NRC FORM 658
(9-1999)

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DATE OF MEETING
01/31/2001

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Docket Number(s)	**PROJECT NO. 669**
Plant/Facility Name	**EPRI**
TAC Number(s) (if available)	
Reference Meeting Notice	**JANUARY 18, 2001**
Purpose of Meeting (copy from meeting notice)	**DISCUSS "GUIDELINES FOR ADDRESSING FATIGUE ENVIRONMENTAL EFFECTS IN A LICENSE RENEWAL APPLICATION"**

NAME OF PERSON WHO ISSUED MEETING NOTICE	TITLE
L. N. OLSHAN	**PROJECT MANAGER**

OFFICE
NRR

DIVISION
DLPM

BRANCH
PD II-1

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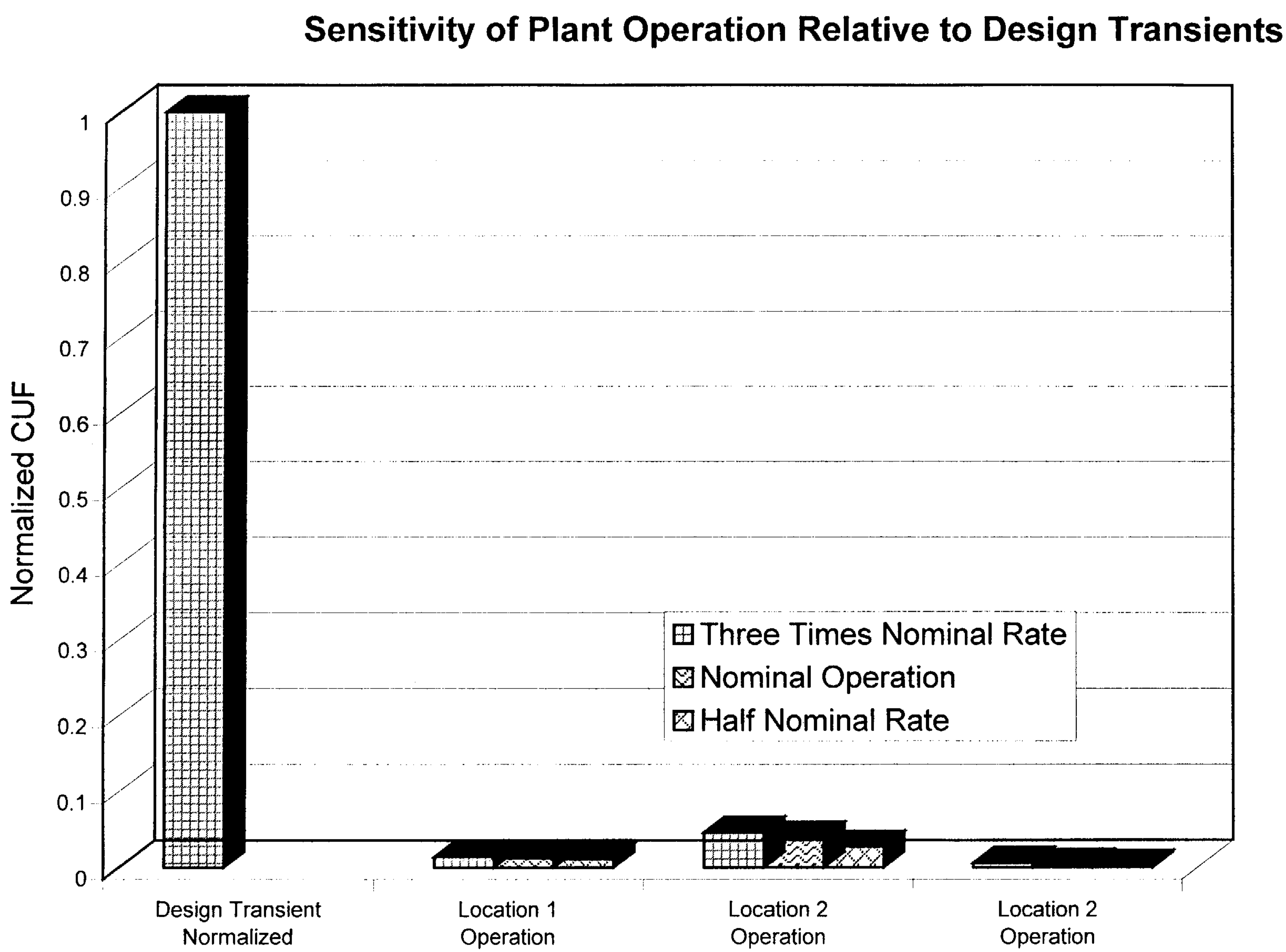

Sensitivity of Plant Operation Relative to Design Transients
Normalized CUF
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Three Times Nominal Rate
Nominal Operation
Half Nominal Rate
Design Transient Normalized
Location 1 Operation
Location 2 Operation
Location 2 Operation

Robert E. Nickell
EPRI Consultant

Fatigue Environmental Effects Data Evaluation

Staff Concern # 2

- Industry has shown that the data scatter for laboratory simulations of reactor water environmental effects is relatively small at strain rates of the order of 0.4 %/sec, where the environmental effects are moderate. However, if the data scatter for more severe environmental effects is large, the basis for a moderate environmental effects Z-factor is not supportable.

