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Your ref: Docket No. 52-006
Our ref: DCP_NRC_003006

August 13, 2010

Subject: AP1000 Response to Proposed Open Item (Chapter 3)

Westinghouse is submitting the following responses to the NRC open item (OI) on Chapter 3. These proposed open item responses are submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in these responses is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following proposed Open Item(s):

OI-SRP3.9.1-EMB-05 R3
OI-SRP3.9.1-EMB-06 R2

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

D. A. Lindgren / FOR

Robert Sisk, Manager
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/Enclosure

1. Response to Proposed Open Item (Chapter 3)

D063
NRO

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ENCLOSURE 1

AP1000 Response to Proposed Open Item (Chapter 3)

AP1000 TECHNICAL REPORT REVIEW

Response to SER Open Item (OI)

OI Response Number: OI-SRP3.9.1-EMB1-05
Revision: 3

Question:

Revision 3:

In response to the WESTEMS audit held June 23-24 in Cranberry, this open item response is being revised to provide confirmatory information and commitments agreed upon at the audit between WEC and the NRC in order to close this open item.

Markups to the WESTEMS User's Manual are included, to be incorporated into the next revision of the manual.

Revision 2:

Follow-up question #1 (WEC Response provided in Rev. 2 of this Open Item):

Westinghouse failed to address the staff's RAI regarding the use of the algebraic summation of three orthogonal vectors as discussed in WESTEMS user manual and user instructions.

Follow-up question #2 (WEC Response provided in Rev. 2 of this Open Item):

The WESTEMS methodology for stress combination is not correct in that it adds the thermal stresses absolutely. ASME NB-3600 requires using the full stress range. Adding thermal stress absolutely decreases the stress range and therefore does not meet ASME NB-3600 requirements.

Follow-up question #3 (WEC Response provided in Rev. 2 of this Open Item):

The thermal stress due to discontinuity item is subtracted in WESTEMS algebraic stress histories calculation as shown below:

$$Snalg = C1PoDo/2t + C2\ Do/2I\ (Mx + My + Mz) - C3Eab\ (\alpha aTa - \alpha bTb)$$

$$Spalg = K1C1PoDo/2t + K2C2\ Do/2I\ (Mx + My + Mz) - K3Ea\ \alpha a\ \Delta T1\ /(2^*(1-\nu)) - K3C3Eab\ (\alpha aTa - \alpha bTb) - Ea\alpha a\ \Delta T2\ /(1-\nu))$$

S13alg = C1PoDo/2t + C2 Do/2I (Mx + My + Mz) **- C3prine *Eab* (α*aTa* – α*bTb)***

ASME Code Section III NB-3653 identified an absolute value is required for this item. The staff is requesting the applicant to provide justification to ensure that WESTEMS method using negative sign for this item meets ASME Code requirements.

Follow-up question #4 (WEC Response provided in Rev. 2 of this Open Item):

In the response of OI-SRP3.9.1-EMB1-05, the applicant provided the following description:

The moment stress term (e.g., in Equation 10) is calculated by:
C2*Mi*Do/(2*I)
Where Mi is the resultant moment range between the peak or valley times in the fatigue pair (from WESTEMS™ User's Manual Section 10.1):

$Mi = [(\Delta M1)^2 + (\Delta M2)^2 + \ldots + (\Delta Mm)^2)]^{0.5}$

Where:
Δ defines the range (difference) between the associated terms for each peak time in the pair;
m = number of moment histories defined by the user. Note that the ranges between each of the signed moment stress terms are first calculated before squaring them.

ASME Code identified that Mi is the range of moment which is occurs when the systems goes from one service load set to another. WESTEMS defines Mi as SRSS for m set of moment ranges. The staff is requesting the applicant to justify the difference.

Revision 1:

In the response of OI-SRP3.9.1-EMB1-05, Westinghouse stated that " Westinghouse has prepared a detailed user instruction for the proper use of the peak selection options in the NB-3600 module, to avoid the improper use of the algebraic summation of three orthogonal vectors that could lead to erroneous results. This instruction will be incorporated into the user documentation and in project analysis plans."

The staff requests Westinghouse to define proper and improper use of the algebraic summation of three orthogonal vectors and provide above mentioned instruction.

