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Richard J. St. Onge
Director, Nuclear Regulatory Affairs and
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10 CFR 50.4

February 25, 2013

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Subject: **Docket No. 50-361**
Response to Request for Additional Information (RAIs 2, 3, and 4)
Regarding Confirmatory Action Letter Response
(TAC No. ME 9727)
San Onofre Nuclear Generating Station, Unit 2

References:

1. Letter from Mr. Elmo E. Collins (USNRC) to Mr. Peter T. Dietrich (SCE), dated March 27, 2012, Confirmatory Action Letter 4-12-001, San Onofre Nuclear Generating Station, Units 2 and 3, Commitments to Address Steam Generator Tube Degradation

2. Letter from Mr. Peter T. Dietrich (SCE) to Mr. Elmo E. Collins (USNRC), dated October 3, 2012, Confirmatory Action Letter – Actions to Address Steam Generator Tube Degradation, San Onofre Nuclear Generating Station, Unit 2

3. Letter from Mr. James R. Hall (USNRC) to Mr. Peter T. Dietrich (SCE), dated December 26, 2012, Request for Additional Information Regarding Response to Confirmatory Action Letter, San Onofre Nuclear Generating Station, Unit 2

Dear Sir or Madam:

On March 27, 2012, the Nuclear Regulatory Commission (NRC) issued a Confirmatory Action Letter (CAL) (Reference 1) to Southern California Edison (SCE) describing actions that the NRC and SCE agreed would be completed to address issues identified in the steam generator tubes of San Onofre Nuclear Generating Station (SONGS) Units 2 and 3. In a letter to the NRC dated October 3, 2012 (Reference 2), SCE reported completion of the Unit 2 CAL actions and included a Return to Service Report (RTSR) that provided details of their completion.

By letter dated December 26, 2012 (Reference 3), the NRC issued Requests for Additional Information (RAIs) regarding the CAL response. Enclosure 1 of this letter provides the responses to RAIs 2, 3, and 4.

P.O. Box 128
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IE36
NRR

There are no new regulatory commitments contained in this letter. If you have any questions or require additional information, please call me at (949) 368-6240.

Sincerely,

Enclosure:

1) Response to RAIs 2, 3, and 4

cc: E. E. Collins, Regional Administrator, NRC Region IV
J. R. Hall, NRC Project Manager, SONGS Units 2 and 3
G. G. Warnick, NRC Senior Resident Inspector, SONGS Units 2 and 3
R. E. Lantz, Branch Chief, Division of Reactor Projects, NRC Region IV

ENCLOSURE 1

SOUTHERN CALIFORNIA EDISON

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

REGARDING RESPONSE TO CONFIRMATORY ACTION LETTER

DOCKET NO. 50-361

TAC NO. ME 9727

Response to RAIs 2, 3, and 4

RAI 2

The Operational Assessment in Attachment 6, Appendix C (Reference 4), pages 3-2 and 4-12, appears to state that tube-to-tube wear (TTW) growth rates are based on the maximum TTW depths observed in Unit 3 at EOC 16 divided by the first Unit 3 operating period (0.926 years at power). Provide justification for the conservatism of this assumption. This justification should address the following:

a. Reference 4, page 3-2 defines "wear index" for a degraded tube and states that the existence of TTW and distribution of TTW depths are strongly correlated to the wear index. This is pictured in Figures 4-4 in terms of TTW initiation. This figure shows that TTW is not expected to have initiated until a threshold value of wear index is reached. This threshold value varies from tube to tube according to a cumulative probability distribution shown in the figure. This figure illustrates that TTW is not expected to have initiated until sometime after BOC 16. This suggests that the observed TTW depth at EOC 16 developed over a smaller time interval than the 0.926 years assumed in the analysis.

b. An independent analysis in Reference 3 also indicates an extremely low probability of instability onset at BOC 16 as illustrated in Figure 8-3. Reference 3, page 106 interprets this figure as indicating that the probability of instability only reaches 0.22 after 3 months and only becoming "high" after 4 months.

c. Reference 3 also considered a variety of different wear rate models to estimate how long it took to develop the observed TTW depths at Unit 3 after instability occurred. These analyses are documented in Appendix A of Reference 3 and produced estimates in the range of 2.5 to 11 months.

RESPONSE

Note: RAI reference 4 is the "Operational Assessment for SONGS Unit 2 SG for Upper Bundle Tube-to-Tube Wear Degradation at End of Cycle 16," prepared by Intertek APTECH for Areva, Report No. AES 12068150-2Q-1, Revision 0, September 2012.

RAI reference 3 is the "SONGS U2C17 Steam Generator Operational Assessment for Tube to Tube Wear," prepared by Areva NP Inc, Document number 51-9187230-000, Revision 0, October 2012.

Basis for Zero Time Initiation Model

The wear rate model in the SONGS Unit 2 operational assessment (OA) is based on the apparent tube-to-tube wear (TTW) growth rates observed in SONGS Unit 3. Industry guidelines define the apparent degradation rate as the change in observed degradation over the operating cycle length. Following standard industry practice, the wear rate model assumes that TTW began at the start of Cycle 16 for Unit 3. The wear rate distribution for SONGS Unit 2 was developed from the distribution of Unit 3 depths divided by the Cycle 16 operation period of 0.926 years at power.

It was recognized that a variation in the time when TTW initiated would affect the wear rate distribution. The OA model for TTW includes conservative assumptions to compensate for the variation in the time when TTW may have begun. These conservative modeling conditions are:

1) Only the maximum TTW depths were used in the determination of wear rate. This produces a faster growth model than one developed from all of the depth data.

2) The TTW rates are based on growth in through-wall depth (i.e., constant-depth growth). Wear processes are typically modeled as constant volume growth which leads to a decreasing depth growth in time.

3) The TTW growth rates are based on 100% power operation for Unit 3. No credit is taken for the potential reduction in TTW rate for 70% power operation.

4) The tube-AVB and tube-TSP growth rates are based on 100% power operation for Unit 3. No credit is taken for the potential reduction in wear rates at AVB and TSP supports for 70% power operation.

