Northeast Utilities System

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October 24, 1996
Docket Nos. 50-213
50-245
50-336
50-423
B15928

Re: GL 96-04

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

Haddam Neck Plant,
Millstone Nuclear Power Station, Unit Nos. 1, 2, and 3
Response to NRC Generic Letter 96-04
Boraflex Degradation in Spent Fuel Pool Storage Racks

In reply to the NRC Generic Letter 96-04[(1)] request for information, this submittal provides a response for Northeast Nuclear Energy Company (NNECO) Millstone Nuclear Power Station Units 1, 2 and 3 and Connecticut Yankee Atomic Power Company (CYAPCO) Haddam Neck Plant. All three of the Millstone units currently have some spent fuel storage racks in their storage pools which contain Boraflex. The Haddam Neck plant does not have any Boraflex racks in their storage pools, hence no further response to the Generic Letter is necessary for the Haddam Neck Plant.

The degradation of Boraflex material in spent fuel storage rack panels is a well documented phenomenon within the nuclear industry. NNECO has followed these Boraflex related issues closely, has monitored for Boraflex degradation and assessed/acted on the reactivity consequences. Monitoring of Boraflex degradation is periodically performed by Boraflex coupon testing, "blackness testing", and monitoring of reactive silica concentrations in the fuel storage pools. Assessment of criticality safety margin is determined by performing conservative analytical calculations and assuring that the physical condition of the Boraflex panels in the fuel storage racks is bounded by the assumptions of the physical condition of the Boraflex panels in the analysis.

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(1) B. K. Grimes letter to All Holders of Operating Licenses for Nuclear Power Plants, "NRC Generic Letter 96-04: Boraflex Degradation in Spent Fuel Pool Storage Racks," dated June 26, 1996.

A068/1

NNECO has been an ongoing and active participant in the Electric Power Research Institute (EPRI) programs which have assessed industry Boraflex performance and concerns. NNECO plans to continue this participation with EPRI in the future and will integrate results of EPRI Boraflex programs into the NNECO program based on the applicability of these results to the individual Millstone fuel storage pools. NNECO and EPRI have worked together on several cooperative programs over the past several years. These NNECO/EPRI programs include: (1) the removal of irradiated Boraflex panels at Millstone Unit No. 2 to perform detailed visual inspections of the Boraflex. (2) the insertion and testing of special surveillance coupons at Millstone Unit No. 2 to follow the degradation of Boraflex as a function of gamma radiation. (3) The performance of gamma dose measurements in spent fuel pools to determine the accuracy of gamma dose predictions used to track Boraflex degradation.

Individual responses to NRC Generic Letter 96-04 are provided in Attachments 1, 2 and 3 for Millstone Units 1, 2 and 3 respectively. Descriptions of the Boraflex panel/rack designs, the current analysis being used for criticality safety margin assessment, results of all monitoring and testing programs, and current criticality safety margins are provided.

Should you have any questions on the information provided, please contact Mr. Robert W. Walpole at (860) 440-2191.

Very truly yours,

CONNECTICUT YANKEE ATOMIC POWER COMPANY
NORTHEAST NUCLEAR ENERGY COMPANY

FOR: T. C. Feigenbaum
Executive Vice President and
Chief Nuclear Officer

BY: [signature]
T. L. Harpster, Director
Nuclear Licensing Services

Subscribed and sworn to before me

this 24th day of October, 1996

[signature]

Date Commission Expires: November 30, 2000

cc: Page 3

cc: H. J. Miller , Region I Administrator
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Docket No. 50-245
B15928

Attachment 1

Millstone Nuclear Power Station, Unit No. 1

Response to NRC Generic Letter 96-04

October 1996

Millstone Nuclear Power Station, Unit No. 1
Response to NRC Generic Letter 96-04

Generic Letter Information Request

Provide an assessment of the physical condition of the Boraflex, including any deterioration, on the basis of current accumulated gamma exposure and possible water ingress to the Boraflex and state whether a subcritical margin of 5 percent can be maintained for the racks in unborated water. Monitoring programs or calculational models in effect or being developed, or an estimation of anticipated concerns based on the specific rack design, are considered an appropriate basis for this response.

Response

Description of Boraflex Panels/Racks

The Millstone Unit No. 1 spent fuel storage racks which contain Boraflex panels were designed by Holtec International and manufactured by CBI Services. The racks were installed in the fuel storage pool in 1988 and were first loaded with irradiated fuel in 1989. There are 10 individual rack modules which contain Boraflex panels in the Millstone Unit No. 1 spent fuel pool which provide a total of 1045 storage cells in a 6.3 inch center to center spacing.

