Enclosure 2, the revised BFN steam dryer stress analysis report, "Browns Ferry Nuclear Plant, Units 1, 2, and 3 Steam Dryer Stress, Dynamic, and Fatigue Analyses for EPU Conditions." Enclosure 2 replaces, in its entirety, the prior version of the subject report that was provided to the NRC by TVA letter dated July 21, 2006.

Note that Enclosures 1 and 2 contain information that General Electric Company (GE) and Continuum Dynamics, Inc. (CDI) consider to be proprietary in nature and subsequently, pursuant to 10 CFR 9.17(a)(4), 2.390(a)(4) and 2.390(d)(1), requests that such information be withheld from public disclosure. Enclosures 3 and 4 are redacted versions of Enclosures 1 and 2, respectively, with the proprietary material removed. Enclosures 3 and 4 are suitable for public disclosure. Enclosures 1 and 2 contain affidavits from GE and CDI supporting this request for withholding from public disclosure.

TVA has determined that the additional information provided by this letter does not affect the no significant hazards considerations associated with the proposed TS changes. The proposed TS changes still qualify for a categorical exclusion from environmental review pursuant to the provisions of 10 CFR 51.22(c)(9).

No new regulatory commitments have been made in this submittal.

If you have any questions regarding this letter, please contact me at (256)729-2636.

I declare under penalty of perjury that the foregoing is true and correct. Executed on this 26th day of July, 2006.

Sincerely,

William D. Crouch

William D. Crouch
Manager of Licensing
and Industry Affairs

Enclosures:

1. Response to Round 7 Requests for Additional Information (Proprietary Information Version)
2. GE-NE-0000-0053-7413-R2-P (Proprietary Information Version)
3. Response to Round 7 Requests for Additional Information (Non-Proprietary Version)
4. GE-NE-0000-0053-7413-R2-NP (Non-Proprietary Version)

cc (w. Enclosures):

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General Electric Company

AFFIDAVIT

I, Louis M. Quintana, state as follows:

(1) I am Manager, Licensing, General Electric Company ("GE") and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Enclosure 1 of TVA's letter, TVA-BFN-TS-431 / TVA-BFN-TS-418, W.D. Crouch to NRC Document Control Desk, entitled "Browns Ferry Nuclear Plant (BFN) – Units 1, 2, and 3 – Technical Specifications (TS) Changes TS-431 and TS-418 – Extended Power Uprate (EPU) – Response to Round 7 Requests for Additional Information (TAC Nos. MC3812, MC3743, AND MC3744)", July 26, 2006. The proprietary information in the Enclosure 1, which is entitled "Tennessee Valley Authority Browns Ferry Nuclear Plant (BFN) Units 1, 2, and 3 Technical Specifications ((TS) Changes TS-431 and TS-418 – Extended Power Uprate (EPU) – Response to Round 7 Requests for Additional Information (TAC Nos. MC3812, MC3743, AND MC3744)", is delineated by a double underline inside double square brackets. Figures and large equation objects are identified with double square brackets before and after the object. In each case, the superscript notation{3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner, GE relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, <u>Critical Mass Energy Project v. Nuclear Regulatory Commission</u>, 975F2d871 (DC Cir. 1992), and <u>Public Citizen Health Research Group v. FDA</u>, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by General Electric's competitors without license from General Electric constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future General Electric customer-funded development plans and programs, resulting in potential products to General Electric;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a. and (4)b. above.

(5) To address 10 CFR 2.390 (b) (4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GE, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GE, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access to such documents within GE is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GE are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2) above is classified as proprietary because it contains results and details of structural analysis methods and techniques developed by GE for evaluations of a BWR Steam Dryer and of other reactor internals, including separators. Development of these methods, techniques, and information and their application for the design, modification, and analyses methodologies and processes for the Steam Dryer Program and to the design and manufacturing of other BWR internal hardware was achieved at a significant cost to GE, on the order of approximately several million dollars.

The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GE asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GE's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GE's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GE.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GE's competitive advantage will be lost if its competitors are able to use the results of the GE experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GE would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GE of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 26th day of July 2006.

Louis M. Quintana

Louis M. Quintana
General Electric Company

Continuum Dynamics, Inc.
(609) 538-0444 (609) 538-0464 fax 34 Lexington Avenue Ewing, NJ 08618-2302

AFFIDAVIT

Re:: Continuum Dynamics, Inc.'s Proprietary Responses to "Request for Additional Information on Steam Dryer Stress Analysis Submitted by Tennessee Valley Authority in Support of Browns Ferry Extended Power Uprate Request". RAIs Received by C.D.I. July 12, 2006.

I, Alan J. Bilanin, being duly sworn, depose and state as follows:

1. I hold the position of President and Senior Associate of Continuum Dynamics, Inc. (hereinafter referred to as C.D.I.), and I am authorized to make the request for withholding from Public Record the Information contained in the documents described in Paragraph 2. This Affidavit is submitted to the Nuclear Regulatory Commission (NRC) pursuant to 10 CFR 2.390(a)(4) based on the fact that the attached information consists of trade secret(s) of C.D.I. and that the NRC will receive the information from C.D.I. under privilege and in confidence.

2. The Information sought to be withheld, as transmitted to TVA Browns Ferry as attachments to C.D.I. Letter No. 06169 dated 26 July 2006, C.D.I. Proprietary Responses to Questions 1, 2, and 4 for C.D.I. Report 05-28P and C.D.I. Proprietary Response to Question 2 for C.D.I. Report 06-11P in "Request for Additional Information on Steam Dryer Stress Analysis Submitted by Tennessee Valley Authority in Support of Browns Ferry Extended Power Uprate Request," prepared by Continuum Dynamics, Inc. dated 26 July 2006.

3. The Information summarizes:

   (a) a process or method, including supporting data and analysis, where prevention of its use by C.D.I.'s competitors without license from C.D.I. constitutes a competitive advantage over other companies;
   (b) Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;
   (c) Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

   The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs 3(a), 3(b) and 3(c) above.

4. The Information has been held in confidence by C.D.I., its owner. The Information has consistently been held in confidence by C.D.I. and no public disclosure has been made and it is not available to the public. All disclosures to third parties, which have been limited, have been made pursuant to the terms and conditions contained in C.D.I.'s Nondisclosure Secrecy Agreement which must be fully executed prior to disclosure.

5. The Information is a type customarily held in confidence by C.D.I. and there is a rational basis therefore. The Information is a type, which C.D.I. considers trade secret and is held in confidence by C.D.I. because it constitutes a source of competitive advantage in the competition and performance of such work in the industry. Public disclosure of the Information is likely to cause substantial harm to C.D.I.'s competitive position and foreclose or reduce the availability of profit-making opportunities.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to be the best of my knowledge, information and belief.

Executed on this 26th day of July 2006.

Alan Bilanin

Alan J. Bilanin
Continuum Dynamics, Inc.

Subscribed and sworn before me this day: 26. July 2006

Eileen P. Burmeister

Eileen P. Burmeister, Notary Public

EILEEN P. BURMEISTER
NOTARY PUBLIC OF NEW JERSEY
MY COMM. EXPIRES MAY 6, 2007

ENCLOSURE 3

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT (BFN)
UNITS 1, 2, AND 3

TECHNICAL SPECIFICATIONS (TS) CHANGES TS-431 AND TS-418 - EXTENDED POWER UPRATE (EPU) - RESPONSE TO ROUND 7 REQUESTS FOR ADDITIONAL INFORMATION (TAC NOS. MC3812, MC3743, AND MC3744)

(NON-PROPRIETARY VERSION)

This enclosure provides TVA's response to the NRC staff's July 19, 2006, Round 7 Requests for Additional Information (RAI) for BFN Unit 1 and BFN Units 2 and 3, respectively). In addition, this enclosure also provides responses to a supplemental Round 7 set of steam dryer questions provided by NRC staff email transmission on July 12, 2006. Where the same or similar information was requested for all BFN units, the responses to the Round 7 RAIs are combined below for all three BFN units. Unless specified otherwise, the responses provided are applicable to all three BFN units.

ENCLOSURE 2

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT (BFN)
UNITS 1, 2, AND 3

TECHNICAL SPECIFICATIONS (TS) CHANGES TS-431 AND TS-418 - EXTENDED POWER UPRATE (EPU) - RESPONSE TO ROUND 7 REQUESTS FOR ADDITIONAL INFORMATION (TAC NOS. MC3812, MC3743, AND MC3744)

(NON-PROPRIETARY VERSION)

EEEB

NRC RAI EEEB.12

In a letter dated October 3, 2005, in question EEIB-B-4, the NRC staff requested detailed information on the modification to the isophase bus cooling. As the December 19, 2005, response did not contain a sufficiently detailed discussion, address the modifications planned for the isophase bus cooling and the replaced transformers. With regards to the transformers, clarify what modification will be made to increase the rating of the main transformers and when the new transformers will be installed.

TVA Response to RAI EEEB.12

The modifications to the isophase bus cooling system include replacement of the cooling coil with a higher capacity coil, replacement of the single cooling fan with dual cooling fans, duct work modifications, damper replacements and replacement and changes to instrumentation and controls.

The existing 42,000 scfm fan will be replaced by two fans rated 39,611 scfm. One fan is required for a majority of the year. For maximum design basis raw cooling water and ambient temperature conditions, two fans may be required. Fan inlet dampers are provided such that each fan will deliver 22,500 scfm to provide the required 45,000 scfm total flow for maximum design basis conditions.

As stated in the response to EEIB.B.4 dated December 19, 2005, the existing Main Bank Transformer (MBT) rating of 448 MVA @ 65°C FOA per phase or 1344 MVA three phase is adequate for operation at EPU. However, the MBTs are being replaced as a material improvement due to aging and reliability concerns. MBT cooling equipment and MBT high and low voltage winding connection hardware is also replaced. The new transformers are rated 500 MVA @ 65°C per phase. The Unit 1 and 2 MBTs including the Unit 1/2 spare have been replaced. The Unit 3 MBTs are scheduled to be replaced in 2010. The Unit 3 EPU outage is currently scheduled for 2008. The existing Unit 3 Main Bank Transformers have been evaluated for aging and life expectancy by the transformer vendor. The evaluation concluded that the existing transformers are adequate for EPU operation but should be replaced between 2010 and 2012 to minimize reliability risk.

NON-PROPRIETARY VERSION

NRC RAI EEEB.13

Since higher capacity recirculation, condensate, and condensate booster pumps are going to be installed, clarify if any modification to the cabling and protective relaying would be required because of the higher load current and provide the status and schedule for those modifications.

TVA Response to RAI EEEB.13

Modifications to the Recirculation Pump power circuit to increase capacity include protective relay setting changes. The Recirculation Pump motors were evaluated by the motor supplier and re-rated for a higher horsepower. The power train cabling including penetrations, buses, and circuit breakers to the Recirculation Pump motors were evaluated and confirmed to be adequate for the higher load. Protective relay settings will be adjusted for the higher rated horsepower. Full protective relaying coordination is maintained with upstream protective devices.

Modifications to the Condensate Pumps to increase capacity include replacement of the motors with larger motors. The existing #2/0 AWG power feed cable to each Condensate Pump will be replaced with a #4/0 AWG cable. Motor feeder breaker protective relay settings will be adjusted for the larger motors. Full protective relaying coordination is maintained with the upstream protective devices.

Modifications to the Condensate Booster Pumps to increase capacity include replacement of the motors with larger motors. The existing 400 kcmil power feed cable to each Condensate Booster Pump will be replaced with a 750 kcmil cable. Motor feeder breaker protective relay settings will be adjusted for the larger motors. Full protective relaying coordination is maintained with the upstream protective devices.

The modifications described above are installed as part of the Unit 1 Restart / EPU effort and will be installed prior to Unit 1 Restart. The Unit 1 Restart / EPU outage is presently scheduled to complete in early 2007. For Unit 2 and 3, the modifications described above will be installed during the EPU outage for each unit. The Unit 2 EPU outage is presently scheduled for 2007, and the Unit 3 EPU outage is presently scheduled for 2008.

NRC RAI EEEB.14 (Unit 1)

Discuss how the main generator breaker rating is modified from the current 36 kA to 37 kA and short circuit rating of 346989 amperes to support operation at extended power uprate conditions for Unit 1.

TVA Response to RAI EEEB.14 (Unit 1)

The Unit 1 generator has been uprated to 1330 MVA, 22 Kv (+/-5%). Considering the -5% minimum operating voltage, this equates to a maximum continuous current of 36.74 kA. The Brown Boveri (ABB) model DR36V1750D generator circuit breaker and associated self-contained cooling plant were evaluated by the generator circuit breaker vendor for 37 kA continuous current and found to contain sufficient design margin to up-rate the circuit breaker from 36 kA to 37 kA continuous current and from 165 kA short circuit to 200 kA short circuit.

As stated in the PUSAR, the Main Isolated Phase Bus Duct is uprated for an asymmetrical current rating of 346,989 amps to support the generator output at EPU conditions. However, only a fraction of this current is generator contribution and consequently only a fraction of this current would pass through the generator circuit breaker. The remaining contribution is from the transmission grid through the Main Bank Transformers. The main generator breaker rating is evaluated and rated for the maximum short circuit current it would be required to withstand and interrupt.

When the PUSAR was written, the short circuit calculations used manufacturing tolerance impedance values of - 7.5% of the specified value for the new Main Bank Transformers, since actual impedance values were not available. Using these values the calculation yielded a required symmetrical current rating of 204,529 Amps, as stated in the PUSAR. Subsequent to the PUSAR and prior to the EEIB-B-4 response dated December 19, 2005, the calculations had been re-performed using actual impedance values for the new Main Bank Transformers and the calculations showed a breaker short-circuit interrupting capability of 196,000 Amps is required and the 200,000 Amp short circuit breaker rating is adequate for 1330 MVA generator operation.

Therefore, the generator circuit breaker at the uprated ratings of 37,000 Amps continuous current and 200,000 Amps rated short circuit current is adequate for EPU operation on Unit 1 at 1330 MVA and no circuit breaker modifications are required. The generator circuit breaker rating changes are nameplate only changes.

NRC RAI EEEB.14 (Units 2 and 3)

Enclosure 4, Section 6.1.1 in Enclosure 4 of the June 25, 2004, submittal, NEDC-33047P, DRF 0000-0011-1328, Revision 2, Browns Ferry Units 2 and 3 Safety Analysis Report for Extended Power Uprate, of the PUSAR, states that the generator breaker is to be modified to have a continuous rating of 36740 amperes for Units 2 and 3; however the December 19, 2005, responses to EEIB-B-4 states that no changes are required in generator breaker rating. Explain the discrepancy and provide a discussion how the continuous and short circuit ratings of the generator breaker will be increased for extended power uprate (EAU) conditions, if needed.

TVA Response to RAI EEEB.14 (Units 2 and 3)

The information in Section 6.1.1 of the Unit 2 and Unit 3 PUSAR regarding the generator breaker continuous current was stated for an uprated 1330 MVA generator.

The Unit 2 and Unit 3 generators are rated at 1280 MVA, 22 kV (+/-5%). Considering the -5% minimum operating voltage, this equates to a maximum continuous current of 35.4 kA. The Unit 2 and Unit 3 generator breakers are rated for 36 kA continuous current and hence adequately rated for continuous current at 1280 MVA. When the PUSAR was written, the short circuit calculations used manufacturing tolerance impedance values of -7.5% of the specified value for the new Main Bank Transformers, since actual impedance values were not available. Using these values the calculation yielded a required symmetrical current rating of 204,529 Amps, as stated in the PUSAR. Subsequent to the PUSAR and prior to the EEIB-B.4 response dated December 19, 2005, the calculations had been re-performed using actual impedance values for the new Unit 1 and 2 Main Bank Transformers (similar results are expected for the new Unit 3 Main Bank Transformers when actual impedance values become available). The calculations showed a breaker short-circuit interrupting capability of 196,000 Amps is required, and the 200,000 Amp short circuit breaker rating is adequate for 1330 MVA generator operation. Therefore, the existing generator circuit breakers at their existing continuous current and short circuit ratings are adequate for EPU operation on Unit 2 and Unit 3 at 1280 MVA as discussed in the December 19, 2005, response to EEIB-B.4.

An uprate of the Unit 2 and 3 generators from 1280 MVA to 1330 MVA is being pursued to make the Unit 2 and Unit 3 generator ratings the same as Unit 1. For this uprate, the Unit 2 and 3 generator circuit breakers should have a continuous current rating of at least 36740 Amps as stated in the PUSAR. Since the generator circuit breakers are the same for all three units, Brown Boveri (ABB) DR36V1750D, the generator breaker continuous current rating could be uprated from 36 kA to 37 kA as is being done for Unit 1 for a generator uprate to 1330 MVA. Also, see reply to EEEB.14 (Unit 1). As stated above, the generator breaker short circuit rating of 200,000 Amps is adequate for 1330 MVA generator operation. The Isolated Phase Bus for Units 2 and 3 are being uprated to 36720 Amps in anticipation of a generator uprate for Units 2 and 3. A transmission study has been completed to evaluate an uprate of the Unit 2 and Unit 3 generators to 1300MW and 200 MVAR capability. The study concluded that at these Post-EPU generator output levels, the post-trip voltages at the safety buses remain adequate. In addition, the study concluded that operation of all three units at EPU electrical outputs of 1300 MWe will not have a significant adverse effect on reliability of the offsite electrical system or on the stability of the Browns Ferry units.

EEMB (Previously EEMB-B)

NRC RAI EEMB.15

Describe the power ascension monitoring plan for steam dryer and main steam lines.

TVA Response to RAI EEMB.15

Refer to the response to RAI EEMB.D.7 below.

NRC RAI EEMB.16

Enclosure 1 of the letter dated April 13, 2006 contained the General Electric (GE) report, GE-NE-0000-0049-6652-01P, Revision 0, General Electric Boiling Water Reactor Steam Dryer Scale Model Test Based Fluctuating Load Definition Methodology, dated March 2006 (SMT Report). [[

]] Explain the modeling of surface roughness, edges, and other geometric parameters at the small scale of 1/17; potential distortions and their consequences; and the range of uncertainty in replicating the existence of the excitation mechanisms, their magnitudes, and their frequency content. Include a discussion of why, when and how 1/6th scale models are used for modeling the S/RVs.

TVA Response to RAI EEMB.16

Surface roughness for the pipes at the [[ ]] will be closely equal to the value for commercial steel (or wrought iron), which is about 0.00015 ft. Edges at the [[ ]] The differences in the scale model S/RVs and the plant S/RVs are:

a. [[ ]]
The difference in [[ ]], which is within the uncertainty of the current SMT.

b. [[ ]]
The fundamental frequency of a valve will change slightly when the sweepolet is modeled. Previous acoustic finite element valve models have shown a [[ ]].
There is current literature that supports the fact that rounding the downstream edge of a cavity will substantially reduce the maximum acoustic pressure and that rounding the upstream edge increases the velocity for peak acoustic resonance but has less affect on the magnitude of the peak acoustic resonance as does rounding the downstream edge.

c. [[ ]]
There have been [[ ]] scale valve tests performed for the Quad Cities (QC) [[ ]]The QC valves were [[ ]] The results of these tests have shown that modeling the [[ ]]

NRC RAI EEMB.17

[[ ]], because they cannot be accurately modeled at 1/17 scale. Discuss what, if any, flow-induced vibration (FIV) excitation mechanisms are precluded by this distortion.

TVA Response to RAI EEMB.17

The main FIV excitation mechanism that could be precluded by this simplification is the potential acoustic resonance of the branch lines that are not included in the scale model. However, it is believed that this is not an issue due to the following reasons:

a. Only those branch lines with full scale diameters less than 2″ have been neglected. The steam column contained in these branch lines is very small compared to the steam volume inside the main steam lines. Therefore, even if excitation of a branch line occurred, the amount of acoustic energy generated by a steam column with such a small cross sectional area would be negligible and unable to excite the entire steam system. These branch lines may be susceptible to local excitation, which could cause local damage to their supports or other structural elements. However, these local resonances will not have enough energy to propagate through the main steam system and reach the dryer.

b. In general, branch lines with full scale diameters less than 2″ are long instrumentation lines used for monitoring flow variables at different locations in the main steam system. These instrumentation lines are usually very long so their first natural acoustic frequencies are low and cannot be excited by the range of typical flow velocities in the main steam lines. Taking the average Main Steam Line (MSL) steam velocity to be [[ ]], the branch line length that would give maximum resonating amplitudes for this flow velocity is given by

$$L = cd/(4St\ V)$$

Assuming maximum resonance occurs at Strouhal values between [[ ]] and taking the speed of sound to be 1600 ft/s (approximate value), the bore length for small diameter branch line would need to fall in the [[ ]] Therefore, it is unlikely that the SMT is missing a significant response by not modeling these small diameter branch lines.

NRC RAI EEMB.18

As mentioned on pages 71, 74, and 114 of the SMT Report, [[

]] Explain how the waterline is modeled, changes that are planned, and the effects of potential distortions on pressures and acoustic mode shapes. The response should take into account that acoustic circuit analysis (ACA) has shown that this water-steam interface's damping significantly affects pressure predictions.

TVA Response to RAI EEMB.18

The waterline region inside the dryer skirt is different from the steam/water interface between the skirt and the vessel inside wall. The following simplifications have been made in each region:

[[

]]

As shown in Figure EEMB.18-1, this geometry is complex so acoustic wave scattering and multi-reflections are expected. GE cannot quantify the conservatism introduced in the system by these simplifications. GE has started a research and development program in order to determine the effect of modifying the full-size plant boundary conditions in the waterline region inside the skirt. The objective of this development program is to obtain a correction factor that can be applied to the scale model test measurements in order to eliminate the conservatism introduced by the simplifications discussed above.

[[

]]

Figure EEMB.18-1

Steam System Boundaries in Full-Size Plant

NRC RAI EEMB.19

As mentioned on pages 70 and 75 of the SMT Report, [[ ]], which the report states will attenuate fluid flow oscillations. Elaborate on how this distortion will affect SMT pressures and what changes could be made to model more prototypic conditions. The reply should take into account that ACA analysis has shown that the steam dome and MSL steam damping significantly affects pressure predictions.

TVA Response to RAI EEMB.19

The primary mechanism for attenuation of acoustic energy in wet steam is heat and mass transfer between the steam and water droplets. As the acoustic waves propagate through the mixture, they cause changes in the steam temperature and pressure. If the steam is compressed and the temperature rises, then the steam condenses on the cooler water droplets to achieve equilibrium. If the steam is expanded and cools, then the temperature difference between the steam and droplets encourages the water droplets to evaporate to achieve equilibrium. Thus, when the steam is subjected to fluctuating pressure oscillations due to the propagation of acoustic waves, the interface between the steam and water is subjected to periods of evaporation and condensation at the same frequency as that of the pressure oscillations.

Most of the heat and mass transfer described above is not reversible, resulting in conversion of acoustic energy into thermal energy. This attenuation mechanism is present in a typical BWR steam system whereas it is not captured in the SMT. Therefore, SMT pressure predictions are expected to be conservative.

It is worth noting that the description of the attenuation mechanisms provided in this RAI response is merely qualitative. Parameters such as droplet size and spatial distribution of droplets have a very significant impact on the attenuation of acoustic waves. The presence of a few, relatively large droplets would cause a more adiabatic behavior of the two-phase mixture whereas fog like conditions with droplet sizes of the order of one micron would facilitate heat and mass transfer between phases. Therefore, quantitative models for the attenuation of acoustic waves in BWR steam systems can only be developed when the distribution of water droplets in steam is known.

No reliable models for predicting the distribution and size of the droplets inside the main steam lines of a BWR exist. [[

]] Even if these conditions were known and well understood, they would be very hard to replicate using the current test apparatus. It would be easier to derive an analytical correction factor for reducing the pressure amplitudes predicted by the SMT.

NRC RAI EEMB.20

As mentioned on pages 70, 71, and 74 of the SMT Report, the array of steam separators in the reactor are described to act like a muffler and the vane bundles which provide some attenuation to acoustic waves. [[
]] Explain how these boundary conditions are represented in the SMT. Also, explain how the differences between the actual boundary conditions and those modeled in the SMT affect the pressures and acoustic mode shapes.

TVA Response to RAI EEMB.20

The [[
]] These components will reflect to some degree incident acoustic waves. Pressure waves traveling from the vessel dome cavity into the dryer will have reflection and transmission through the dryer vanes and perforated plates. The following comparisons between the plant and model scale are noted:

a. The separator opening boundary condition in the full size plant will absorb to some extent incident pressure waves whereas the same will occur in the [[

]] The frequencies that get reflected and absorbed are highly dependent on the geometry.

b. The steam/water interface inside the dryer skirt will also act as a [[ ]] in the full size plant. It is estimated that for water with [[ ]] one can show that this steam/water interface can [[ ]] of the incident pressure waves in the full size plant.

c. The geometry of the steam separators is highly irregular, which will cause wave scattering of the incident waves in the full size plant. In the scale model, there [[

]]

Characterization and flow tests were performed on the Browns Ferry SMT with and without a perforated plate that modeled the steam separators. Adding the separator plate in the SMT [[

]]

On average, for a frequency band of [[

]] on the dryer when the separator plate was installed, see Table EEMB.20-1 below. On average, for a frequency band of [[

]] on the dryer when the separator plate was installed. This signifies that the separator had a greater affect on the [[ ]]

NON-PROPRIETARY VERSION

[[

]]

[[

]]

NRC RAI EEMB.21

As mentioned on pages 72, 73, 75, and 104 of the SMT Report, [[ ]] Also, the piping layouts between the S/RVs and the MSIVs are not prototypic. [[ ]] Elaborate on the sensitivity of the turbulence noise excitation mechanism created by these model distortions. Include in the response similar considerations for the turbine control valves (TCVs) and turbine stop valves (TSVs). Discuss the adequacy of the modeling of these components.

