XN-NF-79-6(NP)

AMENDMENT 1

EXXON NUCLEAR ANALYSIS OF POWER DISTRIBUTION MEASUREMENT UNCERTAINTY FOR WESTINGHOUSE PWR'S

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EXXON NUCLEAR COMPANY, Inc.

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UNCERTAINTY FOR WESTINGHOUSE PWR'S

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1.0 INTRODUCTION

Exxon Nuclear Report XN-NF-79-6 (P & NP), "Exxon Nuclear Analysis of Power Distribution Measurement Uncertainty for Westinghouse PWR'S," was submitted in March 1979 for review by the NRC. Subsequently, requests for additional information were received from the NRC by letters dated November 15, 1979 and January 25, 1980. This Amendment to XN-NF-79-6 (P & NP) provides Exxon Nuclear's responses to these Requests for Additional Information.

2.0 RESPONSES TO REQUEST FOR INFORMATION - NRC LETTER DATED NOVEMBER 15, 1979

Q1. The determination of the measured distribution is dependent upon the measured activation rates in various instrumented thimbles. What criterion is used to determine whether or not a U-235 fission chamber detector is operating properly and giving valid readings?

A1. The determination of whether or not a U-235 fission chamber is operating properly and giving valid readings is performed by plant personnel performing the measurement. The uncertainty analysis utilized maps which typify the measurement process. The maps used were those taken for the purpose of satisfying Technical Specifications regarding power distributions. The detector conditions are, therefore, typical of the conditions to which the uncertainty analysis [illegible] to apply. Utilization of these maps ensures that the analysis encompasses utility actions to ensure proper detector operation.

Q2. How is soluble boron concentration taken into account in the calculated power and activation distributions input to the DETECTOR or INCORE codes?

A2. The calculation of the power and activation distributions uses the calculated critical boron concentration at the exposure for which the calculation is performed. The calculations are performed with the code PDQ. The calculated power and activation distributions thus contain the effect of the boron concentration. The accuracy of the power and activation distributions is not extremely sensitive to the boron concentration; and this is, therefore, not a critical factor in the uncertainty analysis.

Q3. What procedure is applied by the DETECTOR or INCORE code if the control bank position lies part way within the axial node being considered?

A3. Control rod positions in DETECTOR are forced to be an integral number of axial nodes. For rod insertions less than halfway into a node, that node is assumed to be completely unrodded. For rod insertions more than halfway into a node, that node is assumed to be completely rodded.

Q4. What procedure is applied if the calculated power and activation rates do not correspond to the exact core burnup and boron concentration during the measurement?

A4. Two procedures are available if the calculated power and activation rates were not generated at the exact core conditions in terms of boron concentration and exposure. Which procedure is utilized depends on the capabilities of the version of DETECTOR or INCORE that a utility has. One: the calculated factors are supplied at equal exposure intervals and the set of power and activation rates closest to the plant exposure is chosen. Two: two sets of calculated power and activation rates are input at exposures above and below actual plant exposure, power and activation rates at the plant exposure are then determined by interpolation on exposure. The uncertainty analysis was performed using the first method. This method is less accurate than the second method, and thus, the resulting uncertainty will conservatively apply to the second method. Boron concentration effects are included through the use of the calculated critical boron concentration at each exposure at which the power and activation rates are supplied.

Q5. Weighting factors are used to infer power at an uninstrumented assembly from measured values of an instrumented assembly. Is the same procedure used for two symmetric assemblies, one instrumented and the other uninstrumented? Describe how data from an instrumented assembly is weighted and used to infer power at a symmetrically oriented uninstrumented assembly of the same nuclide composition.

A5. The procedure described in Section 3.1 of the report is applied to all assemblies irregardless of whether a symmetric instrumented assembly exists. The influence of a particular thimble on assemblies in the core is limited to those assemblies within a specified radius of the thimble. The most commonly used radius, and the one for which the analysis applies, is $\sqrt{2}$ assembly pitches. Data from an instrumented assembly in one quadrant is not used to infer power at a symmetrically oriented uninstrumented assembly.

Q6. Describe the curr[illegible] followed on the frequency of updating the constants used in [illegible]urement processing codes.

A6. The frequency of updating the constants depends on whether a utility has a version of DETECTOR or INCORE which can interpolate between sets of constants. If the code cannot interpolate, constants are updated at 1,000 MWD/MT intervals; if the code can interpolate, constants are updated at 2,000 MWD/MT intervals.

Q7. Describe any detector instrument problems which may be encountered during flux maps (such as drift) and how these problems are treated.

A7. Detector instrument problems are handled by the plant personnel performing the flux map measurements. Plant personnel indicate that there are two common problems encountered during mapping. These are detector linearity of response to flux levels and drift due to temperature variation of the detector. Detector linearity is typically achieved by determining the voltage plateau of each detector prior to taking a map. Drift due to temperature variation is commonly eliminated by warmup passes for each detector prior to taking a map.

Q8. Please note that the reference to Equation 4.7 and 4.8 in the middle of page 21 should read Equation 4.8 and 4.9 instead.

A8. Noted.