Each fuel storage cell is formed from a stainless steel box which has one Boraflex panel between adjacent storage cells. The Boraflex panels are attached to the box in a "picture frame" design which holds the panels in place via stainless steel strips at the top, bottom and sides of the box. They are more fully described in Reference 3, which was previously submitted to the NRC associated with the license submittal which approved the use of the racks. The design of the Millstone Unit No. 1 racks is such that water ingress to the Boraflex material is minimal, with the following exception: The steel strips which hold the Boraflex panels in place, have at 2 elevations, a 4.3 inch high section where the edge of the Boraflex panels is exposed to the water in the pool. These elevations occur at the midplane of the racks and at the top of the racks.

Physical Condition of the Boraflex

The physical condition of the Boraflex panels in the spent fuel storage pool for Millstone Unit No. 1 is determined from monitoring programs consisting of Boraflex coupon surveillances, blackness testing and pool reactive silica concentration data. These monitoring activities provide the primary means for periodically assessing Boraflex panel degradation.

NNECO provided recently to the NRC (reference 5), a detailed description of the current physical condition and testing associated with the Millstone Unit No. 1 Boraflex panels/racks. This information was provided to the NRC concerning a proposed license amendment (reference 4) which was recently approved by the NRC Staff (reference 12). Most of the information presented below is summarized from the information provided to the NRC in reference 5.

The Millstone Unit No. 1 Boraflex spent fuel racks have received very little gamma radiation exposure to date. NNECO has maintained the gamma dose to the Boraflex at low levels by generally not using the Boraflex racks for recently discharged fuel. NNECO currently has a minimum 1 year decay time requirement for fuel prior to being placed in the Boraflex racks. There are other spent fuel storage racks available in the Millstone Unit No. 1 spent fuel pool which do not contain Boraflex, which make it possible to implement the 1 year minimum fuel decay time for the Boraflex racks. The maximum gamma dose to the Boraflex panels is conservatively calculated to be about 2 $x10^9$ rads. Based on EPRI data (references 1 and 2), this is a very low gamma dose that should not produce any significant Boraflex degradation, either from gap formation or dissolution damage.

Boraflex coupon testing to date has shown no significant material loss, and based on neutron attenuation testing of the coupons, no loss of B-10 ability to attenuate neutrons. Attachment 1-1 provides a more detailed summary of coupon testing to date.

A noteworthy item from Boraflex coupon testing in general, is the brittleness of the irradiated Boraflex material. Calculations were performed to ensure that the Boraflex material for Millstone Unit No. 1 would be able to fulfill its reactivity function during a seismic event, given the brittleness of the irradiated material. This was confirmed by mechanical testing of irradiated Boraflex material followed by detailed analysis.

Blackness Testing has shown that the Boraflex has suffered very little damage. Attachment 1-2 provides a more detailed summary of blackness testing performed. To date, 67 of the 1034 usable storage cells have been blackness tested, with 8 of the 67 cells being tested twice. Only 4 of 274 Boraflex panels tested have shown gaps greater than .5 inch. Those 4 panels had gaps of .8 to .9 inch. Another 4 panels had gaps less than .5 inch. However, it is noteworthy that despite the small number of gaps found, about half of these defects were at the mid-plane elevation where the Boraflex edge is open to water. The size of the observable Boraflex gaps is consistent with the gamma exposure to date, and it appears that the gaps may have a tendency to form preferentially at the elevation where the Boraflex edge is open to water. Overall, this minimal damage confirms the low gamma dose to the Boraflex to date.

In summary, data from these monitoring programs indicate the physical condition of the Boraflex panels in the Millstone Unit No. 1 fuel storage pool are within the expected physical condition of panels with similar exposure as described in References 1 and 2. Because of the very low gamma dose to the Boraflex panels to date, the damage to the Boraflex panels is minimal. Gaps have been found in only a few percent of the Boraflex panels, and what gaps have been found are less than 1 inch in size. Dissolution damage to the Boraflex is not believed to be of any significance yet, since the coupon samples do not show dissolution damage or loss of neutron attenuation ability, and the gamma dose to the Boraflex is too low to give any significant dissolution damage based on EPRI data.