TVA Response to RAI EEMB.21

[[ ]] were tested in the Browns Ferry SMT along with a simplified ball valve arrangement similarly used in the Quad Cities (QC) SMT. The results show some difference on the overall dryer loading. The major difference observed between the [[ ]] (model scale) frequency band. This frequency band showed the [[ ]] pressures.

True, the removal of the [[ ]] No sensitivity tests have been performed between [[ ]] (those using standard piping components). [[ ]]

Preserving the [[ ]]

A notable difference between the model MSIVs and the plant MSIVs is that, in the scale model, the [[ ]] into the flow region whereas the plant [[ ]] This will have a direct impact on the local large-scale turbulent structures in the MSL, since they are directly affected by geometry. Large scale turbulent eddies are responsible for carrying and transporting most of the energy in a turbulent flow. [[ ]] and the vorticity (vorticity has the dimensions of frequency [sec^{-1}]) can be estimated from the [[ ]] one can determine the frequency at which the large scale eddies exist. A rough approximation for the frequency associated with these large scale eddies is [[ ]] This is not the only frequency associated with the model MSIV turbulence, since turbulence is more of a broadband phenomenon. This is, however, an approximation to where most turbulence energy, produced by the MSIVs, will come from, with higher turbulent frequencies leveling off in energy. Because the [[ ]] than the plant MSIVs, the SMT will most likely give [[ ]] for the pressure oscillations that come [[ ]]

NRC RAI EEMB.22

In reference to the discussion on page 46 of the SMT Report, discuss potential periodicities created in the flow resulting from the multiple jets emanating from the top of the dryer into the steam dome.

TVA Response to RAI EEMB.22

There is a possibility that the flow jets exiting the dryer plenum can attach and detach from surfaces on the dryer or steam dome and may set up periodicities. Two potential locations for flow jets attaching and detaching from dryer surfaces are in the exit plenums between banks and on the outer hood faces. The exit plenum should not be significant for the following reasons: (i.) the [[ ]] and (ii.) the horizontal flow leaving the vane bank will tend to keep the flow pinned to the back of the hood. There will be some loading on the tops of the hoods due to the circulation that is trapped between the exit plenum jets but this should be minor because of [[ ]] It is not expected that there is any separation from the steam dome because the curvature of the dome is converging and funneling the flow toward the steamlines. It is expected that the flow over the top edge of the outer hood will always be separated from the face of the dryer. The CFD results shown in the Quad Cities Unit 2 (QC2) benchmark report suggest that there may be [[ ]] in the separation layer, which may lead to some periodicity in the loading if the vortex moves around.

The QC2 operating pressure data do not demonstrate any [[ ]] as data from some other plants do. Review of available data indicates that the periodicity, a [[ ]] peak apparent in time records of operating data, is most common in 5 bank dryers. Like BFN, QC1 and QC2 are symmetric 6 bank dryers. The steam is directed inward by the 3 banks on each side, unlike a 5 bank dryer, where half of the center bank directs flow in one direction and half of the center bank directs flow in the other direction, imparting a rotation or spiral to the flow. This flow phenomenon may also lead to periodicity. Segments of QC2 operating pressure at EPU on each hood are shown below and contain no indication of periodicity. The plots following the QC2 operating pressure are BFN1 SMT results at plant scale. There is some indication [[ ]] basis, but it is not as consistent as other plant data with significant periodicity.

[[

]]

Figure EEMB.22-1: Time Histories of Pressure Sensors on QC2 Plant, 90° Hood, at 2887 MWt

[[

]]

Figure EEMB.22-2: Time Histories of Pressure Sensors on QC2 Plant, 270° Hood, at 2887 MWt

[[

]]

Figure EEMB.22-3: Time Histories of Pressure Sensors on BFN1 SMT at plant scale, 90° Hood, at EPU

[[

]]

Figure EEMB.22-4: Time Histories of Pressure Sensors on BFN1 SMT at plant scale, 270° Hood, at EPU

NRC RAI EEMB.23

In reference to the discussion on page 49 and in Appendix A of the SMT Report, explain the potential excitation mechanisms within the steam dome and their significance in term of the need to understand their source and impact. Address the dependence of these mechanisms on Reynolds number (Re) and their possible distortion in the SMT.

TVA Response to RAI EEMB.23

Two potential excitation mechanisms for acoustics within the steam dome may come from vortex shedding and from the turbulent mixing layer of the steam jet exiting the dryer plenum and, in general, flow turbulence in the steam dome. The vortex shedding instabilities can occur where steam exits the dryers and turns downward during transit to the steam lines, at the entrance of the steam lines, or at any other geometric device that interrupts the shear layer. A non-dimensional order of magnitude analysis concluded that for the full size system parameters (plant scale), [[

]] Blevins also points out that the Strouhal number, an important dimensionless parameter which relates vortex shedding frequency to flow velocity, is independent of Reynolds number for many geometrical objects (Blevins, Figure 3-6). Therefore, it is likely that Reynolds numbers in the dryer and dome region has a negligible effect on the excitation mechanisms. Furthermore, since the [[ ]] any vortex shedding or flow instability in the steam dome at the plant will be likely preserved in the model.

NRC RAI EEMB.24

In reference to the discussion on page 138 of the SMT Report, address how the time shifts are formulated in the stress analyses using an SMT load definition [[

]] ERV and S/RV peaks observed in the Quad Cities Unit 2 (QC2) at different frequencies.

TVA Response to RAI EEMB.24

The multiple ERV and S/RV peaks observed at QC2 are due to the small as-built dimensional differences between individual standpipes. In the SMT testing methodology, [[

]] time shifts in the structural analysis report addresses potential for multiple SRV resonances around this basic frequency. Previous structural analyses for other plants have shown that the [[ ]]time shift resolution is sufficient to characterize the structural sensitivity to the frequency content [[

]]

No multiple resonances were observed in the SMT loading for the TVA analysis. Only one basic frequency at approximately [[ ]] is predicted for the SRV resonance at BFN. The amplitude of this predicted resonance has been scaled up by a factor of 5.16 in the load definition in order to bound the worst case amplitude observed in QC2.

NRC RAI EEMB.25

In reference to the discussion on page 140 of the SMT Report, address how the SMT and the prototype are correlated, so that normal modes are adequately modeled at all the frequencies of interest.

TVA Response to RAI EEMB.25

Modal correlation between SMT and full-scale has not been performed because the data necessary to perform in-plant Experimental Modal Analysis (EMA) is unavailable. The available in-plant data is limited to operational data on the dryer surface which is sufficient to evaluate the load definition process. However a modal analysis would require the availability of acoustic FRF data in a much larger number of measurement points. The latter would also require having a calibrated volume velocity source in the steam plenum, preferably in conditions that are close to operational conditions. The required measurement effort would be prohibitively expensive, if not practically impossible.

The report is referring to the principle that eigenmodes generally become more sensitive to small deviations in geometry and boundary conditions with increasing frequency. This can be understood easily by looking at the relation between a wavelength (lambda) and a geometrical inaccuracy (dX). As long as the ratio dX/Lambda is small (as it is at low frequencies), the impact on the modes will be negligible. With increasing frequency, the wavelength will decrease and the ratio dX/Lambda will become significant leading to a different modal response.

Although the scale model is an accurate representation of the full scale RPV, there will be small differences between both structures and the expectation is that the modal correlation will be better at low frequencies compared to high frequencies. This is not an artifact of the scale model approach, because it can be observed even for structures that are nominally identical.

NRC RAI EEMB.26

The comparison of the operating mode shapes for the pressure data in the SMT and QC2 as presented on pages beginning with page 144 is not clear. Discuss this comparison in more detail.

TVA Response to RAI EEMB.26

The shapes shown are operating pressure shapes and indicate the pressure loading of the dryer at the specific frequencies noted for the operating plant data and for the scale model with its data scaled to plant conditions. The comparisons show the similarity in most cases between the plant and the SMT. Figure EMEB.26-1 is Figure 124 from the SMT Benchmark Report. The plant data, with fewer points as shown in the right depiction, shows good agreement in shape with the SMT data in the left depiction. The 90° Outer Hood pressure shape, with the lower portion of the hood experiencing higher amplitude of pressure [[ ]] than the upper portion, is similar from the plant to the SMT; however, the pressures on the 90° Outer Hood and the 270° Outer Hood are in phase for the plant (moving in the same direction, laterally in the indicated circle on the figure) but out of phase for the SMT (moving in opposite directions, laterally in the indicated circle in the figure). This phase difference is seen in the static depiction as the beige hood dynamic pressure being to the right of the black line representing the undeformed hood for the SMT and to the left of the black line for the plant.

Figure EMEB.26-2 is Figure 130 from the SMT Benchmark Report. It is a more complex pressure shape, and the relative amplitudes of the pressures on the 270° Outer Hood to the pressure on the 90° Outer Hood are different. The SMT pressures on the 270° Outer Hood are nearly equivalent to those on the 90° Outer Hood using the deformation distance as a measure, but for the plant, the 270° Outer Hood is seeing significantly less pressure than the 90° Outer Hood at this frequency. From the plant to the SMT, the shape of the pressure distribution on the 90° Outer Hood is similar.

[[

]]

Figure EMEB.26-1 (Figure 124 from SMT Benchmark Report): QC2 Spatial Pressure Distribution comparison, SMT (Left) & Plant (Right), 23 Hz

[[

]]

Figure EMEB.26-2 (Figure 130 from SMT Benchmark Report): QC2 Spatial Pressure Distribution comparison, SMT (Left) & Plant (Right), 158 Hz

NRC RAI EEMB.27

a) Address why a 1:17.3 small scale model was chosen in lieu of a larger scale model (e.g.,1:8). Address the possibility of error propagation being excessive due to the scaling of the model.

b) Discuss whether there are any friction effects that cause additional ambient noise in the plant using a saturated water vapor compared to the scaled model that uses purely dry air. Discuss whether fouling and buildup on the inside of the plant MSLs considered. Discuss whether those potential friction effects can be neglected and assumed small in the model.

c) The pressure of air is dependent on the temperature and density where treated as an ideal gas. Discuss what temperature of air was chosen for the model, since pressure is linearly dependent on temperature. Address how the model accounts for steam at given pressures and temperatures in the plant.

TVA Response to RAI EEMB.27

a) [[

]]

Error propagation is addressed in Attachment B of the Benchmark Report. Even though it is acknowledged that a larger scale model would have reduced fabrication errors, the uncertainty associated with a [[ ]] scale model is considered acceptable.

b) The presence of wet steam in the plant is expected to cause some attenuation of the acoustic pressure waves due to irreversible heat and mass transfer between the two phases of the steam. This attenuation is precluded in the scale model by the use of dry air instead of steam. Further discussion regarding the attenuation differences between wet steam and dry air has been provided in the response to RAI EEMB.19. However, this type of attenuation is not typically considered as "friction."

Friction causes the conversion of kinetic energy into thermal energy due to the pipe surface roughness. Friction inside pipes is governed by the Moody friction factor, f, which is a function of the nondimensional surface roughness of the inside pipe walls, ε/D, and the Reynolds number of the fluid traveling through the pipes.

[[

]]

Fouling and buildup on the inside of the MSLs would likely increase the friction factor in the full size plant. This would bring the plant friction factor closer to the scale model friction factor, therefore increasing the accuracy of the results. In any case, friction is a second order effect as discussed above and does not have a significant impact on the pressure oscillations measured on the dryer surfaces.

c) [[

]]

The conversion between the SMT conditions and the operating pressure and temperature conditions in the plant is performed by applying the scaling laws described in Section 4.1 of the SMT Benchmark Report

NRC RAI EEMB.28

When calculating the Re for internal flow in a circular pipe on pages A20/A30 of the SMT Report, the diameter of the pipe in the scale model should be that of the plant MSL (1.5 ft) divided by the scale of 17.3, which is 0.0867 ft. [[

]] Discuss what purpose the boundary layer calculation serves. Discuss whether the entry length should be found to determine where in the pipe the flow becomes turbulent.

TVA Response to RAI EEMB.28

[[

]]

Note that the propagation of acoustic waves through the steam lines is a one-dimensional phenomenon for the frequencies of interest. Therefore, Mach number and pipe lengths, not pipe diameters, govern this propagation. From the above discussion, it can be concluded that small variations in the pipe diameter do not have an effect on the acoustic behavior of the piping system.

The purpose of the boundary layer calculation is to show that the flow in both the model and the plant is fully developed by the time it reaches the components expected to be significant sources. It is worth noting that the flow is turbulent from the time it enters the main steam line nozzles. Therefore, the purpose of the calculation contained in Attachment A of the Benchmark Report is not to determine where in the pipe the flow becomes turbulent as the RAI question appears to suggest. Whether an internal flow is laminar or turbulent, it takes a certain amount of pipe length for the flow to become fully developed. This pipe length is the so-called "entrance length" and can be estimated as $L \approx 4.4 \mathrm{Re}^{1/6} D$ for turbulent flow. Calculating the entrance length using this expression is equivalent to determining the point in the pipe where the boundary layer thickness equals the pipe radius as was done in Attachment A of the Benchmark Report.

NRC RAI EEMB.29

In Section 4.3.2 (4), the MSIV internals were modeled and included in the overall scale model; however, the TCV internals were not. Address why were they not modeled. Confirm whether and how the main steam line flow restrictor is included in the model.

TVA Response to RAI EEMB.29

Sensitivity tests have been performed for [[ ]] (Refer to the response to RAI EEMB.21). The main steam line flow restrictors/venturi present in the plant MSLs [[ ]]

NRC RAI EEMB.30

a) Address how the steam colliding with the long radius elbows does not create additional noise in the pipes, which increases the frequency towards resonance, where straight pipes would not. Discuss at what minimum angle can noise generated from steam colliding with the pipe walls be neglected.

b) Considering pipe bends create non-fully developed flow, provide the basis for assuming that the flow is fully developed throughout the entire model. While this effect can be neglected if the pipe length is much larger than the pipe bend radius, provide the minimum pipe radius for this assumption.

TVA Response to RAI EEMB.30

a) When a fluid flows through an elbow, two flow separation regions generally arise. One of the separation regions occurs on the outside radius of the bend, and the other on the inside radius of the bend. Elbows, tees, valves, along with other pipe flow obstructions tend to increase flow turbulence. Since flow turbulence produces more of a broadband spectrum with higher energy at lower wave numbers (larger eddies), [[

]] which should help in providing conservative results. It is difficult to determine the minimum angle in a bend at which the generated turbulent noise can be neglected without testing. However, it can be stated that noise coming from long radius pipe bends should introduce less noise than short radius pipe bends since the short pipe bends disrupt the flow more.

b) Pipe bends do have an effect on the flowing fluid velocity profile. Common factors associated with steady and unsteady flow behavior such as friction factors, f, loss coefficients, K, and vortex shedding, St, become independent of Reynolds number in turbulent flow. The components assumed to [[ ]] Because both the plant and SMT have large MSL Reynolds numbers, signifying turbulent flow, then Reynolds number is not expected to be a significant factor in terms of potential flow instabilities such as vortex shedding from valves.

Maintaining flow velocity profile between the model and plant [[ ]] For example:

[[ ]] are thought to introduce minor differences in terms of pressure oscillations on the dryer.

NRC RAI EEMB.31

Section 7.1 - Table 11 of the SMT Report shows the RMS and peak pressures for the SMT prediction and the plant measurement in the 150-162 Hz band. If sensors P1, P2, and P3 are on one side of the steam dryer and sensors P9, P10, and P11 are in a similar location on the other side of the dryer, discuss why the trends in Table 11 are not similar for the groups. Discuss why there are not similar pressure trends for sensors in symmetric locations.

TVA Response to RAI EEMB.31

The results being discussed are from the replacement dryer in the plant and from the replacement dryer SMT. Sensors P1, P2, P3, P9, P10, and P11 are on the same outer hood; however, the equivalent sensors to P1, P2 and P3 are P10, P11 and P12 as shown in Figure EEMB.31-1. The trends in Table 11 show some similarity, but are not exactly similar between the groups of sensors P1, P2 and P3 and sensors P10, P11 and P12 because the loading provided by the Main Steam Lines (MSL) is not symmetric. The steamline opposite P1, P2, and P3 is longer than the steamline opposite P10, P11, and P12. The constructive and destructive interference of the asymmetric loading at the measurement points on the dryer produces approximately similar trends at groups of sensors that would have exactly similar trends for symmetric loading. A condensed table of these sensors is shown in Table EEMB.31-1.

The discussion above addresses the small differences between the trends observed on opposite sides of the outer hood. After a preliminary review of the draft RAI responses with the NRC, GE was asked to expand the scope of this RAI and address the different trends within the same group of sensors that can be observed for the plant and for the SMT: in the SMT, sensor P1 shows the highest pressure amplitude whereas in the plant the highest pressure amplitude corresponds to P3. That is, in the SMT pressures decrease from P1 to P3 [[ ]] whereas in the plant pressures increase from P1 to P3 [[ ]]

The same trend is observable for the group of sensors located on the other side of the hood (P10, P11 and P12). This observation has generated some concerns regarding the validity of the scaling factor approach used to increase the pressure amplitudes in the S/RV frequency range in order to generate a bounding load definition. At this time, there is an ongoing research program with the objective of assessing the effect that the boundary conditions used in the SMT may have on the pressure measurements on the dryer surfaces, as discussed in RAI EEMB.18. [[

]] Figure EEMB.31-1 shows a typical mode shape for an acoustic mode that has a natural frequency of [[

]]

Figure EMEB.31-2 clearly shows how one could think that trends in sensors P1, P2 and P3 are completely different by looking at the data given in Table 11 when, in fact, the SMT behavior is very similar to the plant behavior. [[

]] At lower frequencies, the separation between nodes and anti-nodes is much greater than the distance between adjacent microphones, therefore decreasing the impact that small deformations of the SMT mode shapes have on the measured pressures.

Since the SMT and Plant behaviors are very similar as shown in Figure EMEB.31-2, the scaling factor approach used by GE for increasing the SMT amplitudes in the S/RV frequency range is considered valid.

[[

]]

[[

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Figure EEMB.31-1. Acoustic Mode believed to be coupled to S/RV resonance
(Natural Frequency: 155 Hz)

[[

]]

Figure EEMB.31-2

Sketch showing how vertical displacement of the mode shapes due to boundary conditions could explain trends shown in Table 11.

NRC RAI EEMB.32

Discuss the potential effects on the S/RVs from possible resonant frequencies that could occur, leading to valve failures. Effects due to vortex shedding were examined for the steam dryer; discuss whether this anomaly would exist in the valves.

TVA Response to RAI EEMB.32

BFN's SRVs are all Target Rock 2 stage valve designs. All valves are identically mounted on 6" X 26" sweepolets (with rounded edges) attached to the 26" main steam lines. The standpipes are designed to be typically 18 ½" high, with a 1500 # bolted flange connection for either mounting an SRV or accepting a blind flange closure.

SRV resonant frequency was calculated to be approximately 123 Hz. The calculations indicate that for the expected EPU steam flow (154 ft/sec) resonance onset should begin at approximately 120% OLTP at the earliest.

SMT testing was conducted utilizing square edged branch connections for conservatism. [[ ]] The sensitivity testing performed for the SRVs was conducted to vary the internal acoustic chamber heights +/- from the plant designed configuration to account for a range of potential as-built variances. These test identified the [[ ]]

BFN Unit 3 has begun baseline vibration monitoring at 105% OLTP conditions. Accelerometers have been mounted on selected SRVs. [[ ]] TVA System Engineering performed a MSRV review to identify Unit 2 and 3 items that, based on work order history, system health, Problem Evaluation Reports (PERs), and/or operating experience at 105% uprate, would demonstrate increased vulnerability under EPU conditions. No MSRV issues related to vibration were found. The only current MSRV issues are related to pilot valve leakage and set point drift which have not been tied to a vibration problem. Based on the above discussion, there is no adverse performance expected at EPU conditions.

NRC RAI EEMB.33

Regarding uncertainty analysis, discuss whether the uncertainties in the venturi calculation from the manufacturer taken into account (accuracy, resolution, and propagated errors). For the exponential pressure/velocity relationship, discuss the basis for the exponent [[ ]]

TVA Response to RAI EEMB.33

The venturi uncertainties from the manufacturer affect the discharge coefficient, C_D. The discharge coefficient is iteratively calculated as a function of Reynolds number using a calibration graph that is provided by the manufacturer. This graph has an associated uncertainty. [[

]]

Page B16 of the Benchmark Report includes a detailed discussion regarding the limitations of estimating the propagation of uncertainties using exponential curve fits such as the one given by Equation (1).

NRC RAI EEMB.34

The SMT Report indicates that the SMT [[

]] In some cases, the SMT data trended in the opposite direction from the QC2 plant data. See, Table 11 [[
]] and Figures 75 to 98, 109, 112, 117, and 120. Discuss the basis for reliance on the SMT in predicting steam dryer loading in Browns Ferry Nuclear Plant (BFN) in light

of these [[ ]]

TVA Response to RAI EEMB.34

[[

]] These underpredictions and the overpredictions in other frequency bands are broken down into bias errors for the SMT based on the QC2 benchmark and, using the Uncertainty Analysis presented in Attachment B of the SMT Benchmark Report, into random error for the specific SMT being evaluated. [[

]]

NRC RAI EEMB.35

On page 175, the SMT Report states that the SMT amplitude measurements associated with S/RV resonances [[

]] Discuss the reliability of this effort based on the significant underprediction of the QC2 plant data by the SMT and the nonlinearity of the data.

TVA Response to RAI EEMB.35

This response specifically discusses the SRV frequency band while the previous response, EEMB.34, addressed the whole frequency range. As seen in Table 11 of the SMT Benchmark Report, [[

]]

NRC RAI EEMB.36

On page 175 of the SMT Report, the vendor recommends power ascension monitoring in light of the error in the SMT load prediction. Discuss the plans to address this recommendation.

TVA Response to RAI EEMB.36

The power ascension monitoring plan for the steam dryer and main steam lines is described in the response to RAI EEMB.D.7.

NRC RAI EEMB.37

Page 19 of the SMT Report states that additional work is on-going to improve the accuracy of the load predictions. Discuss the status and success of this additional work.

TVA Response to RAI EEMB.37

Items that were identified for improvement that were incorporated into the BFN 1 scale model test include:
[[

]]

Apart from improvements already implemented in BFN1, an ongoing SMT research and development program aims at further improving the accuracy of the load definition by:
[[

]]

NRC RAI EEMB.38 (Unit 1)

As Browns Ferry Unit 1 has been shut down since March 1985 and remained in a long term lay-up condition, provide a discussion of the program established to implement NRC IE Bulletin No. 79-14, Seismic Analyses for As-built Safety-related Piping Systems, for restart, consistent with the plant design basis code of record. Discuss with examples the evaluation of the impact of extended power uprate (EPU) conditions on the recovery activities that include ongoing replacement of piping in the reactor coolant, reactor water cleanup, and feedwater (FW) systems; and reinstallation of balance-of-plant piping and new small and large bore pipe supports.

TVA Response to RAI EEMB.38 (Unit 1)

The scope of the 79-14 program is the safety related piping 2-1/2" in diameter and greater and all safety related piping regardless of size which was originally dynamically analyzed by computer. The boundaries of the safety related piping are established by Mechanical engineering and are shown on flow diagrams documented by TVA's calculation process. A walk down instruction (WI) was developed to establish the inspection and data gathering requirements for the 79-14 program. The safety related piping within the 79-14 program boundaries for BFN Unit 1 was inspected to collect the as-built field dimensions using this walk down instruction. The piping data collected included line lengths and pipe orientation, pipe sizes, component (valves, fittings, flanges, etc.) locations and available nameplate data, etc. During the piping walk down, existing support locations were dimensioned. Also, a cursory review of the support against the available support drawing was performed to determine if the existing support generally looked like the drawing.

Using the as-built data, the piping analyses models were generated. The thermal and pressure data used in the analyses are from the operational modes calculation developed for each of the safety related systems for Unit 1. This data included the higher temperatures and pressures due to EPU where applicable. The seismic spectra data input into the analyses was developed for BFN Units 1, 2, and 3. The spectra was reviewed and approved by the NRC (reference SER NUREG 1232, Vol 3, Supplement 1). The pipe analysis results were compared against Design Criteria allowable limits and support changes were made as needed to meet these limits. The BFN design criteria used for all three BFN units piping analysis has been reviewed and approved by the NRC (reference SER NUREG 1232, Vol 3, Supplement 2).

The existing pipe supports were reviewed against the piping analysis output loads to determine acceptability. If the support was judged to be acceptable, then the support was inspected to collect the as-built field dimensions. Using the as-built data, the support was then modeled and analyzed for the new analysis loads. The support analysis results were compared against Design Criteria allowable limits and support changes were made as needed to meet these limits. The BFN design criteria used for all three BFN units support design was reviewed and approved by the NRC (reference SER NUREG 1232, Vol 3, Supplement 2). Supports were modified or new supports were designed as necessary to meet the design criteria limits. The support modifications were issued out of engineering design to construction using TVA's DCN process. All Unit 1 79-14 program DCNs are required to be complete, which includes reconciliation of the final as-built configuration, prior to restart.

There has been no replacement of piping associated with the Unit 1 Restart Project as a result of the EPU conditions. Project piping design wall thickness calculations have been reviewed and documented that verify EPU conditions have no impact on the specified piping wall thickness. The design of piping being replaced for other reasons does include the EPU temperature and pressure parameters for determining the design requirements such as wall thickness. Some examples of why piping is being replaced are as follows: reactor recirculation piping, residual heat removal, core spray and reactor water cleanup piping are being replaced due to intergranular stress corrosion cracking (IGSCC) problems; turbine building main steam and extraction steam piping is being replaced with flow accelerated corrosion (FAC) resistant piping; and service water piping is being replaced due to corrosion.