3.0 RESPONSES TO REQUEST FOR INFORMATION - FROM NRC LETTER DATED JANUARY 25, 1980

Q1. On Page 22, the relative standard deviation of a positive random variable x is apparently defined as the variance of ln x, but the discussion confuses the concepts of parameter and random variable and uses an approximation as an exact value. On the first line, x is termed a "parameter", but standard deviations only are meaningful when applied to random variables. The expression for σ_y^2 *on the fourth line is an approximation for small x and the fifth line should read*

$$\sigma_y^2 = \frac{\sigma_x^2}{E(x)^2}$$

Where the approximation holds provided that $\sigma_x \ll E(x)$*. Please comment on this and on the effects of using the concept of a relative variance, defined as* $\sigma_x^2 / E(x)^2$*, and its square root* $\sigma_x/E(x)$*, which is the coefficient of variation, instead of the relative standard deviation.*

A1. On the bottom line on Page 21 and the top line on Page 22, the word "Parameter" should be replaced by "Random Variable". The equality signs on Lines 4 and 5 should be replaced by approximate equality signs ($\approx$). In Line 5, replace x by E(x).

The approximation leading to the key results assumes that the function $y = \ln x$ can be approximated by the linear terms of a Taylor's series expansion about the mean of x, E(x) or μ.

$$\ln x \approx \ln \mu + (x-\mu)/\mu$$

For example, if $\mu = 2$ and $x = 2.04$, then

$$\ln x = \ln(2.04) = 0.71295$$

$$\ln \mu + (x-\mu)/\mu = 0.69315 + 0.02 = 0.71315$$

In this example, the ratio of the approximate to the exact value is 1.00028.

This approximate expression for ln x is a good approximation if $|x-\mu|/\mu$ is not "too large". This quantity will not be too large if σ_x is "small" relative to μ. In the application in question, σ_x is quite small in a relative sense, certainly less than 5% of μ. Thus, the approximation is judged to be adequate.

The staff question in the last sentence of I+ 1 is not clear. If the question concerns our calling σ_x/μ, a "relative standard deviation" rather than a "coefficient of variation", then we point out that these terms are interchangeable. (See, for example, Page 333 of NBS300, Volume 1, which is a reprint of H. H. Ku's paper, "Notes on the Use of Propagation of Error Formulas", J. of Res. of The National Bureau of Standards - C. Eng. and Inst., Vol. 70C, No. 4, Oct.-Dec.-1966).

Q2. Equation (4.6) is presented as an equality when it is at best an approximation. Please give the details of the derivation and discuss the error in the approximation. In particular, if N_d is sufficiently large, the term involving N_d may be smaller than the error made in using Eq. (4.6).

Q3. Please provide a detailed mathematical model for the method of combining the individual components of Spm/P^m discussed on Page 25.

A3. The method of combining the individual components of S_pm/P^m is explicitly given by Equation (4.6). As was pointed out in the derivation, independence among the random variables was assumed. It is not required that the components be normally distributed in order to calculate S_pm/P^m by error propagation. However, the normality assumption is required when interpreting the standard deviation, i.e., when constructing the tolerance interval.

Q4. The last paragraph on Page 25 claims that a mixture of normals is "adequately described by the normal distribution". This is true only if all the mixture components have approximately the same mean and variance. Even if the combined distribution passes a test for normality, it may be misleading to proceed on the assumption of normality if, as is the case here, it is a tail of the distribution which is of interest. A distribution with a significant departure from normality in a tail may pass a test for normality. Please comment on this observation in view of your assumptions used in the section on coupling factors.

A4. The staff comment appears to reflect a misunderstanding of the subject paragraph. The mixture components do, in fact, have the same means, since the means of the subpopulations are random variables distributed about zero (i.e., zero discrepancy from nominal). Further, each subpopulation has the same variance, and so the conditions necessary for the statement in question to be valid do, in fact, exist.

We believe that the staff places undue emphasis on the importance of the test for normality. We do not attempt in any sense to "prove" normality through application of this test. Rather, the model assumptions, whose validity we have no reason to question, would dictate that the resulting random variable be normally distributed. The normality test is simply a confirmatory exercise to see if the data are supportive of the hypothesized model.

Q5. A chi-square test was used to test for normality on Page 26. Please discuss the merits of this over the W test or the D' test American National Standard Assessment of the Assumption of Normality (Employing Individual Observed Values), ANSI N15.15-1974.

A5. We are certainly aware of other tests for normality, but have no concerns about applying the familiar chi-square test in this instance. The drawback of the chi-square test is its insensitivity in detection when small numbers of observations are involved. Although we consider it inadvisable to apply this test when N<50, and would apply the W-test in this case, for N = 160-180, as in this application, we feel that the chi-square test, though perhaps not "optimum" in a statistical sense in detecting specified kinds of non-normality, is adequate. This is especially so when the normality test is not intended in any sense to "prove" normality. (See discussion under Point 4.)

Q6. The conclusion stated in the first paragraph on Page 26 does not appear to be correct. If the observed value of x^2 is exceeded only with the probability given, this is rather strong evidence that the population from which the data is drawn is <u>not</u> normal. Please comment on this observation.

Q7. In view of the preceding comments, please provide discussion justifying the use of the normal-based tolerance limit used on Page 31 ff, rather than a nonparametric tolerance limit (cf. W. J. Conover, Practical Nonparametric Statistics, Wiley, 1971).

A7. We believe that the discussion under Points 4, 5, and 6 provide ample justification for the use of normal-based tolerance limits.

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