WOLF CREEK
NUCLEAR OPERATING CORPORATION

Terry J. Garrett
Vice President, Engineering

October 3, 2007

ET 07-0046

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

Reference:
1) Letter ET 06-0038, dated September 27, 2006, from T.J. Garrett, WCNOC, to USNRC
2) Letter ET 07-0032, dated July 26, 2007 from T.J. Garrett, WCNOC, to USNRC
3) Letter ET 07-0037, dated August 20, 2007, from T.J. Garrett, WCNOC, to USNRC
4) Telephone Conference Summary dated September 4, 2007, from V. Rodriguez, USNRC (ML072320487)

Subject: Docket No. 50-482: Followup Response to NRC Requests for Additional Information Related to Wolf Creek Generating Station License Renewal Application Time–Limited Aging Analysis

Gentlemen:

Reference 1 provided Wolf Creek Nuclear Operating Corporation's (WCNOC) License Renewal Application for the Wolf Creek Generating Station (WCGS). References 2 and 3 provided WCNOC responses to NRC requests for additional information (RAI) regarding the License Renewal Application Time–Limited Aging Analysis. Reference 4 documents telephone conference calls held on August 17, 2007 and August 31, 2007 to discuss and clarify WCNOC responses.

Attachment I provides an overall summary of WCGS fatigue design and Fatigue Management Program (FMP) followed by the NRC staff questions and the WCNOC responses to the RAIs discussed during the conference calls.

Attachment II provides a summary of the commitments made in this response. License renewal commitment number twenty-one has been revised and a new commitment, number thirty-eight, has been added.

A121
NRR

If you have any questions concerning this matter, please contact me at (620) 364-4084, or Mr. Kevin Moles at (620) 364-4126.

Sincerely,

Terry J. Garrett

TJG/rlt

Attachments I WCNOC Followup Response to NRC Requests for Additional Information
II List of Commitments

cc: E. E. Collins (NRC), w/a
J. N. Donohew (NRC), w/a
V. G. Gaddy (NRC), w/a
V. Rodriguez (NRC), w/a
Senior Resident Inspector (NRC), w/a

STATE OF KANSAS)
) SS
COUNTY OF COFFEY)

Terry J. Garrett, of lawful age, being first duly sworn upon oath says that he is Vice President Engineering of Wolf Creek Nuclear Operating Corporation; that he has read the foregoing document and knows the contents thereof; that he has executed the same for and on behalf of said Corporation with full power and authority to do so; and that the facts therein stated are true and correct to the best of his knowledge, information and belief.

By_____
Terry J. Garrett
Vice President Engineering

SUBSCRIBED and sworn to before me this 3rd day of October, 2007.

RHONDA L. TIEMEYER
MY COMMISSION EXPIRES
January 11, 2010

Rhonda L. Tiemeyer
Notary Public

Expiration Date January 11, 2010

Wolf Creek Nuclear Operating Corporation Followup Responses to NRC Requests for Additional Information

RAI 4.3-1

RAI 4.3-2

RAI 4.3-3

The Nuclear Regulatory Commission (NRC) and representatives of Wolf Creek Nuclear Operating Corporation (WCNOC) conducted two telephone conferences on August 17, 2007 and August 31, 2007. The NRC requested clarification to the Wolf Creek Nuclear Operating Corporation (WCNOC) responses to the requests for additional information (RAI) concerning Wolf Creek Generating Station (WCGS) License Renewal Application (LRA) Time-Limited Aging Analyses (TLAA).

The focus of the RAIs on LRA section 4.3 has been on demonstrating that calculations of cumulative fatigue usage (CUF) done by the management program are acceptable to monitor and track the metal fatigue of the Reactor Coolant System (RCS) components. The RAIs (4.3-1, 4.3-2, 4.3-3) are related to the stress based fatigue (SBF) module of the Fatigue Management Program. SBF is a process used to calculate fatigue usage at specific locations on the reactor coolant pressure boundary from the time history of system parameters (pressure, temperature, flow rates).

The followup response to RAIs 4.3-1, 4.3-2, 4.3-3 begins with an overall summary of Wolf Creek fatigue design and Fatigue Management Program (FMP), followed by responses to the RAIs.

WCGS Fatigue Design and Fatigue Management Program (FMP)

Fatigue Design:
The ASME Boiler and Pressure Vessel Code (Section III) for Class 1 components (Part NB), requires evaluation of the fatigue effects of system transients designated in the component design specifications. The pressure and temperature time histories and anticipated numbers (allowed cycles) of these transients are defined in the component design specifications. The fatigue effects of these design transients have been evaluated by design calculations that are documented in the component design stress reports. The results of the design calculations depend on the assumed numbers of occurrences of specified transients and the number of occurrences experienced depends on the time of operation. These design fatigue calculations are the bases for all safety determinations related to fatigue of primary system pressure boundary components.

Fatigue Management Program:
The Wolf Creek Generating Station (WCGS) FMP is an aging management program to monitor and track the metal fatigue effects of critical temperature and pressure transients experienced by the RCS pressure boundary. The primary task of the FMP is to count and record the numbers of transients that have actually occurred for comparison with the numbers of transients specified for design of the components (allowed numbers of cycles). With the exception of a limited number of locations, for which the environmental effects of the reactor coolant on fatigue is evaluated in accordance with NUREG/CR-6260, the design fatigue calculations remain valid for the period of extended operation provided that no transients occur more than the allowed number of cycles.