Revision 0:

The staff reviewed the basis documents for WESTEMS during the on-site review. In CN-PAFM-06-159, "WESTEMS Software Change Specification for Version 4.5," the applicant generated an algebraic stress histories option to be used in selection of peak and valley times. The option used the following equations to calculate time vs. stress in selecting peak and valley times.

$$Snalg = C1PoDo/2t + C2\ Do/2I\ (Mx + My + Mz) + C3Eab.(\alpha aTa - \alpha bTb.$$

$$Spalg = K1C1PoDo/2t + K2C2\ Do/2I\ (Mx + My + Mz) - K3Ea\alpha a\ \Delta T_1/(2*(1-\nu))- K3C3Eab.(\alpha aTa - \alpha bTb.) - Ea\alpha a\ \Delta T_2/(1-\nu))$$

$$S13alg = C1PoDo/2t + C2\ Do/2I\ (Mx + My + Mz) - C3\text{prine}\ Eab.(\alpha aTa - \alpha bTb$$

The staff noted that the algebraic summation of three orthogonal vectors is mathematically incorrect and physically meaningless. The staff requested the applicant to provide technical justification for this option in selecting peak and valley times for the fatigue evaluation. This concern is identified as **Open Item OI-SRP3.9.1-EMB1-05**.

In its response to RAI-SRP3.9.1-EMB1-05, the applicant noted that WESTEMS uses the algebraic sums of three orthogonal moments to permit the influence of moment and temperature solution reversals to produce a "signed stress intensity", to be used for the selection of peaks and valleys. It also noted that after the peak and valley times are selected, the fatigue evaluation uses the individual moment values from the time history inputs for each transient at the peak and valley times to determine the moment ranges of each moment component, and then the ranges are combined by the square root sum of squares (SRSS) method according to the ASME Code NB-3600 equations to determine the resultant moment range, Mi. The applicant is requested to discuss the technical basis that the use of the algebraic summation of three orthogonal vectors would not lead to erroneous moment stresses that is misleading for the selection of the peaks and valleys. **This is related to OI-SRP3.9.1-EMB1-05.**

References:

1. ADAMS "Chapter 3 SER," ML092150664.
2. WESTEMS™ User's Manual Version 4.5, Volume 2, Rev. 0, "Design Analysis," Westinghouse Electric Company, 2007.
3. LTR-PAFM-10-99, "WESTEMS Version 4.5.2 User's Manual Addendum 2: NB-3600 Moment Loading and Peak Selection Instructions."

Westinghouse Response:

Revision 3:

After discussion during the audit, the remaining concern was that the program documentation should more specifically address the use of SRSS of moment stress terms in the Snalg and Spalg equations for NB-3600 peak selection. To respond to this, Westinghouse will do the following:

1. Update the user manual to explicitly describe two versions of the Snalg and Spalg equations. Each equation will have one version corresponding to the user selection of the SRSS setting and one version without selection of the SRSS setting.
2. In the same location in the user manual, incorporate the information in the User's Manual Addendum 2 (LTR-PAFM-10-99), which provides detailed instructions regarding NB-3600 moment inputs and related user settings, including explicit instruction to select the SRSS setting with the input of orthogonal moment components.
3. Revise the software requirements specification to provide more explicit explanation of the SRSS option for algebraic stress equations in the peak selection process.
4. Add further explanation and example of the variable number of moment tagname inputs, "Mn", defined by the user, in the User's Manual NB-3600 section.

The changes to incorporate this will include at least the following in an update to the explanation in the WESTEMS™ User's Manual Volume 2, Section 10.1.2, calculation step e:

> The stress histories simulate the equation stress intensities in a way to allow the user to account for stress reversals. The program allows the user to designate whether the moment stress inputs are to be combined by square root sum of squares (SRSS), e.g,, when orthogonal moment inputs are provided, or simply algebraically, e.g., when a resultant moment is input. (Detailed guidelines for treatment of moment inputs with the appropriate option selections are provided in WESTEMS™ 4.5.2 User's Manual Addendum 2.) The algebraic stress history equations are represented below for the two cases of the SRSS option.
>
> With SRSS not selected:
>
> **Snalg** = C1*Po*Do/(2*tnom) + [C2*M1*Do/(2*I) + C2*M2*Do/(2*I) + … + C2*Mn*Do/(2*I)] - C3*Eab*(αa *Ta – αb*Tb)
>
> **Spalg** = K1*C1*Po*Do/(2*tnom) + [K2*C2*M1*Do/(2*I) + K2*C2*M2*Do/(2*I) + … + K2C2*Mn*Do/(2*I)] - K3*Ea*αa*ΔT1/(2*(1-ν)) - Ea*αa*ΔT2/(1-ν) - K3*C3*Eab*(αa *Ta – αb*Tb)
>
> **S13alg** = C1*Po*Do/(2*tnom) + [C2*M1,13*Do/(2*I) + C2*M2,13*Do/(2*I) + ... + C2*Mn,13*Do/(2*I)] - C3prime*Eab*(αa *Ta – αb*Tb)