5) The TTW rate model is based on the wear index (WI) as an indicator of initiation and growth of TTW. The wear index is based on depth growth at the supports (AVB and TSP) which conservatively assumes constant depth growth.

By including these assumptions, the Unit 2 TTW growth rate model for 70% power operation was determined to be reasonable and conservative.

Treatment of Variable Initiation Time

To address the RAI question of TTW initiation time and the impact on the allowable inspection interval for Unit 2, additional analysis was performed. A time dependent predictive model (initiation-time model) for estimating the operating period prior to TTW initiation in Unit 3 was developed. This model is illustrated in Figure 1. This figure is a schematic example for a single tube where the rate of increase in the wear index is allowed to vary.

As shown in Figure 1, the growth in the wear index occurs in two stages: pre-initiation and post initiation. The initiation-time model for TTW uses a wear index based only on tube to AVB wear in the upper supports (B03 through B10). This model's wear index (WI) starts to increase at the beginning of the cycle. The basis for this approach was developed from the Unit 3 wear data as follows:

1) Tubes without TTW indications have very few or no AVB wear indications at the lower support bars (B01, B02, B11, and B12).

2) Most tubes with TTW have wear indications in the lower support bars. These tubes typically have significant wear at all four lower support bars. The wear at the lower supports is assumed to occur after TTW has initiated.

3) AVB wear depths (B03 through B10) for tubes with TTW are similar to the wear depths for tubes without TTW. This indicates that the wear rates at individual tube/AVB contact points before TTW initiates is not significantly elevated after TTW has initiated. Thus the increase in AVB wear index after TTW is mainly due to the increase in locations with AVB wear, including wear locations at the lower supports (B01, B02, B11, and B12).

4) For tubes without TTW, few or no TSP wear indications were detected. Most TSP wear occurred in tubes with TTW.

Using the above Unit 3 NDE results, the initiation-time model assumes the development of wear at the lower AVB supports (B01, B02, B11, and B12) and TSPs occurs after TTW initiates. The

TTW initiation time was determined from the change in the wear index in the upper tube supports (B03 through B10). The initiation-time model uses AVB wear in these upper supports as a predictor of TTW since the wear at the other supports is assumed to develop after TTW initiation.

The WI growth rate prior to initiation of TTW was developed from upper AVB support wear data (B03 through B10) for Unit 3 tubes without TTW. The increase in WI after TTW initiation uses AVB wear rate distributions sampled from the number of detected wear locations for tubes with TTW.

The predicted TTW initiation time is calculated by simulating two-stage growth in the WI. The initiation model is constrained to the end state for the calculated wear index from the NDE results. The slopes for the growth in the WI are also constrained to keep the two-stage process bounded by the constant WI growth case illustrated in Figure 1.

A Monte Carlo simulation was performed to compute the distribution of initiation times for each tube. After completion of 1000 trials for each tube, a distribution of initiation times was created and the median value recorded. The median value is used to provide the best-estimate time when TTW began in Cycle 16. The histogram of these median values is shown in Figure 2. By this analysis, a significant number of tubes initiated TTW early in the cycle, especially for SG 3E-088. The TTW growth rates were computed from these data using the maximum TTW depth divided by the cycle length minus the initiation time.

The zero-time initiation model in RAI Reference 4, the independently developed analysis in RAI Reference 3, and the initiation-time model developed in response to this RAI reach conclusions on either the onset of instability or the initiation of TTW in the next operating interval for Unit 2. The approaches used in these models differ in their use of the empirical information provided by the NDE inspection data and the use of steam generator thermal hydraulic properties and support conditions from Units 2 and 3. These differences lead to some variation in predicting the onset of instability or the initiation of TTW. SCE's conclusion is all three approaches provide diverse and comprehensive evaluations supporting the proposed operating interval.

Comparison of TTW Rate Behavior

The wear rate plots as a function of total wear index are shown in Figure 3 for both depth sizing techniques used in RAI Reference 4. The dotted line in each plot is the TTW rate model from Figure 4-13 in RAI Reference 4. This model assumed zero initiation time in establishing the wear rate. The solid line is the regression analysis of the results from the initiation-time model developed for this RAI. This comparison shows the TTW growth function based on the initiation-time model is more conservative than the model used in RAI Reference 4, without adjusting for the other conservative assumptions made in the development of the RAI Reference 4 model.

Significance of Initiation Time

The effect of the initiation-time model developed for this RAI on operating interval is shown in the table below. The allowable operating interval for maintaining structural integrity performance criteria margins for Unit 2 is 1.02 to 1.15 years at 70% power without changing any of the other conservative assumptions incorporated in the RAI Reference 4 model.

Unit 2 Years of Operation at 70% Power		
Case	**Reference 4 - Zero Initiation Time TTW Model**	**RAI TTW Initiation-Time Model**
ETSS Sized	1.33	1.02
AREVA Resized	1.48	1.15

These results represent a margin of at least 2.4 on the planned Unit 2 inspection interval of 150 days (0.42 years at 70% power).