EPU pressure changes do not affect the support design and the EPU temperature changes are minimal in comparison to the pre-EPU temperatures on the affected piping, especially the RCPB piping. EPU has caused minimal modifications to supports on Units 2 and 3. With Unit 1 being similar in design to Units 2 and 3, it can be concluded that the EPU conditions had minimal impact on the overall support design changes made for Unit 1 restart.

NRC RAI EEMB.38 (Units 2 and 3)

In reference to Table 3-6 and Section 3.3.4, Reactors Internal Structural Evaluation of the PUSAR, the reactor internal components such as shroud, shroud support, core plate, top guide, orificed fuel support, fuel channel, jet pump, core spray line and sparger, incore housing and guide tube, vessel head cooling spray nozzle, jet pump instrument penetration, core differential pressure and standby liquid control line and CRD were evaluated qualitatively for the EAU condition. Provide a quantitative evaluation by comparing the key parameters and design transients, loads and load combinations that are used in the design basis analysis report for stresses and cumulative usage factors in each component, against the EAU condition. Confirm whether and how the design basis parameters envelop those of the EAU condition.

TVA Response to RAI EEMB.38 (Units 2 and 3)

Responses are provided in the following pages.

EPU – Extended Power Uprate
RIPD – Reactor Internal Pressure Difference

CLTP – Current Licensed Thermal Power
N – Normal, U-Upset, F – Faulted

Component	EPU RIPDs (psid)			CLTP RIPDs (psid)			EPU Stress or Other Parameter	Allowable Parameter	Remarks
	N	U	F	N	U	F			
Shroud (affected by SH-RIPD & CP-RIPD). Shroud head ΔP Core Plate ΔP	[[							**Allowable Compressive Stress for buckling calc** =7720 psi (Normal/Upset) = 11580psi (Emergency) = 15440 psi (Faulted)	[[
Orificed Fuel support							]]	**Allowable Stresses:** Normal /Upset = 15,580 psi Faulted = 35,440 psi	]]

Component	EPU RIPDs (psid)			CLTP RIPDs (psid)			EPU Stress or Other Parameter	Allowable Parameter	Remarks
	N	U	F	N	U	F			
Shroud Support	[[							Normal/ Upset 34,950 psi. Faulted 69,900 psi	[[
Core Plate							]]	Allowable RIPD for sliding = 73 psi, (N & U) = 48.5 psi (F) Allowable RIPD for Buckling = 28.0 psi (N & U) = 42.0 psi (F)	]]

Component	EPU RIPDs (psid)			CLTP RIPDs (psid)			EPU Stress or Other Parameter	Allowable Parameter	Remarks
	N	U	F	N	U	F			
Top Guide	[[								[[
Fuel Channel,									
Jet Pump (Beam Bolt) Affected by Shroud Supp Plate ΔP								]]	]]

Component	EPU RIPDs (psid)			CLTP RIPDs (psid)			EPU Stress or Other Parameter	Allowable Parameter	Remarks
	N	U	F	N	U	F			
Jet Pump (Riser pipe elbow to thermal sleeve) Affected by Shroud Supp Plate ΔP	[[							Allowable Stresses: = 25350 psi (N/U) = 38025 psi (Emergency) = 60840 psi (Faulted)	[[
Jet Pump Diffuser (N & U, Emergency) Affected by Shroud Supp Plate ΔP							]]	Allowable stress 38.025 ksi (Faulted)	]]

Component	EPU RIPDs (psid)			CLTP RIPDs (psid)			EPU Stress or Other Parameter	Allowable Parameter	Remarks
	N	U	F	N	U	F			
Core Spray Line and Sparger	n/a	n/a	n/a	n/a	n/a	n/a	[[	*Core Spray Line:* ***Normal /Upset*** 23.85 ksi Emergency: 32.175 ksi Faulted 42.90 ksi Core Spray Sparger (Tee Junction) Normal /Upset 21.45 ksi Emergency 32.175 ksi Faulted 42.90 ksi	[[
In-Core Housing and Guide Tube	n/a	n/a	n/a	n/a	n/a	n/a	]]	All conditions Pm+Pb Allowable = 24,900 psi (Normal allowable)	]]

Component	EPU RIPDs (psid)			CLTP RIPDs (psid)			EPU Stress or Other Parameter	Allowable Parameter	Remarks
	N	U	F	N	U	F			
Vessel Head Cooling Spray Nozzle	n/a	n/a	n/a	n/a	n/a	n/a	[[	**Normal/Upset** 24600 psi **Emergency/Faulted** 30015 psi	[[
Jet Pump Instrument Penetration	n/a	n/a	n/a	n/a	n/a	n/a	]]	**Normal/Upset** 46,300 psi **Emergency/Faulted** 25440 psi	
Control Rod Drive	n/a	n/a	n/a	n/a	n/a	n/a	--	--	]]

NRC RAI EEMB.39 (Unit 1)

Section 3.3.5, Flow Induced Vibration, of Enclosure 4 of the June 28, 2004, submittal, NEDC-33101P, DRF 0000-0010-9439, Browns Ferry Unit 1 Safety Analysis Report for Extended Power Uprate, or the PUSAR, states that the safety-related thermowells and sample probes in the piping for the main steam (MS), FW and Reactor Recirculation (RRS) systems were evaluated, and found to be adequate for the increased MS, FW and RRS flows as a result of EPU. Provide a summary of evaluation and technical basis for the acceptability of this conclusion regarding safety-related thermowells and sample probes in the EPU condition.

TVA Response to RAI EEMB.39 (Unit 1)

The technical basis for determining the acceptability of the thermowells and sample probes for EPU conditions is to calculate the alternating stress intensity of the component and compare the calculated stress intensity to the allowable presented in the ASME Pressure vessel code, 1998 Section III, Division 1, Appendix I, Table I-9.2.2. The following is a summary of the process followed.

The first step is to generate a finite element model of the thermowell or sample probe, i.e., the component under evaluation, using plant drawings of the component. This model also includes the pipe weld and the pipe geometry confirmed by TVA. This model is used to calculate the component natural frequency, mode shapes and, later in the evaluation, the stress level.

Next, based on the procedure presented in ASME Pressure vessel code, 1998 Section III, Division 1, Appendix N-1300; using the component mode shape and natural frequency, a calculation is performed to check vortex shedding frequency against the thermowell natural frequency. If vortex-shedding frequency locks-in with a natural frequency does not exist, lift load is generated per Appendix N-1300, section N-1321, equation 69. The lift load is applied statically to the component to calculate the tip displacement. This displacement is amplified per frequencies of the lift load and components. If vortex-shedding lock-in is predicted, tip displacement is generated directly per Appendix N1300, section N-1324.

With the tip displacement available, the maximum stress of the component is calculated using the mode shape and modal stress relation from the finite element analysis for the first mode. Next, the drag load on the component is determined and the maximum stress of the component is calculated using the drag load applied to the finite element model. The stresses due to the lift load and the drag load are combined by the square-root-of-the-sum-of-the-squares (SRSS) method. The resultant SRSS stress level is multiplied by a stress concentration factor of 2 for comparison against the allowable stress level.

The following table is a summary of the limiting stress levels for BFN Unit 1 thermowell and sample probes installed in the Main Steam (MS), Feedwater (FW), and Reactor Recirculation (RRS) Systems. Note that there are sample probes only in the RRS.

System	Thermowell	Sample Probe	Max stress (psi)	Allowable (psi)	Acceptable for EPU
MS	X		9700	13600	Yes
MS		None			
FW	X		1433	13600	Yes
FW		None			
RRS	X		3020	13600	Yes
RRS		X	142	13600	Yes

For the MS thermowell, the component natural frequency is lower than the vortex shedding frequency at the EPU steam flow rate. Therefore, vortex shedding lock-in is conservatively assumed. This is the reason for the relatively high maximum stress of the MS thermowell versus the maximum stress of the FW thermowell.

NRC RAI EEMB.39 (Units 2 and 3)

Section 3.3.5, Flow Induced Vibration, of the PUSAR, states that analyses performed to evaluate the effects of FIV on the reactor internals at EAU conditions were based on vibration data obtained during startup testing of a prototype plant (Browns Ferry Unit 1) or of similar boiling water reactor (BWR) plants. The expected vibration levels for EAU were estimated by extrapolating the vibration data recorded in the prototype plant or similar plants and on GE BWR operating experience. These expected vibration levels were then compared with the established vibration acceptance limits. For the proposed EAU operation at BFN Units 2 and 3, the components in the upper zone of the reactor, such as the moisture separators and dryer, are mostly affected by the increased steam flow. The adverse effects of increased steam flow on the steam dryer is evaluated in a separate analysis. Provide a summary of the quantitative evaluation for the effects of flow induced vibration on steam separators for the proposed EAU condition at Units 2 and 3.

TVA Response to RAI EEMB.39 (Units 2 and 3)

Two methods are used to assess the acceptability of the TVA steam separator at EPU conditions, the extrapolation method, and the comparison method. These two methods are described below.

EXTRAPOLATION METHOD

There are two sources of excitation mechanisms: Flow turbulence and periodic forces generated by the swirling motion of the flow through the separators. Extrapolation to EPU conditions are based on these two excitation forces and are described below.

- Turbulence Excitation

  The magnitudes of the turbulence excitation change with the square of the separator velocity. Because there are no distinct peaks or valleys in the turbulence excitation spectrum, the separator, shroud head, and shroud/top guide assembly vibrate at the structural system natural frequencies. Because the structural natural frequencies are not changed by higher steam flow rates, the vibration frequency is the same irrespective of the power level. The higher EPU steam flow rate only results in higher vibration amplitudes at the structural natural frequencies.

- Periodic Excitation

  For the periodic excitation forces resulting from swirling motion of the steam through the separator tubes, the magnitude increases with the square of the velocity while the forcing frequency increases linearly with the flow velocity. The response spectrum of the shroud/separator sensors shows that there is insignificant response at the calculated periodic forcing frequency of about 29 Hz.

  From the above, it can be seen that shroud head/separator vibration is mainly from flow turbulence. Due to the increase in core flow and power, the separator flow velocity increases. Using the flow velocity squared relationship, the vibration amplitudes are calculated to increase by about 58% from OLTP levels, when 1.02 × EPU is considered. Since the maximum stress intensity at OLTP is less than 2400 psi, the stress intensity at EPU will be less than 3800 psi and is less within the GE allowable stress limit of 10,000 psi.

COMPARISON METHOD

The steam separator is a safety-related component. The fixed axial flow type steam separators have no moving parts and are made of stainless steel. In each separator, the steam-water mixture rising through the standpipe impinges on vanes which give the mixture a spin to establish a vortex where the centrifugal forces separate the water from the steam in each of three stages. The steam leaves the separator at the top and passes into the wet steam plenum below the dryer. The separated water exits from the lower end of each stage of the separator and enters the pool that surrounds the standpipes to join the downcomer annulus flow. A typical steam separator is shown in Figure EEMB.39-1.

The TVA shroud head and steam separator assembly uses GE Model 67PL axial flow steam separators. Each steam separator is mounted on a 6-inch schedule 40 stand pipe. The array of standpipes and steam separators are braced laterally. The 67PL separator has an inner barrel ([[ ]]), a middle tube with skirt ([[ ]]) and an outer tube ([[ ]]). At the top of the separator is the pre-dryer tube ([[ ]]). From the bottom of the skirt to the top of the pre-dryer is about [[ ]] in height.

With the introduction of a smaller diameter and more flexible BWR/6 steam separators (Model AS2B), extensive vibration tests were conducted. Comparison of the dimensions of various elements of model 67PL steam separator with the model AS2B shows the former to be structurally much stronger than the latter. The AS2B separator has an inner barrel ([[ ]]), and an outer tube with skirt ([[ ]]). From the bottom of the skirt to the top of the separator is about [[ ]]" in height.

The results of the BWR/6 separator FIV testing (Reference 1) has shown that the expected maximum flow induced vibration stress is around [[ ]]which is under GE fatigue allowable stress of 10,000 psi. The corresponding stresses for TVA steam separators will be smaller than those for BWR/6 separators.

Also, there are no known structural problems related to temperature or flow effects in steam separators. Thus, EPU is not expected to have any detrimental effect on the structural integrity and functionality of the steam separators.

Reference 1: Letter, K.S. Ananth to Martin Torres, "FIV Testing - BWR/6 Steam Separators," September 9, 1975

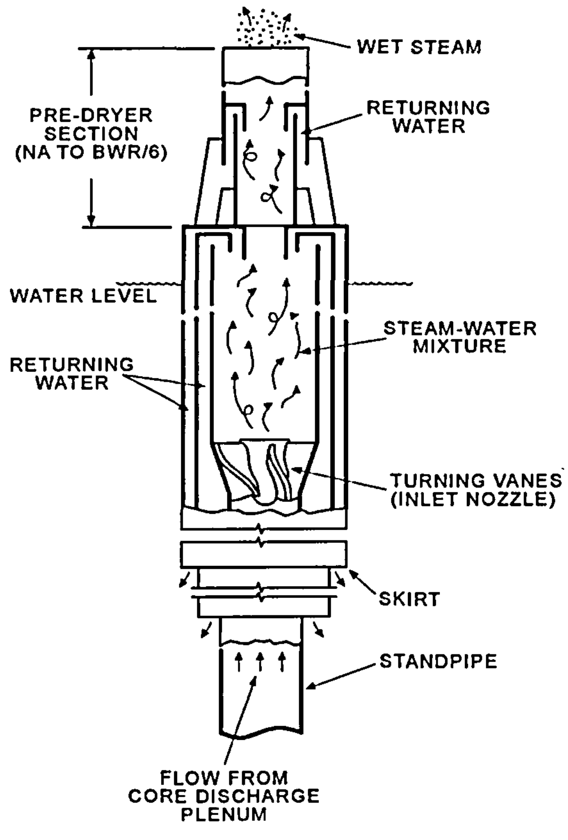

Figure EEMB.39-1
Typical Steam Separator

NRC RAI EEMB.40 (Unit 1)

Section 3.3.5 of the PUSAR states that for the proposed EPU operation for Unit 1, the components in the upper zone of the reactor, such as the moisture separators and dryer, are mostly affected by the increased steam flow. The adverse effects of increased steam flow on the steam dryer is evaluated in a separate analysis. Provide a summary of the evaluation for the effects of FIV on steam separators for the proposed EPU condition.

TVA Response to RAI EEMB.40 (Unit 1)

See the Reply to EEMB.39 (Unit 2/3).

NRC RAI EEMB.40 (Units 2 and 3)

Section 3.5, Reactor Coolant Pressure Boundary (RCPB) Piping, of the PUSAR indicates that the effects of the EAU have been evaluated for the RCPB piping systems and their supports. Other than the main steam (MS) and Feedwater (FW) system, the RCPB piping systems are not significantly affected by the proposed constant operating pressure power uprate (CPPU) at Units 2 and 3. Provide the maximum calculated stress and fatigue usage factors at the current rated and the CPPU conditions in comparison with the Code allowable limits for the feedwater piping and the main steam and the branch piping connected to the MS headers.

TVA Response to RAI EEMB.40 (Units 2 and 3)

The design basis code of record for BFN is the USAS B31.1.0-1967 code; consequently, fatigue usage factors have not been calculated for the MS and FW piping systems.

The following Browns Ferry RCPB piping systems are impacted by EPU:

Unit 2

BFN Unit 2	Description	Calculation No.
Main Steam Loop A	Main steam piping - Loop A (Inside Containment)	CDQ2001880971
Main Steam Loop B	Main steam piping - Loop B (Inside Containment)	CDQ2001880970
Main Steam Loop C	Main steam piping - Loop C (Inside Containment)	CDQ2001880972
Main Steam Loop D	Main steam piping - Loop D (Inside Containment)	CDQ2001880969
Feedwater Piping Loop A	Feedwater piping - Loop A (Inside Containment)	CDQ2003880977
Feedwater Piping Loop B	Feedwater piping - Loop B (Inside Containment)	CDQ2003880978

The only loading conditions for the Main Steam piping that are affected by EPU are those that include the turbine stop valve closure transient. Since the Browns Ferry EPU is a constant pressure power uprate, the temperature and pressure of the Main Steam piping is unchanged from the current design basis. A summary of the highest stressed locations for the Main Steam piping that were affected by EPU are presented in the tables below. Stresses are provided only for the equations that are affected by EPU. The equations are as defined in General Design Criteria No. BFN-50-C-7103, "Structural Analysis and Qualification of Mechanical and Electrical Systems (Piping and Instrument Tubing)."

Branch lines connected to the Main Steam piping were also evaluated. The stresses in the branch piping remain less than the code allowable stresses with negligible increases due to EPU.

As shown in the tables below, the maximum stresses for each of the Unit 2 piping systems impacted by EPU are less than the applicable original code of construction allowable stresses.

Unit 2 Main Steam Loop A

Equation	Current Design Basis (psi)	EPU Stress (psi)[1]	Allowable (psi)	Ratio EPU/ Allowable
9U	17,926 psi	17,926 psi	18,000 psi	0.996
9E	20,921 psi	20,921 psi	27,000 psi	0.775
9E'	19,919 psi	19,919 psi	22,500 psi	0.885
9E''	22,914 psi	22,914 psi	30,000 psi	0.764
9U + 10	25,851 psi	25,851 psi	47,250 psi	0.547

Note 1: The EPU changes do not affect the stresses at the locations with the highest stress ratios.

Unit 2 Main Steam Loop B

Equation	Current Design Basis (psi)	EPU Stress (psi)[2]	Allowable (psi)	Ratio EPU/ Allowable
9U	16,309 psi	16,433 psi	18,000 psi	0.91
9E	21,549 psi	21,819 psi	31,500 psi	0.69
9E'	17,819 psi	18,089 psi	22,500 psi	0.80
9E''	22,566 psi	22,836 psi	35,000 psi	0.65
9U + 10	31,323 psi	31,447 psi	40,500 psi	0.78

Note 2: The EPU Stress is determined by considering the maximum TSV closure stress from any node.

Unit 2 Main Steam Loop C

Equation	Current Design Basis (psi)	EPU Stress (psi)[3]	Allowable (psi)	Ratio EPU/ Allowable
9U	15,936 psi	16,010 psi	18,000 psi	0.89
9E	16,212 psi	16,286 psi	27,000 psi	0.60
9E'	16,967 psi	17,041 psi	22,500 psi	0.76
9E''	17,243 psi	17,317 psi	30,000 psi	0.58
9U + 10	34,180 psi	34,254 psi	40,500 psi	0.85

Note 3: The EPU Stress is determined by considering the maximum TSV closure stress from any node.

<u>Unit 2 Main Steam Loop D</u>

Equation	Current Design Basis (psi)	EPU Stress (psi)[4]	Allowable (psi)	Ratio EPU/ Allowable
9U	18,301 psi	18,910 psi	21,000 psi	0.91
9E	23,279 psi	23,219 psi	31,500 psi	0.74
9E'	19,332 psi	19,941 psi	26,250 psi	0.76
9E''	23,969 psi	24,250 psi	35,000 psi	0.69
9U + 10	28,379 psi	30,971 psi	47,250 psi	0.66

Note 4: The EPU Stress is determined by considering the maximum TSV closure stress from any node.

The only loading conditions for the Feedwater piping that are affected by EPU are those that include the thermal expansion. A summary of the highest stressed locations for the Feedwater piping that were affected by EPU are presented in the tables below. Stresses are provided only for the equations that are affected by EPU. The equations are as defined in General Design Criteria No. BFN-50-C-7103, "Structural Analysis and Qualification of Mechanical and Electrical Systems (Piping and Instrument Tubing)."

As shown in the tables below, the maximum stresses for each of the Unit 2 piping systems impacted by EPU are less than the applicable original code of construction allowable stresses.

Unit 2 Feedwater Loop A

Equation	Current Design Basis (psi)	EPU Stress (psi)	Allowable (psi)	Ratio EPU/ Allowable
11	28,581 psi	29,807 psi	30,000 psi	0.994
9U + 10	40,203 psi	35,924 psi	36,000 psi[5]	0.998

Note 5: The location with the highest stress ratio changed following EPU and the pipe materials at the two locations differ. The current design basis stress shown above corresponds to a material stress allowable for this equation of 40,500 psi while the EPU stress corresponds to a location with a material stress allowable of 36,000 psi.

Unit 2 Feedwater Loop B

Equation	Current Design Basis (psi)	EPU Stress (psi)	Allowable (psi)	Ratio EPU/ Allowable
11[6]	34,181 psi	34,181 psi	37,500 psi	0.911
9U + 10[6]	39,324 psi	39, 324 psi	40,500 psi	0.971

Note 6: The changes in stress due to EPU were determined to be bounded by existing load cases or to have a negligible impact on the current design basis stresses.

Unit 3

BFN Unit 3	Description	Calculation No.
Main Steam Loop A	Main steam piping - Loop A (Inside Containment)	CDQ3001910421
Main Steam Loop B	Main steam piping - Loop B (Inside Containment)	CDQ3001910569
Main Steam Loop C	Main steam piping - Loop C (Inside Containment)	CDQ3001910429
Main Steam Loop D	Main steam piping - Loop D (Inside Containment)	CDQ3001910436
Feedwater Piping Loop A	Feedwater piping - Loop A (Inside Containment)	CDQ3003910729
Feedwater Piping Loop B	Feedwater piping - Loop B (Inside Containment)	CDQ3003910728

The only loading conditions for the Main Steam piping that are affected by EPU are those that include the turbine stop valve closure transient. Since the Browns Ferry Units 2 and 3 EPU is a constant pressure power uprate, the temperature and pressure of the Main Steam piping is unchanged from the current design basis. A summary of the highest stressed locations for the Main Steam piping that were affected by EPU are presented in the tables below. Stresses are provided only for the equations that are affected by EPU. The equations are as defined in General Design Criteria No. BFN-50-C-7103, "Structural Analysis and Qualification of Mechanical and Electrical Systems (Piping and Instrument Tubing)."

Branch lines connected to the Main Steam piping were also evaluated. The stresses in the branch piping remain less than the code allowable stresses with negligible increases due to EPU.

As shown in the tables below, the maximum stresses for each of the Unit 3 piping systems impacted by EPU are less than the applicable original code of construction allowable stresses.

NON-PROPRIETARY VERSION

Unit 3 Main Steam Loop A

Equation	Current Design Basis (psi)	EPU Stress (psi)[7]	Allowable (psi)	Ratio EPU/ Allowable
9U	11,772 psi	12,384 psi	21,000 psi	0.590
9E	14,767 psi	15,110 psi	31,500 psi	0.480
9E'	13,091 psi	13,703 psi	26,250 psi	0.522
9E''	16,086 psi	16,429 psi	35,000 psi	0.469
9U + 10	24,897 psi	28,977 psi	52,500 psi	0.552

Note 7: The EPU Stress is determined by considering the maximum TSV closure stress from any node.

Unit 3 Main Steam Loop B

Equation	Current Design Basis (psi)	EPU Stress (psi)[8]	Allowable (psi)	Ratio EPU/ Allowable
9U	16,876 psi	17,002 psi	18,000 psi	0.945
9E	20,281 psi	20,553 psi	27,000 psi	0.761
9E'	18,387 psi	18,659 psi	22,500 psi	0.829
9E''	20,959 psi	21,231 psi	30,000 psi	0.708
9U + 10	40,231 psi	40,357 psi	40,500 psi	0.996

Note 8: The stress increase due to EPU is bounded by the SRV transient stresses used in the calculation. Therefore, the EPU case is bounded by the current design basis stresses.

Unit 3 Main Steam Loop C

Equation	Current Design Basis (psi)	EPU Stress (psi)[9]	Allowable (psi)	Ratio EPU/ Allowable
9U	15,936 psi	16,010 psi	18,000 psi	0.889
9E	16,272 psi	16,286 psi	27,000 psi	0.603
9E'	18,485 psi	18,558 psi	22,500 psi	0.825
9E''	18,791 psi	18,835 psi	30,000 psi	0.628
9U + 10	34,180 psi	34,254 psi	45,000 psi	0.761

Note 9: The EPU Stress is determined by considering the maximum TSV closure stress from any node.

Unit 3 Main Steam Loop D

Equation	Current Design Basis (psi)	EPU Stress (psi)[10]	Allowable (psi)	Ratio EPU/ Allowable
9U	18,338 psi	18,943 psi	21,000 psi	0.902
9E	22,986 psi	23,290 psi	31,500 psi	0.739
9E'	20,887 psi	21,492 psi	26,250 psi	0.819
9E''	25,535 psi	25,839 psi	35,000 psi	0.738
9U + 10	30,113 psi	37,284 psi[11]	52,500 psi	0.710

Note 10: The EPU Stress is determined by considering the maximum TSV closure stress from any node.

Note 11: Conservatively calculated using the maximum Equation 9U and 10 stresses.

The only loading conditions for the Feedwater piping that are affected by EPU are those that include the thermal expansion. The changes in stress due to EPU were determined to be bounded by existing load cases or to have a negligible impact on the current design basis stresses. The equations shown are those potentially affected by EPU and are as defined in General Design Criteria No. BFN-50-C-7103, "Structural Analysis and Qualification of Mechanical and Electrical Systems (Piping and Instrument Tubing)." The tables below summarize the highest stresses locations.

As shown in the tables below, the maximum stresses for each of the Unit 3 piping systems impacted by EPU are less than the applicable original code of construction allowable stresses.