With SRSS selected:

Snalg = C1*Po*Do/(2*tnom) + {[C2*M1*Do/(2*I)]^2 + [C2*M2*Do/(2*I)]^2 + [C2*M3*Do/(2*I)]^2}$^{0.5}$ - C3*Eab*(αa *Ta – αb*Tb)

Spalg = K1*C1*Po*Do/(2*tnom) + {[K2*C2*M1*Do/(2*I)]^2 + [K2*C2*M2*Do/(2*I)]^2 + [K2*C2*M3*Do/(2*I)]^2 }$^{0.5}$ - K3*Ea*αa*ΔT1/(2*(1-ν)) - Ea*αa*ΔT2/(1-ν) - K3*C3*Eab*(αa *Ta – αb*Tb)

S13alg = C1*Po*Do/(2*tnom) + {[C2*M1,13*Do/(2*I)]^2 + [C2*M2,13*Do/(2*I)]^2 + ... + [C2*Mn,13*Do/(2*I)]^2}$^{0.5}$ - C3prime*Eab*(αa *Ta – αb*Tb)

Where terms are as defined in NB-3653 (note that material properties are all taken at reference (stress free) temperature; and:

M1, M2, … Mn = moment inputs whose range between load cases will form the resultant Mi in NB-3653;

M1,13, , …Mn,13 = moment inputs whose range between load cases will form the resultant moment Mi for NB-3653 Equation 13

(Note: The user may specify the number of moment components, Mn, desired. For example, for input of orthogonal components with SRSS, the Mn would typically be Mx, My, Mz. For input of resultant moments, Mr, without SRSS, only M1 would be used for Mr that results in conservative ranges of Mr for all transients. For branches, M1 and M2 could be used for run and branch side moment resultants, with appropriate adjustment made to the C2 value input to account for the section modulus applicable to each stress term.)

NOTE: WHEN INDIVIDUAL MOMENT INPUTS ARE PROVIDED FOR ORTHOGONAL MOMENT VECTORS, e.g., Mx, My, Mz, THE PEAK SELECTION OPTION FOR SRSS OF MOMENTS SHOULD BE CHECKED.

Similar clarification on the function of moment inputs and the associated forms of the equations will also be added in a revision of the WESTEMS™ 4.5.2 requirements specification.

The user manual update will also provide a cross reference in Section 10.1.1:

"For more details on the use of moment tagname history inputs and their relation to peak and valley selection, see Section 10.1.2 and WESTEMS™ 4.5.2 User's Manual Addendum 2."

In addition to the modifications to the User's Manual, the WESTEMS training program has been enhanced to specifically address use of the SRSS switch when performing fatigue analyses in WESTEMS.

The AP1000 Piping and Fatigue analysis General Methods and Inputs also instructs the fatigue analyst in the proper use of this option.

Also, a verification checklist has been developed to be added to WESTEMS calculations, by which the verifier is required to confirm that this option in the program was used correctly for the analysis performed.

The training materials, fatigue analysis general methods calculation and verification checklist referred to above has been made available in the Westinghouse Twinbrook Office for NRC review at the request of the staff.

Revision 2:

This open item response has been revised to respond to four (4) follow-up questions by the NRC following staff review of the submitted Rev. 1 response and related documentation provided to the WEC Twinbrook Office. The follow-up questions are labeled as 1 thru 4 above and are answered in succession below.

The user instruction referred to in Rev. 1 of this open item response (and made available at the WEC Twinbrook Office for staff review) has been approved as an addendum to the WESTEMS User's Manual Version 4.5 (Reference 2) and has been added as Reference 3 to this response. This document is proprietary and will be submitted on the docket at the request of the NRC separate from this response.