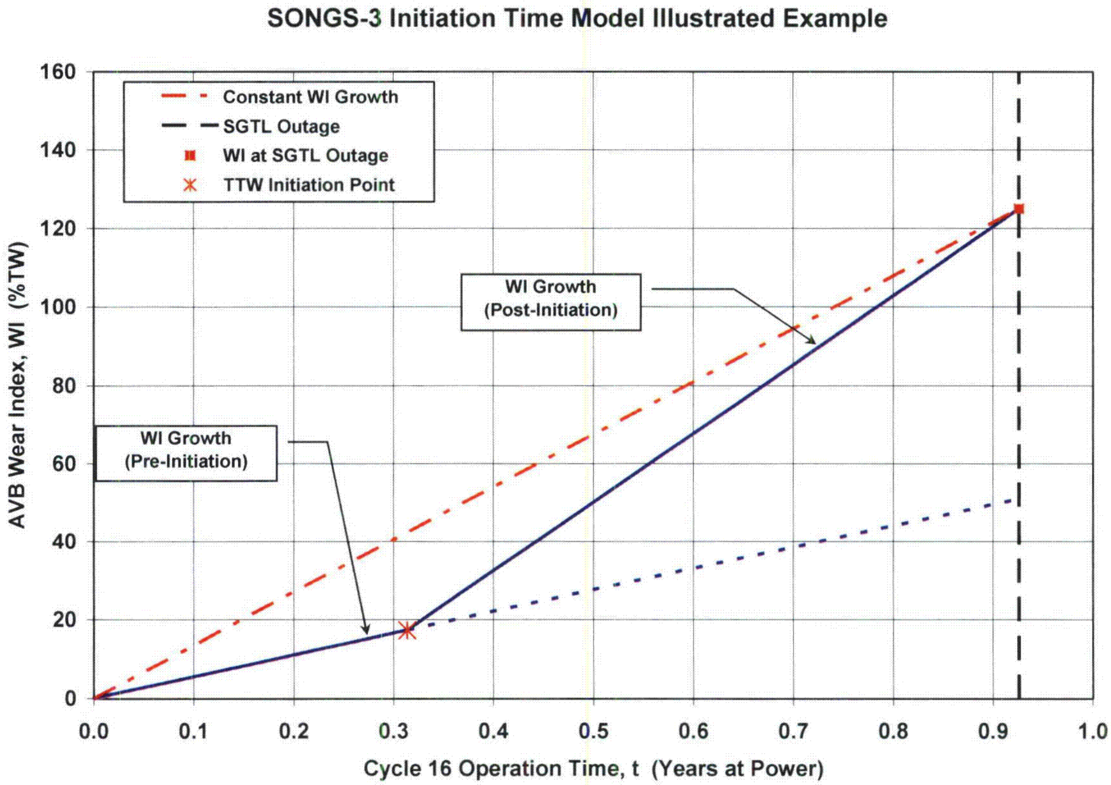


Figure 1 – Model for Estimating TTW Initiation Time

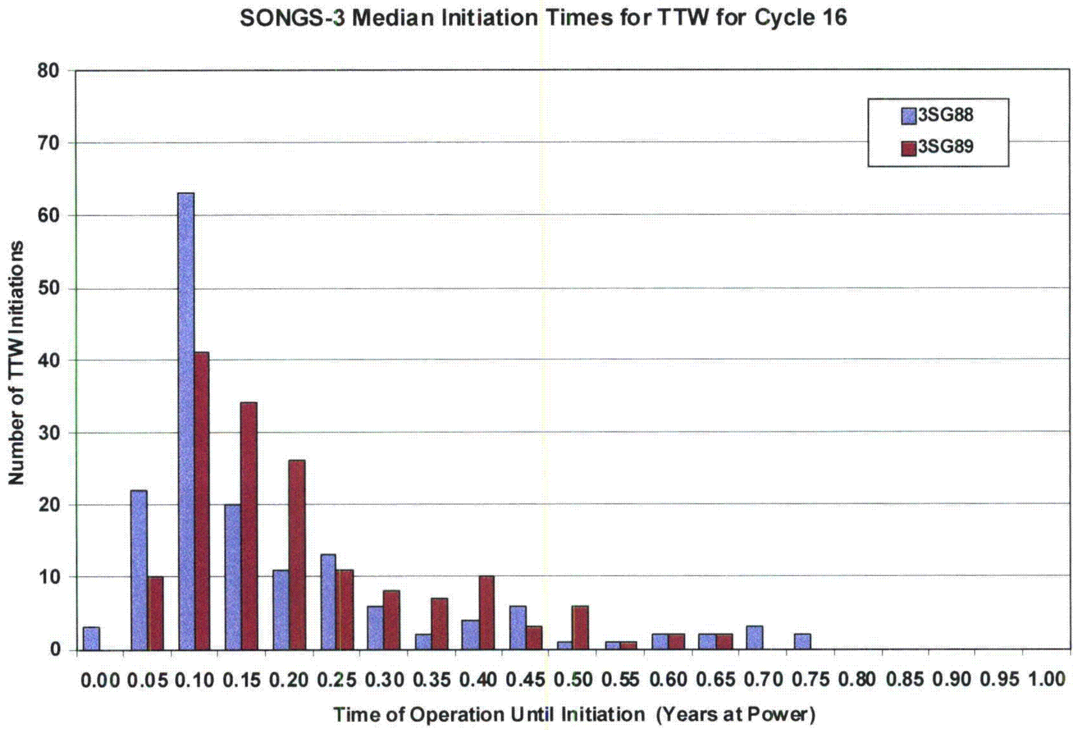
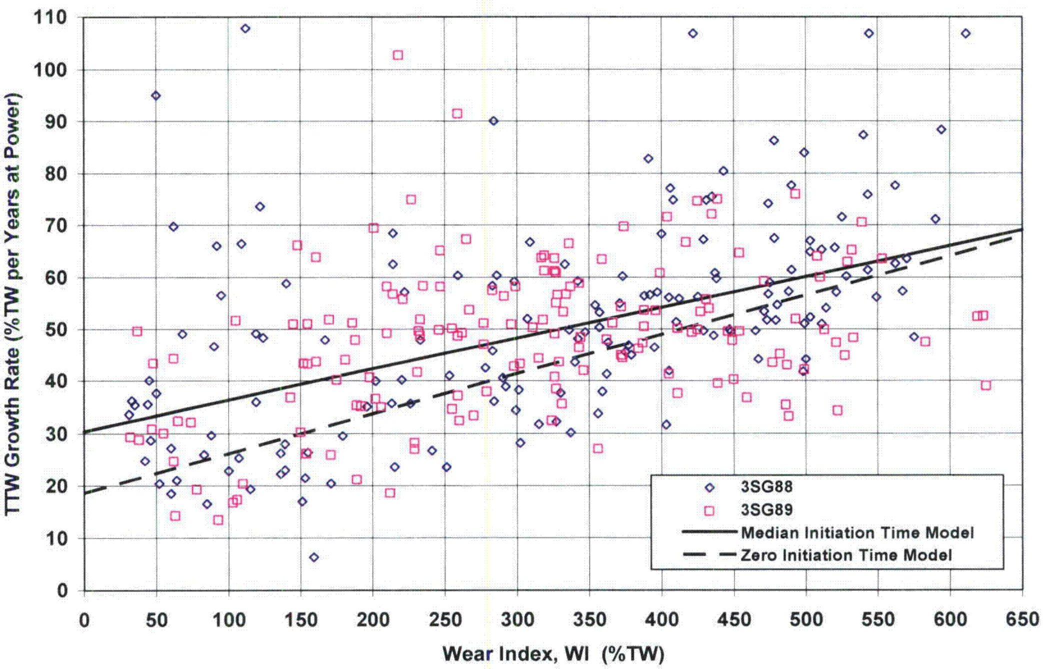