Industry Response

- The industry has analyzed the more severe environmental data carefully, separating the confounding effects of the increasing environmental effects from the data scatter. When this confounding effect is eliminated, the data scatter for the more severe environmental effects is also very small, much less than has been postulated.

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Fatigue Environmental Effects Data Evaluation

Need For Z-Factor

- *PVRC Recommendation*

  The equations used to fit the laboratory-simulated environmental fatigue data do not revert to the equations used to fit laboratory air data when moderate environmental thresholds are met. Instead, even for testing conditions such that simulated reactor water environmental effects are minimal, the equations contain an "environmental shift" much greater than 1. For example, the equation that fits reactor water environmental fatigue data for austenitic stainless steels predicts an asymptotic environmental shift of 2.55, even for temperatures below the environmental threshold.

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EPRI Consultant

Fatigue Environmental Effects Data Evaluation

Interpretation of Recent Japanese Data

- K. Tsutsumi, et al., "Fatigue Life Reduction in PWR Water Environment for Stainless Steels," in: PVP-Vol. 410-2, pp. 23-34, presented at ASME PVP 2000, Seattle, WA, July 24-27, 2000.
- Data scatter for test data in air is about a factor of 2 on cycles at the low-cycle end of the fatigue curve. Japanese researchers have suggested that data scatter in water environments is about a factor of 5. If so, no part of the ASME Code factor of 20 is available to account for moderate environmental effects. The rest of the factor of 20 is allocated to surface roughness, etc.
- Actual data scatter is much less, provided that apples and oranges are not mixed.
- The measure of data scatter is chosen here to be the ratio of the standard deviation to the mean value of a given population.

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EPRI Consultant

Fatigue Environmental Effects Data Evaluation

Interpretation of Recent Japanese Data

- Consider data on austenitic stainless steel specimens at strain amplitudes of 0.58 %, 0.585 %, 0.59 %, 0.595 %, 0.60 %, 0.605 %, and 0.61 % (66 data points) at temperatures of around 300°C.
- Two populations -- relatively low strain rate (43 data points) and relatively high strain rate (0.4 %/sec) (23 data points).
- For the relatively high (0.4 %/sec) strain rate population, the mean value was 1,733 cycles, with a standard deviation of 608 cycles; the ratio is 35 %.
- For the relatively low strain rate population, the increasing environmental effect with decreasing strain rate confounds the data scatter analysis.
- In order to separate environmental effects from data scatter, the ANL reactor water environment data fitting formula is used.

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EPRI Consultant

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Interpretation of Recent Japanese Data

- For the population of relatively low strain rate data, the ANL environmental data fit expression was used to shift the cyclic life to a strain rate of 0.4 %/sec:

$$\ln(N) = 5.768 - 2.030 \ln(\varepsilon_a - 0.126) + T_2^* \eta_1^* O^*$$

where the transformed strain rate is

$\eta_1^* = 0$, for $\eta_1 > 0.4$%/sec,

$\eta_1^* = \ln(\eta_1/0.4)$, $0.0004 \leq \eta_1 \leq 0.4$%/sec, and

$\eta_1^* = \ln(0.0004/0.4)$, $\eta_1 < 0.0004$%/sec.

- T_2^* and O^* are the transformed temperature and dissolved oxygen (DO), respectively, defined as $T_2^* = 0$, for T < 200°C and $T_2^* = 1.0$ for T $\geq$ 200°C; $O^* = 0.260$ for DO < 0.05 ppm and $O^* = 0.172$ for DO $\geq$ 0.05 ppm.

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- For the 43 data points at strain rates of 0.04 %/sec, 0.01 %/sec, 0.004 %/sec, 0.001 %/sec, 0.0004 %/sec, 0.0001 %/sec, 0.00004 %/sec, and 0.00001 %/sec, the data are shifted to a strain rate of 0.4 %/sec.
- Note that $\eta_1{}^* = 0$ for a strain rate of 0.4 %/sec.
- The mean value for the 43 shifted data points is 1776 cycles (compared to 1733 cycles for the 23 data points actually measured at 0.4 %/sec; the mean values are essentially the same, confirming the accuracy of the ANL data fit.
- The standard deviation for the 43 shifted data points is 826 cycles, slightly greater than the 608 cycles for the 23 data points actually measured at 0.4 %/sec.
- The ratio of standard deviation to mean value is 46.5 %.

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EPRI Consultant

Fatigue Environmental Effects Data Evaluation

Conclusions

- Measure of data scatter (i.e., ratio of standard deviation to mean value) very small for both austenitic stainless steels and carbon/LAS steels when the data populations are divided into a set from relatively high strain rate testing and a set from relatively slow strain rate testing.
- Measure of data scatter is also small when the confounding effect of increasing environmental effect as a function of decreasing strain rate is eliminated in the relatively slow strain rate population data by shifting the data with the ANL reactor water environmental data fitting formulas.
- The findings from this analysis support the recommendations of PVRC that moderate environmental effects factors of 3 for carbon and low-alloy steel, and 1.5 for austenitic stainless steels, are conservative. Greater moderate environmental effects factors can be justified.