Response to follow-up question #1:

It is first noteworthy to reiterate that the intended use of moment inputs is not to algebraically sum three orthogonal vectors. The intent of multiple moment inputs is to allow users flexibility in specifying moment stress inputs for selection of peaks and valleys. The supplemental user instruction (Reference 3) documents the possible uses of the moment inputs and associated options, and clearly instructs users to use the SRSS option when the moment inputs represent orthogonal vectors. It also provides instruction for review and verification of the peaks and valleys selected. When a single moment input is used, already representing the resultant moment, the instructions provide guidance for the user to account for moment reversals in the resultant moment input to properly account for the moment ranges between transients.

It is important to recognize that WESTEMS™ uses a two step process for fatigue evaluation. The first step creates stresses for the selection of peak and valley times from each transient history, and saves only the inputs at those times. The second step uses the inputs at each selected time in all transients to form the fatigue stress range pairs and calculate usage factors according to ASME Code.

A more thorough explanation of this process including examples, if determined to be necessary, will be provided at the audit scheduled for 6/23-6/24/10 at WEC Cranberry HQ.

Response to follow-up question #2:

WESTEMS™ meets the requirements of Subsection NB-3600 of the ASME Code as explained below.

WESTEMS™ correctly calculates the stress range for a fatigue pair by determining the pressure stress range, moment stress range, and thermal stress range between the two load case peak times in the pair, and adds these stress ranges absolutely as described in ASME NB-3600 equations. This is documented in Section 10.1 of the WESTEMS™ User's Manual Version 4.5 Volume 2 (Reference 2). The thermal stress input terms $\Delta T1$, $\Delta T2$, Ta, and Tb retained for each load case peak time include their algebraic signs appropriately so that the range calculated between the two load sets is correct. Once the ranges are determined, the stress ranges for each term are correctly added absolutely.

If the statement in the follow-up question is meant to refer to the algebraic stress due to one transient, which is used only for the selection of peak and valley times, the statement is incorrect. The algebraic equations employed in the peak and valley selection allow addition of the thermal stress to the other stresses in the history based on sign consistent with the loading from temperature, pressure and moment inputs, and do not simply add thermal stress absolutely. The peaks and valleys within one transient must be determined considering the signs of the load inputs and their influence on the stress history. For this reason, the user can set the relative sign of the thermal stress history to be consistent with the signs of the pressure and moment stress histories input.

Response to follow-up question #3:

The equations for Snalg, Spalg, and S13alg provided in the Rev. 0 response of this Open Item were in the context of algebraic stress quantities used by WESTEMS™ peak and valley selection, taken from Section 10.1.2 (NB-3600 Peak and Valley Selection) of the WESTEMS™ 4.5 User's Manual Volume 2 (Reference 2). These are not the same as the equations for Sn and Sp in Section 10.1 (Application of ASME Code Criteria Using NB-3600 Models) of the Manual. The Sn and Sp in Section 10.1 represent the same stress range quantities as Sn and Sp in NB-3653, and therefore the absolute values of the stress range terms are added.

As explained in Section 10.1.2 of the Manual, the algebraic stress quantities Snalg, Spalg, and S13alg are used in the first step of the evaluation to determine stress peak and valley times for each transient. The context of the algebraic stress equations referred to above is in step (e) of Section 10.1.2 discussing peak and valley selection. Since the stress is for only one transient, it does not represent a range. The algebraic quantities must be used to account for temperature sign reversals in the transient response, so that the correct range may be calculated in the second step of the analysis process where fatigue usage is calculated.

Since the temperature terms from the 1D analysis solution are calculated with signs conforming to a legacy convention used in previous Westinghouse fatigue analyses, they result in signs on the thermal stress terms that are opposite the conventional positive sign for tension and negative for compression. This is explained in the paragraphs below the algebraic equations in step e of Section 10.1.2. Therefore, when the option is used to determine peaks and valleys based on the combined algebraic stress equations, it is necessary to switch the signs on the thermal stress terms to conform to the conventional sign of the pressure stress term (tension is positive). This is the reason for the negative sign on the thermal stress terms in the Snalg, Spalg, and S13alg equations, so that the algebraic stresses are combined appropriately to provide a stress history from which to determine peak and valley times consistently.