Maintaining 5 Percent Subcritical Margin

Maintaining a minimum 5 percent subcritical margin in the spent fuel storage racks which contain Boraflex panels is assured by performing conservative analytical calculations which determine the maximum storage pool reactivity, and verification that the physical characteristics of the Boraflex panels are within the assumptions made in the analysis.

The previously approved Millstone Unit No. 1 technical specifications required a .90 K-effective limit, therefore, a minimum 10 percent subcritical margin in the spent fuel storage racks was maintained. Since Millstone Unit No. 1 is a BWR, no soluble boron is present in the spent fuel pool water. The previously approved criticality analysis was submitted in 1988 (reference 3).

Key assumptions in that analysis include:

- Maximum reactivity fuel in the rack (K-infinity of 1.3499, in the standard core geometry)
- No boron in the pool water
- Highest reactivity water temperature for the pool water (68°F)
- No credit for radial leakage
- No credit for absorption in the assembly structures
- No penalty for Boraflex degradation

The final reactivity of the pool (K-effective) was the calculated reactivity plus the following:

- Calculational uncertainty based on the analytical method
- Allowance for mechanical tolerances

This analysis provided for a design value of K-effective below 0.90. This criticality analysis calculated a maximum K-effective value of 0.895 including all tolerances, uncertainties and postulated accident conditions. This maximum K-effective value

assumes all fuel is at the maximum reactivity, with no penalties for any Boraflex degradation.

The Boraflex degradation observed to date has not resulted in any loss of reactivity function, therefore, the value of 0.895 is still the maximum K-effective of the spent fuel pool. The conclusion that the Boraflex degradation observed to date has not resulted in any loss of reactivity function is based on the following:

(1) Calculations show that even if Boraflex gaps as large as 1 inch occur in <u>every</u> Millstone Unit No. 1 Boraflex panel at the <u>same</u> elevation, the reactivity effect is very small (about .002 delta-k). The current Millstone Unit No. 1 racks have a very small percentage of Boraflex panels with gaps and not all at the same elevation. The resultant reactivity effects of the actual Millstone Unit No. 1 Boraflex gap distribution is insignificant.

(2) Dissolution damage to the Boraflex panels in the racks is more difficult to ascertain. Dissolution damage is inferred not to be occurring to any significant extent based on the Boraflex coupon measurements which have not shown any significant material loss and no loss in measured ability of B-10 to attenuate neutrons. Further, in the case of Millstone Unit No. 1, the gamma exposure to the Boraflex is so low (maximum panel dose of about 2 $x10^9$ rads) that EPRI data would not expect any significant dissolution damage yet. Therefore since no significant Boraflex dissolution has occurred yet, no significant reactivity loss has occurred.

The Millstone Unit No. 1 currently approved (reference 12) technical specifications anticipates some future Boraflex degradation that would affect reactivity. The calculational method of the analysis was fully consistent with the original analysis (reference 3) in terms of the analytical assumptions made, with the exception of allowance for Boraflex gap formation, and the allowed maximum fuel reactivity. The maximum fuel K-infinity allowed in the spent fuel pool is a K-infinity value of 1.24 in the cold standard core geometry. Millstone Unit No. 1 has never had fuel in the spent fuel pool with a K-infinity larger than 1.24. With this maximum fuel K-infinity limit, Boraflex gaps of up to 5 inch in height in <u>every</u> panel can be accommodated even if they are all at the <u>same</u> elevation, and still maintain a maximum K-effective value of 0.896 including all tolerances, uncertainties and accident conditions. The 5 inch axial gap allowance is equivalent to about 3.6% Boraflex height shrinkage. A 4% width shrinkage is also included in the calculations. The maximum Boraflex gap (5 inches) and width shrinkage (4%) values were selected based on EPRI data, which are expected to bound future shrinkage measurements. There are too few gaps at this time to draw a conclusion as to whether the formation of shrinkage induced gaps will be axially random, or will tend to form at the mid plane elevation where the Boraflex edge is more open to water. Therefore, to conservatively ensure that future gap measurements are

bounded by the criticality analysis, we have assumed the worst case, which is that the gaps will form all at the same elevation ("in-line gaps"). By assuming 5 inch "in-line gaps" for every Boraflex panel in the criticality analysis, about 20%-25% of the Boraflex reactivity worth has been lost.

Also as discussed in the response to NRC questions, (reference 5), there is sufficient conservatism in the criticality analysis to accommodate at least 10% uniform thinning (dissolution) of the Boraflex in the proposed criticality analysis.

