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June 4, 2013

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

Subject: **Docket No. 50-361**
Supplement to Response to Request for Additional Information (RAI 71) 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. Email from Mr. James R. Hall (USNRC) to Mr. Ryan Treadway (SCE), dated March 15, 2013, Request for Additional Information (RAIs 68-72) Regarding Response to Confirmatory Action Letter, San Onofre Nuclear Generating Station, Unit 2
4. Letter from Mr. Richard J. St. Onge (SCE) to Document Control Desk (USNRC), dated April 16, 2013, Response to Request for Additional Information (RAI 71) Regarding Confirmatory Action Letter Response, 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 e-mail dated March 15, 2013 (Reference 3), the NRC issued Requests for Additional Information (RAIs) regarding the CAL response. SCE provided the response to RAI 71, in a letter dated April 16, 2013 (Reference 4). Enclosure 1 of this letter provides a supplement to the RAI 71 response.

P.O. Box 128
San Clemente, CA 92674

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. Supplement to RAI 71 Response

cc: A. T. Howell III, 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

SUPPLEMENT TO THE RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

REGARDING RESPONSE TO CONFIRMATORY ACTION LETTER

DOCKET NO. 50-361

TAC NO. ME 9727

Supplement to RAI 71 Response

RAI 71

Reference 1, Response to RAI 2 – It is stated on page 4 of 18 that a median value of initiation time was selected for each tube based on 1000 trials. For purposes of evaluating a conservative probability estimate that one or more tubes do not meet the 3 delta P criterion, why is it conservative to consider a median value of initiation time for each tube, rather than sampling from the distribution of initiation times developed for each tube during a given Monte Carlo trial of the tube population? Would sampling the distribution of initiation times for each tube be a more conservative approach, as it would be expected to stretch out the tails of the resulting overall probability distribution for not meeting the 3 delta P criterion? For a probabilistic assessment such as this, what is the justification for not considering a potentially large source of uncertainty associated with a key input parameter?

RESPONSE SUPPLEMENT

Note: RAI Reference 1 is SCE's "Response to Request for Additional Information (RAIs 2, 3, and 4) Regarding Confirmatory Action Letter Response," dated February 25, 2013. SCE responded to RAI 71 via letter "Request for Additional Information (RAI 71) Regarding Confirmatory Action Letter Response," dated April 16, 2013. This response supplements the response to RAI 71 and provides additional explanation of the technical basis for the median initiation-time distribution model.

Supplement to RAI 71 Response - Technical Basis for Median Initiation-Time Distribution Model

Introduction

The purpose of this supplement is to provide further details into the technical basis for the median initiation-time model and how it compares with the distribution of discrete initiation times (t_{INIT}) from the complete data set. This supplement presents a comparison of two model simulations, one based on the discrete values from the initiation-time model described in the RAI 70 response, and the other based on the median initiation time distribution. This discussion focuses on the main question in RAI 71, specifically, "Why is it conservative to consider a median value of initiation time for each tube, rather than sampling from the distribution of initiation times developed for each tube during a given Monte Carlo trial of the tube population?"

The figure of merit used in the comparison is how well each model explains the measured depth distribution for Unit 3 steam generator E-088 (3E-088) after 0.926 years at power. This is accomplished by performing a benchmarking process where the cumulative distribution functions (CDF) of the predicted tube-to-tube wear (TTW) depth from each model are compared with the observed non-destructive examination (NDE) depths in 3E-088. Steam generator 3E-088 was chosen because it was the more limiting (worst) of the two generators in terms of the TTW depths detected at the end of the operating period. The data set for the 3E-088 depth distribution used in this comparison is based on EPRI ETSS 27902.2, which is the more conservative sizing case (Case 1) evaluated in the Unit 2 operational assessments (OA).

Distribution of Initiation Times

The initiation-time model described in the RAI 2 response produced a distribution of TTW initiation times based on a bi-linear behavior in the growth of the wear index for a given tube. Once the initiation time is determined, the TTW rate is calculated from

$$WR_{TTW} = \frac{d_{TTW}}{(t_{CYC} - t_{INIT})}$$

where d_{TTW} is the maximum NDE depth of the TTW indication in the tube and t_{CYC} is the operating period (0.926 years at power).

The bases for this model are discussed in the SCE response to RAIs 2, 68, 69, and 70. The initiation-time model provides minimum constraint on the solution for the time in the cycle when in-plane instability occurs and permits numerical solutions for t_{INIT} that can approach the end of the operating interval, i.e., $t_{INIT} \rightarrow 0.926$ years at power. Such simulations will lead to extreme values in wear rate that are unbounded and potentially unrealistic ($t_{CYC} - t_{INIT}$ approaching zero). This must be considered when modeling the uncertainties in wear rates that are derived from the simulated data and the reason for the extremes values.

For 3E-088, there are 161 tubes that were evaluated. For a simulation involving 1000 trials per tube, the solution data set has 161,000 discrete values for t_{INIT} and corresponding wear rate for each steam generator. The corresponding distributions developed from the initiation times of all simulated values are plotted in Figure 1. The distribution for initiation times using median values for each tube (161 data points) is also plotted. This figure illustrates the global distribution of TTW initiation times for Unit 3 steam generator 3E-088. It can be seen that the two distributions for the initiation times are comparable. This is a direct consequence of the diversity in distributional form exhibited by the individual tube initiation time samples shown in Figure 2 from the RAI 71 response. Because of the diversity among the individual tubes, the cumulative distribution for median initiation times covers the full range of this key variable.

Nature of Tubes with TTW

As described in the RAI 71 response, three distinct categories for the tubes were established based on the distribution of initiation times calculated from the initiation-time model. Examples of tubes falling within these groups are shown in Figure 2.