Unit 3 Feedwater Loop A

Equation	Current Design Basis (psi)	EPU Stress (psi)	Allowable (psi)	Ratio EPU/ Allowable
11	37,461 psi	37,461 psi	37,500 psi	0.999
9U + 10	40,800 psi	40,800 psi	45,000 psi	0.907

Unit 3 Feedwater Loop B

Equation	Current Design Basis (psi)	EPU Stress (psi)	Allowable (psi)	Ratio EPU/ Allowable
11	32,181 psi	32,181 psi	37,500 psi	0.858
9U + 10	36,186 psi	36,186 psi	45,000 psi	0.804

NRC RAI EEMB.41 (Unit 1)

In reference to Table 3-8 and Section 3.3.4, Reactors Internals Structural Evaluation, of the PUSAR, the reactor internal components such as shroud, core plate, top guide, fuel channel, jet pump, core spray line and sparger, incore housing and guide tube, were evaluated qualitatively for the EPU condition. Provide a quantitative evaluation by comparing the key parameters and design transients, loads and load combinations that are used in the design basis analysis report for stresses and fatigue usage factors (CUFs) in each component, against the EPU condition. Confirm whether and how the design basis parameters envelop those of the EPU condition.

TVA Response to RAI EEMB.41 (Unit 1)

See the response to RAI EEMB.38 (Units 2 and 3)

NRC RAI EEMB.41 (Units 2 and 3)

Section 3.5 of the PUSAR states that the supporting structure for the MS piping system is currently being evaluated for increased loading associated with the limiting transient at EAU conditions. Any supporting structure modifications deemed necessary due to EAU increased transient loads will be completed prior to EAU implementation. Provide the results of the evaluation and identify the supports that are added or modified for the proposed power uprate condition for the RCPB piping systems.

TVA Response to RAI EEMB.41 (Units 2 and 3)

For BFN Units 2 and 3, the only modification required to support EPU operation for the supporting structure is to reinforce a welded attachment on one Unit 2 Main Steam (Line D) pipe support, specifically Support No. 2-47B400S0110. This modification is addressed by DCN No. 51303, which will be installed prior to the implementation of EPU on Unit 2. Unit 3 requires no modifications. The design for the Unit 3 support corresponding to 2-47B400S0110 is slightly different than its Unit 2 counterpart. The stresses for this support meet the allowables for the increased loading due to EPU.

For BFN Units 2 and 3, no modifications are required to the building structure as the increase in loads transmitted to the building structure as a result of EPU are within the existing capacity of the structure.

NRC RAI EEMB.42 (Unit 1)

Section 3.4, Reactor Recirculation System (RRS), of the PUSAR states that RRS components (e.g., pumps and valves) will be evaluated at EPU conditions to ensure that safety and design objectives are met. Provide a summary of the evaluation for the RRS piping and components regarding the structural and pressure boundary integrity. Also, provide a summary of the calculated maximum stress and fatigue usage factor for critical components at the EPU condition. The components should include recirculation pumps and valves and their supports, which may require a modification after the EPU.

TVA Response to RAI EEMB.42 (Unit 1)

For BFN Unit 1, the reactor recirculation system piping and components were reanalyzed due to several changes associated with restart activities such as pipe material replacement, valve operator changes due to NRC GL 89-10, IE bulletin 79-14 program inspections, etc. The reanalysis was performed utilizing EPU conditions. The results of the analyses show that the recirculation piping and components meet the stress limits. Restart modifications are in progress. Final stress results which reflect the final as-built configuration are not yet available for all systems.

The design basis code of record for BFN is the USAS B31.1.0-1967 code; consequently fatigue analysis of piping and components is not a requirement at BFN. However fatigue evaluation was performed on the RHR system return connection tees to the Recirculation piping. The maximum usage factor for these two piping tees is 0.23.

NRC RAI EEMB.42 (Units 2 and 3)

In Section 3.4 of the PUSAR states that the reactor recirculation system (RRS) components (e.g., pumps and valves) will be evaluated at EAU conditions to ensure that safety and design objectives are met. Provide a summary of the evaluation for the reactor recirculation pumps and valves at the EAU condition. Discuss the effects of EAU on vibration due to the vane-passing frequency of the RRS pump to accommodate the increase in thermal power. Confirm whether a modification is required for the RRS piping and supports after the EAU and identify the modification if any.

TVA Response to RAI EEMB.42 (Units 2 and 3)

For BFN Units 2 and 3, the reactor recirculation system piping and components were reanalyzed for EPU conditions. Piping was analyzed as described in PUSAR Section 3.5.1 and no modifications were required. System components were also evaluated for any changes associated with EPU conditions and no modifications were required for system components (e.g., pumps and valves).

Vibration monitoring of the BFN Unit 2 reactor recirculation, residual heat removal, and reactor water cleanup piping inside the drywell was performed during power ascension following the

Spring 2003 refueling outage to assess the effects of EPU on vibration associated with the reactor recirculation pumps. The predominant frequencies of the measured responses correspond to the pump impeller vane passing frequencies (five times running speed) with contributions from the second harmonic of the vane passing frequency (ten times running speed) in many cases. Analyses were performed to extrapolate the measured responses at the vane passing frequency for pump speeds equal to 1665 and 1725 rpm. These analyses indicated that piping stresses would be acceptable for the higher pump speeds expected for EPU conditions.

NRC RAI EEMB.43 (Unit 1)

Section 3.5, Reactor Coolant Pressure Boundary (RCPB) Piping, of the PUSAR states that the pressure, temperature, and flow changes due to EPU were incorporated into the TPIPE analysis computer model for the affected RCPB piping systems. It also states that the analysis effort included changes due to NRC IEB 79-14 walkdown data, seismic design criteria and spectra changes, and piping and piping component replacement design changes. Confirm whether the computer code TPIPE has been reviewed and approved by NRC for use of piping analysis for Unit 1. Provide a summary of TPIPE analysis and applied loads and load combinations for normal, upset, emergency and faulted conditions. Discuss changes in seismic design criteria and spectra for EPU that deviate from the design basis analysis of record for Unit 1. Also, discuss American Society of Mechanical Engineers Code, Section XI Editions and Addenda or other Codes you used for piping and component modifications and replacements in the affected piping system as a result of EPU.

TVA Response to RAI EEMB.43 (Unit 1)

The TPIPE program is described in the BFN FSAR, Appendix C, section C.3.7, and has been bench marked against the NRC program EPIPE in accordance with the Standard Review Plans, NUREG-0800, section 3.9.1.II and NUREG/CR-1677. TPIPE is TVA's program used for pipe analysis for all three units at BFN.

TPIPE calculates stresses, movements, accelerations of the piping and calculates loads at equipment and supports for pressure, deadweight, thermal, and dynamic loading conditions. The post processor portion of TPIPE combines the pipe stresses and compares the stresses to the appropriate code allowable for the normal, upset, emergency and faulted conditions as required by the design criteria. The load combinations and allowables for BFN piping are in the BFN FSAR, Appendix C, Tables C.3-1A, C.3-1B, and C.3-1C. These tables cover the safety related piping at BFN except torus attached piping. The BFN design criteria used for all three BFN units piping analysis was reviewed and approved by the NRC (reference SER NUREG 1232, Vol 3, Supplement 2). The load combinations for torus attached piping load combinations are presented in the BFNP Torus Integrity Long Term Program Plant Unique Analysis Report (PUAR), TVA report CEB-83-34, revision 2, dated December 10, 1984. The torus program was reviewed and approved by the NRC (reference U.S. Nuclear Regulatory Commission Safety Evaluation of Browns Ferry Nuclear Plant, Units 1, 2, and 3, Mark I Containment Long Term Program, Pool Dynamic Loads Review, May 6, 1985).

The seismic design criteria and spectra are not changed for EPU and are not affected by EPU.

The piping Design Code of Record for Browns Ferry Nuclear Power Plant is the 1967 version of the USAS B31.1.0 - Code for Power Piping. The requirements of this code are supplemented by the additional quality assurance requirements found in the design, construction, and procurement specifications, as well as bills of materials, procurement documentation, and vendor manuals which were produced prior to OL. System specific codes and standards committed to after OL are located in the individual system design criteria and are included as applicable when performing engineering evaluations, repairs, replacements and modifications.

Major components, piping materials and valves were procured to ASME Section III, 1995 Edition w/ Summer 1996 Addenda reconciled to 1986 Edition.

Piping and components are being installed in accordance with the USAS B31.1 code 1967 edition with post modification inspections conducted in accordance with the ASME Section XI 1995 edition/1996 addendum.

Procurement of piping or components associated with maintenance activities are evaluated with the primary goal of procuring "like-for-like" replacement components and/or parts.

Bulk piping materials (i.e., pipe fittings, etc.) are procured as ASME Section II, generally to the highest available ASME Section III Class classification.

NRC RAI EEMB.43 (Units 2 and 3)

Section 3.11, Balance-of-Plant Piping (BOP) Evaluation, of the PUSAR indicates that for EAU conditions, the loss-of-coolant accident (LOCA) torus shell response loads were reevaluated using a more realistic reactor pressure vessel (RPV) depressurization to within the capability of the available number of main steam relief valves. These loads were found to be acceptable and there are no adverse effects on the torus shell attached structures. Discuss the EAU LOCA loads using the more realistic RPV depressurization in comparison with the LOCA loads originally defined for Units 2 and 3.

TVA Response to RAI EEMB.43 (Units 2 and 3)

The summary of the evaluation of the LOCA dynamic loads, including the pool swell loads, vent thrust loads, condensation oscillation (CO) loads, and chugging loads for EPU conditions is contained in Section 4.1.2.1 of NEDC-33047P. The result of the evaluation for the DBA-LOCA dynamic loads at EPU conditions concluded that thermal-hydraulic conditions (e.g., drywell pressurization rate, containment pressures and temperatures, and vent flow rates) during a postulated LOCA with EPU would result in loads that remain bounded by the loads previously defined generically for Mark I plants during the Mark-I Containment Long Term Torus Integrity Program (LTTIP) in Reference 1, and defined specifically for BFN-2/3 in References 3 and 4. The generic load definition of Reference 1 was accepted by the NRC per Reference 2. The BFN-2/3 Plant-specific dynamic loads in References 3 and 4, were accepted by the NRC in Reference 5.

As part of the EPU LOCA loads evaluation, the containment pressure and temperature response was calculated for the Intermediate Break Accident (IBA), and Small Break Accident (SBA). These two cases had been originally calculated for the Mark I LTTIP and documented in Reference 3. These two events assume rapid depressurization of the RPV with operation of the Automatic Depressurization System (ADS). The IBA and SBA calculations were used to determine the LOCA pressures and temperatures to be combined with the postulated IBA and SBA LOCA and SRV hydrodynamic loads in the torus structural evaluations of Reference 4. For the EPU IBA evaluations, analysis assumptions were used consistent with the assumptions used for the Reference 3 analyses. However, for the EPU SBA evaluation the modeling was adjusted. The text in Section 3.11 of NEDC-33047P; "more realistic RPV depressurization to within the capability of the available number of MSRVs, " refers to the modeling approach used to simulate the EPU SBA containment response. The original analysis, which was used to generate the results for Reference 3, modeled ADS actuation at 10 minutes with a non-mechanistic RPV depressurization, which begins at 600 seconds and is forced to completion by 1200 seconds. This approach produces a rapid but unrealistic suppression pool temperature rise in that the Reference 3 calculation does not account for the actual number of SRVs in the BFN units. The EPU calculation of the SBA containment response used the SHEX code to perform a mechanistic calculation, which modeled the ADS using only the available BFN ADS valves. A review of the EPU SBA calculation confirmed that EPU SBA pressures and temperatures, which can occur concurrent with the postulated SBA hydrodynamic loads, are bounded by the values determined from Reference 3 and evaluated in Reference 4.

References

1. GE Nuclear Energy, "Mark I Containment Program Load Definition Report," NEDO-21888, Revision 2, November 1981.
2. NUREG-0661, "Mark I Containment Long-Term Program Safety Evaluation Report," July 1980.
3. "Mark I Containment Program Plant Unique Load Definition Browns Ferry Nuclear Plants 1, 2, and 3," NEDO-24580, Rev. 2, January 1982
4. BFN Report CEB-83-34, "Browns Ferry Nuclear Plant Torus Integrity Long-Term Program Plant Unique Analysis Report," Rev. 2, December 10, 1984.
5. Letter from USNRC to H. G. Paris, TVA, entitled "MARK I CONTAINMENT PROGRAM - Browns Ferry Nuclear Plant Units 1, 2 and 3," May 6, 1985 (A02 850513 002).

NRC RAI EEMB.44 (Unit 1)

Section 3.5.1, Pipe Stresses, of the PUSAR states that the Unit 1 piping analyses effort stress results, including EPU as well as the other changes, involving the RCPB systems were checked against the USAS-B31.1.0, 1967 Code stress criteria and found acceptable. The report also indicates that all CUFs satisfy the code requirements. Provide the calculated maximum stress and fatigue usage factors at the most critical locations for each of evaluated RCPB piping systems.

TVA Response to RAI EEMB.44 (Unit 1)

Calculated pipe stresses for RCPB piping are maintained within the allowable stresses as defined by the BFN design criteria. The load combinations and allowables for BFN piping are also in the BFN FSAR, Appendix C, Tables C.3-1A, C.3-1B, and C.3-1C. These tables cover the safety related piping at BFN except torus attached piping. The BFN design criteria used for all three BFN units piping analysis was reviewed and approved by the NRC (reference SER NUREG 1232, Vol 3, Supplement 2). The load combinations and allowables for torus attached piping are presented in the BFNP Torus Integrity Long Term Program Plant Unique Analysis Report (PUAR), TVA report CEB-83-34, revision 2, dated December 10, 1984 (see Table A-4). The torus program was reviewed and approved by the NRC (reference U.S. Nuclear Regulatory Commission Safety Evaluation of Browns Ferry Nuclear Plant, Units 1, 2, and 3, Mark I Containment Long Term Program, Pool Dynamic Loads Review, May 6, 1985). The design basis code of record for BFN is the USAS B31.1.0-1967 code, consequently fatigue analysis of piping and components is not a requirement at BFN. However fatigue evaluation was performed on the RHR system return connection tees to the Recirculation piping. The maximum usage factor for these two piping tees is 0.23. It should be noted that many of these Unit 1 calculations have been reviewed by NRC Region II.

Unit 1 is currently performing restart modifications and final stress results which reflect the final as-built configuration are not available for all systems. The core spray system is complete and the summary of maximum stresses is as follows.

Calc Number / Rev	System	Code Eq.	Post-EPU Stress	Allowable (psi)	Post-EPU Stress Ratio	Notes
CDQ1-075-2002-0030 / 009	075	Eq. 10	14368	27038	0.531	N1-175-4RA
		Eq. 11	19841	41438	0.479	
CDQ1-075-2002-0031 / 007	075	Eq. 10	10003	27038	0.370	N1-175-4RB
		Eq. 11	15258	41438	0.368	

NRC RAI EEMB.44 (Units 2 and 3)

Section 3.11 of the PUSAR indicates that, for those BOP piping analyzed, the maximum stress levels and fatigue analysis results were reviewed for the increases in temperature, pressure and flow rate. Provide the maximum calculated stresses and fatigue usage factors for the evaluated BOP piping systems, including those attached to the torus shell.

TVA Response to RAI EEMB.44 (Units 2 and 3)

The design basis code of record for BFN is the USAS B31.1.0-1967 code; consequently, fatigue usage factors have not been calculated for the BOP piping systems.

Unit 2

Portions of BOP piping were analyzed for the effect of EPU on piping pressures and temperatures. A summary of the highest stressed locations for selected BOP piping affected by EPU are presented in the tables below. Stresses are provided only for the equations that are affected by EPU. The equations are as defined in General Design Criteria No. BFN-50-C-7103, "Structural Analysis and Qualification of Mechanical and Electrical Systems (Piping and Instrument Tubing)".

As shown in the tables below, the maximum stresses for each of the Unit 2 piping systems impacted by EPU are less than the applicable original code of construction allowable stresses.

Other BOP power train piping such as extraction steam, heater drains and vents, and condensate was originally supported based on criteria for deadweight and thermal. This piping was concluded to be acceptable for the small increases in pressures and temperatures due to EPU based on a review of the piping and support configurations.

Unit 2 Torus Attached Piping Systems

Calc Number/ Rev	System	Code Eq.	Pre-EPU Stress (psi)	Post-EPU Stress (psi)	Allowable (psi)	Post-EPU Stress Ratio	Notes
CD-Q2071-882301	RCIC	Eq. 11	32,922	32,922	37,500	0.878	See Note 1.
CD-Q2073-871755	HPCI	Eq. 11	30,645	30,645	37,500	0.817	See Note 1.
CD-Q2073-883012	ECCS Ring Header	Eq. 11	34,133	32,860	34,250	0.959	See Note 2.
CD-Q2074-870644	RHR	Eq. 11	25,380	29,100	37,500	0.776	
CD-Q2075-881234	CS	Eq. 11	16,616	17,641	37,500	0.470	
CD-Q2075-895121	CS	Eq. 11	29,368	30,073	37,500	0.802	
CD-Q2071-870643	RCIC Branch Line	Eq. 11	37,388	30,400	37,500	0.811	

Note 1: Load cases with increases due to EPU are bounded by other load cases resulting in no change at these locations.

Note 2: DCN 65786 adds reinforcing to a branch connection on the torus ring header to bring the stresses to within the code of construction code allowable stresses.

Unit 3

Portions of BOP piping were analyzed for the effect of EPU on piping pressures and temperatures. A summary of the highest stressed locations for selected BOP piping affected by EPU are presented in the tables below. Stresses are provided only for the equations that are affected by EPU. The equations are as defined in General Design Criteria No. BFN-50-C-7103, "Structural Analysis and Qualification of Mechanical and Electrical Systems (Piping and Instrument Tubing)."

As shown in the tables below, the maximum stresses for each of the Unit 3 piping systems impacted by EPU are less than the applicable original code of construction allowable stresses.

Other BOP power train piping such as extraction steam, heater drains and vents, and condensate was originally supported based on criteria for deadweight and thermal. This piping was concluded to be acceptable for the small increases in pressures and temperatures due to EPU based on a review of the piping and support configurations.

Unit 3 Torus Attached Piping Systems

Calc Number/ Rev	System	Code Eq.	Pre-EPU Stress (psi)	Post-EPU Stress (psi)	Allowable (psi)	Post-EPU Stress Ratio	Notes
CD-Q3071-920001	RCIC	Eq. 11	34,715	34,715	37,500	0.926	See Note 3
CD-Q3071-920012	HPCI	Eq. 11	34,352	34,352	37,500	0.916	See Note 3
CD-Q3073-920014	ECCS Ring Header	Eq. 11	35,773	35,616	37,500	0.950	See Note 4
CD-Q3075-920009	HPCI	Eq. 11	28,609	28,612	37,500	0.763	
CD-Q3075-920010	HPCI	Eq. 11	34,443	34,443	37,500	0.919	See Note 3

Note 3: Load cases with increases due to EPU are bounded by other load cases resulting in no change at these locations.

Note 4: DCN 65815 adds reinforcing to a branch connection on the torus ring header to bring the stresses to within the code of construction code allowable stresses.

NRC RAI EEMB.45 (Unit 1)

Section 3.5.1, of the PUSAR, states that for high energy lines, the postulated break/crack locations were identified and evaluated based on the analyses results. The higher EPU pressure effects on the pipe whip restraints have been evaluated and found acceptable. Confirm whether the determination of the postulated high energy line break (HELB) locations is based on the NUREG -800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants LWR Edition (SRP) Section 3.6.2, MEB 3-1 criteria. Identify HELB locations resulting from analyses for EPU conditions that are different from the original locations specified in the UFSAR for Unit 1. Provide a summary of the evaluation regarding the higher EPU pressure effects on the pipe whip restraints and the jet impingement loads on affected components.

TVA Response to RAI EEMB.45 (Unit 1)

SRP Section 3.6.2, MEB 3-1 criteria is not a licensing commitment for BFN.

Break locations are shown in Appendix M of the FSAR for Main Steam and Feed Water piping. These locations remain unchanged. Pipe break locations for HPCI, RCIC, and RWCU are not specifically shown in Appendix M, Section M.6.9. However, breaks determined and evaluated for these systems have not resulted in the addition of any additional whip restraints.

The whip restraints were evaluated (References 1 and 2) and accepted based on comparison of the higher EPU pressure to the pressure used in the original design calculations. The increase in pressure, in general, was less than 4% of the pressure used in the original design. No modifications were required due to this increase in pressure. Modifications and evaluations were initiated as part of the corrective action program for discrepancies identified during field walk-downs performed to verify that the whip restraints were installed with no significant changes in configuration from the original drawings.

Walk-downs have been conducted outside the drywell to identify and evaluate any potential targets of jet impingement and impact (References 1 and 3) and inside the drywell to identify and evaluate any adverse effect to LPCI and primary containment integrity. However, due to ongoing restart modification work activities, final confirmatory walk-downs to assure completion of work for whip restraint discrepancies and identify any additional targets will be completed prior to Unit 1 startup.

References:

1. Calculation CDQ199920030255, Attachment V

2. Calculation CDQ199920032406, Pages 3 and 4

3. Calculation CDQ199920050012

NRC RAI EEMB.45 (Units 2 and 3)

Section 3.11, Table 3-7c of the PUSAR indicates that no results were provided associated with the percentage increase in the MS piping stress because the TSV transient was not considered previously for Browns Ferry. Provide the maximum stresses and fatigue usage factors resulting from the EAU evaluation for the BOP main steam piping outside the containment in comparison with the code allowable limits. Confirm whether any modifications are required for the BOP piping and supports following the EAU at BFN. Identify these modifications if any.

TVA Response to RAI EEMB.45 (Units 2 and 3)

Calculation CDN000120021138 for Units 2 and 3 evaluated the BOP Main Steam piping outside containment for the effects of EPU. Code Equations 8, 10, and 11 are not impacted by EPU since there are no changes to the pressure or temperature. Code Equation 9b is affected as analysis for a turbine stop valve closure transient has been added to the calculation. The maximum Equation 9b stress ratios for the Units 2 and 3 Main Steam piping outside containment following the implementation of EPU are provided below. All stresses are less than the applicable original code of construction allowable stresses.

Condition	EPU Stress (psi)	Allowable (psi)	Ratio EPU/ Allowable
Equation 9b	17,563 psi	18,000 psi	98%

For Units 2 and 3, there are no modifications required to piping, pipe supports or building steel for the Main Steam piping outside containment following EPU.

NRC RAI EEMB.46 (Unit 1)

Section 3.5.2, Pipe Supports, of the PUSAR states that the TSV closure transient affects on the MS piping increased due to the EPU pressure and flow changes. The MS analysis included the TSV transient and the stresses from this event were found acceptable. All existing RCPB piping supports were qualified as-is or were modified as required to meet design criteria. New added supports were qualified based on the new analyses loads. Provide the maximum calculated stress at the critical locations for the evaluated supports and include a comparison against the Code allowable limits. Also, identify supports that were required to be modified or added in each of RCPB piping systems for the EPU for Unit 1. Provide the schedule for completion of all support modifications, and piping repair and replacement. Confirm whether RCPB piping analyses were performed based on the final configuration after the modification.

TVA Response to RAI EEMB.46 (Unit 1)

Unit 1 piping and supports were analyzed to the BFN design criteria and established BFN methods. All supports stresses are maintained below the allowable stresses as defined in the design criteria and the BFN FSAR, Appendix C, Table C.3-2. The stress analysis and the support loads from the analysis include the changes due to EPU where applicable. It should be noted that many of these Unit 1 calculations have been reviewed by NRC Region II.

The support loads used for the evaluation of RCPB piping supports included changes due to seismic spectra, NRC Bulletin 79-14 inspection data, changes made due to new valves and pipe routing changes, updated thermal operating modes including EPU temperatures. The EPU changes were included in the analysis along with the other changes described and therefore TVA can not determine if a support was modified due to EPU. The changes due to EPU generally had minimal impact on the supports in comparison to the other changes incorporated into the analysis for the restart of Unit 1. EPU pressure changes do not affect the support design and the EPU temperature increases are minimal in comparison to the pre-EPU temperatures on the affected piping, especially the high temperature RCPB piping. EPU has caused minimal modifications to supports on Units 2 and 3. With Unit 1 being similar in design to Units 2 and 3, it can be concluded that the EPU conditions had minimal impact on the overall support design changes made for Unit 1 restart.

Based on current schedule, all support modifications and repairs will be completed in late 2006.

The piping analysis is initially based on the 79-14 inspection data for existing piping and supports or based on the design drawing locations for new piping and supports. During field implementation of the new designs, any deviations from the design drawings outside of the established tolerances of the TVA's construction specifications are identified back to engineering for evaluation. These deviations to the original issued designs are evaluated and incorporated into the final analyses and design output documents as required.

NRC RAI EEMB.47 (Unit 1)

Section 3.11, Balance-of-plant Piping Evaluation, of the PUSAR noted that balance-of-plant (BOP) piping analyses were performed for changes due to NRC IEB 79-14 walkdown data, seismic design criteria and spectra changes, piping and piping component replacement design changes, the increased post-loss of coolant accident (LOCA) temperatures in the torus, turbine stop valve closure transient and the increased EPU pressure, temperature and flow changes. Provide the calculated maximum stress and CUFs for each of the evaluated BOP piping and supports at the EPU condition including a comparison with the code allowable limits. Provide a summary of the modification in piping and supports for each of the BOP systems due to the impact of the proposed EPU operation.

TVA Response to RAI EEMB.47 (Unit 1)

Calculated pipe stresses for BOP piping are maintained to be within the allowable stresses as defined by the BFN design criteria. The load combinations and allowables for BFN piping are in the BFN FSAR, Appendix C, Tables C.3-1A, C.3-1B, and C.3-1C. These tables cover the safety related piping at BFN except torus attached piping. The BFN design criteria used for all three BFN units piping analysis was reviewed and approved by the NRC (reference SER NUREG 1232, Vol 3, Supplement 2). The load combinations and allowables for torus attached piping are presented in the BFNP Torus Integrity Long Term Program Plant Unique Analysis Report (PUAR), TVA report CEB-83-34, revision 2, dated December 10, 1984 (see Table A-4). The torus program was reviewed and approved by the NRC (reference U.S. Nuclear Regulatory Commission Safety Evaluation of Browns Ferry Nuclear Plant, Units 1, 2, and 3, Mark I Containment Long Term Program, Pool Dynamic Loads Review, May 6, 1985). The design basis code of record for BFN is the USAS B31.1.0-1967 code, consequently fatigue analysis of piping and components is not a requirement at BFN and none was performed on the BOP piping.