For a selected number of critical pressure boundary locations, Reference LRA Table 4.3-2, the FMP includes calculating estimates of the CUF caused by the transients that have occurred. These estimates are calculated in one of two ways, (1) cycle based fatigue monitoring (CBF) or (2) stress based fatigue monitoring (SBF). The locations for which CUF is calculated by the FMP include six of seven (6 of 7) locations where the environmental effect of the reactor coolant on fatigue is evaluated in accordance with NUREG/CR-6260 [(NUREG/CR-6260 locations) (RPV inlet nozzles, RPV outlet nozzles, safety injection (BIT) nozzles, accumulator safety injection-RHR nozzles, hot leg surgeline nozzle, and charging nozzles)]. For the NUREG/CR-6260 locations, the FMP calculates CUF using appropriate environmental factors (F_{en}).

Cycle Counting:
The FMP includes a transient cycle counting module. This module tracks the numbers of occurrences of specified design transients either by automated computer analysis or by manual input of data. Implementation of the cycle counting module included a retrospective analysis to identify the specified design transients that had occurred before the FMP was implemented. Since the cycle counting module was implemented, transient cycles have been identified and tabulated to maintain an ongoing catalogue of transient occurrences. Those transients that are counted manually are updated periodically. The tabulated results of the cycle counting module are reviewed periodically (approximately once per fuel cycle) to verify that none of the cycle counts are approaching their specified limits on occurrences.

Cycle Based Fatigue Monitoring:
Cycle based fatigue monitoring (CBF) computes fatigue usage accrual from the actual transient cycles that have occurred and the fatigue usage per cycle calculated in the component design reports. This assumes that the severity of the transients are as assumed in the transient definitions (pressure and temperature variations vs. time), which are part of the component design specifications. CBF usage calculations require no data or information other than the numbers of transients that have occurred and the information in design fatigue analyses.

Stress Based Fatigue Monitoring:
The stress based fatigue (SBF) module computes CUF for several predetermined locations based on the actual plant operating history. Typically, SBF usage calculations produce a lower CUF than CBF usage calculations, because actual transients are less severe (i.e., have smaller peak to peak pressure and temperature changes and occur more slowly) than assumed by the design specification transient definitions.

Currently, SBF is not part of the plant licensing basis. SBF usage data are acquired for a small number of critical locations for potential future use should a corrective action limit on accrued cycles or CBF calculated CUF be reached. SBF data for two locations will be used if necessary to support the NUREG/CR-6260 evaluation at WCGS: (1) the RCS hot leg surge line nozzle, and (2) the charging and alternate charging nozzles of the reactor coolant system.

Implementation of the SBF module requires a conservative baseline estimate of accrued CUF prior to beginning of monitoring and a conservative methodology for calculating usage from the time histories of temperature, pressure, and fluid flow rates. RAIs 4.3-1,

4.3-2 and 4.3-3 have addressed both of these aspects, Baseline CUF and CUF Calculations, of the SBF module.

Baseline CUF Estimates: Current estimates of the baseline CUF for SBF monitored locations were calculated using data accrued during almost ten years of operation of the data acquisition system and plausible assumptions regarding the severity of transients during the period before monitoring. However, because a number of transients occurred more frequently during the period before monitoring than during the monitored period, the assumptions used in the baseline calculations cannot be proved to be conservative. Therefore, revisions of the baseline calculations are required to assure that the CUF starting points for monitoring are above the actual accrued CUF for the components at the time monitoring was implemented (See followup response to RAI 4.3-3).

CUF calculations: RAIs 4.3-1 and 4.3-2 relate to the mathematical methods used to track stresses at the monitored locations and calculation of fatigue usage from the peak to peak changes in these stresses. The RAIs have primarily addressed the formulations used to reduce the tensor stress at the monitored location to a scalar quantity that can be calculated as a function of time. The bases for the mathematical methods used to calculate the scalar description of stress at the monitored points is follows:

1. The locations of the monitored points, including the precise location on the pipe circumference are chosen based on the results of the detailed design basis fatigue analyses for the components.
2. The transfer functions that convert loads (pressure, temperature, temperature change, and bending moments) are based on the detailed design basis fatigue analyses for the components.
3. When maximum stresses from different loads occur at closely spaced, but not identical locations, the maximum stresses from the two locations are added to give a stress value that exceeds the actual stress at either location. An example of this is that stresses from bending moments are maximum on the pipe OD while maximum stresses from thermal transients occur on the pipe ID. For SBF calculations, moment stresses on the OD are added to thermal gradient stresses on the ID. This gives a stress value (and time variation of the stress value) for the fatigue calculation that is greater than actually occurs on the either the ID or the OD.
4. The scalar stress formulation algebraically adds stress contributions that are in fact orthogonal (e.g., maximum hoop stress from pressure is added to maximum axial stress from bending moments) and the algebraic signs for the terms are chosen so that the variation in calculated stress is maximized for the most significant transients.
5. Methods for calculation of thermal stress ranges, which account for the majority of fatigue usage, have been shown to substantially over estimate (by as much as a factor of 2.0) the stress determined from detailed three dimensional time dependent calculations of stress distributions.