Figure 2 – Simulation Results from Time Dependent Initiation Model

ETSS 27902.2 Sizing



AREVA Resized

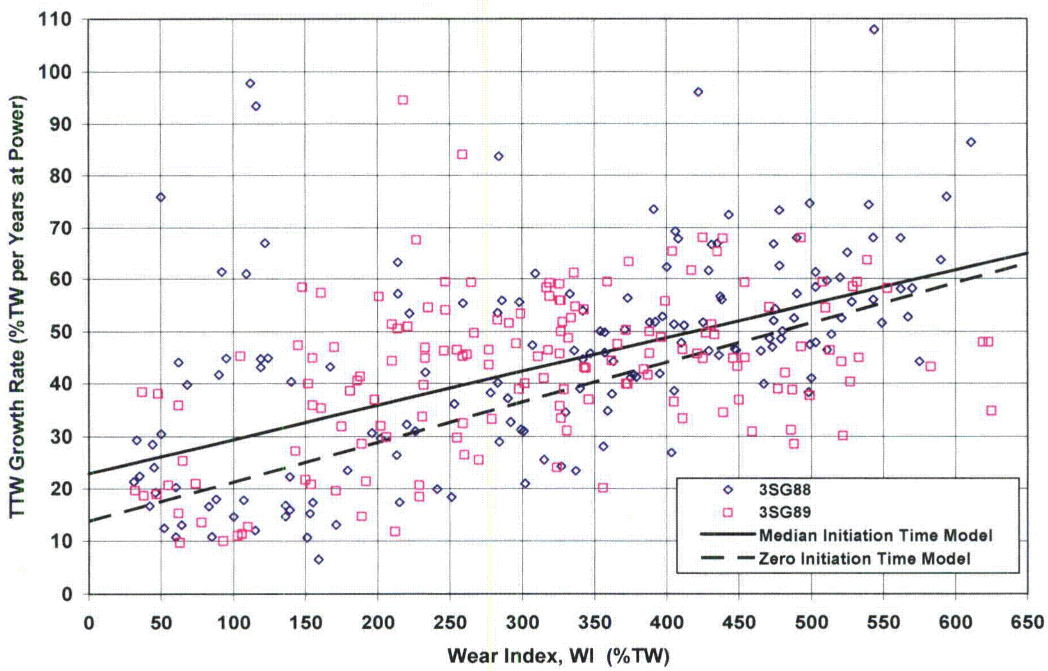


Figure 3 – Tube-to-Tube Wear Rate Comparisons

RAI 3

Regarding Reference 4, describe the sensitivity of the results in Figure 5-4 to the definition of "wear index." If alternate definitions significantly affect the results, what is the justification for the definition being used?

RESPONSE

Note: RAI Reference 4 is the "Operational Assessment for SONGS Unit 2 SG for Upper Bundle Tube-to-Tube Wear Degradation at End of Cycle 16," prepared by Intertek APTECH for Areva, Report No. AES 12068150-2Q-1, Revision 0, September 2012.

The justification of the (WI) used in RAI Reference 4 is the ability of the WI, as a correlating parameter, to describe SONGS Unit 3 TTW. The WI is an empirical relationship that uses parameter(s) to best explain the Unit 3 non-destructive examination (NDE) data. The NDE data used in the OA model were the TTW through-wall depth and the presence or absence of TTW in tubes within the high wear region. The WI was used to establish the initiation and growth models for TTW.

The WI selection process evaluated several alternative definitions and determined the goodness-of-fit for each. The alternatives considered included the number of affected supports as well as the tube-specific wear magnitudes. The alternatives assessed represent the state of degradation for a given tube based on existing wear at anti-vibration bar (AVB) supports and tube support plates (TSP).

The WI alternatives are combinations of scalar measures that consider the number of support locations with tube wear and the amount of wear at each location. The selection of the WI alternative was based on which definition provided the best correlation (regression fit) of the observed NDE results for Unit 3 and the ability to apply it to Unit 2. The selection process reviewed several alternative definitions for the WI. AVB wear, TSP wear, and various combinations of the two were tested to determine which gave the best regression fit to the Unit 3 data.

The functional form used in this study was a second order response surface with a first-order interaction term:

$$D_{TTW} = A_1 + A_2 D_{AVB} + A_3 D_{TSP} + A_4 D_{AVB} D_{TSP} + A_5 D_{AVB}^2 + A_6 D_{TSP}^2 \qquad (1)$$

where:

$A_1 \ldots A_6$	fitting coefficients
D_{TTW}	wear depth of TTW for a given tube
D_{AVB}	sum of AVB wear depths
D_{TSP}	sum of TSP wear depths

From Equation 1, four other alternative relationships were tested:

$$D_{TTW} = A_1 + A_2\, D_{AVB} + A_3\, D_{TSP} + A_4\, D_{AVB}\, D_{TSP} \quad (2)$$

$$D_{TTW} = A_1 + A_2\, D_{AVB} + A_3\, D_{TSP} \quad (3)$$

$$D_{TTW} = A_1 + A_2\, (D_{AVB} + D_{TSP}) \quad (4)$$

$$D_{TTW} = A_1 + A_2\, D_{AVB} \quad (5)$$

Each alternative was evaluated using a sequence of increasingly simplified models based on the above full response surface form. An estimation of the model coefficients and the evaluation of goodness-of-fit measures were obtained by non-linear regression analysis. Table 1 contains the descriptions and results for the sequence of the five models evaluated.