For the majority of the tubes with TTW, most TTW initiations were calculated by the model to occur early in Cycle 16. Approximately 85% of the tubes showed this behavior where the distribution is biased (skewed) towards zero initiation time, and the calculated median initiation times were less than about 0.3 years at power. Examples of tubes that exhibited this bias towards early initiation times are shown in Figure 2a (Group A).

Approximately 10% of the tubes have median initiation times approximately mid-way through the cycle as shown in Figure 2b (Group B). In this case, the median times fell within 0.3 to 0.6 years at power.

Tubes with initiations beyond mid-cycle range (> 0.6 years at power) are shown in Figure 2c (Group C). For very few tubes, typically tubes with very low wear indices and/or few affected anti-vibration bars (AVB), very late initiation times and unrealistically high TTW growth rates are calculated. These occurrences are not strongly related to the AVB wear index and are more likely caused by impacts from unstable neighbor tubes. There were only a few instances (less than 5% of the tubes) where this was observed.

The characteristics of tubes and the individual group categories are important in understanding the overall population of wear rates and the source of uncertainties. The Group A tubes exhibited early initiation times in Cycle 16. Group A tubes were the most challenging to tube integrity for Unit 3 since these tubes had the largest TTW depths as shown in Figure 3; both on an average basis and the observed extremes. For the in situ pressure testing (ISPT) performed on Unit 3, 126 out of the 130 tubes tested were Group A which included the 8 tubes that did not pass ISPT.

Less severe were the Groups B and C tubes as evident in the distribution of depths (Figure 3). Four ISPT tubes were from Group B and all 4 passed. None of the Group C tubes required ISPT. The Group C tubes and some Group B tubes had row/column locations that placed them at the ends of a column with a continuous string of tubes with TTW. These tubes are most likely victim tubes which didn't go unstable on their own but suffered impacts from a neighboring unstable tube. In such cases, it is not expected that the initiation times calculated for these tubes will be correct for all trials in the simulation.

Distribution of Wear Rates

A plot showing the simulated TTW growth rate results for the 161 tubes is shown in Figure 4. The calculated wear rates are plotted versus the wear index for each tube. All three groups show scatter in wear rate values, which is most notable in both number and magnitude for Groups B and C. About 2% of the simulations produced wear rates exceeding 200% through wall (TW) per years at power.

The Group A tubes exhibited early initiation times and cover the full range of wear indices. It is expected that because of the broad coverage, the Group A tubes reflect instability conditions. A few trials produced very high wear rate outcomes again due to calculated initiation times near the end of the cycle period.

The Groups B and C tubes fall under a narrower range of wear indices, especially the Group C tubes. Results from these tubes will produce wear rates that are outliers if the tubes were not unstable but are victims.

As mentioned earlier, the extreme wear rates are created by TTW depths being divided by growth periods approaching zero (i.e., those simulations producing initiation times near the end of cycle period of 0.926 years at power). This behavior is shown in Figure 5 where the TTW rates begin to accelerate when the initiation times exceed 0.6 years at power. It is likely that these extreme values are a mathematical artifact of the simulation model.

Unit 3 Benchmark Process

A benchmark comparison has been developed which provides comparisons between alternative model projections of Unit 3 TTW depth data and the actual NDE measured values. The comparisons include those between overall depth distributions, upper-tail distributions, and extreme-value distributions as produced by the candidate models. The latter comparison provides the most important metric regarding the ability of a given model to predict the structural integrity of the worst flaw present. The extreme-value distribution also provides a quantifiable measure of the relative conservatism of a model relative to the worst observation contained in a benchmark data set.

The Unit 3 benchmark model consists of a Monte Carlo simulation which creates data sets from a chosen model for comparison with a selected benchmark data set. In this case the benchmark data consists of the 161 measured TTW depths obtained from 3E-088. This was the most severely affected of the Unit 3 steam generators. The simulation convolutes a growth rate distribution with a random TTW initiation-time function to produce a distribution of predicted TTW depths which can be compared with the benchmark.

Figure 6 shows the basic benchmarking model logic which is a modified parameter estimation process in which simulated data sets obtained using Monte Carlo methods are compared with a known data set. In the simulation process, the adjustable parameters are those of a global lognormal growth rate distribution. The initiation-time distribution was that for the full data set of discrete times.

Following the iterative procedure shown in Figure 6, the lognormal distribution parameters were varied until an acceptable estimate of the depth distribution was achieved. This occurred when Ln[Mean] equaled 3.89 and Ln[StDev] equaled 0.37. This lognormal distribution represents the global wear rate behavior that produces the observed Unit 3 depths and serves as a target wear rate model to compare with other model results. The benchmark comparison is shown in Figure 7. The dotted red line is the depth distribution from the benchmark simulation which agrees well with the NDE depth distribution for 3E-088.

Predicted Unit 3 Depth Distribution

The benchmark process was again used to evaluate the specific wear rate results from the median-time and discrete-time simulations. The discrete-time model fully represents all of the simulated initiation-time results (161,000 data points). As discussed, the difficulty of using all discrete values to infer wear rates is the possibility of extremely high predicted wear rates for TTW that initiates near the end of the cycle (see Figure 5). This was a particular problem for Group C tubes. The median-time model was initially developed in response to the mathematical difficulty with the discrete-time model. In this case, the initiation-time distributions for each tube were replaced by the median value of the distribution. This increased the numerical stability of the growth rate computations with little loss of fidelity in the overall initiation-time distribution (Figure 1).