The RAI questions and responses that follow are a continuation of a series of questions and responses regarding the mathematical methodology of stress based fatigue monitoring (SBF). Currently, SBF is not part of the plant licensing basis. SBF usage

data are acquired for a small number of critical locations for potential future use should a corrective action limit on accrued cycles or CBF calculated CUF be reached.

RAI 4.3-1 Followup Discussion

Based on the discussion with the applicant, the staff indicated that the response to this RAI requires clarification. The staff requested that the applicant address the following:

(1) Clearly define 1D thermal (virtual) stresses for different locations on the component (nozzle, nozzle inner radius) and thermal conditions (stratification). In addition, explain how the 1D thermal stress is derived for the surge line hot leg nozzle under stratification.

(2) In its response, the applicant stated that "In a general sense, it is very difficult, if not impossible, to mathematically prove that the 1D thermal (virtual) stress differences will bound the actual stress intensity ranges for all hypothetical transient pairings that could be devised."

(a) Explain what is the limitation of 1D virtual stress methodology.
(b) Describe what kind of conditions cannot be mathematically proved to be conservative.

(3) In its response, the applicant stated that the stress range computed using the 1D thermal (virtual) stress methodology is not an upper bound for the stress range computed using the stress tensor methodology from the ASME Code. Provide justification to demonstrate ASME Code compliance using the 1D thermal (virtual) stress methodology.

RAI 4.3-1 Followup Response

The response is directed at the questions underlying RAI 4.3-1: (1) provide a clear definition of the (1-dimensional) stress computed by the FatiguePro software, (2) discuss the inherent limitations of using a 1D stress in FatiguePro, and (3) demonstrate how using a 1D stress can be considered compliant with the ASME Code with respect to fatigue computation.

(1) Clearly define 1D thermal (virtual) stresses for different locations on the component (nozzle, nozzle inner radius) and thermal conditions (stratification). In addition, explain how the 1D thermal stress is derived for the surge line hot leg nozzle under stratification.

The general methodology of the SBF will be described in the following sections using the monitored NUREG/CR-6260 locations, hot leg (HL) surge line nozzle and charging nozzles, as examples.

For each location monitored in the FatiguePro StressBased Fatigue (SBF) module, a *Transfer Function* is created, which is a set of parameters and equations that take as input various available plant instrument signals, and results in a (1D) scalar computed stress value. The time history of this stress value is used to identify the maximum and minimum peaks of transient cycles so that upper bound estimates of alternating stress

of each cycle can be calculated. The transfer functions and definitions for the scalar stress parameter are defined at specified points on the reactor coolant pressure boundary. For the HL surge line nozzle and the charging nozzles the highest fatigue usage locations were determined to be in the vicinity of the nozzle to pipe welds. These locations were selected based on the results of the design basis fatigue calculations, which identify locations where calculated fatigue usage is high. Transfer Functions were developed individually for each FatiguePro SBF location, using the same engineering principles as used in component design analyses. Development of the Transfer Functions takes full advantage of the local geometry and symmetry of the monitored location in deriving the equations for the scalar stress value. For example, all but one of the SBF monitored locations (pressurizer lower head) are on pipes or nozzles where the local geometry is essentially that of a pipe. For pipe geometry, the directions of principal stresses are known. All of the monitored locations are on free surfaces where some tensor stress components are zero. These geometric considerations provide part of the basis for reducing the characterization of stress to a single scalar value. Reducing the description of stress to a scalar value also relies on the fact that the nature of the loadings that result from the transients are well defined (e.g., pressure changes, pipe bending moments, and temperature gradients). The development of each Transfer Function at each location is documented in one or more engineering calculations, and the resulting Transfer Functions are enumerated in a technical report, all produced and verified under the auspices of a Nuclear QA Program.

At Wolf Creek, the Transfer Functions for the charging nozzles and steam-generator feedwater nozzles were developed by Structural Integrity Associates (SIA), and documented in SIR-95-052, "Transfer Function and System Logic Report, Transient and Fatigue Monitoring System for Callaway Plant/Wolf Creek Generating Station". Transfer Functions for the 5 pressurizer locations Pressurizer Surge Line (SRGLINE), Hot Leg Surge Line Nozzle and Pressurizer Surge Line Nozzle (HL_NOZZLE, SRG_NOZ), Pressurizer Lower Head (at the weld between the vessel head and the nozzle insert) (LHEAD), and Pressurizer Spray Nozzle (SPR_NOZ)) were developed by Westinghouse, and are documented in WCAP 14173, "Global to Local Transformations and Stress Transfer Functions for Pressurizer Surge Line, Pressurizer Lower Head, and Pressurizer Spray Line". Those documents provide the definition of the stress computed by FatiguePro for each monitored SBF location. For the pressurizer surge line and surge line nozzles, the selections of monitoring locations and development of the transfer functions were based on revised design basis fatigue calculations performed in response to NRC Bulletin 88-11. The results of those analyses are documented in WCAP-12893, "Structural Evaluation of the Wolf Creek and Callaway Pressurizer Surge lines, Considering the Effects of Thermal Stratification," March 1991. The calculations described in WCAP-12893 are the current design basis evaluations of the various effects of stratified fluid conditions in the pressurizer surge line on fatigue usage of the pipe and nozzles.