After the algebraic stress quantities Snalg, Spalg, and S13alg are used to determine the peak and valley times in each individual transient, the input values of ΔT1, ΔT2, Ta, and Tb are saved, with their respective signs, for each time selected. These signed values are then used in step 2 of the fatigue evaluation to form the stress pairs between load sets, so that the correct ranges are calculated in the actual Sn, Sp, and S13 stress ranges used for the fatigue calculation.

Response to follow-up question #4:

The Mi range defined by ASME Code NB-3653.1 is determined by taking the range of the individual directional moment components and then determining the resultant. This is represented by the equation above. The ASME Code explicitly states that resultant moments from different load sets shall not be used to calculate the range. This is because the effect of sign reversals in individual directional moment components would be lost if the resultants are taken before the range is calculated. If the user supplies the directional moment components, e.g., as M1, M2, M3, WESTEMS™ calculates the ranges and the resultant according to the ASME Code using the equation provided in this question. If the user chooses to supply one resultant moment input, e.g., as M1, the user must supply the M1 inputs for each load case so that the ranges between load cases conservatively account for any sign reversals in any of the individual directional moment components. This latter methodology has been classically employed in piping fatigue analyses to simplify inputs, so the variable number of moment histories allowed accommodates this approach. Application of this approach is illustrated in examples included in the user instructions previously provided in response to this OI, "WESTEMS™ 4.5.2 NB-3600 Moment Loading and Peak Selection Instructions for User," which has been incorporated as WESTEMS™ Version 4.5.2 User's Manual Addendum 2 (Reference 3).

Revision 1:

This open item response has been revised to respond to the follow-up request by the NRC to the Rev. 0 response.

The draft user instruction for proper use of the peak selection options with respect to NB-3600 detailed moment inputs is provided in a separate document ("WESTEMS™ 4.5.2 NB3600 Moment Loading and Peak Selection Instructions for User"). The instructions define how to prevent improper algebraic summation of moment stresses using the program settings for peak selection. They also describe where the algebraic summation of moment stress inputs (not moment components) is appropriate and the associate program settings. This instruction will be included in the analysis plan for the AP1000 piping analyses and will also be incorporated in the next revision of the WESTEMS™ User Manual.

The above mentioned draft user instruction has been made available for staff review at the Westinghouse Twinbrook office.

Revision 0:

WESTEMS™ provides the user with various options to control the selection of peak and valley times in each transient to be used in the fatigue calculations, using general algebraic stress equations. However, the moment stress terms in the algebraic equations used for the peak and valley time selection are not equivalent to the resultant moment stress used in the later actual fatigue stress range calculation per ASME Code. After the peak and valley times are selected, the fatigue evaluation uses the individual moment values from the time history inputs for each transient at the peak and valley times to determine the moment ranges of each moment component, and then the ranges are combined by the square root sum of squares (SRSS) method according to the ASME Code NB-3600 equations to determine the resultant moment range, Mi. Therefore, the moment stress term (e.g., in Equation 10) is calculated by:

C2*Mi*Do/(2*I)

Where Mi is the resultant moment range between the peak or valley times in the fatigue pair (from WESTEMS™ User's Manual Section 10.1):

$$Mi = [(\Delta M1)^2 + (\Delta M2)^2 + \ldots + (\Delta Mm)^2)]^{0.5}$$

Where:

Δ defines the range (difference) between the associated terms for each peak time in the pair;
m = number of moment histories defined by the user. Note that the ranges between each of the signed moment stress terms are first calculated before squaring them.

The fatigue evaluation must correctly consider the moment stress ranges in the NB-3600 equations. One option available for moment inputs is to use moment history inputs via "tagnames" (data point labels) specified for the model. It is the responsibility of the user to provide the moment histories in a manner that reflects appropriate moment stresses coincident with the thermal and pressure stresses with respect to the selection of peaks and valleys, as well as appropriate maximum stress ranges in the evaluation. The moment tagname input approach allows the user to input as many tagnames as needed to represent the moment stress ranges in the model.

When using this approach, the user needs the ability to account for the possibility of sign reversals in the moment histories. For example, in a piping system that is normally hot but experiences a transient where cold water is injected, the components in or adjacent to that section may experience reversals in one or more moment component signs. To allow the user to account for sign reversals, the moment terms in the general algebraic stress history equations are inserted independently. These are not intended to represent physical stress quantities in the component (as assumed in the question posed), but rather are provided as a manipulative tool for the user to combine the appropriate influence of moments in the stress histories to make the automated process select the peaks and valleys determined to be appropriate.