As shown in reference 4, since there is <u>currently</u> no loss in Boraflex reactivity function, the maximum value of K-effective is .843 for the Boraflex racks in the Millstone Unit No. 1 spent fuel pool, including all tolerances, uncertainties and postulated accident conditions. This value assumes the Boraflex racks are completely filled with maximum reactivity fuel (K-infinity value of 1.24).

In summary, the Millstone Unit No. 1 racks are maintaining a subcritical margin of 10 percent reactivity in unborated water, as required by technical specifications. Further, since the maximum fuel reactivity allowed in the Millstone Unit No. 1 spent fuel pool has been limited to a K-infinity of 1.24, and to date the Boraflex degradation has not affected its reactivity control capability, the maximum pool K-effective is far below 0.90.

Generic Letter Question

Submit to the NRC a description of any proposed actions to monitor or confirm that this 5 percent criticality margin can be maintained for the lifetime of the storage racks and describe what corrective actions could be taken in the event it cannot be maintained.

Response

To maintain 5 percent criticality margin in the spent fuel pool (10 percent criticality margin per Millstone Unit No. 1 technical specifications), the physical condition of the Boraflex panels must be verified to be within the assumptions in the criticality analysis. The monitoring programs which verify this are discussed next.

Monitoring for Boraflex Gaps

Blackness testing is used to verify that the actual Boraflex gap sizes are bounded by the criticality analysis. A summary of the Boraflex Blackness testing program to date for Millstone Unit No. 1 is provided in Attachment 1-2. As discussed in Reference 5, NNECO has committed to performing blackness testing about every 2 years for Millstone Unit No. 1. Performing blackness testing will ensure that the gap assumptions in the proposed criticality analysis (reference 4) are confirmed by the actual gap measurements.

Monitoring for Boraflex Dissolution Damage

Monitoring for Boraflex dissolution damage is performed by 2 methods, Boraflex coupon testing, and use of EPRI's RACKLIFE program to project dissolution damage based on measured Spent Fuel Pool Silica concentrations. As described earlier, at least 10% uniform thinning of the Boraflex can be accommodated by the proposed criticality analysis. This provides an adequate cushion to ensure that dissolution damage is allowed for, to maintain criticality margins.

Boraflex Coupon Testing

A summary of the Boraflex surveillance coupon monitoring program to date for Millstone Unit No. 1 is provided in Attachment 1-1. Boraflex coupon testing to date has shown no significant material loss, or loss of Boron-10 ability to attenuate neutrons. Coupons are currently located in 2 sections of the Boraflex racks. The coupons are intended to be maintained such that they bound the highest gamma dose to the Boraflex panels. Irradiated Boraflex coupons were removed from the spent fuel pool in 1994 and in 1996. The 1994 results are described in Attachment 1-1. Results from the 1996 coupon testing are not yet available. The coupon testing and frequency is controlled by station procedures and will continue as long as Boraflex is credited in the

criticality analysis. Evidence of dissolution damage from coupon tests will be evaluated in combination with RACKLIFE predictions to determine what actions are necessary to maintain the criticality analysis bounding.

EPRI RACKLIFE computer program

Currently, evaluation of the EPRI RACKLIFE computer program is being performed with the expectation to predict the future amount of Boraflex dissolution of individual panels in the Millstone Unit No. 1 fuel storage pool. RACKLIFE uses the measured Silica concentrations in the spent fuel pool (see Figure 1 for Millstone Unit No. 1), along with rack dimensions, pool dimensions, fuel inventory and chemistry information to determine Boraflex dissolution damage. The RACKLIFE program also provides a fuel management tool which will allow evening out the gamma doses to individual Boraflex panels, thus minimizing overall degradation of the Boraflex. Given that the future amount of Boraflex dissolution can be determined, the reactivity loss due to dissolution can be calculated, and the useful lifetime of the Boraflex racks can be predicted. The reactivity change from Boraflex dissolution calculated from RACKLIFE can be used to ensure that adequate allowance has been made in the criticality analysis.

Other means for dissolution damage determinations

Should the Boraflex coupons or RACKLIFE program not be definitive for determination of dissolution damage, 2 additional methods are possible for Millstone Unit No. 1. (1) EPRI's BADGER equipment for in-situ B-10 areal density measurement can be used to provide a determination of the extent of dissolution damage. (2) Millstone Unit No. 1 is planning a partial spent fuel pool re-rack late in operating Cycle 16 (current operating cycle). When this is performed, 2 of the 10 individual rack modules are currently planned to be removed from the spent fuel pool. Selected Boraflex panels can be examined in the 2 removed racks to quantify the dissolution damage for incorporation into the criticality analysis for remaining Boraflex racks.