The transfer functions are based on the fatigue analysis from the design stress report (DSR). The DSR provides a basis for selecting the critical point in the component being monitored, for the various stress terms that affect that location, and the set of plant transients that contribute significant fatigue usage. The direct stress terms (pressure and piping moments) from the DSR are used in the Transfer Functions. For the pressurizer surge line, WCAP-12893, the DSR, and the detailed design calculations for

the DSR, provide equations for the bending moments produced by thermal stratification in the surge line.

We will outline the Transfer Function for the Hot Leg Surge Nozzle (HL_NOZZLE Location). The location is at the pipe end of the nozzle to pipe thickness transition 60 degrees from the top of the pipe:

P = ((BBPT403) + (BBPT405)) / 2 { average Hot Leg Pressure }

σ_{pres} = 1.2 * 2.45 * P [psi]
Ttm = mean pipe wall temperature along the top of the surge line, based on fluid temperature (WCAP 14173, Table E.2-2)
Tbm = mean pipe wall temperature along the bottom of the surge line, based on fluid temperature (WCAP 14173, Table E.2-2)

MREL = component-specific moment relationship (WCAP 14173, pp. 8 – 9) that includes the effects of thermal stratification

T = (Ttm + Tbm) / 2 = surge line mean temperature

ΔT = (Ttm – Tbm) = surge line stratification (metal) delta-T

(M_X, M_Y, M_Z) =piping moments at the RCS surge nozzle, as a function of MREL, T, and ΔT (see WCAP 14173, p. E-5)

$Mxz = \sqrt{(M_X^2+M_Z^2)}$

σ_{pipe} = 1.8 * (4.005*Mxz + 7.2521*|M_Y|) [psi]

Ttn = temperature at the top of the HL surge nozzle (WCAP 14173, pp. A-21 – A-23)
Tbn = temp. at the bottom of the HL surge nozzle (WCAP 14173, pp. A-24 – A-26)

$\sigma_{therm} = 1.7 * (\int GF_{top}(\tau)\, {}^{d}/_{d\tau}(Ttn(t-\tau)\, d\tau + \int GF_{bot}(\tau)\, {}^{d}/_{d\tau}(Tbn(t-\tau)\, d\tau$ [psi]

$\sigma_{total} = (\sigma_{press} + \sigma_{pipe} + \sigma_{therm}) / 1000$ [ksi]

The Transfer Function for the Charging Nozzle (CHRG_NOZ Location) was given in a previous response to RAI 4.3-1 (Attachment I to ET 07-0032). For clarity the equations are repeated here:

$$\sigma_{thermal} = \int \begin{matrix} Green's \\ Function \end{matrix} * T_{Loc}\, dt, \quad \text{[ksi]}$$

$\sigma_{pressure} = 0.0047 * P_{chg}$, [ksi]
$\sigma_{piping} = 0.039 * (CL\_TEMP) - 0.017 * (T_{chg}) - 1.54$, [ksi]
$\sigma_{total} = \sigma_{thermal} + \sigma_{pressure} + \sigma_{piping}$

The transfer function equations are parallel to the definition of peak stress, S_p, for piping analyses in ASME Code NB-3653.2 (equation 11). The ASME Code uses the scalar stress parameter, S_p, in the equations for peak stress and alternating stress used for

fatigue calculations of pipes. S_p is similar to the scalar (one dimensional) stress parameters used in the fatigue monitoring transfer functions. The ASME Code uses alternating stress, half of the range of peak stress, with the fatigue design curve to determine fatigue usage.

As shown by the above equations, the scalar stress used in the fatigue management program to define stress range and alternating stress for the charging nozzles and the HL surge line nozzle (and also for other SBF locations with pipe geometry) are:

1. Pressure stress term representing the pipe circumferential (hoop) stress. The pressure hoop stress is determined from a finite element analysis for pressure loading. The maximum pressure stress is always in the circumferential direction. Hoop and axial pressure stresses are always positive.
2. Bending moment stress term representing the axial bending stress at the OD of the pipe. Bending moments on pipes always produce maximum stress in the axial direction on the pipe OD. FatiguePro does not monitor purely mechanical transients such as seismic events. For the transients monitored by FatiguePro, moments are produced by the thermal expansion of the piping and by thermal stratification of the fluid in the pipe. One conservative simplification used in computing the moment stresses is that the torsional moment (moment about the axis of the pipe) is combined by square-root-sum-of-squares (SRSS) with one or both of the bending moments to produce a resultant moment. Combining the torsional moment with a bending moment always produces upper-bound stress intensity and maximizes variations in moment stresses during cycles. The definition of bending stress includes a sign. This is necessary to correctly compute the alternating stress if the direction of a bending moment reverses during a cycle. The choice of the algebraic sign for the moment term is such that pressure stress and moment stress both change in a positive direction for plant heatup.
3. The thermal stress term, is the stress at the the ID surface of the pipe from the through wall temperature gradient The thermal stress is typically biaxial on the inside surface of the pipe. The sign of the thermal stress depends on whether the temperature of the ID surface is colder than the average wall temperature (positive thermal stress on ID) or hotter than the average wall temperature (negative thermal stress on the ID).