The first alternative evaluated was the full second order model with six coefficients (Eq. 1). This provided a reference set of measures to which simplified WI definitions could be compared. As can be seen from Table 1, this bivariate model explains slightly more than 50% of the variation of TTW flaw depth seen in the Unit 3 data. This model (R^2 correlation of 0.53 and a standard error of estimate of 10.6% TW) was compared with an intrinsic value of the data scatter estimated from a subset of the Unit 3 TTW depth data. The subset of data selected for this estimate covers a relatively narrow range of the independent variables (AVB and TSP indices) and represents a lower limit for smooth surface correlations. The corresponding standard deviation for this subset is approximately 9.9%. Based on this comparison, the full second order model (Model 1) compares well with this value and provides a suitable reference base-model for evaluating each alternate WI.

The second alternative (Eq. 2) eliminates the higher order terms while retaining the cross-product ($D_{AVB}*D_{TSP}$) term. This simplification results in only a slight degradation in model performance, explaining slightly less than 50% of the Unit 3 data variation. The third alternative (Eq. 3) is the simplest of the bivariate models and has no cross-product term. The marginal reduction in performance is inconsequential. The fourth alternative (Eq. 4) is actually a variation on the third in which the number of undetermined coefficients in the model is reduced by one. This alternative has similar goodness-of-fit (R^2) and standard error of estimates as alternatives 1 through 3. It is concluded that alternatives 1 through 4 are basically equivalent having similar capability in correlating the observed NDE data to each definition of the WI.

The final alternative (Eq. 5) redefines WI only in terms of AVB wear. This alternative explains slightly more than 30% of the variation in the TTW depth data. Alternative 4 (summation of AVB and TSP) was selected as the definition of WI. This simplification resulted in the ability to define the TTW depth prediction model in terms of a single wear related quantity with accuracy comparable to a much more complex model of the group and is the basis for the WI definition used in RAI Reference 4.

Table 1

Goodness of Fit for the Five Candidate WI Models		
Model Equation	**R^2 [Note 1]**	**Residual St. Dev. [Note 2]**
1	0.527	10.57
2	0.496	10.91
3	0.492	10.95
4	0.488	10.99
5	0.325	12.63

Notes:

1) R^2 is a fraction of the data variation explained by the regression model
2) The standard deviation of the residuals represents the standard error of estimate for the model

RAI 4

Regarding Reference 4, does the definition of "wear index" include summing the depths of 2-sided wear flaws at a given AVB intersection? If not, explain why SCE's approach is conservative.

RESPONSE

Note: RAI Reference 4 is the "Operational Assessment for SONGS Unit 2 SG for Upper Bundle Tube-to-Tube Wear Degradation at End of Cycle 16," prepared by Intertek APTECH for Areva, Report No. AES 12068150-2Q-1, Revision 0, September 2012.

No, the WI does not include the summation of non-destructive examination (NDE) depths on tubes with 2-sided wear as determined by the +Point™ examination.

The WI is based on bobbin NDE depth data. Bobbin inspection provides a consistent database for both units that can be used to define the state of wear degradation. From this database, a direct correlation between the two units was made to implement the WI parameter in predicting the initiation and growth of TTW.

The approach using bobbin data to define the WI is appropriate for the following reasons:

1) The bobbin coil responds to the wear volume around the full circumference of the tube and accounts for multiple wear locations, when present.
2) The WI model assumes support effectiveness is defined by the size of the larger gap between the tube and a single AVB. The model assumes that bobbin wear depths are directly related to the increase in the tube to AVB gap as wear progresses. The WI based on bobbin depth is a direct measure of support effectiveness.

The above identifies that the determination of WI based on tracking bobbin depth growth is an appropriate measure since it is directly related to the increase in the tube to AVB gap.

When the definition of WI is changed to include summation of 2-sided wear depths, it results in a change to both the model correlations as well as the OA calculation algorithm. The effect of including 2-sided wear, from the +Point™ data, in the calculation of the WI results in an approximate 30% increase in the index across the full range of the data. The +Point™ WI for Unit 3 increases accordingly and data shown in Figure 4-1 of RAI Reference 4 shifts to the right by a factor of approximately 1.3. Since a similar shift would occur in the WI for Unit 2, the predictions of TTW initiation as well as the TTW rates occur at approximately the same point on the WI axis resulting in a minor net effect.

A study using the Unit 3 data was performed to evaluate the predictive models and compares the two WI models (bobbin-based versus +Point™-based). The Unit 2 and 3 inspection databases contain 2-sided AVB wear depth data collected from the +Point™ inspection. This allowed the development of alternative TTW initiation and depth (wear rate) models which were compared with the present bobbin-based WI model.

Bobbin and +Point™ based initiation models were developed using a logistic regression process. The resulting logistic functions are shown in Figure-1. The predictive ability of the two models was evaluated by simulating the TTW initiation process. This was accomplished by

presenting each function with its respective set of Unit 3 WIs and counting the predicted number of TTW occurrences. Both the bobbin-based and +Point™-based models produced similar (approximately 320 occurrences) results. This demonstrates that the incorporation of the +Point™-based WI doesn't improve the initiation model's ability to predict the presence of TTW. Since the Unit 2 initiation model was developed by benchmarking the Unit 3 model, there will be no improvement to the prediction of TTW initiation for Unit 2.

Additionally, the study compared the ability of the two approaches to predict the depths of the TTW flaws in Unit 3. Figure 2 shows the results of correlating TTW wear depths with the bobbin-based and +Point™-based WIs. Figure 3 shows the two correlations plotted on a common scale. The +Point™ WI shifts to the right (higher WI values when 2-sided wear depths are included in the summation).