This intention is indicated in Section 10.1.2 of the WESTEMS™ 4.5 User's Manual (Reference 1) as quoted below:

"Algebraic stress histories are created for use only in the selection of peak and valley times.

For the selected times, the parameters for the actual fatigue evaluation are saved, corresponding to: Pressure, Moments, $\Delta T1$, $\Delta T2$, Ta, Tb. The stress histories simulate the equation stress intensities in a way to account for stress reversals:

Snalg = C1*Po*Do/(2*tnom) + C2*Mx*Do/(2*I) + C2*My*Do/(2*I) + C2*Mz*Do/(2*I) - C3*Eab*(αa *Ta – αb*Tb)

Spalg = K1*C1*Po*Do/(2*tnom) + K2*C2*Mx*Do/(2*I) + K2*C2*My*Do/(2*I) + K2*C2*Mz*Do/(2*I) - K3*Ea*αa*ΔT1/(2*(1-v)) - Ea*αa*ΔT2/(1-v) - K3*C3*Eab*(αa *Ta – αb*Tb)

S13alg = C1*Po*Do/(2*tnom) + C2*Mx13*Do/(2*I) + C2*My13*Do/(2*I) + C2*Mz13*Do/(2*I) - C3prime*Eab*(αa *Ta – αb*Tb)

Where terms are as defined in NB-3653 (note that material properties are all taken at reference (stress free) temperature; and:

Mx, My, Mz = moment components whose resultant is Mi in NB-3653; (*Note: in this discussion, moments are designated as Mx, My, Mz as typical examples. The user may specify the number of moment components, Mi, desired.*)

The algebraic sums of these terms permit the influence of moment and temperature solution reversals to produce a "signed stress intensity", to be used for the selection of peaks and valleys. Note that in the basic application of this technique, the thermal stress terms are subtracted to account for the algebraic signs resulting from the temperature solutions, compared to the standard convention of tensile and compressive stress signs (i.e., tensile stress is positive). It is noted that the sum of the moment stress terms here is not equivalent to the resultant moment stress used in the later actual fatigue stress range calculation."

These aspects of the peak and valley selection tool enable control of the NB-3600 analysis peak and valley times selection in a manner that the user justifies. As with any analysis tool that provides such flexibility, the final inputs and results must be verified by the user to be applicable for the problem being analyzed. The user manual provides the details of how the inputs and options switches are used to calculate the stresses so that the user can adequately manage the analysis. The ultimate peak and valley inputs selected for the fatigue evaluation are printed in the fatigue analysis output files, and are verified independently as part of the quality assurance (QA) process. No additional information is needed to satisfy the QA requirements.

Response to follow-up question:

The WESTEMS™ NB-3600 peak selection options include a switch for using the SRSS combination of moments when detailed individual moment components are input. Westinghouse has prepared a detailed user instruction for the proper use of the peak selection options in the NB-3600 module, to avoid the improper use of the algebraic summation of three orthogonal vectors that could lead to erroneous results. This instruction will be incorporated into the user documentation and in project analysis plans.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None

Response to SER Open Item (OI)

OI Response Number: OI-SRP3.9.1-EMB1-06
Revision: 2

Question:

Revision 2

In response to the WESTEMS audit held June 23-24 in Cranberry, this open item response is being revised to provide confirmatory information and commitments agreed upon at the audit between WEC and the NRC in order to close this open item.

Revision 1:

Follow-up question (WEC Response provided in Rev. 1 of this Open Item):

The benchmark for WESTEMS is not acceptable. The WESTEMS validation and verification calculation demonstrates that the stress result is incorrect. he inside surface of the charging piping for temperature cooldown during charging shutdown and return to service transient was noted to be under compression. However, inside surface for temperature cooldown must be under tension based on system conditions – it cannot be in compression as indicated.