These three stress terms are added together to get the scalar stress at the analysis location. Given that the radial stress on the ID surface of a pipe equals –P (P = pressure), the absolute value of the radial stress is always small compared to the absolute values of the hoop and circumferential stresses. In a three dimensional analysis, the maximum variation in stress intensity for a cycle will be either the variation in axial stress or the variation in hoop stress, whichever experiences the maximum variation during a cycle. If the pressure stress experiences a larger change during a cycle than the moment stress, the stress intensity variation will be the change in hoop stress. If the piping moment stress experiences a larger change during a cycle than the pressure stress, the stress intensity variation will be the change in axial stress. In a three-dimensional tensor stress analysis with the dominant variation being a pressure change, the alternating stress will have contributions from pressure and temperature gradient but not from moment loads, which affect only the axial stress. In a three

dimensional tensor stress analysis with the dominant variation being piping moment load changes, the alternating stress will have contributions from moment, temperature gradient, and pressure, but the contribution from pressure will be less than the variation included in the transfer function (for a straight pipe the axial stress and axial stress variation are half of the hoop stress and hoop stress variation). In the scalar analysis used by FatiguePro, pressure variations, moment variations, and temperature changes that produce through wall temperature gradients all contribute to the calculated alternating stress. This gives a conservative upper bound calculation for the alternating stress for any transients where the three terms in the equation change in the same direction. This is the case for the specific transients that contribute the majority of the fatigue usage in design calculations (e.g., heatup-cooldown). Alternating stress for transients that involve changes in only one of the three stress terms (e.g., fast temperature transients such as in-surge/out-surge cycles, at constant pressure without significant changes in pipe average temperature) are calculated accurately by the transfer function equations. Alternating stress for transients that involve changes in the pressure stress term and the thermal stress term but not the piping moment stress term or transients that involve changes in thermal stress term and piping moment stress term but not pressure stress are calculated accurately by the transfer function equations. These scenarios describe the specific transients that contribute most significantly to fatigue usage (heatup/cooldown, surge line stratification, loss of charging/letdown), therefore, the transfer function equations produce conservative values for alternating stress and conservative estimates of fatigue usage.

(2) In its response, the applicant stated that "In a general sense, it is very difficult, if not impossible, to mathematically prove that the 1D thermal (virtual) stress differences will bound the actual stress intensity ranges for all hypothetical transients pairings that could be devised."

- **(a) Explain what is the limitation of 1D virtual stress methodology.**
- **(b) Describe what kind of conditions cannot be mathematically proved to be conservative.**

Prior responses to TLAAA025 and RAI 4.3-1 have stated that it is difficult or impossible to prove that the FatiguePro 1D stress methodology is conservative in all cases. These statements were made regarding the general methodology, and have more to do with the open nature of the questions asked than any limitations or lack of confidence in the methodology. Given a specific set of transfer functions, it is often possible to mathematically construct a hypothetical transient pair that has a smaller 1D stress range than the corresponding stress range calculated by a full 3D tensor analysis. Thus the method is not provably conservative for all hypothetical transient pairs.

However, since the Transfer Functions are constructed with the intent of capturing the maximum stress range for all fatigue-significant transients postulated in the component design, the FatiguePro 1D stress analysis is demonstrably conservative for all load pairs that include those significant transients. The non-conservatism is limited to unrealistic transients (e.g. RCS temperatures less than 70°F, large stratification DTs at low system temperatures, etc.) or transients that cause very little usage (e.g. Small Step Load Change, Charging Flow Step Decrease).

The only circumstances where the transfer function equations can give a non-conservative calculation of the alternating stress is if the pressure stress term and piping moment stress term vary in opposite directions such that the changes of the two terms offset each other. Although it is possible to define hypothetical transients for which the pressure stress and piping moment stress terms cancel each other, this is not characteristic of the specified design transients as listed in the design report. Therefore, the transfer function methodology gives conservative results for fatigue monitoring of expected plant conditions.

(3) In its response, the applicant stated that the stress range computed using the 1D thermal (virtual) stress methodology is not an upper bound for the stress range computed using the stress tensor methodology from the ASME Code. Provide justification to demonstrate ASME Code compliance using the 1D thermal (virtual) stress methodology.

As defined by the ASME Code, Fatigue Usage is a function of stress intensity ranges between transient pairs. The FatiguePro methodology is compliant with the ASME Code because for each individual location, the stress ranges generated by the 1D virtual stresses (via the Transfer Functions) for fatigue-significant transients bound the 'actual' stress ranges for those same transients. The use of a scalar parameter for peak stress and alternating stress is compliant with the ASME Code if it bounds the alternating stress that would be calculated by a full three dimensional tensor analysis. Use of a scalar parameter for the calculation is specifically endorsed for the case of pipe geometry in equations presented in NB-3653.

In many cases, our vendor has validated the FatiguePro methodology by simulating transients from the design fatigue analysis. In all such cases, the usage calculated by FatiguePro is the same or greater than the usage from the design analysis (which demonstrates that the FatiguePro 1D stress ranges are bounding for the stress intensity ranges computed in the design analysis). The overall conservatism of the FatiguePro methodology has been demonstrated in several papers, including a case study of the Wolf Creek charging nozzle (submitted previously as part of the initial reply to RAI 4.3-1, Attachment I to ET 07-0032).