Table 1 provides a comparison of the R^2 and residual standard deviation values for the two methods. The WI models produce approximately the same results for the two measures.

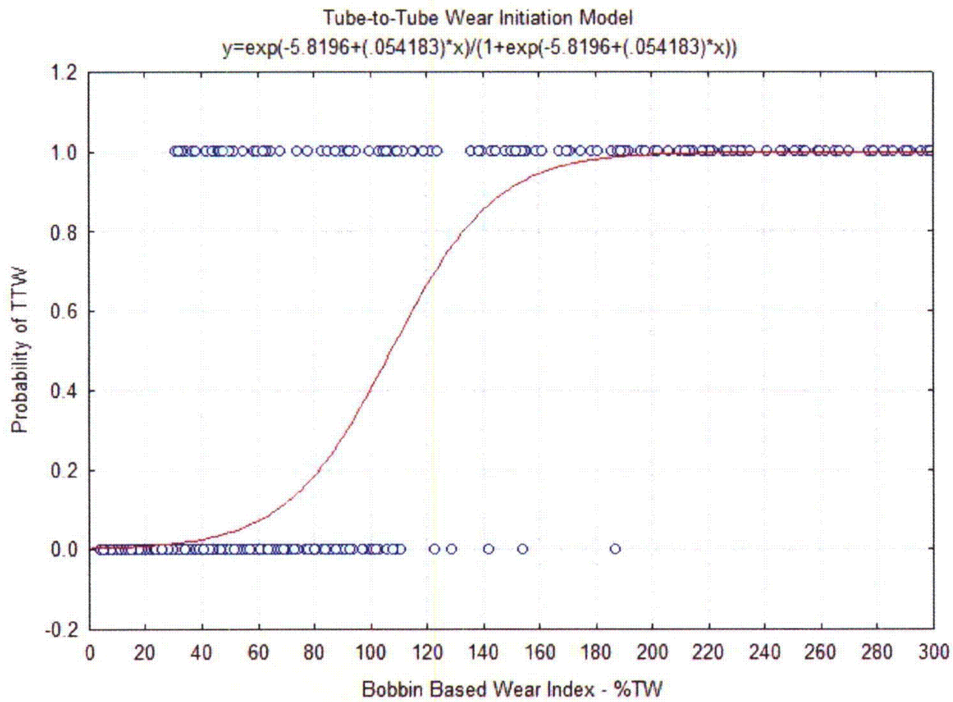
Table 1

Comparison of Bobbin and +Point™ Wear Indices for Correlating TTW Depths		
WI Model	**R^2 - Percent of Variation Explained by Correlation**	**Std Deviation of Residuals**
Bobbin WI	48.87%	10.994
+Point™ WI	49.17%	10.963

The WI for Unit 2 tubes was further evaluated against the TTW depth correlation using the two WI models. Figure 4 shows the values for bobbin WI and +Point™ WI plotted for each tube with detected support wear in the high wear region. The dominant wear is due to tube-AVB contact. The +Point™ WI is higher than the bobbin WI. There is an approximate 35% average increase in the WI for the +Point™ WI.

The effect of these differences on TTW depths (growth rates) was evaluated by processing the Unit 2 wear indices for the two models through the correlation given in Figure 3. The resulting variation in predicted TTW depths is shown in Figure 5. The average difference between the correlated depths is less than 3% with most of the depths falling within +/- 5% which is insignificant compared with the much larger differences in WI values. This illustrates the offsetting effect between the shift in the WI correlations and the final application in the OA.

Based on the comparisons discussed above, the use of the bobbin-based WI is appropriate for the Unit 2 OA.



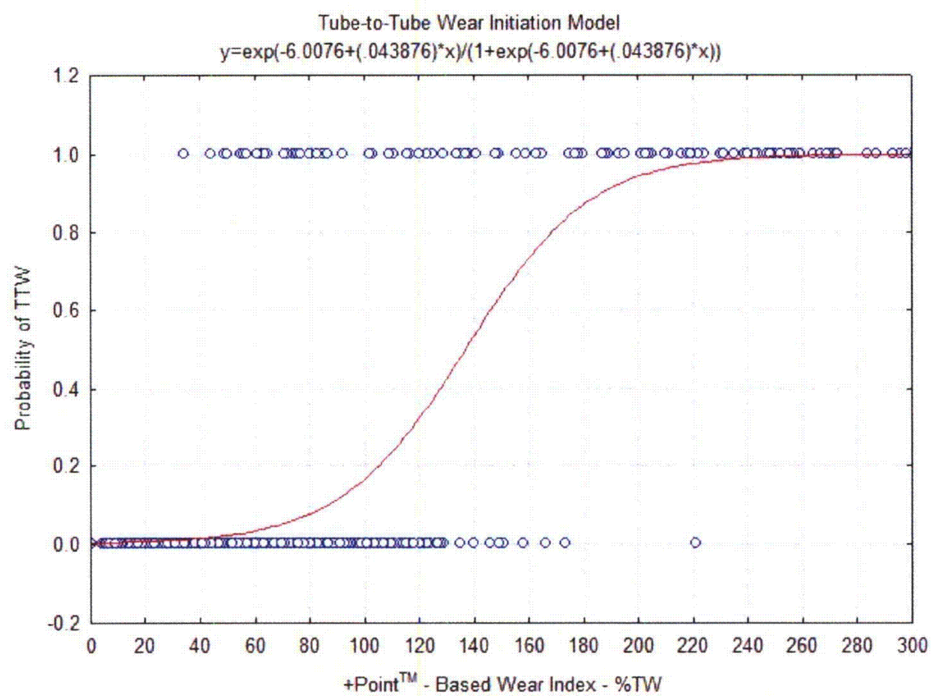
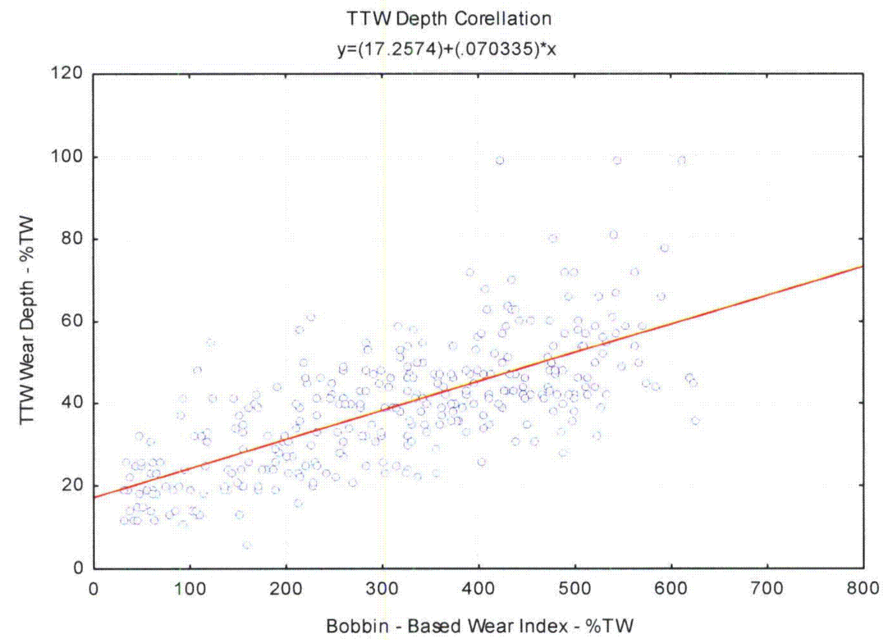