Each of the above initiation time models provides descriptions of two distributions for the Unit 3 benchmark model. A Beta distribution was used to represent the initiation-time distributions 3E-088 in Figure 1. The global wear rate distributions were obtained from overall fits to the initiation time model data sets for the wear rates. In the case of the discrete-time model this set consists of 161,000 data points. No points are eliminated (uncensored) in the present benchmarking process for this model. In the case of the median-time model the set is reduced to 161 points.

The lognormal parameters for these two models and the target benchmark case are:

Wear Rate Model	Ln [Mean]	Ln [Std Dev]
Unit 3 Benchmark Target	3.89	0.37
Discrete-Time (161,000 points)	3.97	0.57
Median-Time (161 points)	3.91	0.46

As can been seen, these lognormal parameters provide faster growth rates (conservative) than the target benchmark goal shown in Figure 7.

The results of the benchmarking process are shown in Figure 8 and Figure 9. Figure 8 shows the overall distributional comparison of the two models with the Unit 3 benchmark. Both of the models studied are conservative in the upper-tail region with regard to the Unit 3 benchmark.

The extreme-value benchmarks are shown in Figure 9 for the both models. As can be seen from the figures, the median-time model provides a mean estimate of the worst depth of about 120% TW which is conservative compared to the maximum NDE depth of 99% TW. A depth of 100% TW represents a lower 5% probability estimate for this model. The discrete-time model is more conservative and gives a mean extreme depth of 180% TW and a corresponding probability of having 99% TW depth that is very remote (<0.09%).

Summary

Following is a summary of this assessment:

1) Both the median and discrete time models give conservative estimates of the Unit 3 NDE depths when sampling from their respective initiation-time distributions as shown in Figure 1.
2) The discrete-time model produces some wear rate outcomes that are not realistic. These outcomes represent outliers in the initiation-time simulation process caused by very late initiation times (divide by near-zero growth intervals as shown in Figure 5). Sampling from the discrete-time distribution produces extreme wear rates that are unreasonable.
3) Benchmark calculations based on a global wear rate using discrete-time values over predicts the 3E-088 TTW depths in the upper tail and in the extremes.
4) Use of the median initiation times is conservative and gives a better benchmark with Unit 3 depths for the same benchmark model conditions.

In the context of the three questions contained in RAI 71, the following answers are provided from the findings of this evaluation:

Why is it conservative to consider a median value of initiation time for each tube, rather than sampling from the distribution of initiation times developed for each tube during a given Monte Carlo trial of the tube population?

Sampling the distribution of median initiation times for each tube resulted in a conservative estimate of the Unit 3 wear depth. This is a direct consequence of the diversity in distributional form exhibited by the individual tube initiation time samples shown in Figure 2. Because of the diversity among the individual tubes, the cumulative distribution for median initiation times covers the full range of this key variable and is comparable to the distribution of individual initiation times.

Would sampling the distribution of initiation times for each tube be a more conservative approach, as it would be expected to stretch out the tails of the resulting overall probability distribution for not meeting the 3 delta P criterion?

Both the median and discrete time models give conservative estimates of the Unit 3 NDE depths. Use of all outcomes from the full simulation (uncensored discrete times) does produce a more conservative representation of wear rate than the median-time model. But as shown in the benchmark calculations (Figure 8), the resulting global wear rate when discrete time values are used over predicts the TTW depths observed in Unit 3 in the upper tail and in the extremes. Use of the median initiation times is conservative and gives a better benchmark with Unit 3 depths under these conditions.

For a probabilistic assessment such as this, what is the justification for not considering a potentially large source of uncertainty associated with a key input parameter?

The discrete data set of initiation times produces wear rate outcomes that are not realistic. These outcomes represent outliers in the initiation-time simulation process. Most of the large extreme values are the result of the few tubes at row/column locations that are at the end of column strings. These tubes were not challenging to tube integrity but produce outcomes of mathematically high wear rate values because of simulated initiation times approaching 0.926 years at power (divide by zero issue). Considering these outliers in the treatment of uncertainty and the determination of error estimates does not replicate the Unit 3 behavior.

The potential source of uncertainty associated with the TTW initiation times is considered and included in the OA. Despite the difference in the treatment of the simulated initiation times, the median time model does a better accounting of the uncertainty since it gives a better benchmark. The ability of the distribution of median times to produce a similar distributional behavior for the full simulated data justifies its use in the OA.