RAI 4.3-2 Followup Discussion

Based on the discussion with the applicant, the staff indicated that the response to this RAI requires clarification. The staff requested that the applicant address the following:

The applicant evaluated the fatigue cumulative usage factor (CUF) at the top of the pipe for all stratification cases. The top of the pipe may not be the most critical stress location for either bending or stratification. For bending, the maximum stress location is at an angle from top of the pipe. The maximum stratification stress is right above or below the temperature discontinuity.

Justify why these two critical locations were not evaluated. The current evaluation eliminates one of the bending moment components and is not in compliance with the ASME Code.

RAI 4.3-2 Followup Response

Question RAI 4.3-2 refers to Table E.2-1 of WCAP-14173. This table defines the transfer functions for the surge line pipe (SRGLINE monitoring location) away from the HL and pressurizer nozzles. The transfer functions were developed for a location along the pipe, other than the end points, where the fatigue usage calculated by design fatigue analyses was found to be maximum.

The surge line pipe location is not a location for which environmental effects of the reactor coolant are required to be evaluated. For "newer vintage Westinghouse plants" the critical location on the pressurizer surge line for evaluation of environmental effects has been determined to be the RCS HL surge line nozzle. The fatigue usage at the SRGLINE monitored location from design calculations, which include effects of thermal stratification, is relatively small (less than 0.1).

The stress intensity for the M_y moment for a 1 in-kip moment is 0.0 psi because the SBF monitoring location is on the neutral axis for that bending moment. The more general question is why the monitored location is specified to be the top of the pipe when the maximum stress from bending occurs at an angle away from the top of the pipe if $|M_y|$ is greater than zero. ASME Code, Section III, NB-3653.2, equation 11 uses the resultant bending moment in the equation for definition of peak stress. The resultant moment would include a contribution from M_y corresponding to the bending stress at the peak location.

WCAP-14173, page E-2, states: "Stresses for the pressurizer surge line critical component, a pipe girth weld, were developed based on the latest analyses addressing thermal stratification for NRC Bulletin 88-11 [Reference WCAP-12893]. These included global piping analyses to obtain moment relationships as a function of temperature and stratified conditions in the surge line, and finite element analyses to determine stresses due to various loadings." The location for the evaluation is shown in Figure E.2-1 of WCAP-14173, to be the top of the pipe. This selection of the SBF monitoring location was based on a review of the detailed calculations that had been performed to evaluate thermal stratification of the surge line in response to NRC Bulletin 88-11. Transfer functions were developed for top of the pipe SBF location.

The fatigue usage from thermal striping (stress fluctuations at the hot/cold interface of the stratification) were evaluated by a separate calculation as described in WCAP-14173, Appendix C. The fatigue usage from striping is added to the fatigue usage from pressure, moment, and thermal gradient variations. Inclusion of fatigue usage from striping as a separate term includes the effects of local stresses at the temperature discontinuity in the fatigue usage of the monitored location even though the interface is not at the top of the pipe.

The SBF locations for the pressurizer were selected by Westinghouse as part of the development of the transfer function report primarily because of concerns with surge line stratification, and significant fluid temperature fluctuations such as result from in-surges and out-surges through the surge line and from variations in spray flow through the spray line. Locations such as the knuckle radius on the pressurizer OD where the surge line nozzle joins the pressurizer lower head, which have high calculated CUF in design calculations, are monitored by cycle counting and cycle based fatigue (CBF) usage calculations. These locations are not included in the SBF monitoring program. OD locations are less significantly affected by rapid fluid temperature fluctuations than ID locations and there are no environmental effects that may affect usage on pipe and component OD surfaces. Therefore, for these locations, design calculations, cycle counting, and CBF will provide a sufficient basis for aging management of fatigue for the period of extended operation.

RAI 4.3-3 Followup Discussion

Based on the discussion with the applicant, the staff indicated that the response to this RAI requires clarification. The staff requested that the applicant address the following:

In its response dated August 20, 2007, the applicant stated that fatigue usage for steam generator feedwater nozzles is principally accumulated during heatup and cooldown (e.g., from feedwater flow cycling during standby periods). The applicant concluded that fatigue usage for Period 1 (1984-1995) can be reasonably estimated by multiplying the usage accumulated during Period 2 (1996-2005) by the ratio of the number of heatup and cooldown events during Period 1 to the number of those events during Period 2.

As stated in RAI 4.3-3, the transient tracking report indicates that seven loss of offsite power cycles and two loss of load cycles occurred between 1984 and March 1992, and that these two transients did not occur again between March 1992 and December 2005.

For example, for group 3, steam generator feedwater nozzle, a loss of offsite power and loss of load transients may cause the feedwater temperature to drop significantly. On this basis, the staff believes that the validity of these CUF backward projections using the ratio of heatup and cooldown events may not be conservative.

Also for group 1, normal and alternate charging nozzles, the applicant stated that the Period 2 transients are typical for the Period 1 transients of charging and alternate charging. The applicant's backward projection ignored severity of transients by using only the cycles ratio. For example, the loss of charging transient has three different types. The loss of charging and prompt return to service does not contribute a significant temperature change (around 50 °F). The loss of charging and delay return to service has a significant temperature step change (about 500 °F). The applicant combined different type of transients and used the ratio to determine the baseline fatigue usage factor.