Figure 1 – Comparison of Initiation Models Based on Bobbin and +Point™ Wear Index Models



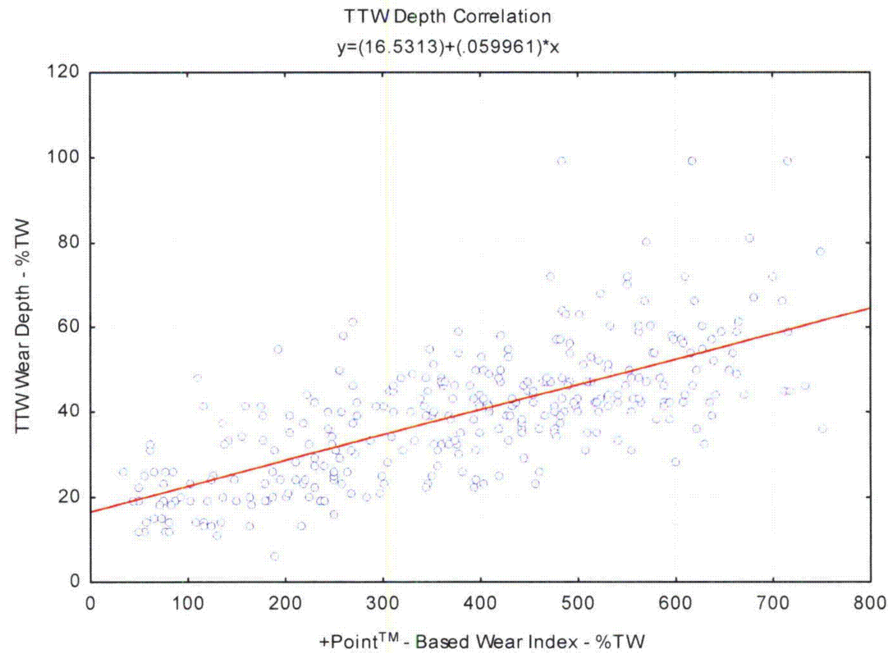


Figure 2 – Wear Depth Correlations for Wear Rate Model Based on Bobbin and +Point™ Wear Indices

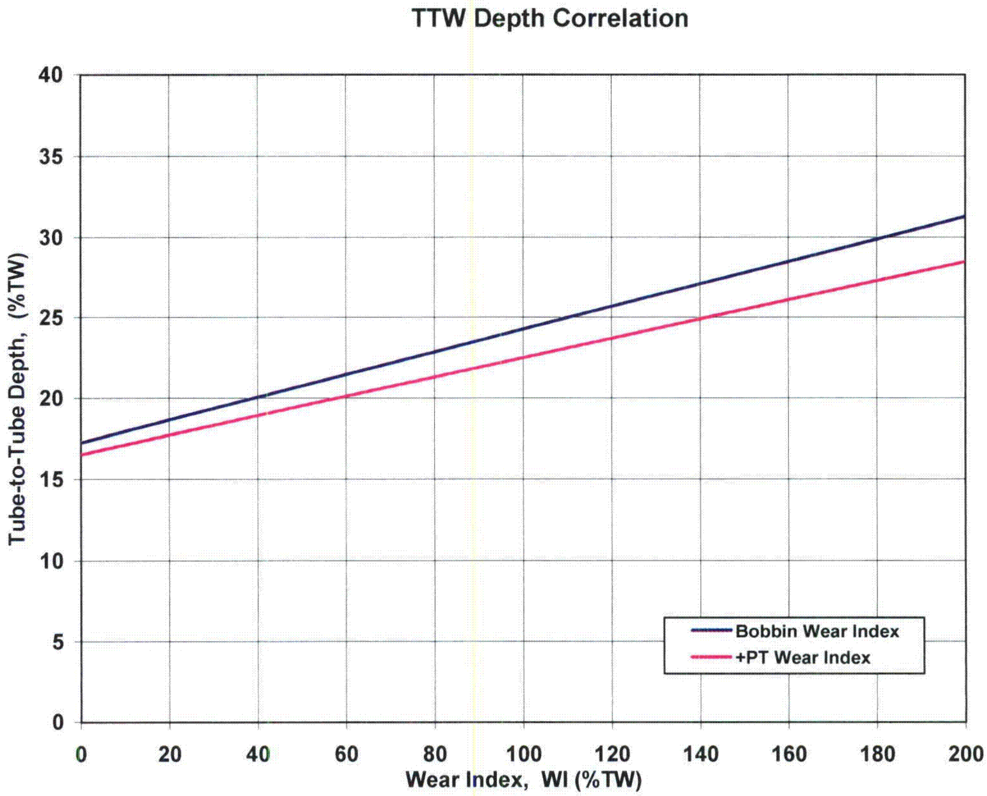


Figure 3 – Comparison of Wear Depth Regression Fits for Bobbin and +Point™ Wear Indices