Unit 1 is currently implementing modifications to support restart, and final stress results which reflect the final as-built configuration are not available for all systems. The core spray system is complete and the summary of maximum stresses is as follows:

Calc Number / Rev	System	Code Eq.	Post-EPU Stress	Allowable (psi)	Post-EPU Stress Ratio	Notes
CDQ1-075-2003-1024 / 013	075	Eq. 11	33657	37500	0.898	Eq 11 met N1-175-1R
CDQ1-075-2003-1025 / 012	075	Eq. 11	36712	37500	0.979	Eq 11 met N1-175-1RA

Unit 1 BOP supports were analyzed to the BFN design criteria and established BFN methods. All supports stresses are maintained below the allowable stresses as defined in the design criteria. Support allowable stresses for safety related supports (other than torus related supports) are as shown in the BFN FSAR, Appendix C, Table C.3-2. The load combinations and allowables for torus attached piping supports are presented in the BFNP Torus Integrity Long Term Program Plant Unique Analysis Report (PUAR), TVA report CEB-83-34, revision 2, dated December 10, 1984 (see sections 4.3.4 and 4.3.5). The stress analysis and the support loads from the analysis include the changes due to EPU where applicable.

It should be noted that many of these Unit 1 calculations have been reviewed by NRC Region II.

The support loads used for the evaluation of BOP piping supports included changes due to seismic spectra, NRC Bulletin 79-14 inspection data, changes due to new valves and pipe routing changes, and updated thermal operating modes including EPU temperatures. The EPU changes were included in the analysis along with the other changes described; therefore, TVA can not determine if a support was modified due to EPU affects alone. However, the changes due to EPU are judged to have had minimal impact on the supports in comparison to the other changes incorporated into the analysis for the restart of Unit 1. EPU pressure changes do not affect the support design and the EPU temperature increases are minimal in comparison to the pre-EPU temperatures on the affected piping. EPU has caused minimal modifications to supports on Units 2 and 3. With Unit 1 being similar in design to Units 2 and 3, it can be concluded that the EPU conditions had minimal impact on the overall support design changes made for Unit 1 restart.

NRC RAI EEMB.48 (Unit 1)

Section 3.11, Balance-of-plant Piping Evaluation, of the PUSAR notes that the design basis accident (DBA) / LOCA dynamic loads, including the pool swell loads vent thrust loads, condensation oscillation (CO) loads and chugging loads were re-evaluated and found acceptable. Provide a summary of the evaluation and the basis for your acceptance conclusion. Also, confirm whether other applicable dynamic loads such as relief valve discharging loads and annulus asymmetric pressurization loads are also evaluated. Confirm whether these evaluations conclude the acceptability of BOP piping in comparison with those of the Unit 1 design basis analyses.

TVA Response to RAI EEMB.48 (Unit 1)

The evaluation of LOCA dynamic loads for EPU is discussed in PUSAR Section 4.1.2.1 and includes pool swell, CO, chugging loads, and vent thrust loads. The results of this evaluation determined that the LOCA dynamic loads are not affected by EPU. Therefore, there is no EPU effect on BOP piping evaluations for LOCA dynamic loadings. Additionally, main steam relief valve loads and subcompartment pressurization were evaluated for EPU conditions and the results are provided in PUSAR Sections 4.1.2.2 and 4.1.2.3, respectively.

NRC RAI EEMB.49 (Unit 1)

Enclosure 1 of the April 13, 2006 submittal contained the GE report, GENE-0000-0052-3661-01-P, Test Report # 1 Browns Ferry Nuclear Plant, Unit 1 Scale Model Test, Class III, dated April 2006 (Test Report #1). Discuss which specific polymer was used to construct the Unit 1 dryer model using stereolithography.

TVA Response to RAI EEMB.49 (Unit 1)

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NRC RAI EEMB.50 (Unit 1)

If the acoustic Finite Element Model (FEM) of the RPV volume referenced in Test Report #1 is used to define the loading and/or response of the steam dryer, the corresponding document should be submitted for review.

TVA Response to RAI EEMB.50 (Unit 1)

The acoustic FEM was not used to define the pressure loading on the steam dryer. As described in Section 3.1 of GE-NE-0000-0053-7413-R2, the CDI acoustic circuit model was used to develop the pressure loading on the dryer based on the SMT measurements.

NRC RAI EEMB.51 (Unit 1)

a) The acoustic FEM characterization testing in Section 6.1 of Test Report #1 apparently [[ ]]. Previous scale model test reports indicate that [[

]]. Address the effects [[

]] acoustic FEM model.

b) Figures 77 to 84 of Test Report #1 purport to show that graphically operating acoustic mode shapes on the surface of the RPV are not understandable. Discuss the significance of these shapes for the RPV. Address whether acoustic modes and pressures will be extrapolated to the surface of the dryer.

TVA Response to RAI EEMB.51 (Unit 1)

The acoustic FEM was not used to define the pressure loading on the steam dryer. As described in Section 3.1 of GE-NE-0000-0053-7413-R2, the CDI acoustic circuit model was used to develop the pressure loading on the dryer based on the SMT measurements.

NRC RAI EEMB.52 (Unit 1)

a) Table 4 on page 51 of Test Report #1 defines the increments of the adjustments made to the S/RV cavity heights (if any). [[

]]. Also, Ziada and Shine (Ziada, S. and Shine, S., "Strouhal Numbers of Flow-Excited Acoustic Resonance of Closed Side Branches," Journal of Fluids and Structures, Vol. 13, pages 127-142, 1999) point out that valves in tandem can induce higher loads than individual valves. Discuss whether adjustments were made on adjacent valves simultaneously over a matrix of positions to truly maximize excitation. For example, discuss whether an adjustment on Valve 1 of MSL A of [[ ]]" was combined with an adjustment on Valve 4 of [[ ]]."

b) Provide the basis for using [[

]], considering that only microphone M10 measurements show an S/RV acoustic resonant excitation. Address whether microphone locations have shown different, more conservative sensitivities.

TVA Response to RAI EEMB.52 (Unit 1)

a) For the Browns Ferry Unit 1 scale model test, the only increments of [[
]] No adjustments were [[
]] The autopower spectrum of a dryer outer hood pressure sensor was examined while the [[

]] would have been visually observed.

b) [[

]] Also, the dryer outer hood is one of the components of major interest. After receipt of this question, results from other sensors on the outside of the dryer were examined. The results indicate that the chosen segment is consistently among the top segments for the segments examined and for the frequency ranges examined. Figures 1 and 2 are a comparison for outer hood locations of the linear average autopower spectrum of the selected segment to the whole time record and the other segments determined to be high amplitude segments. Figures 3 through 6 contain comparisons for skirt and closure plate locations. As noted in the report text, the selected segment is almost always higher than the whole record. The selected segment is also generally but not always higher in amplitude than the other segments determined to be high amplitude segments. It is higher in amplitude in some frequency bands than the other segments determined to be high amplitude segments but lower in amplitude in other frequency bands.

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NRC RAI EEMB.53 (Unit 1)

The amplitude units in Figures 50-61 of Test Report #1 should be clarified. Discuss whether they are spectra over a specific frequency bandwidth, or spectral densities.

TVA Response to RAI EEMB.53 (Unit 1)

The amplitude units in Figures 50 to 61 are peak linear Pascals. They could be considered 0 to peak amplitude as well. Figures 50 to 55 and 59 to 61 are at plant scale, while Figures 56 to 58 are at model scale. The plant scale autopower spectra were processed from the scale model time records scaled to full scale in both time and amplitude. [[

]]

NRC RAI EEMB.54 (Unit 1)

a) [[

]]. The [[ ]] used as inputs to the LIA and ACM models are different, presumably because the input locations are different for the two models and the most conservative increments were chosen as inputs. Explain why different increments were chosen for the two models.

b) Explain how the pressures on the dryer will be generated with LIA or ACM analysis.

c) Figures 87-90 of Test Report #1 show that the pressure spectral levels computed using the chosen [[ ]] increments exceed those of spectra computed using the full time records, but are consistently lower than those computed using a peak-hold average. The tonal levels near the S/RV singing frequencies, as well as the broad-band levels of the 2.5 second increments are lower than the peak-hold levels. However, no bias error is assigned to the choice of the 2.5-second increment in the uncertainty analysis. Explain why these bias errors for the dryer loading frequency ranges (A-E) in representative 2.5 second increment selections relative to the peak-hold spectra are not estimated and included in the total correction factors.

d) Discuss what assurances there are that the time history segments chosen for the load definitions are bounding, when they are based on pressures measured at essentially only two locations on the dryer faces.

TVA Response to RAI EEMB.54 (Unit 1)

a) [[

]]

b) The LIA was not used to define the pressure loading on the steam dryer. As defined in Section 3.1 of GE-NE-0000-0053-7413-R2, the CDI acoustic circuit model was used to develop the pressure loading on the dryer based on SMT measurements.

c) Peak hold spectra are always conservative because they keep the highest measured value for every frequency band. In general, the amplitudes of peak hold spectra increase as we increase the duration of the recorded time interval. This is due to the fact that the probability of recording spurious phenomena increases as we increase the duration of the time record. These phenomena may cause high pressure amplitudes that are not necessarily representative of the steady state operation of the system and usually have very short durations. When computing the peak hold spectra, these short-duration, high-amplitude transients contribute to increasing the amplitude of the final spectra.

As discussed above, peak hold power spectra calculated using long time records are generally very conservative and are not representative of the steady-state operation of the system. This is especially true when the system of interest experiences short-duration, high amplitude peaks due to flow instabilities and other unstable phenomena, which is the case of the SMT system. Therefore, the application of a bias error relative to peak-hold spectra would result in a significant overprediction of the typical loads applied to the dryer over a long period of time. Linear averaging of long time records usually gives a more realistic representation of the steady-state, continuous operation of a system because it tends to flatten the peaks caused by short-duration, transient phenomena.

A detailed evaluation of the uncertainty associated with the selection of the [[ ]] segment that was used in the ACM has been included in Section 9 of the latest version of the BFN steam dryer stress, dynamic and fatigue analyses for EPU conditions (GENE-0000-0053-7413-R2). The results obtained in this evaluation are summarized below and show that the selected time segment is conservative based on linear average spectra as well as time history data.

[[

]]

d) Previous SMT work with a large number of sensors has shown that the dryer outer hood sensors are generally representative of the response of the dryer as a whole in terms of selecting a high amplitude segment. Therefore, it is justified to use these four sensors for obtaining a representative uncertainty associated with the selection of the ACM time segment. As discussed in section c) of this RAI, a detailed analysis of the uncertainty associated with the selection of the reduced time segment has shown that it is possible to assure with 95% confidence level that the selected segment is bounding based on linear average spectra and time history data.

NRC RAI EEMB.55 (Unit 1)

The plant conditions for the QC2 data in Figures 62-67 should be clarified. Address whether they are at OLTP or EPU.

TVA Response to RAI EEMB.55 (Unit 1)

The plant conditions for the QC2 plant and QC2 SMT data and the BFN1 SMT data in Figures 62 through 67 are EPU.

NRC RAI EEMB.56 (Unit 1)

The SMT data shows that at EPU [[ ]] (lock-in excitation of acoustic modes within valve standoff pipes by flow instabilities over the pipe openings) [[ ]] (prior to mitigation by Acoustic Side Branches - ASBs). The blind flanges, S/RVs, and

MS relief valves have been modeled geometrically at a very small 1/17 scale. Some provisions have been made to vary the length of their standpipes, to account for fabrication tolerances established by BFN. However, other parameters affect the occurrence and strength of the lock-in excitation mechanisms (such as surface roughness, sharpness of edges, valve internal geometry, etc., all of which are hard to simulate in a small scale model). Discuss what other steps or larger scale tests have been made to evaluate the excitation mechanisms observed in the model and assure that the 1/17 scale model is an adequate representation of the excitation mechanisms that will occur. Assuming the model is correct, discuss those plans being made to avoid operating the reactors at lock-in conditions, where feedback between the flow instabilities and the acoustic modes can nonlinearly cascade into strong FIV excitation mechanisms that are hard to simulate or predict.

TVA Response to RAI EEMB.56 (Unit 1)

See the response to RAI EEMB.16. At this time, there are no provisions for testing BFN-specific S/RVs at a larger scale. The last part of this question is addressed in the response to RAI EEMB.32.

NRC RAI EEMB.57 (Unit 1)

Section 10.3, BFN1 SMT Load Definition Process, of Test Report #1, is unclear. Explain the process.

TVA Response to RAI EEMB.57 (Unit 1)

Section 10.3, BFN1 SMT Load Definition Process, covers the treatment of the SMT data to incorporate the random and bias errors that are discussed in the SMT Benchmark Report, Attachment B, Uncertainty Analysis of BWR Steam Dryer Scale Model Test Load Definition Methodology. Figure EEMB.57-1 below has a circle around the words, "Correct data for random & bias errors," that indicates this step in the Load Definition Development from SMT data flow-chart. The bias error is an error by frequency band based on the difference between SMT and plant results for the benchmark. The random error is an error by frequency band that is specific to the system being tested and the change in system response as flow increases.

[[

]] The bias errors come directly from the SMT Benchmark Report. The random errors come from Section 9.0, Uncertainty Analysis, of Test Report # 1 Browns Ferry Nuclear Plant, Unit 1 Scale Model Test. Figure EEMB.57-1 below contains the bias errors and random errors used to determine these composite factors. This weighting function or filter is shown in Figure 96 in Section 10.4 of the BFN1 SMT Report. [[

]]

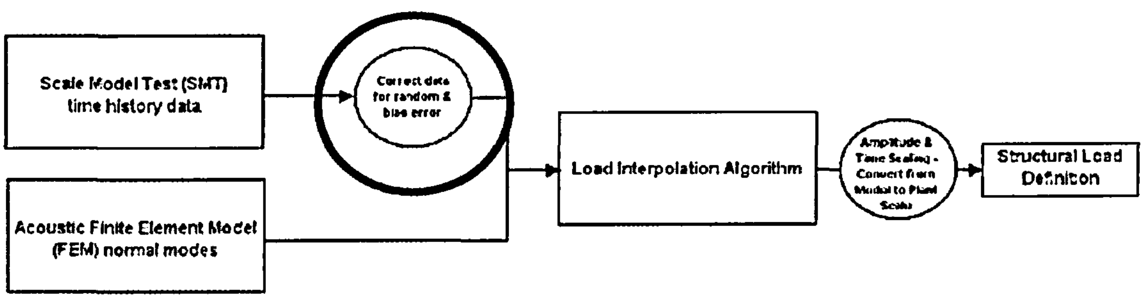

Figure EEMB.57-1
(Figure 131 from SMT Benchmark Report with orange circle added):
Flow-chart for Load Definition Development from SMT data

Table EEMB.57-1
Summary of Bias Errors, Random Errors and Weighting Factors by Frequency Band.

[[

]]

NRC RAI EEMB.58 (Unit 1)

In Section 3.5 of Test Report #1, discuss how the unknown absorptivity of the rigid flange at the steam/water interface between the RPV and the steam dryer will affect the model. Discuss how choosing [[ ]] maximize reflected amplitude.

TVA Response to RAI EEMB.58 (Unit 1)

See the response to RAI EEMB.18.

NRC RAI EEMB.59 (Unit 1)

In Section 3.5.1 of Test Report #1, discuss why the outlet of the [[

]] if the model is scaled 1:17.3. Discuss how this approximation more accurately models the resonating chamber of the steam dryer for plant scale.

TVA Response to RAI EEMB.59 (Unit 1)

Percent open areas in the plant will be the same in the model. The plant steam separators have surfaces that will reflect, absorb, and/or scatter incident pressure waves. Since there was no surface in the steam separator area of the SMT [[

]] as the plant separators as a rough approximation to preserving some of the wave reflection characteristics of the plant separators. See also, RAI EEMB.20 response.

NRC RAI EEMB.60 (Unit 1)

Discuss whether the pipe sizing (error of 0.5 percent on page 22 of Test Report #1) was considered in the March 2006 benchmark report.

TVA Response to RAI EEMB.60 (Unit 1)

The approach for pipe sizing discussed on p. 22 is the same approach used in the March 2006 benchmark report for the QC2 sub-scale model piping specification.

NRC RAI EEMB.61 (Unit 1)

Section 3.5.3.5 of Test Report #1 states that rounded edges at the entrance of a cavity have been shown to attenuate the amplitude of a cavity resonance. The GE SMT uses sharp edges. Address what edges are present in the plant.

TVA Response to RAI EEMB.61 (Unit 1)

The BFN units have 6″ X 26″ sweepolets, with smooth rounded edges for the SRV standpipe branch connections at 25 locations per unit.

NRC RAI EEMB.62 (Unit 1)

The acoustic frequencies calculated in Table 1 of Test Report #1 are not in the range evaluated in the SMT Report, [[ ]]. Discuss whether the frequencies in Table 1 are scaled frequencies. Discuss what this demonstrates in relation to the plant frequencies.

TVA Response to RAI EEMB.62 (Unit 1)

The MSRV and blind flange standpipe acoustic resonances shown in Table 1 are calculated for the full plant scale. [[ ]] The values shown in Table 1 are consistent with the standpipe resonance frequencies observed in plants with instrumented dryers (see Section 3.3.2 of the March 2006 benchmark report). [[

]]

NRC RAI EEMB.63 (Unit 1)

Describe the microphone arrangement (i.e., placement for minimal ambient noise, temperature compensation, etc.).

TVA Response to RAI EEMB.63 (Unit 1)

[[

]]

NRC RAI EEMB.64 (Unit 1)

Address why microphones [[
]]. Discuss how the locations for the microphones on the steam dryer were chosen, outside of being symmetrically spaced on the dryer.

TVA Response to RAI EEMB.64 (Unit 1)

The purpose of the SMT is primarily to evaluate the pressures on the dryer surface in operational conditions for the various power levels (flow rates) considered. Microphones were not utilized at the MSIVs or the SRV as these locations were not being used to develop input for the dryer loads. The CDI ACM was used to develop loads based on main steam line measured pressures at prescribed locations consistent with the ACM QC methodology.

Ideally, the locations of the microphones [[

]] Due to limited accessibility of the SMT dryer, the number of microphones that can be instrumented [[

]] To optimize the accuracy of the load definition for the subsequent stress analysis (given the limited number of sensors that can be installed), [[

]]

NRC RAI EEMB.65 (Unit 1)

Section 6.1 of Test Report #1, references "the Acoustic Finite Element Modeling Report for BFN1." Indicate whether this document been submitted for review.

TVA Response to RAI EEMB.65 (Unit 1)

The "Acoustic Finite Element Modeling Report for BFN1" has not been submitted for review. This report contains an approach that was not used for generating the BFN1 acoustic loads. Therefore, it is not part of the final submittal for BFN.

NRC RAI EEMB.66 (Unit 1)

Address how variations in length sensitivities affect the uncertainty analysis.

TVA Response to RAI EEMB.66 (Unit 1)

Length uncertainties in the plant and scale model dimensions increase the frequency uncertainty of the SMT predictions. The effect of the plant and scale model length uncertainties in the SMT frequency predictions can be quantified using Equation (90), contained in Attachment B of the SMT Benchmark Report. This equation is written below for convenience:

$$u_{\%}(f_p) = \sqrt{u_{\%}^2(f_m) + u_{\%}^2(L_m) + u_{\%}^2(L_p) + \frac{1}{4}\left(u_{\%}^2(T_{0,m}) + u_{\%}^2(T_{0,p})\right)} \tag{90}$$

where:

$u_{\%}(f_p)$: *Uncertainty associated with the plant frequencies predicted using SMT data.*

$u_{\%}(f_m)$: *Uncertainty in the scale model frequency measurements (associated with data acquisition and signal processing test equipment)*

$u_{\%}(L_m)$: *Uncertainty in scale model lengths due to fabrication and measurement errors.*

$u_{\%}(L_p)$: *Uncertainty in plant lengths due to fabrication and measurement errors.*

$u_{\%}(T_{0,m})$: *Uncertainty in the air temperature measured in the scale model.*

$u_{\%}(T_{0,p})$: *Uncertainty in the plant steam temperature.*

The values for the dimensional tolerances of Equation (90) depend on the acoustic cavity of interest. Typical values are provided in Tables 7 and 8, Attachment B of SMT Benchmark Report. [[

]]

NON-PROPRIETARY VERSION

NRC RAI EEMB.67 (Unit 1)

In Figures 73, 74, and 75 of Test Report #1, [[ ]]. Discuss the physical phenomena causing the data to be as collected. Address why the data is so different from the data at the other sensors.

TVA Response to RAI EEMB.67 (Unit 1)

[[

]] The resonance reaches a peak amplitude at approximately EPU, then decreases in amplitude. The other sensors shown in Figures 74 and 75 are not responding to this resonance.

NRC RAI EEMB.68 (Unit 1)

Figures 63 to 65 indicate that the BFN SMT steam dryer loading data [[ ]]. Discuss the evaluation of the steam dryer loading at BFN in light of the QC2 SMT data [[ ]].

TVA Response to RAI EEMB.68 (Unit 1)

[[

]] The response to RAI EEMB.69 below provides more information on the specific sources for different portions of the BFN1 frequency spectra.

[[

]]

By applying these weighting factors that include the bias error, the differences in amplitude between the QC2 SMT and QC2 plant results are incorporated into the BFN steam dryer loading from SMT results.

NRC RAI EEMB.69 (Unit 1)

Discuss the source of the specific resonance peaks in the frequency spectra indicated in the BFN SMT data. See Figures 62 to 67 of Test Report #1.

TVA Response to RAI EEMB.69 (Unit 1)

It is difficult to determine, with absolute certainty, which components act as sources to give the frequency content in the BFNP SMT [[ ]] These tests were performed in the Quad Cities SMT but not for Browns Ferry. Because there is a lot of similarity between BWRs in general, the sources for the frequency content in the BFNP can be taken to be similar to the sources for the frequency content in the QC SMT. Because [[ ]] this signifies that the pressure oscillations in this frequency band are influenced by [[ ]] The [[ ]] Further explanation of the frequency content observed in the Quad Cities SMT can be found in Section 6 of the Benchmark Report. As discussed above, it has been shown that pressure fluctuations in steam systems of [[ ]] so the general behavior observed in the [[ ]]

NRC RAI EEMB.70 (Unit 1)

Discuss the ability to correct the [[

]] shown in Figures 69 to 76 of Test Report #1.

TVA Response to RAI EEMB.70 (Unit 1)

Please see the response to RAI EEMB.35 above.

The remaining questions in this enclosure were provided to TVA by email transmission dated July 12, 2006.

CDI Report No. 05-28P (Revision 1, May 2006), "Bounding Methodology to Predict Full Scale Steam Dryer Loads from In-Plant Measurements" (Proprietary)

NRC RAI EEMB.A.1

CDI report 05-28 indicates that increasing main steam line (MSL) damping in the three new "bounding" acoustic circuit models (ACMs) leads to higher dryer loads. Discuss the physical explanation for this trend.

TVA Response to RAI EEMB.A.1

[[

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NRC RAI EEMB.A.2

CDI suggests that the Bounding Pressure ACM (the least conservative of the new ACM configurations) may be applied to any boiling water reactor (BWR) plant with MSL velocity Mach numbers less than 0.122 with no uncertainty or bias error (see page 21 and page 67 of CDI 05-28P). The stated justification is the comparison of the Bounding Pressure ACM simulations to the Quad Cities Unit 2 (QC2) steam dryer pressure measurements. However, the dominant loading mechanism in the QC plants prior to installation of the acoustic side branches (ASB) was singing of the safety relief valves (SRVs) and electromatic relief valves (ERVs), which depend on parameters other than MSL flow Mach number, such as SRV and ERV standpipe dimensions. Further, the graphs in Appendix A indicate that the Bounding Pressure ACM is not bounding for some locations in the 150 Hz range. Provide justification for the assumption of no uncertainty for the Bounding Pressure ACM, including any specific parameters and their bounds.

TVA Response to RAI EEMB.A.2

[[

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NRC RAI EEMB.A.3

Provide the basis for selecting the Bounding Pressure ACM, rather than the other ACMs, for the Browns Ferry Nuclear Plant (BFN).

TVA Response to RAI EEMB.A.3

The ACM Bounding Pressure model represents the most developed CDI ACM and was used by Vermont Yankee which achieved EPU power successfully.

NRC RAI EEMB.A.4

Discuss the underprediction of the Modified Prediction curve for Pressure Sensors P13, P14, P15, P16, and P23 in Figures 4.1 and 4.2.

TVA Response to RAI EEMB.A.4

P13, P14, P16, and P23 are all inside the steam dryer. As the FEM is driven by pressure differences across the steam dryer, [[

]] P15 is on the outside of the dryer, and is conservatively predicted by the Bounding Pressure ACM. See Figure 5.1 on page 22 of CDI Report No. 05-28.

CDI Report No. 06-11P (Revision 1, May 2006), "Hydrodynamic Loads on Browns Ferry Nuclear Unit 1 Steam Dryer to 200 Hz" (Proprietary)

NRC RAI EEMB.B.1

The steam dryer peak loads estimated by the ACM on the BFN dryers are extremely high (similar to those on the QC dryers prior to the modifications to the SRV and ERV standpipes). Explain the potential impact of these high loads on plant components, such as valves and piping. Discuss possible means to mitigate these loads.