The staff requests that the applicant further justify the validity of these backward projections or consider all transients in addition to the heatup and cooldown events.

RAI 4.3-3 Followup Response

Backward projection of CUF was used for NUREG/CR-6260 locations (Surge Line Hot Leg Nozzle, Charging Nozzles), and for several locations not covered by NUREG /CR – 6260 locations (Pressurizer Lower Head, Pressurizer Spray Nozzle, Pressurizer Surge Nozzle, Pressurizer Surge Line, S/G Feedwater Nozzles). While the ratios used for back-projection do incorporate accumulated fatigue effects from all transients that occurred during PERIOD2, it does not account for transients which occurred more frequently in PERIOD1 than during PERIOD2.

Thus, the existing baseline may be unconservative with respect to those transients with relatively more occurrences in PERIOD1 than given by the cycle ratio used in the projection (i.e. 1.625 for Charging locations, 2.25 for all others). Therefore, Wolf Creek will prepare an updated baseline that adequately bounds all transients experienced prior to the start of CUF monitoring. The existing baseline CUF for all monitored locations will

be increased to bound the potential CUF contribution from the transients that were under-represented in the existing baseline.

Responses to Specific Points in the RAI:

(A) The RAI identifies two transients that are not accounted for when using the back-projection approach. The transient tracking report indicates that seven loss of offsite power cycles and two loss of load cycles occurred between 1984 and March 1992, and that these two transients did not occur again between March 1992 and December 2005. While those events are present in the cycle counts in LRA Table 4.3-1, the transients that actually occurred were not as severe as the design transients as specified in the Westinghouse Systems Standard 1.3F. Review of operator logs has verified that none of those transients need have been counted.

The counted events did not include any auxiliary feedwater actuation, therefore these events were no more serious that a normal reactor trip. (Note that all 3 events, which included a reactor trip, were also counted as Reactor Trips.)

(B) Since WCGS implemented the modified operating procedure (MOP) prior to 1995, it is reasonable to suspect that heatups during PERIOD1 would have many more insurge/outsurge cycles than in PERIOD2. WCNOC agrees with this assertion, and will commit to updating the baseline to account for this factor. The baseline will be increased based on the expected number of additional insurge/outsurge cycles that would be accumulated in a pre-MOP environment.

(C) In the follow-up discussion, the reviewers further noted that the CUF back-projection did not consider the relative severity of Charging and Letdown transients. This was done for two reasons: (1) because it was assumed that the mix (proportions) of transients would be about the same in both periods, and (2) because the severity of actual charging events does not reflect the a-priori ranking of the design event categories. However, in the revised baseline Wolf Creek will explicitly consider the differential contribution of fatigue for each category of charging event.

Discussion of Loss of Load and Loss of Offsite Power Events:

Regarding the upset events cited as causing additional fatigue during PERIOD1, all 9 of those events in the cycle record were counted over conservatively. The actual events were much less severe than defined in the design events, to the point where they would contribute no additional usage over normal operating events. Considering each in turn:

<u>Loss of Load Event:</u>

Per the Westinghouse System Std. 1.3F:

> This transient involves a step decrease in turbine load from full power (turbine trip) without immediate automatic reactor trip. These conditions produce the most severe pressure transient on the Reactor Coolant system under upset conditions. The reactor eventually trips as a consequence of a high pressurizer level trip initiated by the Reactor Protection System. Since redundant means for

> tripping the reactor are provided by the Reactor Protection System, a transient of this nature is not expected, but is included to ensure conservative design.

Thus, unless there is a delay between the turbine trip and the reactor trip, and a corresponding pressure spike, this event is no different from a normal reactor trip.

Two such events were counted in the (W) Transient Evaluation Report (ICE-ICAT(97)-012, Rev. 0, Westinghouse, April 1998); both were also counted as Reactor Trip Events. Review of the operator logs for the days of these events (8/4/86 and 9/10/86) demonstrate that on both days, the reactor trip immediately followed the loss of load. Without any delay between trips, there was no pressure spike, and so no additional usage beyond that associated with a normal trip would be accrued.

[Note that this event demonstrates an additional conservatism in the fatigue management program for cycle counting and CBF. A single loss of load event was counted as both a loss of load and a reactor trip cycle. In design analyses, the initiating event (e.g. loss of load) includes the transient from the reactor trip so a reactor trip is not counted separately.]

<u>Loss of Off-Site Power Event:</u>

Per the Westinghouse Systems Std. 1.3F:

> This transient applies to a blackout situation involving the loss of outside electrical power to the station, assumed to be operating initially at 100 percent power, followed by reactor and turbine trips. The reactor coolant pumps are deenergized, as are all electrical loads connected to the turbine –generator bus, including the main feedwater and condensate pumps. As the reactor coolant pumps coast down, RCS flow reaches an equilibrium value under natural circulation. This condition permits removal of core residual heat through the steam generators which by this time are receiving feedwater, assumed to be at 32^0F, from the Auxiliary Feedwater System. For equipment design purposes it is conservatively assumed that all auxiliary feedwater pumps operate within one minute following the blackout. Later in the transient the auxiliary feedwater pumps are operated under manual control to obtain stable plant conditions. Steam is removed for the reactor cooldown through power operated relief valves provided for this purpose.