Corrective actions in the event criticality margin cannot be maintained.

Should any significant degradation of the Boraflex be identified in the future, there are measures which could be taken to assure acceptable safety margins can be maintained. These include administrative controls on fuel loadings and usage, not crediting Boraflex material in the criticality analysis, use of additional fixed poisons, or fuel pool re-racking.

Calculations are currently under way to evaluate using fuel burnup credit instead of Boraflex credit for all Millstone Unit No. 1 Boraflex racks. This is the preferred approach for corrective action, should the required criticality margin not be maintained.

Also, plans are underway to evaluate fuel storage pool re-racking options in the future, including a partial re-rack toward the end of Cycle 16, which removes 2 of 10 Boraflex racks; and a possible further phased re-rack which eventually would eliminate all Boraflex racks from the Milistone Unit No. 1 spent fuel pool. These evaluations are still in progress.

Generic Letter Question

Describe the results from any post operational blackness testing and state whether blackness testing, or other in-situ tests or measurements, will be periodically performed.

Response

Blackness testing is the primary means used to assess gap formation and degradation in the Boraflex panels. Blackness testing has been periodically performed to evaluate gap formation in the Millstone Unit No. 1 Boraflex panels and will continue to be periodically performed in the future.

Blackness Testing has shown that the Boraflex has suffered very little damage. To date, 67 of the 1034 usable storage cells have been blackness tested, with 8 of the 67 cells being tested twice. Only 4 of 274 Boraflex panels in these cells that have been tested to date have shown gaps greater than .5 inch. Those 4 panels had gaps of .8 to .9 inch. Another 4 panels had gaps less than .5 inch. The size of the Boraflex gaps found is consistent with the gamma exposure to date.

To date, there have been two blackness test measurements performed for Millstone Unit No. 1. The results of these measurement are summarized in Attachment 1-2. Although the defect rate in the Boraflex panels determined from blackness testing measurements is extremely small at this time (less than 3%), it appears that a non-random formation of Boraflex gaps may exist at the elevation where the Boraflex edge is exposed to water. Due to the specific design of the Millstone Unit No. 1 Boraflex racks, there is a potential for accelerated gap formation and degradation at the elevation of the 4.3 inch Boraflex edge open to water. Also, a specific area of the pool was found to exhibit most of the gaps. Since this area also has relatively higher flow velocities than other areas of the pool, these observations are not surprising. Blackness testing is currently planned to be performed at about two year intervals in the future. Overall, however, the low gamma dose to the Boraflex to date is consistent with the minimal damage to date.

Generic Letter Question

Chronological trends of pool reactive silica levels, along with the timing of significant events such as refuelings, pool silica cleanups, etc., should be provided. Implications of how these pool silica levels relate to Boraflex performance should be described.

Response

Chronological spent storage pool reactive silica concentration data for the Millstone Unit No. 1 pool is provided in Figure 1. Data is provided for the period 1/89 through 6/96, with refueling outages noted. Silica levels near zero, as shown on Figure 1, are indicative of demineralizer operation. Current spent fuel pool silica levels for Millstone Unit No. 1 are approximately 3.5 ppm, when demineralizers are not in service. The Millstone Unit No. 1 spent fuel pool demineralizers are not generally in service during the operating cycle. During refuel outages, the demineralizers are in service since the spent fuel pool and reactor vessel are connected and RCS silica levels are desired to be minimized. Since there is generally no spent fuel pool silica removal during the operating cycle, the silica concentrations will continue to rise (like a PWR). Because the Boraflex racks are such an enormous source of silica, it difficult to draw conclusions based on silica levels alone. Other factors such as the amount of Boraflex, pool size, fuel inventory and demineralizer characteristics make conclusions or comparisons difficult. The RACKLIFE program was developed to consider all of these characteristics to determine how much Boraflex dissolution is occurring. The tracking of silica does provide indication of relative Boraflex degradation. Based on the silica data observed to date, no indication of severe degradation or rapidly increasing degradation has been observed. The observed rates of silica increase during the operating cycles appear to be similar to those observed in PWR's.

Currently, evaluation of the EPRI RACKLIFE computer program is being performed with the expectation to predict the future amount of Boraflex dissolution of individual Boraflex panels in the Millstone Unit No. 1 fuel storage pool.