TVA Response to RAI EEMB.B.1

The conservatisms introduced into the SMT modeling and methodologies have been to default to the most conservative condition. The ACM conservatisms continue this approach. The BFN Unit 3 vibration monitoring for 105% OLTP has been initiated to establish a baseline for the current MSL component vibration response. Results to date indicate that the plant response is less than that predicted by the conservative SMT conditions. During power ascension, components most susceptible to FIV are to be monitored and piping vibration shall also be monitored against acceptance criteria. The monitoring program throughout power ascension will identify component and piping response. Review of the monitoring results will be conducted and engineering evaluations are to be made to insure FIV loads are acceptable. While a general 50% increase is anticipated for piping vibration due to EPU conditions, it must be recognized that the BFN MSL velocities are much less than those experienced at the QC plants primarily due to the increased diameter of the MSL (26″ vs. 20″).

Based on the conservatism incorporated in the SMT, [[

]]

Mitigation of acoustic resonance has not been currently planned. Should plant conditions warrant mitigation, such approaches as acoustical side branches would be considered, if required to sustain EPU operating conditions.

NRC RAI EEMB.B.2

The comparison of the Bounding Pressure ACM and directly measured dryer surface pressures in the Scale Model Test (SMT) BFN facility at original licensed thermal power (OLTP) and extended power uprate (EPU) conditions is mixed (see Figure 4.1 in CDI report 06-11P). At some locations (away from the 0-180° centerline, and on exterior dryer surfaces excluding the skirt), the ACM and SMT maximum pressures agree fairly well. Near the 0-180° centerline, the ACM significantly underestimates the peak pressures. CDI suggests that, since the Bounding Pressure ACM includes a steam/water interface and the SMT is constructed of a nearly rigid interface, that the SMT data is biased high. ACM also underpredicts at Microphones M4 and M12, which are located on 90° and 270° side of the skirt. CDI has provided no explanation for this underprediction. Provide a more detailed explanation of the reasons for the ACM/SMT dryer surface pressure discrepancies, including a schematic of microphone locations referenced against the 0-180° centerline. Has an ACM been developed of the BFN SMT that includes near-rigid surfaces at the steam-water boundary? If so, did that ACM also underestimate dryer loads at the 0-180° centerline? Further, what uncertainty and/or bias error should be applied to the Bounding Pressure ACM based on comparisons to the SMT measurements?

TVA Response to RAI EEMB.B.2

[[

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The microphone locations for the 0-180 centerline are shown in Figures 24 and 26 of GENE-0000-0052-3661-01-P, Test Report # 1 Browns Ferry Nuclear Plant, Unit 1 Scale Model Test, Class III, dated April 2006 (Test Report #1).

NRC RAI EEMB.B.3

According to CDI Report 05-28P and Section V of CDI Report 06-11P, no uncertainty to the ACM loads appears to be included when Bounding Pressure ACM was applied at BFN. Based on the comparison of the Bounding Pressure ACM predictions to the measured SMT test data, as well as comparisons of the ACM predictions to actual QC2 steam dryer data, discuss the uncertainty and/or bias error of the Bounding Pressure ACM when applied at BFN.

TVA Response to RAI EEMB.B.3

While bias and uncertainty were not discussed in CDI Report 05-28P, bias and uncertainty in the Bounding Pressure ACM, as applied to BFN, are discussed in Section 5 of CDI Report No. 06-11 Rev. 2.

NRC RAI EEMB.B.4

CDI Report 05-28P suggests that a signal conditioning approach be used to remove MSL pressure signals due to localized flow turbulence from the data input to the ACM. Specify whether this approach was used to define the BFN loads, and if so, the revised errors/uncertainties associated with the ACM.

TVA Response to RAI EEMB.B.4

Signal conditioning was not used in the BFN analysis.

NRC RAI EEMB.B.5

Discuss the advantages and disadvantages of the use of pressure transducers versus strain gages to collect MSL data, and the method to be applied to collect representative pressure fluctuation data at each collection location with the pressure transducers.

TVA Response to RAI EEMB.B.5

The dynamic pressure sensor (DPS) transducers being selected for BFN have a number of distinct advantages in their application of measurement of dynamic pressure fluctuations in the Main Steam Lines (MSLs). Advantages are: simplicity of direct measurement, reduction in the number of instruments relied upon, not impacted by piping response (variations in piping wall thickness, pipe bending moments, structural vibration from FIV and pump discharge), ruggedness, improved reliability, and less uncertainty.

Off-setting these advantages is the increase in cost associated with design and installation of the DPS. For Units 2 and 3, there will be an additional increase in the dose required for personnel installing the instruments.

GE-NE-0000-0053-7413-R0-P (Revision 0, May 2006), "Browns Ferry Nuclear Plant Units 1, 2 and 3 Steam Dryer Stress, Dynamic and Fatigue Analyses for EPU Conditions (Proprietary)

NRC RAI EEMB.C.1

The BFN operating experience described in Section 2.2 includes fatigue cracking of drain channels in the steam dryer at all three units. Discuss whether any weld reinforcement was performed after the fatigue cracking events and the consideration of such reinforcement in the finite element model discussed in the report.

TVA Response to RAI EEMB.C.1

Steam Dryer Drain Channel Cracking was the subject of GE SIL 474 (10/26/1988). The SIL addressed the experience of these components exhibiting cracks at BWR/4, 5, and 6 plants. The drain channels are fabricated from 0.12" thick stainless steel and attached to the dryer with 0.12" fillet welds. In the original welded configuration, a crevice existed at the root of each weld because it was not a full penetration weld. Units 1, 2, and 3 have exhibited cracking since initial operation. Units 2 and 3 have had the drain channel welds repaired and additional mitigation weld reinforcements applied to the existing fillet welds to ¼" minimum. These repairs have been periodically inspected subsequent to 105% OLTP operation and reported as satisfactory. Unit 1 will have these modifications and repairs made prior to restart.

The finite element modeled the drain channel, but not the attachment welds. The weld stress intensity is addressed through the application of weld factors for the reinforced weld.

NRC RAI EEMB.C.2

The stress analysis results for the drain channel under OLTP conditions, presented in Table 6-4, appear inconsistent with the field fatigue cracking experience (e.g., the results predict that the maximum peak stress intensity for the drain channel is 6331 psi, which is much smaller than the fatigue limit of 13,600 psi). Discuss this difference in prediction and field experience.

TVA Response to RAI EEMB.C.2

Table 6-4 presents the EPU results with the appropriate weld factors. This table does not specifically reference the drain channels but incorporates the drain channel stress as part of the skirt. Figure 6-37 provides a detail on the drain channel and identifies a maximum skirt/drain channel stress intensity (at the bottom of a drain channel) stress intensity of [[ ]] This value is increased by the weld factor to [[ ]] The location is consistent with the drain channel cracking and only within 2.3% of 13600 psi. [[

]] The modification of reinforcement planned for increasing these welds to ¼" fillets will provide further weld strength and mitigation for cracking based on BWR field experience. In addition it is planned to "turn" the reinforcement weld around the bottom corner (location of the peak stress) of the drain channel and continue the reinforcement inside as far as accessible to remove the crevice condition.

The operating experience of BFN Units 2 and 3 at 105% of original licensed thermal power with the drain channel weld repairs and reinforcements has been positive based on post modification inspections.

NRC RAI EEMB.C.3

Tables 6-1 through 6-5 present the stress analysis results for the steam dryer components, with the exception of the tie bars. Provide the stress analysis results for the tie bars. Explain whether the results are consistent with the tie bar fatigue cracking experience at BFN Unit 3.

TVA Response to RAI EEMB.C.3

The upper tie bars are modeled [[ ]] - a representation that provides an accurate evaluation of loads acting on the welded joints. A separate evaluation and analysis employing these loads has demonstrated that the upper tie bars have sufficient structural capacity to resist fatigue limits - weld stress, including a weld factor of [[ ]] Based on BFN operating experience at 105% OLTP, the upper tie bars are being removed and replaced with a modified design that is significantly more robust (towel bar configuration). This modification has had positive operational experience and has not demonstrated any fatigue failures on several EPU operated units.

NRC RAI EEMB.C.4

In Section 6, BFN presents the stress analysis results for steam dryer at OLTP and EPU power levels but not at any intermediate power level. However, the stresses can be higher at an intermediate power level if valve singing takes place at that level. Explain whether the stresses calculated at the EPU power level bound the stresses calculated at the intermediate power levels.

TVA Response to RAI EEMB.C.4

The BFN Unit 1 Scale Model Test Report [GENE-0000-0052-3661-01] illustrates the predicted BFN Unit 1 stream dryer fluctuation loads from reactor power levels below OLTP to above EPU. Figures 4-1 thru 4-6 (Figures 68-69 and 73-76 from the BFN1 Scale Model Test Report), all shown below, illustrate the trend of the S/RV resonances as reactor power is increased. Figures EEMB.C.4-1 and EEMB.C.4-2 are spectrograms showing the evolution of all frequency content as reactor power is increased. These plots show the behavior of the S/RV resonances at [[ ]] Figures EEMB.C.4-3 through EEMB.C.4-6 are frequency cuts illustrating the behavior of only the S/RV resonance signal content in the [[ ]] bands, respectively. These plots more clearly show the trend of the S/RV resonance amplitude with reactor power level. Figure EEMB.C.4-6 shows the same frequency cuts expressed as a function of Strouhal number. These plots show that the peak S/RV resonance amplitudes occur at EPU power levels; therefore, the EPU load case bounds the loads that exist at intermediate reactor power levels. The stress analysis results reported in GE-NE-0000-0053-7413-R2-P bound the stresses that would be induced in the steam dryer at intermediate power levels.

[[

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Figure EEMB.C.4-1

[[

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Figure EEMB.C.4-2

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Figure EEMB.C.4-3

[[

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Figure EEMB.C.4-4

[[

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Figure EEMB.C.4-5

[[

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Figure EEMB.C.4-6

NRC RAI EEMB.C.5

In the Executive Summary and the tables in Section 6, the report mentions a manway cover as one of the steam dryer components. Describe the geometry, material, and location of the manway cover.

TVA Response to RAI EEMB.C.5

The manway, located on the 90° azimuth of the existing cover plate, was ~ 11" x 15" x 3/8" thick, and was welded with a ¼" fillet weld to the cover plate. Initial plans were to reinforce this weld to 3/8" to eliminate the undersize weld. However, the current modification will replace the cover plate with a continuous [[ ]] and will eliminate the manway in its entirety. The manway was originally required only for initial construction personnel access inside the dryer for inspection purposes.

NRC RAI EEMB.C.6

Discuss the difference between the following two components mentioned in the tables in Section 6: outer hood face plates and exterior hood plates - outer banks.

TVA Response to RAI EEMB.C.6

The outer hood face plates are shown in the referenced report in Figure 6-15. These are the slanted hood plate faces that are opposite the MSL nozzles at the 90° and 270° azimuths. The Exterior Hood plates - Outer banks, shown in Figure 6-16, are those components that are welded to the ends/sides of the outer hood face plates. In the modified dryer, the thickness of the outer hoods is [[ ]] while the exterior hood plates-outer banks will retain their original thickness equal to ½".

NRC RAI EEMB.C.7

Section 6.1 discusses a study using a detailed model of the skirt and water to determine the mass added to the skirt to represent the water. For this study, BFN uses a super element representing water and skirt and places boundary conditions on radial and vertical motion of water. The limit on the radial movement at the interface of the water with the RPV wall and steam separators is reasonable. Provide an explanation of the limit on the vertical movement at the bottom elevation of the dryer skirt.

TVA Response to RAI EEMB.C.7

Bottom elevation is constrained [[in]] and consequently [[ ]] throughout the duration of the analysis. This is a reasonable assumption since the [[ ]]

NRC RAI EEMB.C.8

According to discussion in Section 6.1, the finite element model used to perform dynamic stress analysis of steam dryer does not include a super element representing a model of skirt and surrounding water. Does this imply that the dynamic stress analysis can be performed using modal superposition method in ANSYS computer program? If so, explain why modal superposition method is not used to perform stress analysis.

TVA Response to RAI EEMB.C.8

The steam dryer finite element analysis model [[

]] Use of an [[ ]] in the finite element analysis would allow one to use modal superposition method in the ANSYS analysis, however, the modal superposition method [[ ]] are fundamentally equivalent since both methods solve the same system of equations of motion by means of direct integration. The [[ ]] was opted for due to the fact the method had been well tested [[ ]] and did not require any additional pre- and post-processing software generation and verification.

NRC RAI EEMB.C.9

In Section 6.3, BFN states that pressure loading on the skirt and both hoods exhibits high peaks in the 100-125 Hz range. Provide the spatial distribution of these high-peak loadings. Also, provide similar information for loading on the other components (e.g., cover plate and hood top plate) experiencing high stresses under EPU conditions. Identify the component mode shapes that may be significantly contributing to the high peak stress intensities (>13,600 psi) reported in Table 6-4.

TVA Response to RAI EEMB.C.9

Figure EEMB.C.9-1 (Figure 6-1 of GE-NE-0000-0053-7413-R2-P), shown below, illustrates the frequency content of the load applied to the structural FEM. This figure shows that the signal is dominated by the frequency content in the [[ ]] frequency band. Figure EEMB.C.9-2 (Figure 3-5 of GE-NE-0000-0053-7413-R2-P) also shown below, illustrates the spatial distribution of the load applied to the entire BFN Unit 1 FEM. Because the load is dominated by the [[ ]] signal content, this figure effectively shows the spatial distribution of the [[ ]] load component on the dryer. With the [[ ]] modifications, all components are below the fatigue acceptance criteria.

[[

]]

Figure EEMB.C.9-1

[[

]]

Figure EEMB.C.9-2

NRC RAI EEMB.C.10

Section 6.4 states that the fundamental frequencies for the skirt are below 33 Hz, and those for the outer and inner hoods are below 77 Hz and 62 Hz, respectively. Provide the fundamental frequencies for the other components (e.g., cover plate and hood top plate) that experience peak stress intensities higher than the fatigue limit under EPU conditions.

TVA Response to RAI EEMB.C.10

Please note that these components which previously experienced stress intensities higher than the fatigue limit with the exception of the top hood plate, as well as the hood face are replaced in the current modification with [[ ]] hence, changing their fundamental frequencies. The top hood plate is preserved in the latest modification, however the [[ ]] is able to isolate it from excessive stresses. The latest modification version provides fundamental frequencies as follows:

Original Dryer	Modified Dryer
Hood face: [[ ]]	Replacement Hood face: [[ ]]

The figures below [[ ]]

[[

]]

[[

]]

Figure EEMB.C.10-1

NRC RAI EEMB.C.11

Section 6.6 presents results for stress analyses for loading histories shifted upward and downward in frequency by 10%. The results show that ±10% shift could increase the stress intensity by as much as 100%. Aligning dryer hood (and other dryer component) resonance frequencies with peaks in the dryer loading spectra could further increase the stress intensities. Explain the basis for not performing stress analysis by aligning dryer resonance frequencies with peak drive frequencies, or at least analyzing dryer stresses at more refined time shifting increments of ±2.5%, 5%, 7.5%. Submit any new results.

TVA Response to RAI EEMB.C.11

An analysis of Table 6-2 shows that the nominal load case [[

]] This indicates the nominal load case [[

]] The observed trend appears to negate an assumption of missing resonance excitations in the range from [[ ]] and consequently any immediate need of performing multiple dynamic analyses at the above-mentioned intervals.

NRC RAI EEMB.C.12

BFN uses [[ ]] in its dynamic stress analysis of steam dryer. This damping ratio is higher than the one used for Vermont Yankee steam dryer stress analysis. Provide a justification for using this higher value. Provide the damping ratios at the significant frequencies for the BFN Unit 1 steam dryer. Evaluate the sensitivity of the stress results to the damping value assumed in the analysis and submit any new evaluation results.

TVA Response to RAI EEMB.C.12

A [[ ]] damping ratio was utilized on the BFN steam dryer analysis due to several reasons. The [[ ]] damping is considered to be a realistic damping level for a non-safety related component such as the steam dryer. The predicted stress levels at BFN are closer to the [[

]] versus the lower predicted stress levels at Vermont Yankee. It should further be noted that the analysis for the [[ ]] for certain portions of the dryer design. The BFN licensing basis for safety related welded structures is 2% damping, and for non-safety related structures the BFN licensing basis damping is 5%. Based upon the preceding discussion, BFN concluded that [[ ]] damping provide a conservative structural damping for this non-safety related component. At about [[ ]] a predominant driving frequency, the damping ratio is approximately [[ ]]

NRC RAI EEMB.C.13

Section 8 identifies the proposed BFN steam dryer modifications, some of which are shown in Figure 8-1. However, these modifications do not cover all the components experiencing high stress intensity (>13,600 psi) under EPU conditions, as identified in Table 6-4. The components that are not being modified but experience high stress intensities include vane bank top plates, outer hood stiffeners, inner hood face plates, trough, and base plate. Explain how the high stress intensities (>13,600 psi) will be mitigated in these components under EPU conditions so that fatigue cracking can be avoided. Identify the methods for inspecting the dryer after the modifications are made and then during the operation.

TVA Response to RAI EEMB.C.13

The dryer modification arrangements shown in Figure 8-1 are some of the modification concepts that were previously evaluated. More recently, BFN has developed a modification design that incorporates the [[ ]] The top hood plate is retained and re-attached to the new hood face [[ ]] These modifications result in component stress intensities for the modified dryer below the fatigue endurance limit stress of 13,600 psi. See response to RAI EEMB.C.19 for post modification inspection.

NRC RAI EEMB.C.14

Since only two seconds of SMT data is used to define dryer loads, and since the SMT BFN report indicates that all two second increments have levels below those in 'peak-hold' plots of the data, what bias error/uncertainty is TVA assigning to the load data?

TVA Response to RAI EEMB.C.14

This RAI is addressed in Section 9.0 of GENE-0000-0053-7413-R2.

NRC RAI EEMB.C.15

Discuss the source of the pressure peak near 175 Hz in Figure 6-1.

TVA Response to RAI EEMB.C.15

Review of the BFN main steam line geometries does not identify any MSL components that would contribute this frequency content. This review suggests that the frequency content near 175 Hz is not a deep cavity resonance similar to the ~120 Hz frequency content. Also, the 175 Hz content is similar to the lower frequency steam dome acoustic mode frequency content in two regards: 1) amplitude of resonance is much lower than S/RV resonance and closer to amplitude of lower frequency steam dome acoustic mode resonances, and 2) the frequency content is more broadband than an S/RV resonance and is more similar to the appearance of the steam dome acoustic resonances. Figure EEMB.C.15-1 below contains the same data as presented in Figure 6-1 of GE-NE-0000-0053-7413-R2-P; however, the axes are presented in linear scale rather than log scale. This more clearly shows that the amplitude of the 175 Hz frequency content is substantially lower than the S/RV resonance. The plots contained in Appendix D of GENE-0000-0052-3661-01 show the more broadband nature of this frequency content as measured in the SMT. GE testing has shown that the majority of the fluctuating load applied to the steam dryer is contributed by steam dome acoustic modes excited by various aero-acoustic sources in the BWR main steam system. The steam dome acoustic modes with pressure anti-nodes adjacent to the main steam nozzles are considered to be more susceptible to excitation than modes without anti-nodes close to the main steam nozzles because the majority of the main steam system sources exist in the main steam lines. It is considered probable that this load component is contributed by a steam dome acoustic mode as described above.

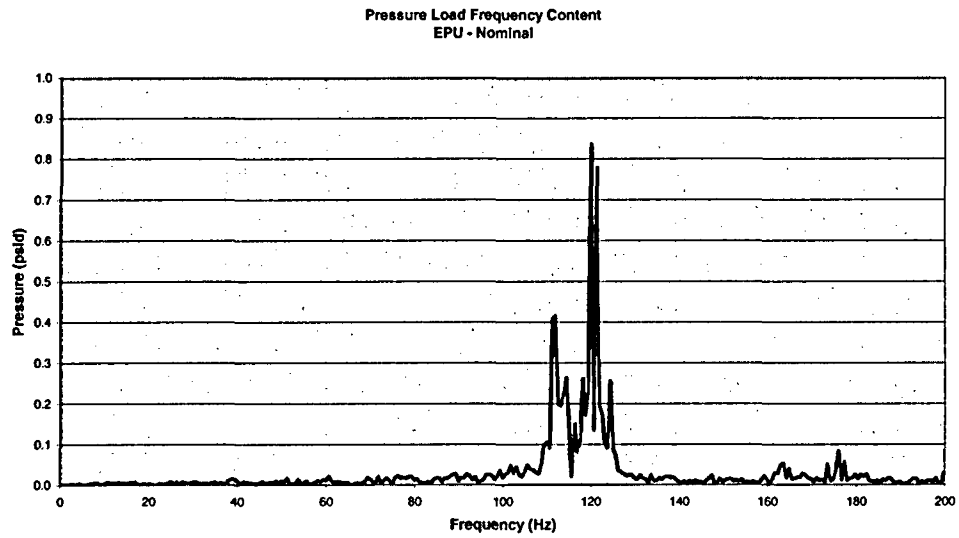

Figure EEMB.C.15-1

NRC RAI EEMB.C.16

Discuss the statement in Section 6.3 that the loading on the steam dryer is "reasonably symmetric."

TVA Response to RAI EEMB.C.16

The spatial distribution of the steam dryer loading, which is controlled by steam dome acoustic modes, will exhibit a distribution consistent with the mode shapes of the steam space. There are both symmetric and asymmetric modes in this volume. Generally, the major axes of symmetry and asymmetry, in the frequency range of interest for the loading, are defined by a line between the MS nozzles (90°-270°) and the centerline of the dryer (0°-180°). The load applied to the BFN steam dryer, as shown in Figure 3-5 of GE-NE-0000-0053-7413-R2-P, illustrates this; it is asymmetric about the axis between the MS Nozzles (90°-270°) and symmetric about the steam dryer centerline. Because the amplitude of the S/RV resonances in the MSL may vary from one MSL to the next, the load applied on the steam dryer will not be exactly equal on both sides of the dryer. The comment in the report was meant to communicate that the loads on each side of the dryer have very similar spatial distributions with respect to each other. This is a result of the acoustic mode shapes of the BWR steam dome that are excited by dominant frequencies in the pressure load as discussed in the response to RAI EEMB.C.9 above.

NRC RAI EEMB.C.17

Provide an example of the stress intensity calculation using the applicable weld factors discussed in Section 6.7.

TVA Response to RAI EEMB.C.17

The methodology of calculating stress intensities using applicable weld factors is outlined in Reference 8 of GE-NE-0000-0053-7413-R2. The actual calculations are easily traced by analyzing any row of Table 6-3 or Table 6-4 where the final column is the result of multiplying columns 2, 5, and 7.

NRC RAI EEMB.C.18

Section 6.8 indicates that the outer hood is the limiting component. Compare the design margin for the cover plate and outer hood plate provided in Table 6-5.

TVA Response to RAI EEMB.C.18

Refer to Table 6-4 and 6-5, page 19 of the subject report. The [[

]] is shown higher than the [[

]] consequently reducing the peak stress level and bringing the design margin of the [[

]]

The BFN planned dryer modification will eliminate these higher peak stress intensities by [[

]]

NRC RAI EEMB.C.19

Discuss the post-modification inspection procedures for the steam dryer modifications.

TVA Response to RAI EEMB.C.19

Post modification inspection will be conducted employing visual inspection (VT-2) and will provide a baseline for future inspections. GE SIL 644 and BWRVIP-139 currently provide guidance for these dryer inspections.

GE-NE-0000-0055-2994-R1-P (June 2006), "Addendum to Browns Ferry Nuclear Plant Units 1, 2 and 3 Steam Dryer Stress, Dynamic and Fatigue Analyses for EPU Conditions (Proprietary)

NRC RAI EEMB.D.1

The Executive Summary states that the "load definitions which are based on the SMT methodology are conservative due to the nature of the boundary condition modeling in the test apparatus, component replication, and due to the amplitude scaling used to bound the uncertainties in the SRV [safety relief valve] resonance frequency range." With the significant uncertainties in the SMT modeling and the appearance of high frequency resonance peaks in the BFN Unit 1 scale model under simulated EPU conditions that appear similar to the resonance peaks in the scale model testing for Quad Cities Unit 2, discuss the reliability of applying the SMT results to BFN in the absence of actual plant data to confirm those results.

TVA Response to RAI EEMB.D.1

Prior to use of the SMT for BFN, GE reviewed in-vessel instrumented steam dryer data from four different BWRs. This data shows marked similarity in the excitation mechanisms and system response that control the BWR steam dryer fluctuating loads [GE-NE-0000-0049-6652-01P, Rev. 0]. It is because of this similarity that the benchmark performed for the QC2 plant configuration is a valid assessment of the viability of the current SMT method for predicting BFN loads. This plant data review is also relevant because it provides insight into the characteristics of the loads expected for BFN Units 1, 2, and 3. BFN Units 1, 2, and 3 are typical BWRs; they have no features that are dramatically different than the BWRs for which in-vessel, instrumented steam dryer data already exists. Considering this, the BFN steam dryer loads are expected to show the same general load components as observed for the other BWRs. See GE-NE-0000-0049-6652-01P, Rev. 0 for a more detailed discussion of this.

In the SMT benchmark report, GE-NE-0000-0049-6652-01P, Rev.0, it is apparent that the GE SMT methodology [[

]] The benchmark acknowledges variability in the accuracy of the S/RV resonance predictions. To maintain conservatism in the overall approach, [[

]]

In addition to applying this very conservative approach of determining a correction factor using only the worst prediction, effectively ignoring the good predictions, GE has also selected the load after performing sensitivity tests where the S/RVs were adjusted to produce the highest load obtainable within a reasonable range of plant dimensional uncertainty. In effect, GE tuned the system to obtain the highest amplitude response rather than leaving the system at a "nominal" condition.