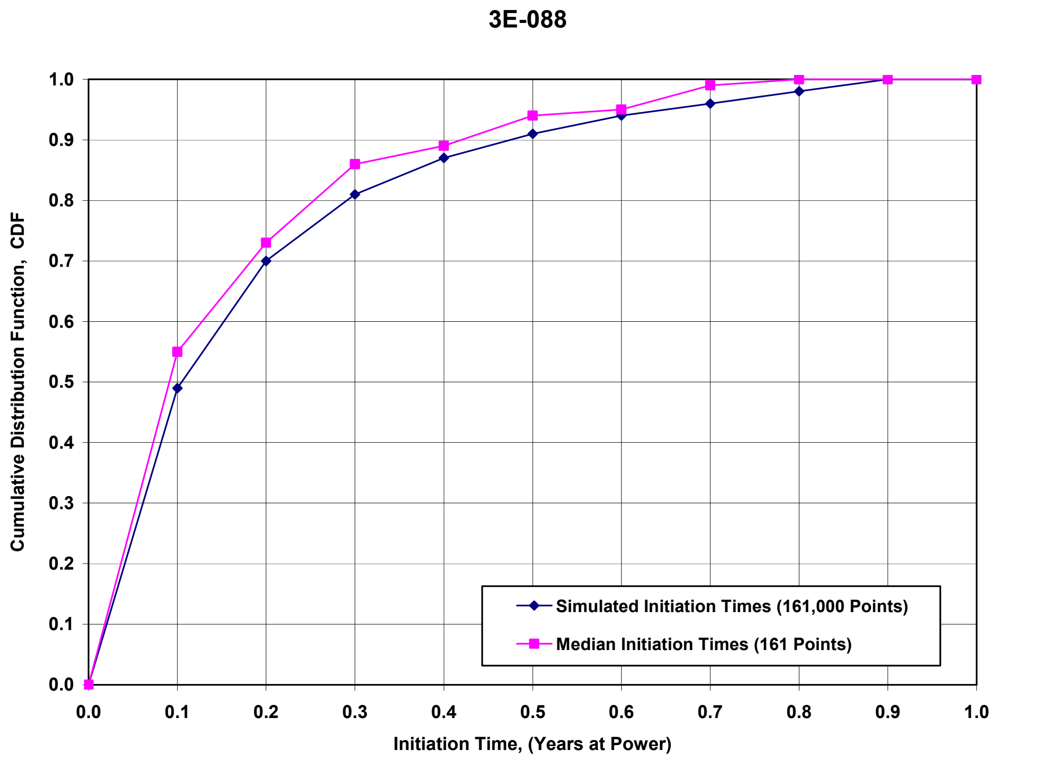
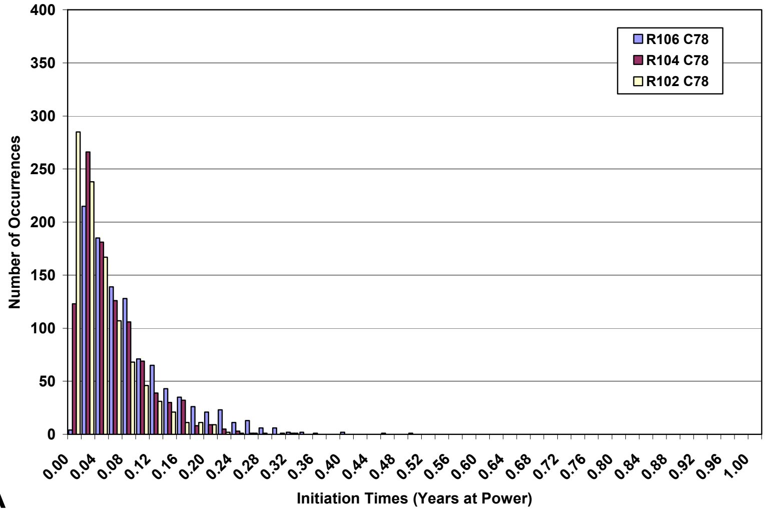
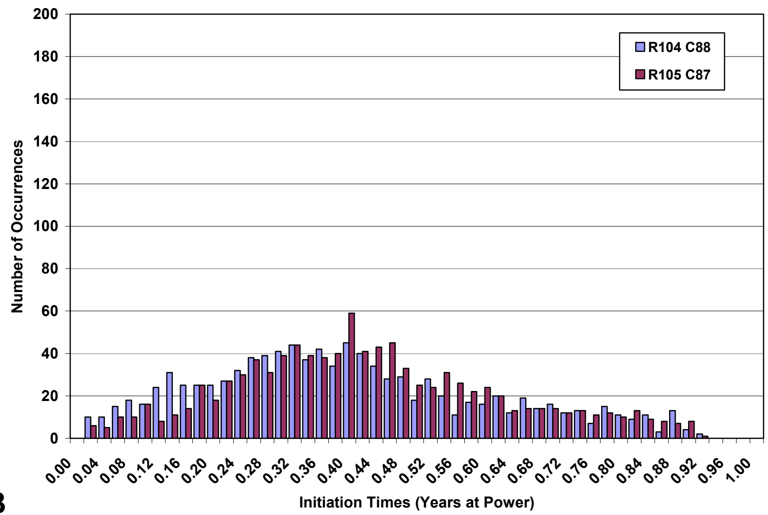


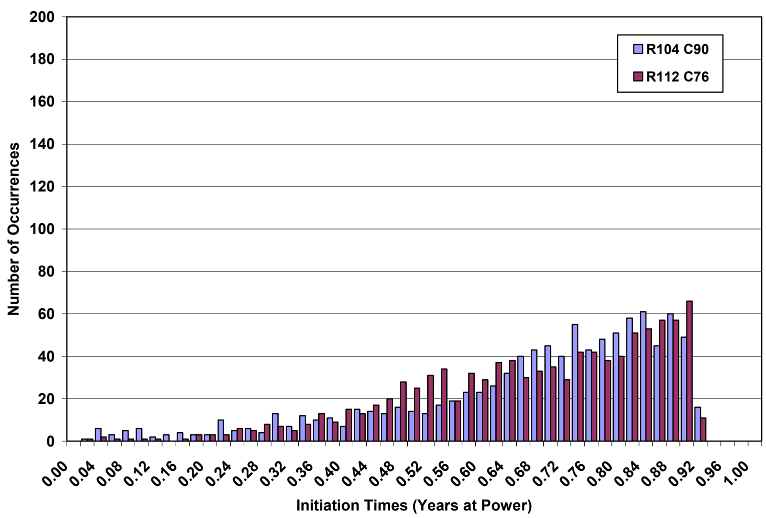
Figure 1 – Cumulative Distributions for Initiation Times for 3E-088 (Median vs. All Data)