Attachment 1-1
Coupon Surveillance Program Summary
Millstone Unit No. 1

Coupon Pre-Characterization

Reference:
Holtec Letter 10210-A01, "Pre-Characterization of Coupons for the Millstone Unit No. 1 Boraflex Surveillance Program," Stanley E. Turner, Holtec International, 2/15/91.

Thirty-two Boraflex coupons were made for the Millstone Unit 1 coupon surveillance program. Of these thirty-two, thirty are expected to be used and two coupons were archived.

The coupons were pre-characterized by measuring each coupon for weight and specific gravity, hardness, length, width, and thickness. The coupons were then put in stainless steel (SS) jackets.

Surveillance Coupon Examination 1

Reference:
Holtec Report HI-961509, "Examination of the Millstone-1 Boraflex Surveillance Coupons Summary Report No. 1," Stanley E. Turner, Holtec International, 4/13/94.

Four Coupons labeled 1-8, 1-11, 1-12, and 1-15 were tested as part of the first coupon surveillance program. The following tests were performed:

Physical observation and photography
Neutron attenuation
Neutron radiography
Dimension checks
Weight and density
Shore A hardness

Observation of the coupons showed some insignificant edge erosion on the bottom edge of the coupons. No change in the measured neutron attenuation was found, which inferred no loss in B-10 areal density in the coupons. Based on the density increase measured, the estimated dose to the coupons was 1.0×10^9 Rads. Given the relatively small dose exposure, changes in the physical condition of the Boraflex were expected to be minimal.

Attachment 1-2
Summary of Blackness Testing
Millstone Unit No. 1

First Testing Campaign

Reference:
Holtec Report HI-9513786, "Blackness Testing in Selected Cells of the Millstone Unit No. 1 Spent Fuel Storage Racks," Stanley E. Turner, Holtec International, October, 1995.

The first blackness testing for Millstone Unit No. 1 was performed on the following dates:

8/2/95 - 8/3/95
9/14/95 - 9/15/95

There were 63 Boraflex cells tested. The 63 cells tested resulted in the testing of 246 Boraflex panels.

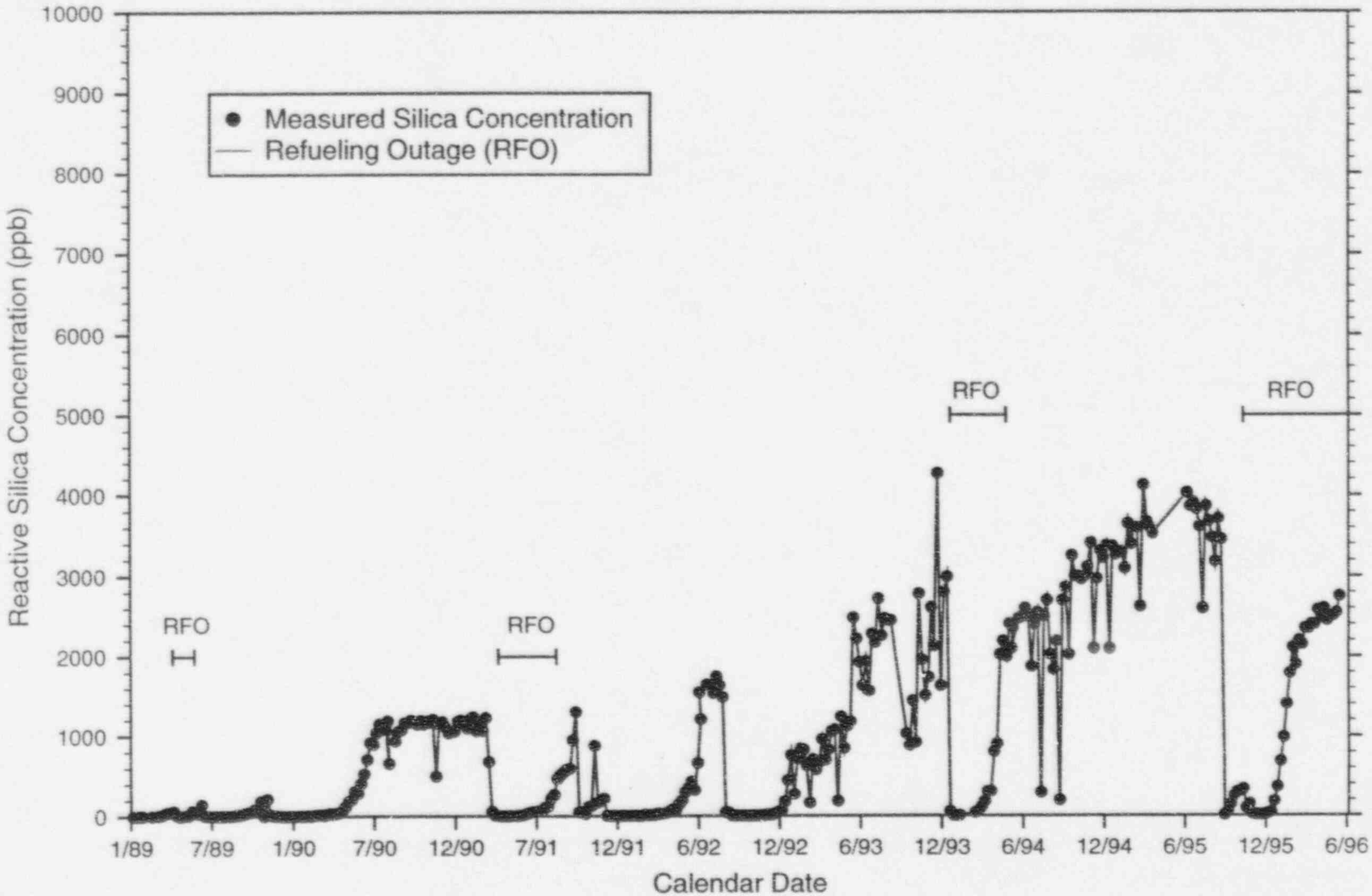
For the 63 Boraflex cells measured, 42 Boraflex cells in pool regions VIII and IX were tested and 21 Boraflex cells in region X were tested. Only 1 small gap was found in regions VIII and IX. In Region X, four small gaps (3 @ 0.8 inches, 1 @ 0.9 inches) were detected with possible indications of a few other gaps of less than .5 inch. About half of these gaps were in the "open edge" elevation where Boraflex panel edges are open to water.