GE has also applied a load uncertainty for the S/RV load component that is based on the S/RV frequency cut in the range where the load is actually increasing. Figure EEMB.D.1-1 (Figure 75 from the BFN SMT report, GENE-0000-0052-3661-0) shows the trend of the S/RV resonances as reactor power is increased. This figure shows that the S/RV resonance peaks at EPU. In fact, over the 110-125% range of power, the S/RV resonance amplitude is not increasing significantly. The random error correction term utilized in the BFN load definition was obtained from the pressure-velocity relationship that exists over the 60-110% power range. Using the velocity relationship in this range introduces a conservative uncertainty value for the SMT fluctuating pressure uncertainty. This was done specifically to increase conservatism in the predicted loads. The conservatism of the S/RV amplitude predictions has been further increased by [[

]] thereby increasing the conservatism in the loads.

GE has addressed the areas of uncertainty in the current SMT methodology by applying conservative assumptions, test configurations, correction factors, and uncertainty values. Therefore, the S/RV resonance amplitudes predicted by the SMT for BFN1, 2, and 3, as applied to the structural analysis, are expected to be significantly higher than will exist in the actual plant conditions. The structural analysis results based on the SMT load definition are expected to be bounding for EPU conditions.

[[

]]

Figure EEMB.D.1-1

NRC RAI EEMB.D.2

The Executive Summary states that power ascension curves will be developed that will allow startup, collection of plant measurements, and additional structural analysis as necessary and maintain stresses below the 13,600 psi fatigue endurance limit. Discuss the basis for development of a reliable limit curve that confirms that the BFN steam dryer stress limits will not be exceeded during EPU power ascension where a stress analysis (including appropriate uncertainties) that demonstrates that the stress on the steam dryer components will be within the fatigue endurance limits under EPU conditions has not been provided.

TVA Response to RAI EEMB.D.2

GE report, GE-NE-0000-0053-7413-R2-P, "Browns Ferry Nuclear Plant Units 1, 2, and 3 Steam Dryer Stress, Dynamic, and Fatigue Analyses for EPU Conditions," July 2006, documents the structural analysis for the planned outer hood and cover plate modifications. These modifications replace the components previously exceeding the fatigue endurance limits and reduce the stress on the remaining top plate. With these modifications, all steam dryer components are within the fatigue endurance limits under EPU conditions. Note that additional uncertainty has been added to the BFN limit curves as described in Section 10 of GENE-0000-0053-7413-R2-P.

NRC RAI EEMB.D.3

Table 3 presents the results of the stress analysis for the BFN steam dryers with the planned modifications. Some BFN steam dryer components are calculated to be above the fatigue endurance limit under EPU conditions. If additional uncertainties needed to be addressed, more steam dryer components might be predicted to exceed their fatigue limit. Discuss the ability to conclude that the structural integrity of the BFN steam dryers will be maintained under EPU conditions based on the results of the submitted stress analysis.

TVA Response to RAI EEMB.D.3

As mentioned previously, the BFN dryer modification arrangement has been revised. The most recently analyzed modifications incorporate [[

]] Consequently the uncertainty determination has been revised to address this conservative dryer modification approach.

NRC RAI EEMB.D.4

Confirm whether the steam dryer stresses presented in Tables 2 and 3 are calculated at operating temperature. Explain whether these stresses were modified to account for the temperature effect before being presented in Tables 2 and 3.

TVA Response to RAI EEMB.D.4

The fatigue limits are based on [[ ]] applicable for the dryer operating conditions for the material of concern. The loads developed in the SMT were [[

]] The dryer material properties outlined in Table 4-1 of the May report are adjusted for the operating temperatures. Therefore the stresses are accurate for the dryer operating conditions.

NRC RAI EEMB.D.5

Table 3 compares the maximum stress intensity calculated for the steam dryer components to the stress limits for ASME Design Fatigue Design [[ ]]. Explain the specific locations for which the fatigue limit for [[

]] fatigue limit?

TVA Response to RAI EEMB.D.5

[[ ]] was selected as the screening curve for decisions related to development of modifications or reduction in power ascension limit curves to ensure component stresses remain under the limits established by Code. It is not intended to use [[ ]]for establishment of fatigue endurance limits for dryer components. The inclusion of the comparison [[ ]] was inserted to demonstrate that additional margin as per ASME design allowables exists on several components [[
]] column indicated that the stress range on the component exceeded the limitation imposed in the use of [[ ]] and thus not allowed by Code.

The current dryer modification provide all component stresses below the fatigue endurance limit, [[
]]

NRC RAI EEMB.D.6

Section 4 discusses the development of Power Ascension Limit Curves for BFN. Discuss the basis for the conservatism of the power ascension curves in maintaining the stress of the BFN steam dryer components below the fatigue endurance limit where the curves are either scaled up or down until the limiting stress is at the acceptance criterion. Describe the conditions under which the Level 1 and 2 Power Ascension Limit Curves will be considered reached or exceeded.

TVA Response to RAI EEMB.D.6

The structural analysis is a linear analysis; scaling the amplitude of the input loads while maintaining the same frequency content and spatial distribution will result in a linear scaling of the stresses in the dryer. Scaling the input loads so that the stresses in the dryer are at or below the acceptance criteria, then maintaining plant operation such that the measured MSL pressures remain below the pressures assumed in the analysis (after scaling) will assure that the stresses in the dryer components are maintained below the fatigue endurance limit. With the inclusion of the end-to-end uncertainty, the "Level 1" operating limit curves assure that there is sufficient conservatism in the operating limits to maintain the stresses in the dryer components below the fatigue endurance limit.

A limit curve for a particular measurement location is exceeded when the measured MSL pressure, as resolved in the frequency domain, exceeds the limit curve at any point in the defined frequency spectrum.

NRC RAI EEMB.D.7

Describe the BFN Power Ascension Procedure, including (a) the stress limit curves to be applied for evaluating steam dryer performance; (b) specific hold points and their duration during power ascension with sufficient time intervals for interaction with NRC staff during power ascension; (c) activities to be accomplished during hold points that are of sufficient duration to accomplish those activities; (d) plant parameters to be monitored; (e) inspections and walkdowns to be conducted for steam, feedwater, and condensate systems and components during the hold points; (f) the method to be used to trend plant parameters; (g) acceptance criteria for monitoring and trending plant parameters, and conducting the walkdowns and inspections; and (h) actions to be taken if acceptance criteria are not satisfied.

TVA Response to RAI EEMB.D.7

(a) Stress Limit Curves

Limit Curves (LC) - as a result of the extensive revised dryer modifications, TVA's approach to BFN limit curves has changed.

- Defined to ensure dryer stresses are maintained below fatigue endurance limit
  - Level 1 LC based on SMT predictive loading, ACM load definition, and FEA for modified dryer. These curves will utilize the end to end uncertainty determination developed from use of the SMT data generation including an additional 50% reduction for the establishment of the Level 1 LC. As such, the level 1 LC represents the analytical limit reduced by the total uncertainty.
    - Table 2 provides the actions to be taken if the Level 1 LC are exceeded
  - Level 2 LC represent 80% of the level 1 LC. These curves will be used for evaluation of plant data as collected for each unit's power ascension.
    - Table 2 provides the actions to be taken if the Level 2 LC are exceeded
  - Eight MSL pressure locations, 2 per MSL, to be monitored for LC evaluation

Refer to Section 10 of GENE-0000-0053-7413-R2-P for a detailed discussion of the Limit Curve development.

(b) Hold points and durations

Power plateau increases of approximately 5% OLTP

- Intermediate power increases of approximately 2.5% OLTP for monitoring and system testing
- Power increases to be dependent upon operational and/or environmental limitations

EPU Test Plateaus

Relative to OLTP %	100	105	110	115	120
Relative to EPU %	83.3	87.5	91.7	95.8	100
Rx MWt	3293	3458	3622	3787	3952

Operational hold periods to be typically 24 hours in duration to evaluate data, perform walk-downs, and stabilization of plant conditions for 2.5% OLTP power increases above each of the 5% OLTP power plateaus

Minimum 96 hour holds at each of the 5% OLTP power plateau increases to perform steam dryer analysis allowing NRC review.

Note that the 24 hour operational hold and 96 hour NRC review hold periods can run concurrently.

c) Activities during hold points

Data Collection

Monitor MSL pressures hourly during initial power ascension above OLTP

- Moisture carryover measurements per SIL 644
- Plant data indicative of off-normal dryer performance, such as Rx level, steam flow, and feed flow imbalance to be monitored hourly during initial power ascension

Evaluations

- Initiate collection of MSL pressure data at OLTP for U1, and perform ACM and stress analysis in order to evaluate plant performance relative to the limit curves.

- Limit curves will be utilized for evaluating the MSL pressure data at and above OLTP for Unit 1 and at and above 105% OLTP for U2, 3.

Reporting
- TVA will provide notifications to the NRC staff consisting of data and evaluations performed during EPU power ascension testing at and above CLTP at specified power levels and if the steam dryer stress acceptance is exceeded.
- Plant data collected at the power plateaus above OLTP from the SDMP, plant inspections and walkdowns, and evaluation of steam dryer performance based on this data will be provided to the NRC staff. TVA shall not increase reactor power above the power plateau for a minimum of 96 hours from the time of the NRC's receipt of this information. This process will be repeated at each of the 5% OLTP power plateaus until 120% OLTP
- Results of the Steam Dryer Monitoring Plan (SDMP) will be submitted to the NRC in a report within 60 days from completion of steam dryer power ascension testing.

Table 1 - Steam Dryer Surveillance Requirements During Reactor Power Operation above a Previously Attained Power Level

Parameter	**Surveillance Frequency**
1. Moisture Carryover (MC)	Every 24 Hours (Notes 1 and 2)
2. Main Steam Line (MSL) Pressure Data from Dynamic Pressure Sensors	Hourly when initially increasing power above a previously attained power level AND At least once at every 2.5% (nominal) OLTP power step
3. Main Steam line data from accelerometers	(Note 3) At least once at every 2.5% (nominal) power step above OLTP AND Within one hour after achieving every 2.5% (nominal) power step above OLTP

Notes:

1. Moisture Carryover (MC) to be in accordance with the Recommendations of GE SIL 644, Sup 1, Rev. 1. Provided that the performance criteria are not exceeded, when steady state operation at any given power level exceeds 168 consecutive hours, moisture carryover monitoring frequency may be reduced to once a week.

2. If MC cannot be determined within 24 hours of achieving a 5% power plateau, an orderly power reduction shall be made within the subsequent 12 hours to a power level at which MC was previously determined to be acceptable.

3. MSL pressure data shall be measured hourly when increasing power above a level at which data was previously attained. Data is required once at each 2.5% power step above 100% CLTP, and within one hour of achieving each 2.5% OLTP step in power, i.e. 102.5%, 105%, 107.5%, 110%, 112.5%, 115%, 117.5%, and 120% of OLTP. If the surveillance is met at a given power level, additional surveillances do not need to be performed at that power level where data had been previously obtained.

(d) Plant parameters to be monitored and system monitoring plan

- Plant Parameters to be Monitored for dryer performance

  GE SIL 644 provides guidance on the monitoring of plant parameters primarily to insure the moisture content monitoring is as accurate as possible and that contributing effects of plant parameters are under stood. As such the following plant parameters will be monitored and trended during EPU power ascension for each power increase increment:

  - Moisture Carryover
  - Reactor power, and rod pattern adjustments
  - Core flow
  - Core inlet sub-cooling
  - Reactor water level
  - Individual main steam line flows and MSL flow element pressure data

- Total Feedwater flow
- CRD flow

- MSL Pressure Data
  - Dynamic pressure sensors to be utilized to directly measure dynamic pressure fluctuations in MSLs
  - Two sensor locations per MSL, at the same locations as documented in the QC2 ACM Benchmark, will be utilized to minimize the uncertainty contribution. Note that Unit 1 will use redundant sensors (total of 2) at each location for added reliability due to the required plant Restart activities to be conducted for testing and inspection inside the drywell. Units 2, 3 do not require redundant sensors.
  - ACM Benchmark Methodology locations dictate the precise locations for sensor installation
  - Sensor data to be utilized for: Limit Curve monitoring, and ACM plant input for load definition determination
  - Data collection at each 2.5% OLTP power increase above CLTP

- System monitoring plans

  Plant parameter monitoring will be done via the plant Integrated Computer System (ICS) and a TVA software program called Dataware. The Dataware Program collects the information from ICS and is used to display the data in predefined groups, with limits, and trended over time. It is TVA's plan to use ICS and Dataware to do performance monitoring and analyze selected parameters from the following systems:

  1. Main Steam
  2. Feedwater
  3. Feedwater Heaters
  4. Main Turbine/Generator
  5. Condensate
  6. Recirc System

The above list is an example and may expand during the development of the actual EPU power ascension procedure. Other system performance monitoring and trending will be done for system parameters not in ICS and will be collected locally. Examples of these are:

- Bus Duct Cooling System
- Raw Cooling Water System

(e) Inspections/walkdowns (Steam, FW, Condensate systems)

The following systems will also be monitored for flow induced vibration effects by visual walkdown and/or via remote camera:

1. High Pressure Heaters
2. Condensate System
3. EHC Hydraulics
4. Main Steam (Turbine Bldg.)
5. Feedwater Systems (Turbine Bldg.)
6. Low Pressure Heaters

These observations will perform general inspections to evaluate equipment performance, identify the presence of abnormal vibration effects, and the presence of abnormal noises or signs of deteriorating material condition. Potential concerns and or issues identified as a part of these visual inspections and observations will be evaluated by Engineering.

(f) Trending Plant Parameters

Plant parameter trending will be done via the plant Integrated Computer System (ICS) and a TVA software program called Dataware. The Dataware Program collects the information from ICS and is used to display the data in predefined groups, with limits, and trended over time. For parameter that are recorded and collected manually they will be trended via an excel type spread sheet.

(g)and(h) Acceptance Criteria/Actions to be taken if not satisfied

Potential concerns and or issues identified as a part of visual inspections and observations will be evaluated by Engineering. For items that are deemed to be unacceptable at the current test plateau, power will be reduced to the previously known plateau where the conditions were not observed. Subsequent power increase will only be done after resolution of the issue.

For each of the above system monitoring plans, the collected data will be trended and evaluated by Engineering at each test plateau. Any anomalies will be investigated; and if determined to be unacceptable, power will be reduced to the previously known power level at which the performance was acceptable.

Table 2 - Steam Dryer Performance Criteria and Required Actions

Performance Criteria	Required Actions if Performance Criteria Exceeded and Required Completion
Level 2: Moisture Carryover (MC)>0.2% OR MC > 0.1% and increases by > 50% over the average of the three previous measurements taken above OLTP OR Pressure data > Level 2 Spectra (Note 1)	1. Promptly suspend reactor power ascension until an engineering evaluation concludes that further power ascension is justified. 2. Before resuming reactor power ascension, the steam dryer performance data shall be reviewed as apart of an engineering evaluation to assess whether further power ascension can be made without exceeding the Level 1 criteria
Level 1: MC $\geq$ 0.3% OR Pressure data exceed Level 1 Spectra	1. Promptly initiate a reactor power reduction and achieve a previously acceptable power level within two hours, unless an engineering evaluation concludes that continued power operation at the current power level or power ascension is acceptable. 2. Within 24 hours, re-measure MC and perform an engineering evaluation of steam dryer structural integrity. If the evaluation does not support continued plant operation, the reactor shall be placed in a hot shutdown condition within the following 24 hours. If the evaluation supports continued operation, implement step 3. 3. If the engineering evaluation supports continued operation, reduce further power ascension step increases and plateau levels to nominal increases of 1.25% and 2.5% of OLTP, respectively, for any additional power ascension.

Notes:

1. The steam dryer limit curve spectra and dryer stress to MSL frequency correlations shall be determined and documented in an engineering calculation or report. Acceptable level 2 shall be based on maintaining $\leq$ 10.88 ksi. Acceptable

Level 1 Spectra shall be based on maintaining $\leq$13.6 ksi. The Level 1 and Level 2 limit curves and stress limits shall be adjusted for uncertainty.

Long Term Actions

- BFN dryers will be inspected prior to EPU operation and at each of the following two refueling outages following completion of the EPU power ascension.
- Inspections to be per SIL 644, and/or BWRVIP-139, latest approved versions.
- Moisture carryover measurements will continue after power ascension based on SIL 644 recommendations.
- Equipment associated with temporarily installed pressure and vibration monitoring may be removed from service following achievement of one operating cycle.

NRC RAI EEMB.D.8

Section 4 states that a comparison of the plant, steam dryer, main steam line, and safety relief valve configuration for the three BFN units shows that the three units are virtually identical, and that the stretch power uprate operating experience at Units 2 and 3 would be directly applicable to Unit 1. Discuss the data and analysis used to make this comparison between the three units.

TVA Response to RAI EEMB.D.8

Plant design information and as-built measurements were the basis of the comparison. The reactor internals for all three units were compared and found to be designed and fabricated to the same details that would affect their dynamic response. Exceptions noted to the Reactor internals included the design change from Unit 1 to the Units 2 and 3 for the dryer hold-down configurations. The initial Unit 1 design incorporated hold-down posts as the mechanism employed to limit the dryer uplift under LOCA conditions for a main steam line break. Units 2 and 3 eliminated the hold-down posts to utilize the adjacent lifting lugs in a dual capacity to also serve as the uplift restraint. As such the adjoining Reactor head lugs were realigned to be positioned over the lifting lug instead of the previously utilized hold-down posts. There is a ½" clearance maintained between these components under non-accident conditions, so they do not serve as an operating restraint and the dryer frequencies are unaffected. Likewise there have been different reactor internal modifications and repairs implemented between the units since initial operation. These have been made to internal components which are not impacting the dryer response. All other dryer components have repairs that are the same between units or will be made the same prior to EPU operation (i.e., the dryer drain channel weld repairs and weld reinforcement).

All MSL components are the same design (i.e., safety relief valves). The piping configurations were compared based on the detailed walk-downs conducted for the BFN units' restart evaluations in response to the 79-14 criteria. It was found that certain piping configuration details exhibited some tolerance differences. These differences were incorporated into the SMT sensitivity tests to the extent possible to account for component locations differences from the Reactor vessel, and the slight differences of the configuration of the MSL standpipes with mounted valves. The BFN units each has 25 (26" X 6" 1500 lb. flanged) sweepolets: 13 have SRVs mounted, and 12 are blind flanged.

It was found that the dimension differences between the units were either bounded by the Unit 1 dimensions, or inconsequential based on the SMT sensitivity tests with a single exception. The outlier is the second SRV in the A MSL for Unit 3. It was found that the branch connection for this valve was slightly further away from the upstream elbow of the SRV header. It could be conservatively postulated that due to the branch being further away from the elbow it could be exposed to slightly higher flow than seen on the other BFN units. Note that the SRV in question is mounted 30° off the inside of the downcomer elbow so that the flow is expected to be less than maximized. For conservatism it was assumed that the Unit 3 valve could experience higher flows and develop greater resonance response. This conservatism, is addressed in the limit curves in order to determine the actual plant response and to remove the threat for exceeding the fatigue limits.

NRC RAI EEMB.D.9

Section 5.1 describes the ASME Code Load Combinations for the BFN steam dryers. For Upset 2 conditions, the report states: "No FIV load was applied for this load combination because the reverse flow through the steamlines will have disrupted the postulated acoustic sources in the steamlines." Provide the magnitude of the reverse flow velocity, and explain the basis for assuming that valve "singing" (i.e., self-reinforcement of flow instabilities over valve standpipe openings by acoustic modes within the standpipe) will not take place.

TVA Response to RAI EEMB.D.9

A more appropriate wording for the report would have been [[

]] The basic scenario is that when the turbine stop valves (TSVs) close and seal the MSLs, the flow in the steamlines stagnates at the turbine end of the MSLs. Once the momentum of the steam flow in the MSLs is absorbed, the stagnation pressure provides the driving source for the reverse flow. [[

]]

The reverse flow velocity [[

]] (at a power level of 102% EPU). There is the possibility that the flow slug will excite a resonance in the S/RV standpipe as it passes the standpipe. The distance between the vessel and the nearest S/RV standpipe is approximately 55 feet. Because the "singing" load will travel about 10 times faster than the flow slug, the reverse flow must be sustained for about 0.3 seconds at a velocity above the resonance onset velocity of [[ ]] in order for both the flow impact load and the "singing" load to be coincident on the dryer. [[

]] The standpipes that are closest to the vessel are about 80% the distance from the TSV to the vessel. [[

]]

The [[

]] is made in order to create a bounding value for the flow impact load term. This assumption neglects irreversible flow losses in the steamline as the flow passes in both directions. At the plant operating conditions assumed for this event, the pressure drop between the vessel and the upstream side of the turbine stop valve (the pressure drop associated with an average MSL flow of [[ ]] is 65 psi. The dynamic pressure associated with this flow velocity is about 13.5 psi, so it is readily apparent that the [[

]]

In addition, the vessel will begin to pressurize as soon as the TSVs close, further reducing the differential pressure driving the reverse flow. Given these conditions, [[

]]

NRC RAI EEMB.D.10

The BFN steam dryer stress report does not include an end-to-end uncertainty evaluation for the stress analysis for the BFN steam dryers. There are numerous aspects of the stress analysis that need to be evaluated for bias error and random uncertainty. For example, the steam dryer benchmarking report in the March 9 submittal indicates that steam dryer pressure loading obtained from the scale model test facility significantly underestimates the actual pressure loads measured in the instrumented steam dryer at Quad Cities Unit 2. The benchmark report calculates bias error and random uncertainty for the small scale model test facility, but the trends of scale model data compared to the actual plant data need to be assessed. Further, the applicability of bias error and random uncertainty calculated for the small scale test facility using Quad Cities Unit 2 data needs to be assessed for BFN. In an enclosure to the May 5 submittal, no uncertainty is indicated to be applied to the acoustic circuit model in calculating the BFN steam dryer stress. The May 5 submittal enclosure also indicates that the acoustic circuit model underpredicts the pressure measurements for some sensors on the steam dryer scale model. Provide an end-to-end uncertainty evaluation for the BFN steam dryer stress analysis, including information on the bias errors and uncertainties associated with the scale model test facility and its inputs, the MSL instrumentation and location, the acoustic circuit model load definitions, and stress response simulations.

TVA Response to RAI EEMB.D.10

This RAI is addressed in Section 9.0 of GENE-0000-0053-7413-R2.

NRC RAI EEMB.D.11

Discuss the susceptibility of the MSL safety relief valves to singing at power levels between current licensed thermal power and EPU conditions. The information is requested to include all valve locations along the MSLs, valve geometries, estimates of standpipe acoustic resonance frequencies, and estimates of MSL flow speeds that could cause singing.

TVA Response to RAI EEMB.D.11

The SRVs are [[ ]] during normal plant operation, from OLTP/CLTP to EPU. Calculations have estimated that maximum shear wave resonance for the SRVs [[ ]] conditions are reached. However, SMT data shows that the SRV [[ ]] RAI EEMB.C.4 addresses the expected development of these resonances at intermediate power levels between OLTP/CLTP and EPU.

The blind flanges are [[ ]]

It is GE's experience that the 1/4 wave acoustic standpipe mode [[ ]]

Refer to GENE-0000-0052-3661-01 Figures 6 through 9 to view SMT valve locations along the MSL. The following table gives detailed plant information for BFN:

Table EEMB.D.11-1

Description	Notes
Main steam flow	OLTP: 13.4 Mlb/hr 105% OLTP: 14.2 Mlb/hr EPU (120 % OLTP): 16.4 Mlb/hr
Main steam piping	26″ OD, 1″ wall thickness
Estimated MSL velocities	OLTP: 129 ft/sec 105% OLTP: 132 ft/sec EPU (120 % OLTP): 153 ft/sec
Branch (standpipe) connections	26″ X 6″ Sweepolets, 1500 lb flange, 18-1/2″ above MSL (typical), 25 locations (12 blind flanges)
SRV locations	MSL A - 3 SRVs MSL B - 4 SRVs, 2 at end of dead leg out of steam flow MSL C - 3 SRVs, 2 at end of dead leg out of steam flow MSL D - 3 SRVs
SRV configuration	Target Rock (Weir) 6″ X 10″ Relief Valve, Model 7567F. Rounded dome at top of internal chamber (average height of 18 5/8″).
Estimated acoustic frequency	Blind flange: [[ ]] SRV: [[ ]]

Estimated velocity at onset of resonance	Blind flange: [[ ]]

Attachment 1 to Enclosure 1 provides information on the Units 1, 2, and 3 comparison.

MSL SRV susceptibility to signing at power levels between CLTP and EPU conditions: The Unit 3 vibration monitoring results do not show any onset of resonance in the SRVs at 105% OLTP conditions. The SMT test results indicated that the resonance in the SRVs would begin just after 100% and continue to peak at approximately 120% OLTP. However the conservatisms in the modeling due to the use of square edged branch connections would introduce earlier onset and higher amplitudes than the plant configuration. The [[

]] The onset resonance calculations indicate that SRV resonance would occur no earlier than at EPU conditions, such that intermediate power levels are not expected to pose SRV resonance issues.

NRC RAI EEMB.D.12

The Executive Summary indicates that additional modifications are being evaluated to reduce the stress at certain BFN steam dryer locations. Discuss the plans for additional steam dryer modifications.

TVA Response to RAI EEMB.D.12

BFN has developed a modification design that incorporates [[

]] These modifications result in component stress intensities below the acceptance criteria.

NRC RAI EEMB.D.13

Many CDI proprietary acoustic circuit analysis codes and modeling configurations were developed for the Quad Cities plants and later for Vermont Yankee based on the in-plant measurement data taken at QC2. The ACM presented in CDI report 05-28, submitted to NRC with Enclosure 6 of TVA May 5, 2006 letter, was developed for BFN based on QC2 startup test data at 930 MWt power level with main steam flow velocity about 200 feet per second to bound pressure sensors on the outside of the dryer. However, the results of ACM show underprediction in comparison with the SMT data while the inputs at the steam line locations are the same. In light of the discrepancy between the test data and analytical results, evaluate the degree of uncertainty and underprediction by the current ACM when used for BFN.