a) Group A



b) Group B



c) Group C

Figure 2 – TTW Initiation Times from the Simulation for Selected 3E-088 Tubes

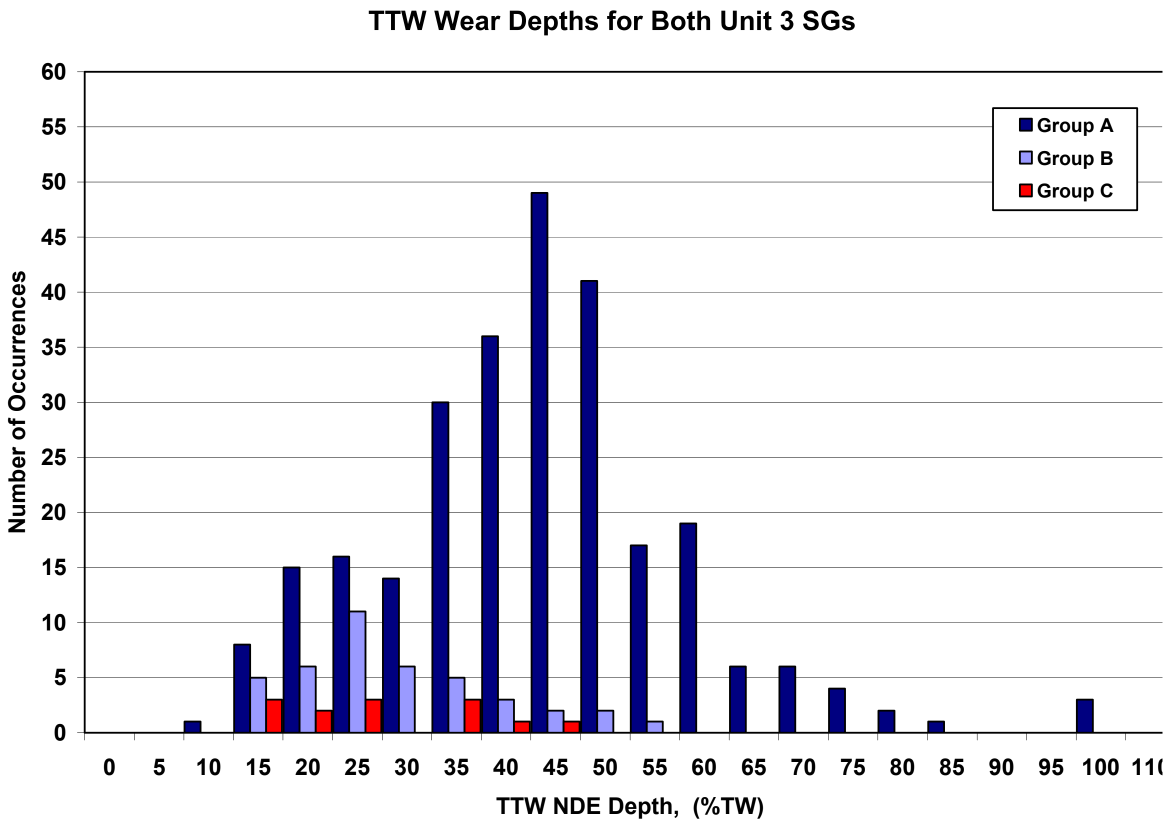


Figure 3 – Histogram of Maximum NDE Depths for the Three Tube Categories