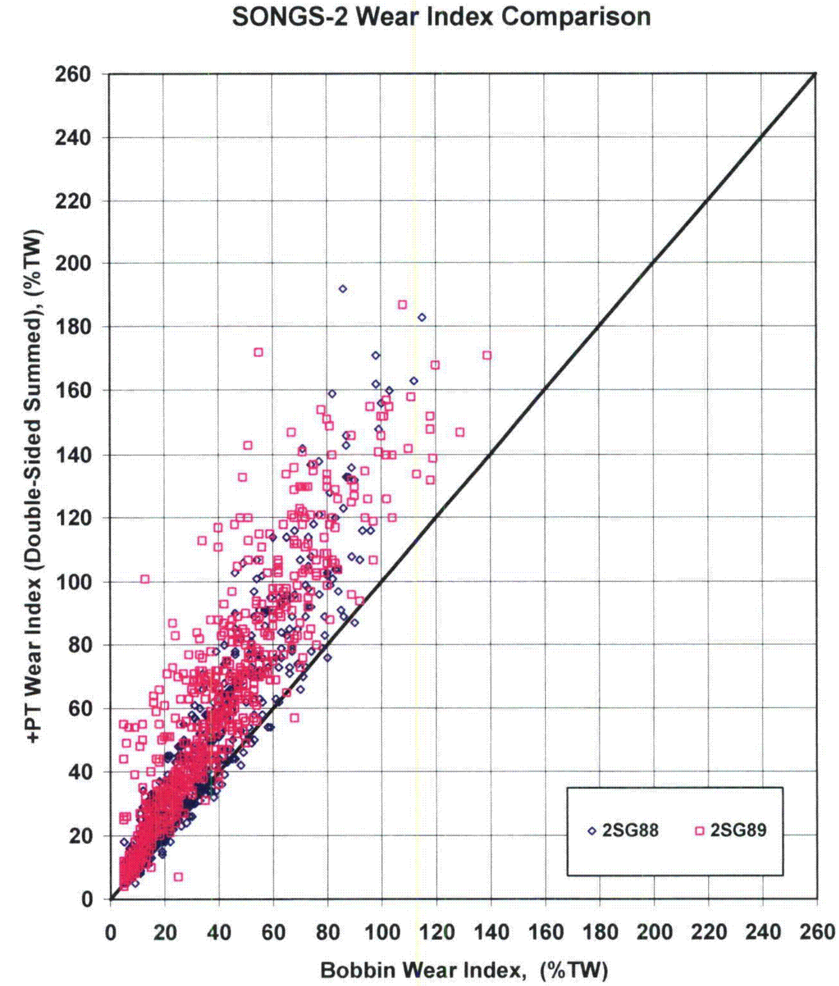


Figure 4 – WI Comparison between Bobbin-Based and +Point™-Based Models

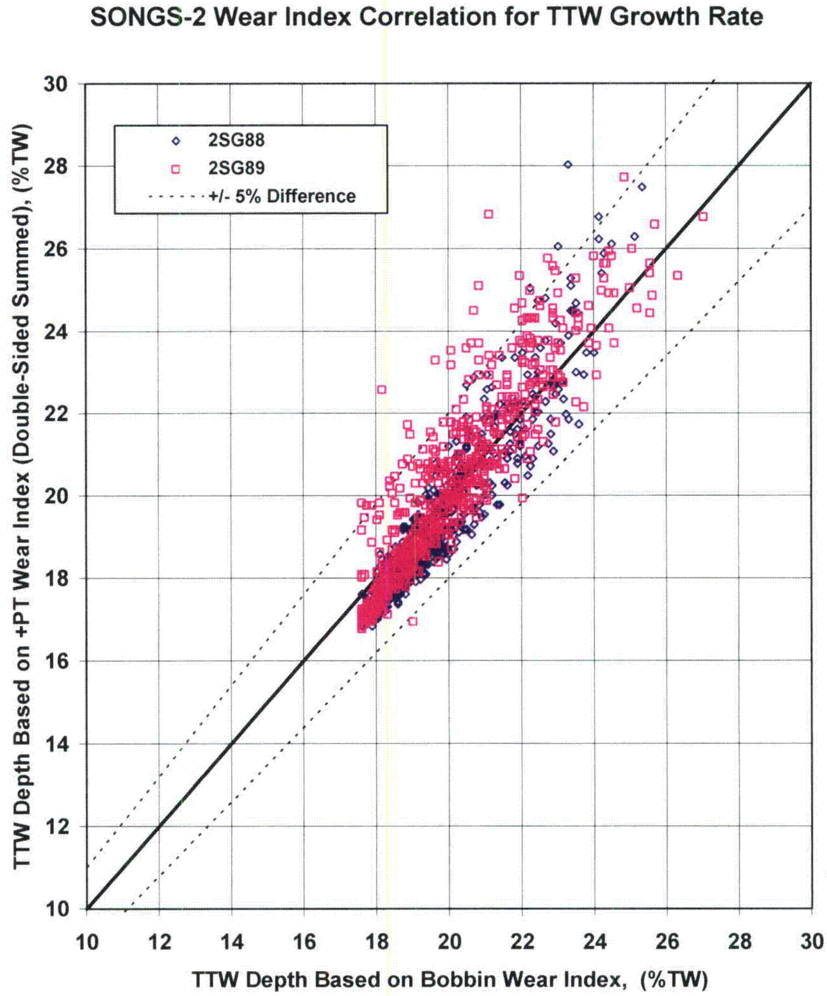


Figure 5 – Wear Rate Comparison between Bobbin-Based and +Point™-Based Models