Revision 0:

The staff reviewed WESTEMS validation package CN-PAFM-06-161. The applicant's validation package compared WESTEMS results with results of MAXTRAN79 and THERST. The applicant stated that the comparison used slightly different material properties. The comparison also showed the results are different with different programs. However, the applicant considered that the validation was acceptable even with a significant difference in ΔT calculation and stress result comparison. The staff noted that computer program benchmark must use the same input model in alternate calculations or hand calculations. The staff noted that use of a slightly different model and different material properties to compare the results with approximation may not be adequate to benchmark a computer program. The staff requested the applicant to provide benchmark acceptance criteria to validate the computer code calculation. This concern is identified as **Open Item OI-SRP3.9.1-EMB1-06**.

References:

1. ADAMS "Chapter 3 SER," ML092150664.

Westinghouse Response:

Revision 2:

After discussion during the audit, the remaining concern was a question regarding the sign of the thermal stress plotted for Spalg-OD – the algebraic Total stress on the outside of the pipe. For the example shown, it was expected that the thermal stress on the OD should be opposite in sign to the thermal stress on the ID. This was investigated further by review of the source code. It was discovered that the coded equation for Spalg on the OD of the pipe used the wrong sign on the ΔT1 thermal stress term. Since the ΔT1 term dominated the stress, the plots of the ID Spalg and OD Spalg were very similar. It is noted that the ΔT2 stress term and the pressure and moment stress terms are correctly coded.

This error has been entered into the Westinghouse CAPs system and will be corrected according to the process in Westinghouse Quality Policies and Procedures. An error notice will be issued to users describing the error and a temporary workaround/resolution.

The error workaround/resolution is: "Fatigue results at the outside pipe wall location will not control in an NB-3600 fatigue analysis, since the pressure and moment stress terms are the same in the NB-3600 equations when applied for either ID or OD, and the thermal stress ranges at the inside are more severe since the transients are applied at the inside. NB-3600 results at the outside pipe wall location should be disregarded until the Sp-alg-OD calculation has been corrected in the next software version."

The error report mentioned above has been made available at the Westinghouse Twinbrook Office for NRC review at the request of the staff.

Revision 1:

This open item response has been revised to respond to a follow-up question by the NRC following staff review of the submitted Rev. 0 response and related documentation provided to the WEC Twinbrook Office.

Response to follow-up question:

It is a correct observation that the thermal stress on the inside surface of a pipe subjected to a temperature cooldown will be in tension. This is correctly reflected in the WESTEMS™ results based on the option selected for the run observed in the benchmark case, and the associated sign convention.

The WESTEMS™ NB-3600 module was modeled after the analysis process used for piping fatigue analysis at Westinghouse since the 1970s. The 1-D temperature solution methodology employed in that process (using previous programs THERST, MAXTRAN, and FATCON) used an arbitrary convention that produced NB-3600 $\Delta T1$ and $\Delta T2$ values with signs at the inside surface to match the direction of the temperature excursion. When multiplied by the appropriate NB-3600 factors, the temperature term ranges are converted to stress values. Since the fatigue analysis process considers the range of all parameters between load sets, this convention still produces the correct stress range values for the fatigue analysis pairs. Since the ranges are determined for each stress term using a consistent sign convention for the temperature terms, there is no need for consideration of conventional tension or compression for the signs of the individual thermal stress terms. In WESTEMS™, for analysis using Moment Stress Range inputs, the fatigue analysis process produces the correct stress ranges using the sign convention consistent with THERST.

However, in recognition of the use of the past convention, when the WESTEMS™ peak selection options are used that allow the individual transient stress histories to combine the thermal stress terms with the pressure stress and potentially the moment stress terms, the signs of the thermal stress terms are intentionally reversed to maintain consistency with the pressure stress term, which uses the conventional positive value for tension, which is the expectation described in the review comment above. This is discussed in the WESTEMS™ User's Manual Volume 2, Section 10.1.2. This allows the user to assign the inputs appropriately considering conventional signs on the algebraic stress terms when determining the history to be used for peak and valley selection. The fatigue stress range pair calculations remain correct because the ranges of the individual thermal, pressure, and moment stress terms in Equations 10 and 11 are calculated independently before combining to determine the total stress ranges. Therefore, the fatigue stress ranges are always calculated correctly.

Revision 0:

Westinghouse has benchmarked WESTEMS™ NB-3600 analysis using consistent inputs and defined acceptance criteria. The documentation can be made available for review at the request of the staff.

Design Control Document (DCD) Revision:
None

PRA Revision:
None

Technical Report (TR) Revision:
None