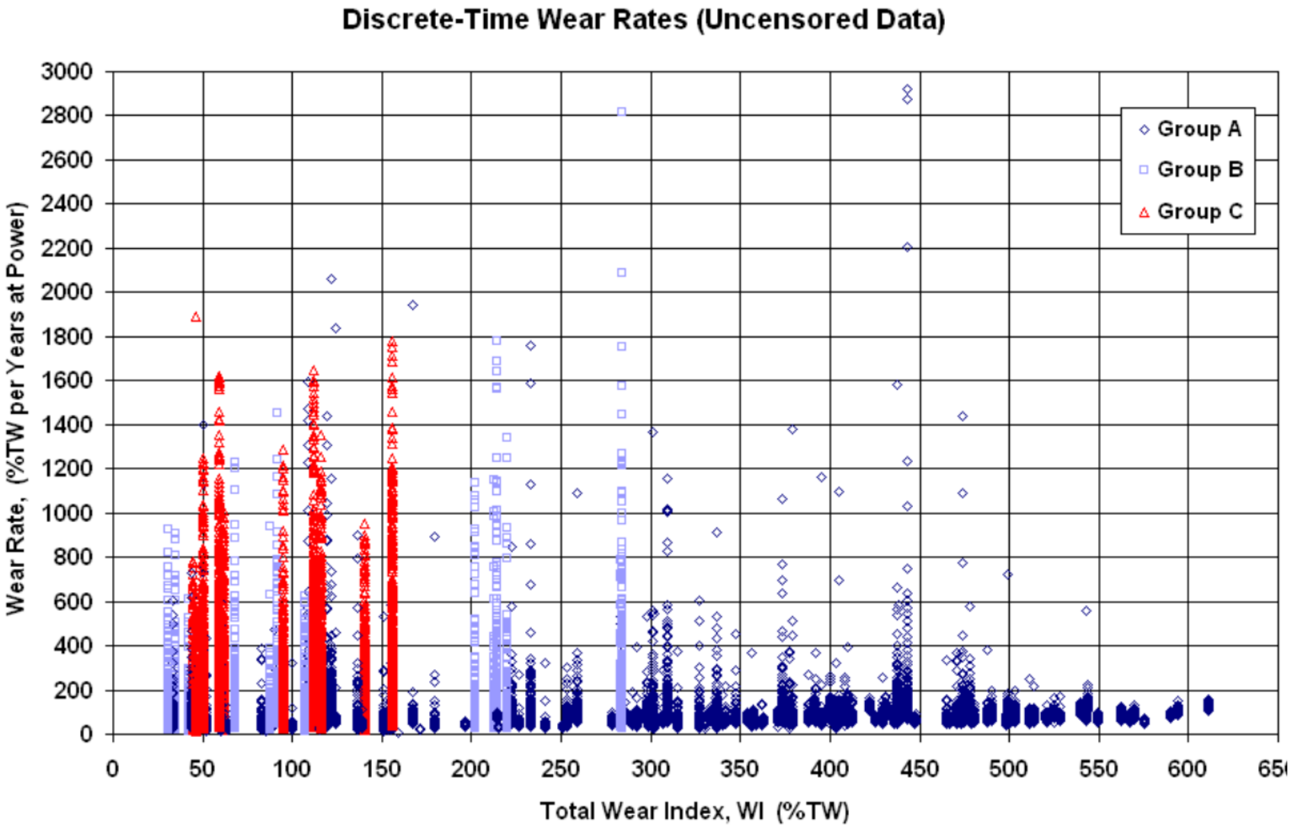


Figure 4 - Discrete Wear Rates Derived from Initiation-Time Model for 3E-088

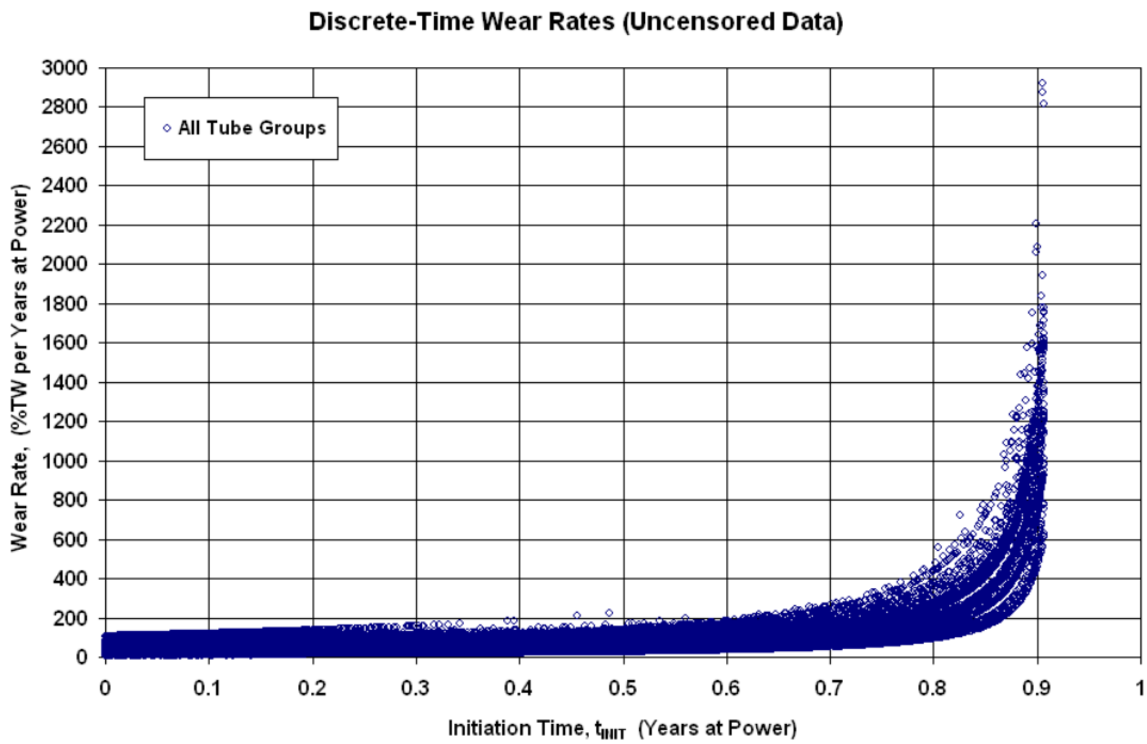


Figure 5 – Wear Rate as a Function of Initiation Time

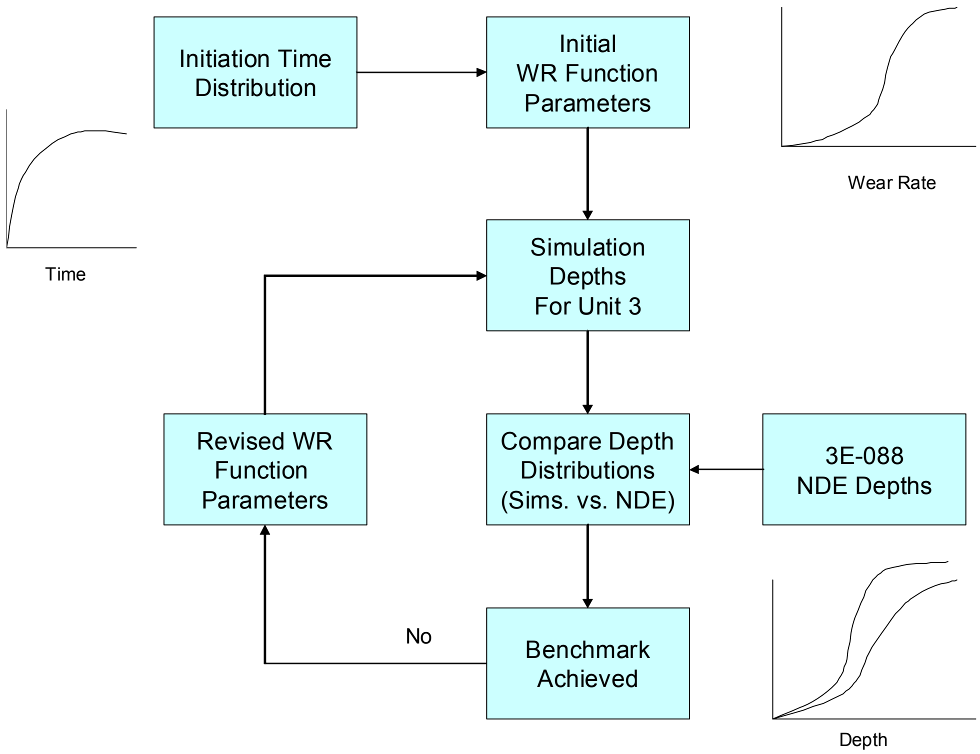