Second Testing Campaign

Reference:
Letter Report HI-961502, Stanley E. Turner, Holtec International, to Millstone Nuclear Station, "Letter Report on Blackness Testing in Selected Cells of Millstone Unit No. 1 (Second Campaign)," June 10, 1996.

The second blackness testing was conducted on 5/31/96. 12 cells, containing 47 Boraflex panels were tested. Cells which contained the four largest gaps identified in the first campaign were measured and the Boraflex gaps were found to be unchanged from the first campaign. Some cells were tested which had not been tested in the first campaign, and no new gaps were found except for cell N25. Cell N25 had two small gaps about 0.4" and indication of another small gap possibly forming. The gaps in N25 were not at the elevation where the Boraflex edge is open to water.

Figure 1
Measured Spent Fuel Pool Reactive Silica Concentration versus Time
Millstone Unit 1



Docket No. 50-336
B15928

Attachment 2

Millstone Nuclear Power Station, Unit No. 2

Response to NRC Generic Letter 96-04

October 1996

Millstone Nuclear Power Station, Unit No. 2
Response to NRC Generic Letter 96-04

Generic Letter Question

Provide an assessment of the physical condition of the Boraflex, including any deterioration, on the basis of current accumulated gamma exposure and possible water ingress to the Boraflex and state whether a subcritical margin of 5 percent can be maintained for the racks in unborated water. Monitoring programs or calculational models in effect or being developed, or an estimation of anticipated concerns based on the specific rack design, are considered an appropriate basis for this response.

Response

Description of Boraflex Racks

The Millstone Unit No. 2 spent fuel storage racks were designed and fabricated by Combustion Engineering. These racks are designed such that each individual cell contains its own poison box, which can be removed from the cell for inspection and replacement, if necessary. The poison box contains the Boraflex panels. The Millstone Unit No. 2 storage racks are a "flux trap" design, where water is between the Boraflex panels of adjacent cells to provide thermalization of neutrons for capture by the poison panels.

The spent fuel storage racks which contain Boraflex panels were approved by the NRC in Reference 7. These racks were installed in the Millstone Unit No. 2 fuel storage pool in 1986. The current configuration of the Millstone Unit No. 2 fuel storage pool contains three regions, designated Regions A, B and C. Regions A and B have Boraflex panels of identical design. Region C does not contain any Boraflex. Therefore, this response addresses only Regions A and B.