TVA Response to RAI EEMB.D.13

There is only one acoustic circuit analysis code. This code has been set up for several modeling configurations. CDI has not conducted a bias and uncertainty analysis on the SMT data. (See the response to RAI EEMB.A.2).

NRC RAI EEMB.D.14

The ACM results may be considered to underestimate the loading on the steam dryer as indicated above. With the underpredicted loading, the finite element analysis results show the calculated stresses are exceeding the fatigue allowable limits during the operation at EPU conditions. The licensee proposed using the reverse engineering calculation to lower the peak stress to 13.6 ksi by multiplying the analytical results by a factor of 0.59 to established analytical limit curves. Discuss how to refine the SMT load definition that can valid the analytical results for use at BFN and visa versa, to have a realistic acceptable load definition rather than artificially scaling down the analytical results to meet the endurance limit without a technical basis.

TVA Response to RAI EEMB.D.14

GE-NE-0000-0053-7413-R2-P, "Browns Ferry Nuclear Plant Units 1, 2, and 3 Steam Dryer Stress, Dynamic, and Fatigue Analyses for EPU Conditions," July 2006, documents the structural analysis for the planned outer hood and cover plate modifications. These modifications replace the components previously exceeding the fatigue endurance limits and reduce the stress on the remaining top plate. With these modifications, all steam dryer components are within the fatigue endurance limits under EPU conditions even with the conservative SMT load definition. No scaling of the SMT load definition is necessary.

As a result of the revised planned modification approach, stresses exceeding the acceptance criteria have been eliminated and will not have to be scaled down.

NRC RAI EEMB.D.15

The licensee proposed to establish power ascension limit curves by further scaling down the analytical limit curves to account for uncertainties associated the SMT load definition, structural analysis and the monitoring instrumentation. The licensee does not provide a detailed evaluation and calculation regarding the Level 1 and Level 2 limit curves. The limit curves so established may be conservative for BFN. However, provide the technical basis regarding the uncertainty factors to be used.

TVA Response to RAI EEMB.D.15

The end-to-end uncertainty evaluation is provided in Section 9 of GE-NE-0000-0053-7413-R2-P, "Browns Ferry Nuclear Plant Units 1, 2, and 3 Steam Dryer Stress, Dynamic, and Fatigue Analyses for EPU Conditions," July 2006.

ATTACHMENT 1

COMPARISON OF VARIOUS PIPING SEGMENTS OF MAIN STEAM LOOPS

Comparison of Various Piping Segments of Main Steam Loop A

Between Units 1, 2 and 3

A Loop

		UNIT 1		UNIT 2					UNIT 3				
Segment #	Item	Unit 1 Span in ft	Cumulative span length	Unit 2 Span in ft	Difference in Length between Unit 1 and 2	% Difference U2 VS. U1	Cumulative span length	% Dif From Nozzle	Unit 3 Span in ft	Difference in Length between Unit 1 and 3	% Difference U3 VS. U1	Cumulative span length	% Dif From Nozzle
A1 to A2	Noz to first Ell	4.000	4.000	3.833	0.167	-4%	3.833	-4%	4.000	0.000	0%	4.000	0%
A2 to A3	Ell to 5D Bend	35.792	39.792	35.375	0.417	-1%	39.208	-1%	35.395	0.397	-1%	39.395	-1%
A3 to A4	5D Bend to 2nd Ell	12.417	52.209	13.000	-0.583	5%	52.208	0%	12.833	-0.416	3%	52.228	0%
A4 to A5	2nd Ell to 71ASRV	2.833	55.042	2.880	-0.047	2%	55.088	0%	2.880	-0.047	2%	55.108	0%
A5 to A6	71ASRV to SP	2.646	57.688	2.660	-0.014	1%	57.748	0%	2.750	-0.104	4%	57.858	0%
A6 to A7	SP to SP	4.958	62.646	4.958	0.000	0%	62.706	0%	5.000	-0.042	1%	62.858	0%
A7 to A8	Sp to 71MSRV	3.125	65.771	3.125	0.000	0%	65.831	0%	3.458	-0.333	11%	66.316	1%
A8 to A9	71M SRV to SP	6.250	72.021	6.167	0.083	-1%	71.998	0%	6.167	0.083	-1%	72.483	1%
A9 to A10	SP to SP	3.167	75.188	3.125	0.042	-1%	75.123	0%	3.125	0.042	-1%	75.608	1%
A10 to A11	SP to 71BSRV	3.080	78.268	3.104	-0.024	1%	78.227	0%	3.104	-0.024	1%	78.712	1%
A11 to A12	71B to 3rd Ell	7.417	85.685	7.290	0.127	-2%	85.517	0%	7.354	0.063	-1%	86.066	0%
A12 to A13	3rd Ell to 4th Ell	18.416	104.101	18.390	0.026	0%	103.907	0%	18.500	-0.084	0%	104.566	0%
A13 to A14	4th Ell to 1st MSIV	5.080	109.181	5.310	-0.230	5%	109.217	0%	5.375	-0.295	6%	109.941	1%
A14 to A15	1st to 2nd MSIV	24.604	133.785	24.680	-0.076	0%	133.897	0%	24.559	0.045	0%	134.500	1%

See GE SMT Sensitivity Test. That varied length of this section

The above data is taken from the following Problem Numbers/Calculation Numbers

Unit	Stress Problem	Calculation No.	Rx Nozzle Azimuth
1	N1-101-3R	CDQ1-001-2002-0348	72
2	N1-201-3R	CD-Q2001-880971	72
3	N1-301-3R	CD-Q3001-910421	72

Comparison of Various Piping Segments of Main Steam Loop A

Between Units 1, 2 and 3

A Loop S/RV Evaluation Only

Segment #	Item	UNIT 1 Unit 1 Span in ft	UNIT 1 Cumulative span length	UNIT 2 Unit 2 Span in ft	UNIT 2 Difference in Length between Unit 1 and 2	UNIT 2 % Difference U2 VS. U1	UNIT 2 Cumulative span length	UNIT 2 % Dif From Nozzle	UNIT 3 Unit 3 Span in ft	UNIT 3 Difference in Length between Unit 1 and 3	UNIT 3 % Difference U3 VS. U1	UNIT 3 Cumulative span length	UNIT 3 % Dif From Nozzle
A1 to A2	Noz to first Ell	4.000	4.000	3.833	0.167	-4%	3.833	-4%	4.000	0.000	0%	4.000	0%
A2 to A3	Ell to 5D Bend	35.792	39.792	35.375	0.417	-1%	39.208	-1%	35.395	0.397	-1%	39.395	-1%
A3 to A4	5D Bend to 2nd Ell	12.417	52.209	13.000	-0.583	5%	52.208	0%	12.833	-0.416	3%	52.228	0%
A4 to A5	2nd Ell to 71ASRV	2.833	55.042	2.880	-0.047	2%	55.088	0%	2.880	-0.047	2%	55.108	0%
A5 to A8	71ASRV to 71M	10.729	65.771	10.743	-0.014	0%	65.831	0%	11.208	-0.479	4%	66.316	1%
A8 to A11	71M SRV to 71B	12.497	78.268	12.396	0.101	-1%	78.227	0%	12.396	0.101	-1%	78.712	1%
A11 to A12	71B to 3rd Ell	7.417	85.685	7.290	0.127	-2%	85.517	0%	7.354	0.063	-1%	86.066	0%
A12 to A13	3rd Ell to 4th Ell	18.416	104.101	18.390	0.026	0%	103.907	0%	18.500	-0.084	0%	104.566	0%
A13 to A14	4th Ell to 1st MSIV	5.080	109.181	5.310	-0.230	5%	109.217	0%	5.375	-0.295	6%	109.941	1%
A14 to A15	1st to 2nd MSIV	24.604	133.785	24.680	-0.076	0%	133.897	0%	24.559	0.045	0%	134.500	1%

See GE SMT Sensitivity Test. That varied length of this section

The above data is taken from the following Problem Numbers/Calculation Numbers

Unit	Stress Problem	Calculation No.	Rx Nozzle Azimuth
1	N1-101-3R	CDQ1-001-2002-0348	72
2	N1-201-3R	CD-Q2001-880971	72
3	N1-301-3R	CD-Q3001-910421	72

Comparison of Various Piping Segments of Main Steam Loop B

Between Units 1, 2 and 3

B Loop

		UNIT 1		UNIT 2					UNIT 3					
Segment #	Item	Unit 1 Span in ft	Culumative span length	Unit 2* Span in ft	Difference in Length between Unit 1 and 2	% Difference U2 VS. U1	Cumulative span length	% Dif From Nozzle	Unit 3 Span in ft	Difference in Length between Unit 1 and 3	% Difference U3 VS. U1	Cumulative span length	% Dif From Nozzle	
B1 to B2	Noz to 1st Ell	3.871	3.871	4.120	-0.249	6%	4.120	6%	4.000	-0.129	3%	4.000	3%	See GE SMT Sensitivity Tests
B2 to B3	1st Ell to 5D Bend	35.250	39.121	35.030	0.220	-1%	39.150	0%	35.969	-0.719	2%	39.969	2%	
B3 to B4	5D Bend to Hdr	11.330	50.451	9.790	1.540	-14%	48.940	-3%	11.167	0.163	-1%	51.136	1%	
B4 to B5	Tee @ Hdr to SP	3.708	54.159	3.310	0.398	-11%	52.250	-4%	3.667	0.041	-1%	54.803	1%	Dead Leg Section W/O Flow
B5 to B6	SP to SP	5.042	59.201	5.270	-0.228	5%	57.520	-3%	5.083	-0.041	1%	59.886	1%	
B6 to HPCI	SP to HPCI Con	11.042	70.243	11.386	-0.344	3%	68.906	-2%	11.167	-0.125	1%	71.053	1%	
HPCI to B7	HPCI to 71D SRV	1.500	71.743	1.265	0.235	-16%	70.171	-2%	1.500	0.000	0%	72.553	1%	
B7 to B8	71D to 71C SRV	3.313	75.056	3.790	-0.477	14%	73.961	-1%	3.417	-0.104	3%	75.970	1%	
B8 to B9 capped end	71C to End Hdr Cap	1.760	76.816	2.750	-0.990	56%	76.711	0%	1.750	0.010	-1%	77.720	1%	
B4 to B10	Tee @ Hdr Con to 71ESRV	6.658	57.109	6.580	0.078	-1%	55.520	-3%	6.667	-0.009	0%	57.803	1%	
B10 to B11	71E to 71FSRV	3.396	60.505	3.370	0.026	-1%	58.890	-3%	3.438	-0.042	1%	61.241	1%	
B11 to B12	71F to 2nd Ell	7.031	67.536	7.280	-0.249	4%	66.170	-2%	7.458	-0.427	6%	68.699	2%	
B12 to B13	2nd Ell to 3rd Ell	18.480	86.016	18.000	0.480	-3%	84.170	-2%	18.125	0.355	-2%	86.824	1%	
B13 to B14	3rd Ell to 4th Ell	4.667	90.683	4.582	0.085	-2%	88.752	-2%	4.750	-0.083	2%	91.574	1%	
B14 to B15	4th Ell to 1st MSIV	7.211	97.894	7.050	0.161	-2%	95.802	-2%	6.850	0.361	-5%	98.424	1%	
B15 to B16	1st to 2nd MSIV	23.020	120.914	22.830	0.190	-1%	118.632	-2%	22.850	0.170	-1%	121.274	0%	

The above data is taken from the following Problem Numbers/Calculation Numbers

Unit	Stress Problem	Calculation No.	Rx Nozzle Azimuth
1	N1-101-2RB	CDQ1-001-2002-0347	108
2	N1-201-2RB	CD-Q2001-880970	108*
3	N1-301-2RB	CD-Q3001-910569	108

***All dimensions are from the T-Pipe analysis.**

*** May be bounded by SMT replication tolerance**

Comparison of Various Piping Segments of Main Steam Loop B

Between Units 1, 2 and 3

B Loop S/RV Evaluation - active steam flow only

		UNIT 1		UNIT 2					UNIT 3				
Segment #	Item	Unit 1 Span in ft	Culumative span length	Unit 2* Span in ft	Difference in Length between Unit 1 and 2	% Difference U2 VS. U1	Cumulative span length	% Dif From Nozzle	Unit 3 Span in ft	Difference in Length between Unit 1 and 3	% Difference U3 VS. U1	Cumulative span length	% Dif From Nozzle
B1 to B2	Noz to 1st Ell	3.871	3.871	4.120	-0.249	$\boxed{6\%}$	4.120	$\boxed{6\%}$	4.000	-0.129	$\boxed{3\%}$	4.000	$\boxed{3\%}$
B2 to B3	1st Ell to 5D Bend	35.250	39.121	35.030	0.220	-1%	39.150	0%	35.969	-0.719	2%	39.969	2%
B3 to B4	5D Bend to Hdr Tee	11.330	50.451	9.790	1.540	$\boxed{-14\%}$	48.940	$\boxed{-3\%}$	11.167	0.163	-1%	51.136	1%
B4 to B10	Tee @ Hdr Con to 71ESRV	6.658	57.109	6.580	0.078	-1%	55.520	$\boxed{-3\%}$	6.667	-0.009	0%	57.803	1%
B10 to B11	71E to 71FSRV	3.396	60.505	3.370	0.026	-1%	58.890	$\boxed{-3\%}$	3.438	-0.042	1%	61.241	1%
B11 to B12	71F to 2nd Ell	7.031	67.536	7.280	-0.249	$\boxed{4\%}$	66.170	-2%	7.458	-0.427	$\boxed{6\%}$	68.699	2%
B12 to B13	2nd Ell to 3rd Ell	18.480	86.016	18.000	0.480	$\boxed{-3\%}$	84.170	-2%	18.125	0.355	-2%	86.824	1%
B13 to B14	3rd Ell to 4th Ell	4.667	90.683	4.582	0.085	-2%	88.752	-2%	4.750	-0.083	2%	91.574	1%
B14 to B15	4th Ell to 1st MSIV	7.211	97.894	7.050	0.161	-2%	95.802	-2%	6.850	0.361	$\boxed{-5\%}$	98.424	1%
B15 to B16	1st to 2nd MSIV	23.020	120.914	22.830	0.190	-1%	118.632	-2%	22.850	0.170	-1%	121.274	0%

See GE SMT Sensitivity Tests

Comparison of Various Piping Segments of Main Steam Loop C

Between Units 1, 2 and 3

C Loop

		UNIT 1		UNIT 2					UNIT 3					
Segment #	Item	Unit 1 Span in ft	Cumulative span length	Unit 2 Span in ft	Difference in Length between Unit 1 and 2	% Difference U2 vs. U1	Cumulative span length	% Dif From Nozzle	Unit 3 Span in ft	Difference in Length between Unit 1 and 3	% Difference U3 vs. U1	Cumulative span length	% Dif From Nozzle	
C1 to C2	Noz to 1st Ell	4.000	4.000	3.792	0.208	-5%	3.792	-5%	4.063	-0.063	2%	4.063	2%	See GE SMT Sensitivity Test
C2 to C3	1st Ell to 5D Bend	34.583	38.583	34.083	0.500	-1%	37.875	-2%	34.333	0.250	-1%	38.396	0%	
C3 to C4	5D Bend to Tee @ Hdr	12.000	50.583	12.770	-0.770	6%	50.645	0%	12.790	-0.790	7%	51.186	1%	
C4 to C5	Tee @ Hdr to SP	3.5	54.083	2.36	1.14	-33%	53.005	-2%	3.7	-0.2	6%	54.886	1%	Dead Leg No Flow
C5 to C6	SP to SP	5.000	59.083	5.130	-0.13	3%	58.135	-2%	5.063	-0.063	1%	59.949	1%	
C6 to C7	Sp to 71H SRV	13.000	72.083	12.420	0.58	-4%	70.555	-2%	12.583	0.417	-3%	72.532	1%	
C7 to C8	71H to 71G SRV	3.417	75.500	3.402	0.015	0%	73.957	-2%	3.385	0.032	-1%	75.917	1%	
C8 to C9 Capped End	71G to Hdr Cap	1.729	77.229	1.694	0.035	-2%	75.651	-2%	1.693	0.036	-2%	77.610	0%	
C4 to C10 (RCIC)	Tee to 71JSRV	9.875	60.458	8.980	0.895	-9%	59.625	-1%	10.100	-0.225	2%	61.286	1%	
C10 to C11	71J to 2nd Ell	6.583	67.041	7.547	-0.964	15%	67.172	0%	7.541	-0.958	15%	68.827	3%	
C11 to C12	2nd Ell to 3rd Ell	18.427	85.468	18.250	0.177	-1%	85.422	0%	18.740	-0.313	2%	87.567	2%	
C12 to C13	3rd Ell to 4th Ell	4.375	89.843	4.580	-0.205	5%	90.002	0%	4.580	-0.205	5%	92.147	3%	
C13 to C14	4th Ell to 1st MSIV	6.906	96.749	6.938	-0.032	0%	96.940	0%	6.958	-0.052	1%	99.105	2%	
C14 to C15	1st to 2nd MSIV	23.604	120.353	23.750	-0.146	1%	120.690	0%	23.646	-0.042	0%	122.751	2%	

The above data is taken from the following Problem Numbers/Calculation Numbers

Unit	Stress Problem	Calculation No.	Rx Nozzle Azimuth
1	N1-101-4R	CDQ1-001-2002-0349	252
2	N1-201-4R	CD-Q2001-880972	252
3	N1-301-4R	CD-Q3001-910429	252

Comparison of Various Piping Segments of Main Steam Loop C

Between Units 1, 2 and 3

C Loop S/RV Evaluation - Active steam flow only

		UNIT 1		UNIT 2					UNIT 3				
Segment #	Item	Unit 1 Span in ft	Cumulative span length	Unit 2 Span in ft	Difference in Length between Unit 1 and 2	% Difference U2 vs. U1	Cumulative span length	% Dif From Nozzle	Unit 3 Span in ft	Difference in Length between Unit 1 and 3	% Difference U3 vs. U1	Cumulative span length	% Dif From Nozzle
C1 to C2	Noz to 1st Ell	4.000	4.000	3.792	0.208	-5%	3.792	-5%	4.063	-0.063	2%	4.063	2%
C2 to C3	1st Ell to 5D Bend	34.583	38.583	34.083	0.500	-1%	37.875	-2%	34.333	0.250	-1%	38.396	0%
C3 to C4	5D Bend to Tee @ Hdr	12.000	50.583	12.770	-0.770	6%	50.645	0%	12.790	-0.790	7%	51.186	1%
C4 to C10 (RCIC)	Tee to 71JSRV	9.875	60.458	8.980	0.895	-9%	59.625	-1%	10.100	-0.225	2%	61.286	1%
C10 to C11	71J to 2nd Ell	6.583	67.041	7.547	-0.964	15%	67.172	0%	7.541	-0.958	15%	68.827	3%
C11 to C12	2nd Ell to 3rd Ell	18.427	85.468	18.250	0.177	-1%	85.422	0%	18.740	-0.313	2%	87.567	2%
C12 to C13	3rd Ell to 4th Ell	4.375	89.843	4.580	-0.205	5%	90.002	0%	4.580	-0.205	5%	92.147	3%
C13 to C14	4th Ell to 1st MSIV	6.906	96.749	6.938	-0.032	0%	96.940	0%	6.958	-0.052	1%	99.105	2%
C14 to C15	1st to 2nd MSIV	23.604	120.353	23.750	-0.146	1%	120.690	0%	23.646	-0.042	0%	122.751	2%

Comparison of Various Piping Segments of Main Steam Loop D

Between Units 1, 2 and 3

D Loop

Segment #	Item	UNIT 1: Unit 1 Span in ft	UNIT 1: Cumulative span length	UNIT 2: Unit 2* Span in ft	UNIT 2: Difference in Length between Unit 1 and 2	UNIT 2: % Difference U2 vs. U1	UNIT 2: Cumulative span length	UNIT 2: % Dif From Nozzle	UNIT 3: Unit 3 Span in ft	UNIT 3: Difference in Length between Unit 1 and 3	UNIT 3: % Difference U3 vs. U1	UNIT 3: Cumulative span length	UNIT 3: % Dif From Nozzle	
D1 to D2	Noz to 1st Ell	4.000	4.000	4.000	0.000	0%	4.000	0%	4.000	0.000	0%	4.000	0%	See GE SMT Sensitivity Test.
D2 to D3	1st Ell to 5D Bend	35.531	39.531	35.210	0.321	-1%	39.210	-1%	35.188	0.343	-1%	39.188	-1%	
D3 to D4	5D Bend to 2nd Ell	12.417	51.948	12.970	-0.553	4%	52.180	0%	12.500	-0.083	1%	51.688	-1%	
D4 to D5	2nd Ell to 71KSRV	3.250	55.198	2.890	0.360	-11%	55.070	0%	3.000	0.250	-8%	54.688	-1%	
D5 to D6	71K to SP	2.677	57.875	2.685	-0.008	0%	57.755	0%	2.750	-0.073	3%	57.438	-1%	
D6 to D7	SP to SP	4.938	62.813	4.918	0.020	0%	62.673	0%	5.000	-0.062	1%	62.438	-1%	
D7 to D8	Sp to 71NSRV	3.080	65.893	3.080	0.000	0%	65.753	0%	3.167	-0.087	3%	65.605	0%	
D8 to D9	71N to SP	6.125	72.018	6.196	-0.071	1%	71.949	0%	6.208	-0.083	1%	71.813	0%	
D9 to D10	SP to SP	3.167	75.185	3.063	0.104	-3%	75.012	0%	3.063	0.104	-3%	74.876	0%	
D10 to D11	SP to 71LSRV	3.040	78.225	3.104	-0.064	2%	78.116	0%	3.125	-0.085	3%	78.001	0%	
D11 to D12	71LSRV to 3rd Ell	7.080	85.305	7.260	-0.180	3%	85.376	0%	7.167	-0.087	1%	85.168	0%	
D12 to D13	3rd Ell to 4th Ell	18.500	103.805	18.415	0.085	0%	103.791	0%	17.958	0.542	-3%	103.126	-1%	
D13 to D14	4th Ell to 1st MSIV	5.145	108.950	5.365	-0.220	4%	109.156	0%	5.489	-0.344	7%	108.615	0%	
D14 to D15	1st to 2nd MSIV	24.906	133.856	25.150	-0.244	1%	134.306	0%	24.844	0.062	0%	133.459	0%	

The above data is taken from the following Problem Numbers/Calculation Numbers

Unit	Stress Problem	Calculation No.	Rx Nozzle Azimuth
1	N1-101-1RA	CDQ1-001-2002-0346	288
2	N1-201-1RA	CD-Q2001-880969	288
3	N1-301-1RA	CD-Q3001-910436	288

*All dimensions are from the stress isometric in the referenced calculation except Unit 2, which is based on the TPIPE analysis.

Comparison of Various Piping Segments of Main Steam Loop D

Between Units 1, 2 and 3

D Loop S/RV Evaluation

		UNIT 1		UNIT 2					UNIT 3				
Segment #	Item	Unit 1 Span in ft	Cumulative span length	Unit 2* Span in ft	Difference in Length between Unit 1 and 2	% Difference U2 vs. U1	Cumulative span length	% Dif From Nozzle	Unit 3 Span in ft	Difference in Length between Unit 1 and 3	% Difference U3 vs. U1	Cumulative span length	% Dif From Nozzle
D1 to D2	Noz to 1st Ell	4.000	4.000	4.000	0.000	0%	4.000	0%	4.000	0.000	0%	4.000	0%
D2 to D3	1st Ell to 5D Bend	35.531	39.531	35.210	0.321	-1%	39.210	-1%	35.188	0.343	-1%	39.188	-1%
D3 to D4	5D Bend to 2nd Ell	12.417	51.948	12.970	-0.553	4%	52.180	0%	12.500	-0.083	1%	51.688	-1%
D4 to D5	2nd Ell to 71KSRV	3.250	55.198	2.890	0.360	-11%	55.070	0%	3.000	0.250	-8%	54.688	-1%
D5 to D6	71K to 71N SRV	10.695	65.893	10.683	0.012	0%	65.753	0%	10.917	-0.222	2%	65.605	0%
D8 to D9	71N to 71L SRV	12.332	78.225	12.363	-0.031	0%	78.116	0%	12.396	-0.064	1%	78.001	0%
D11 to D12	71LSRV to 3rd Ell	7.080	85.305	7.260	-0.180	3%	85.376	0%	7.167	-0.087	1%	85.168	0%
D12 to D13	3rd Ell to 4th Ell	18.500	103.805	18.415	0.085	0%	103.791	0%	17.958	0.542	-3%	103.126	-1%
D13 to D14	4th Ell to 1st MSIV	5.145	108.950	5.365	-0.220	4%	109.156	0%	5.489	-0.344	7%	108.615	0%
D14 to D15	1st to 2nd MSIV	24.906	133.856	25.150	-0.244	1%	134.306	0%	24.844	0.062	0%	133.459	0%

See GE SMT Sensitivity Test.

ENCLOSURE 4

TENNESSEE VALLEY AUTHORITY
BROWNS FERRY NUCLEAR PLANT (BFN)
UNITS 1, 2, AND 3

TECHNICAL SPECIFICATIONS (TS) CHANGES TS-431 AND TS-418 - EXTENDED POWER UPRATE (EPU) - RESPONSE TO ROUND 7 REQUESTS FOR ADDITIONAL INFORMATION (TAC NOS. MC3812, MC3743, AND MC3744)

(NON-PROPRIETARY VERSION)

Enclosure 4 is GE report, GE-NE-0000-0053-7413-R2-NP, entitled, *Browns Ferry Nuclear Plant Units 1, 2, and 3 Steam Dryer Stress, Dynamic, and Fatigue Analyses for EPU Conditions*, dated July 2006.