Figure 6 - Flowchart for Unit 3 Benchmark Process

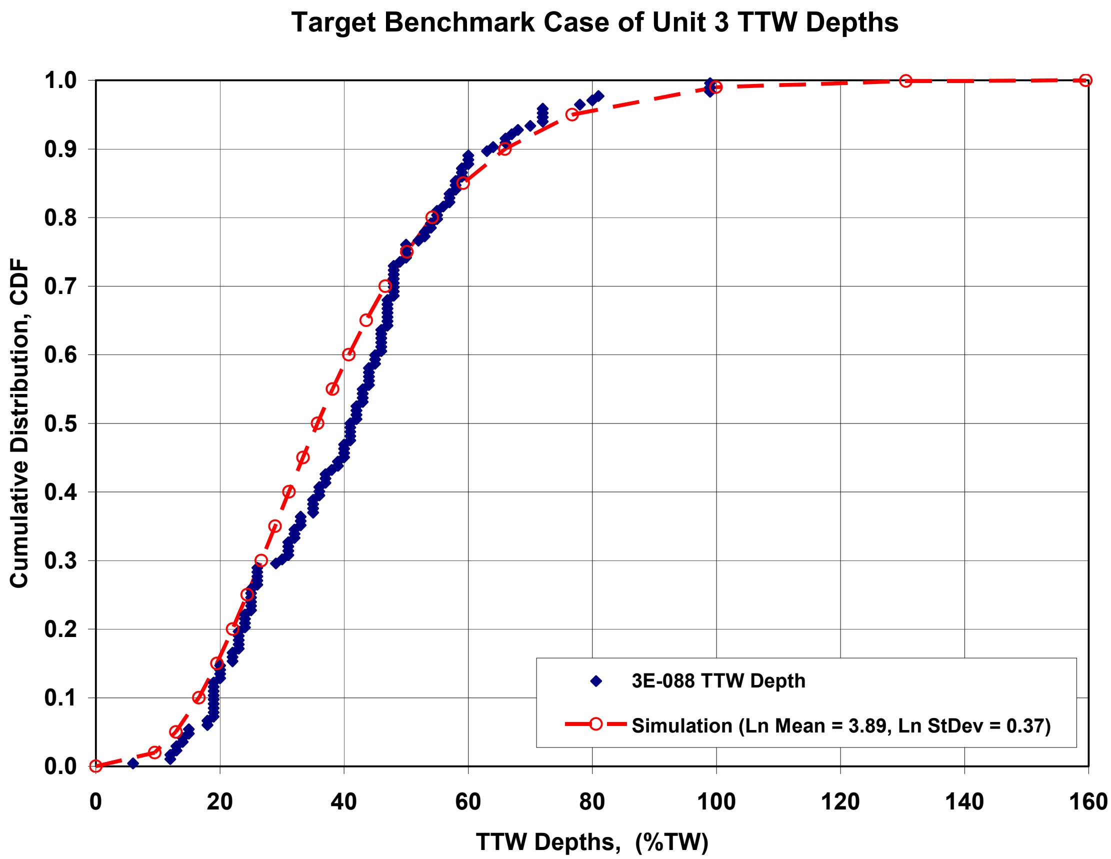


Figure 7 - Parameters for a Lognormal Wear Rate Model that Best Benchmarks the Maximum NDE Depths in 3E-088 (Discrete Initiation Time Data Set)