The (W) Transient Evaluation Report identified seven of these events. Of these, only one involved a reactor trip, and that event was counted as both a reactor trip and a loss of power. For the remaining six, the plant remained operating normally at 100% power all day. The design event never occurred, because in all seven cases, outside power was only partially lost, and was supplemented by the timely activation of the emergency diesel generators. Thus, none of the severe consequences of this event (e.g., RCP's deenergized, aux. feedwater initiation, electrical equipment offline) occurred, and so none of the associated temperature and pressure transients occurred.

LIST OF COMMITMENTS

The following table identifies those actions committed to by Wolf Creek Nuclear Operating Corporation in this document. Any other statements in this letter are provided for information purposes and are not considered regulatory commitments. Please direct questions regarding these commitments to Mr. Kevin Moles, Manager Regulatory Affairs at Wolf Creek Generating Station, (620) 364-4126.

	COMMITMENT SUBJECT	LRA, Appendix A, Section	COMMITMENT DESCRIPTION
21	Metal Fatique of Reactor Coolant Pressure Boundary (RCMS 2006-218)	A2.1	Prior to the period of extended operation, the Metal Fatigue of Reactor Coolant Pressure Boundary program will be enhanced to include: **1) Cycle Count Action Limit and Corrective Actions** An action limit will be established that requires corrective action when the cycle count for any of the critical thermal and pressure transients is projected to reach a high percentage (e.g., 90%) of the design specified number of cycles before the end of the next fuel cycle. If this action limit is reached, acceptable corrective actions include: 1. Review of fatigue usage calculations. • To determine whether the transient in question contributes significantly to CUF • To identify the components and analyses affected by the transient in question. • To ensure that the analytical bases of the leak-before-break (LBB) fatigue crack propagation analysis and of the high-energy line break (HELB) locations are maintained. 2. Evaluation of remaining margins on CUF based on cycle-based or stress-based CUF calculations using the WCGS fatigue management program software.

			3. Redefinition of the specified number of cycles (e.g., by reducing specified numbers of cycles for other transients and using the margin to increase the allowed number of cycles for the transient that is approaching its specified number of cycles). **2) Cumulative Fatigue Usage Action Limit and Corrective Actions** An action limit will be established that requires corrective action when calculated CUF (from cycle based or stress based monitoring) for any monitored location is projected to reach 1.0 within the next 2 or 3 fuel cycles. If this action limit is reached, acceptable corrective actions include: 1. Determine whether the scope of the monitoring program must be enlarged to include additional affected reactor coolant pressure boundary locations. This determination will ensure that other locations do not approach design limits without an appropriate action. 2. Enhance fatigue monitoring to confirm continued conformance to the code limit. 3. Repair the component. 4. Replace the component. 5. Perform a more rigorous analysis of the component to demonstrate that the design code limit will not be exceeded. 6. Modify plant operating practices to reduce the fatigue usage accumulation rate. 7. Perform a flaw tolerance evaluation and impose component-specific inspections, under ASME Section XI Appendices A or C (or their successors), and obtain required approvals by the NRC Corrective action limits for cumulative fatigue usage will be established to assure that sufficient margin is maintained to allow one cycle of the highest fatigue usage per cycle transient to occur without exceeding CUF = 1.0. (This includes consideration of environmental effects for NUREG/CR6260 locations.) This may require that corrective action is taken more than 2 or 3 fuel cycles before CUF is projected to exceed 1.0.

			This is because the projections will be based on historical experience, which is not expected to include many of the low probability design transients. The low probability design transients to be used in the evaluation will include: • Aux. Spray Actuation, Spray Water Diff.>320F • Excessive Feedwater Flow • Reactor Trip – Cooldown with no SI • COMS • Reactor Trip – No Inadvertent Cooldown with Turbine Over-speed • Reactor Trip - Cooldown with SI • Inadvertent RCS Depressurization • Accumulator Safety Injection • Operating Basis Earthquake **3) 10 CFR 50 Appendix B procedural and record requirements.** [Prior to the period of extended operation, changes in available monitoring technology or in the analyses themselves may permit different action limits and action statements, or may re-define the program features and actions required to address fatigue time-limited aging analyses. (TLAAs)] **Reference: ET 06-0038** **Due: March 11, 2025** **Revised ET 07-0031, ET 07-0046**
38	Metal fatigue baseline CUF	N/A	Backward projection of CUF was used for NUREG/CR-6260 locations (Surge Line Hot Leg Nozzle, Charging Nozzles), and for several locations not covered by NUREG /CR –6260 locations (Pressurizer Lower Head, Pressurizer Spray Nozzle, Pressurizer Surge Nozzle, Pressurizer Surge Line, S/G Feedwater Nozzles). While the ratios used for back-projection do incorporate accumulated fatigue effects from all transients that occurred during PERIOD2, it does not account for transients which occurred more frequently in PERIOD1 than during PERIOD2.

			Therefore, Wolf Creek will prepare an updated baseline that adequately bounds transients experienced prior to the start of CUF monitoring. The existing baseline CUF for all monitored locations will be increased to bound the potential CUF contribution from the transients that were under-represented in the existing baseline. **Reference: ET 07-0037, ET 07-0046** **Due: January 31, 2008**