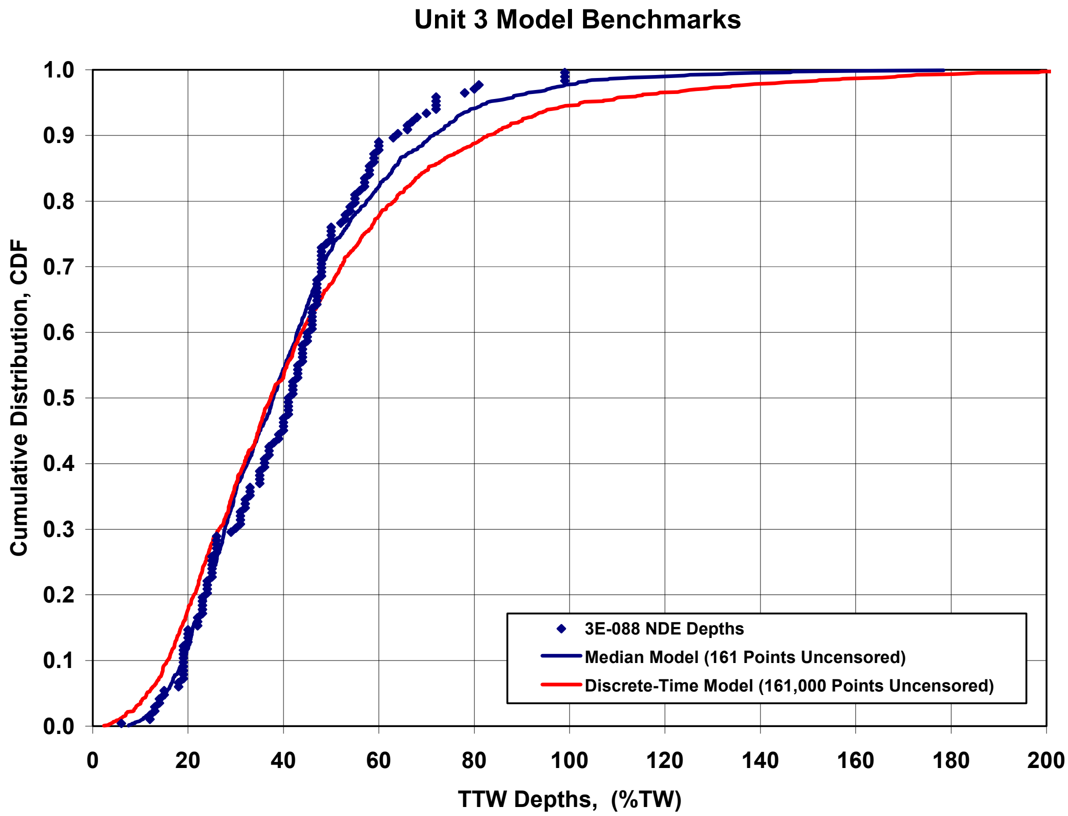
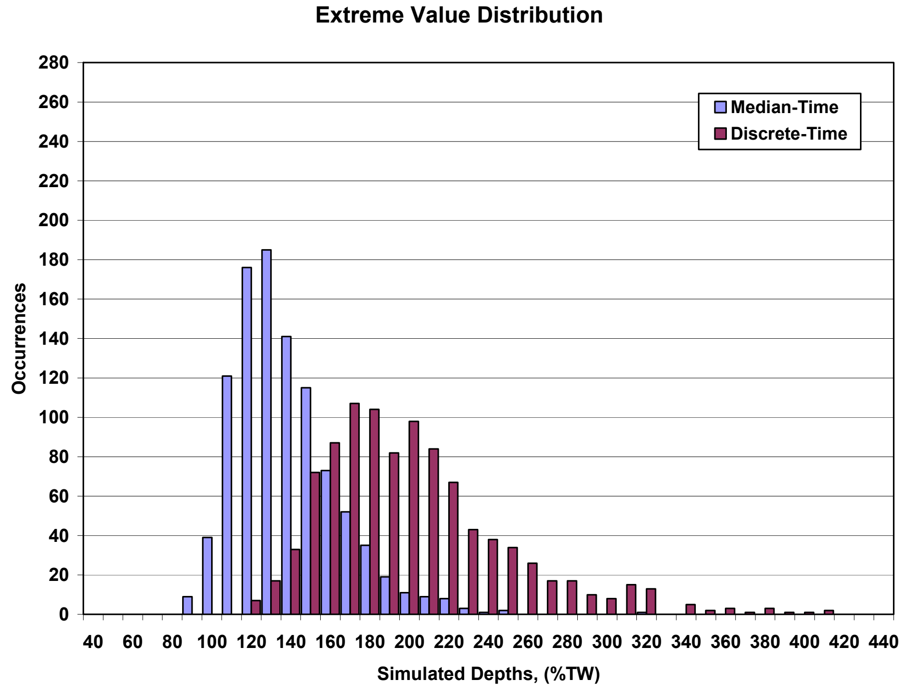
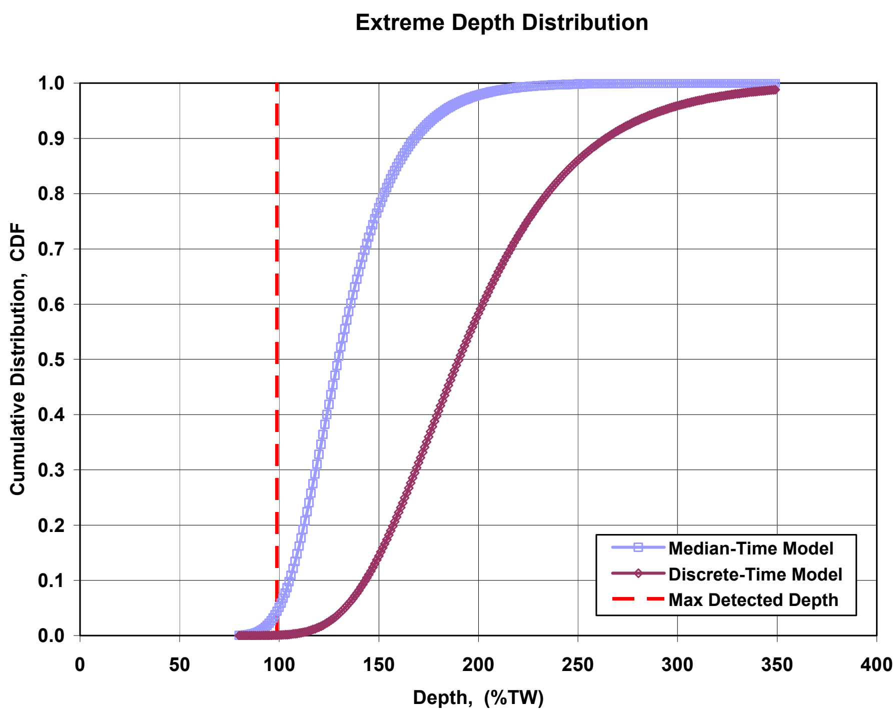


Figure 8 - Simulated Depths for Discrete-Time and Median-Time Based Models



a) Data Histogram



b) Cumulative Distribution

Figure 9 - Extreme Depths for Discrete and Median-Time Based Models: a) Data Histogram and b) Cumulative Distribution