The structure of the individual poison boxes at Millstone Unit No. 2 are formed by four stainless steel angles at each corner of the cell. To these corners, a sandwich consisting of two stainless steel cover plates housing the Boraflex panel are attached to the inside of the four corner angles by resistance spot welding. The Boraflex panel is slightly less thick than the stainless steel cavity formed by the cover plates to accommodate insertion of the panels with some clearance. The design of the Millstone Unit No. 2 racks is such that the Boraflex panels are not restrained and shrinkage is therefore accommodated with less susceptibility to cracking. The design of

the Millstone Unit No. 2 racks is such that water ingress to the Boraflex material is minimal.

Physical Condition of the Racks

The physical condition of the Boraflex panels in the spent fuel storage pool for Millstone Unit No. 2 is determined from monitoring programs consisting of coupon surveillances, blackness testing and pool reactive silica concentration data.

In addition, Millstone Unit No. 2 is unique in that it is possible to remove Boraflex panels from the spent fuel pool to directly evaluate Boraflex performance. The Millstone 2 spent fuel racks, because of their design, allow removal of the poison boxes, which contain the Boraflex panels. This allows for direct removal, testing and/or replacement of the poison material. Millstone Unit No. 2 has removed 2 poison boxes to date. Both poison boxes were removed in late 1991.

The Boraflex panels at Millstone Unit No. 2 have received a gamma dose to date averaging about 9×10^{9} rads, with a peak panel dose of about 2.5×10^{10} rads.

Boraflex coupon testing prior to 1990 generally showed no significant material loss, and had changes in thickness, shrinkage, hardness and density consistent with what would be expected of Boraflex based on EPRI reports . The 1990 coupon examinations showed significant Boraflex loss due to a unique feature of the coupon. The coupon material loss was from a vent hole which penetrates both sides of the coupon cover. The removal of a coupon in 1990, showed complete erosion of the Boraflex material near the vent hole. Further exams showed that all the remaining coupons in the pool also had complete erosion of the Boraflex in their vent holes. The coupons are located between adjacent storage racks and are believed to be in a relatively high flow location. Visual examination of 24 Boraflex panels with similar vent holes in the actual storage racks found no such erosion. The actual racks have a vent hole only on 1 side, not on both sides like the coupon. Also the vent hole in the racks is near the top on the active fuel height, and not important from a neutronic point of view. The value of future coupon tests will be diminished due to the presence of the eroded Boraflex material in the vent holes. A summary of results from 4 irradiated coupon tests are shown in Attachment 2-1. A fifth coupon test is planned for 1996.

A noteworthy item from Boraflex coupon testing in general, is the brittleness of the irradiated Boraflex material. Calculations were performed to ensure that the Boraflex material for Millstone Unit No. 2 would be able to fulfill its reactivity function during a seismic event, given the brittleness of the irradiated material, and this was confirmed.

Blackness Testing has shown that the Boraflex has suffered from shrinkage induced gaps typical of what would be expected from that described in EPRI reports (reference 1 and 2). Three campaigns of blackness testing have been performed for the Millstone Unit No. 2 racks. The largest known gaps are less than 2 inches in height, and the gaps are randomly distributed in the axial direction. Some larger gaps (2.9 inches and 2.2 inches) were found during the second blackness test campaign. However, as described below, the 2 poison boxes containing these panels/gaps were removed for examination and replaced with new (spare) poison boxes. Blackness testing has been performed at least once on 185 of the 384 cells which contain Boraflex. Many of these 185 tested locations have had blackness testing performed 2 or 3 times. Attachment 2-2 summarizes the blackness test results.

Two poison boxes were removed from Millstone Unit No. 2 racks for destructive examination in late 1991. This allowed direct visual observation of the poison performance. The 2 rack locations (D-9 and J-9) were cells with high gamma radiation history and the largest observed gap sizes. Attachment 2-3 describes the results of a cooperative evaluation between Millstone 2 personnel and EPRI to perform a visual examination of Boraflex panels from rack location D-9. In addition, portions of Boraflex panels from rack location J-9 were used to perform neutron attenuation testing. The neutron attenuation testing of five test specimens from the J-9 panels showed no significant difference in Boron-10 areal density from the original boraflex, even after several years of service with a total gamma exposure of about 2×10^{10} rads. This provides direct evidence that dissolution damage to the Boraflex panels is not significant at this time.

Millstone Unit No. 2 and EPRI have also worked together on a cooperative program involving special surveillance coupons which are periodically removed, examined and re-installed in the Millstone Unit No. 2 spent fuel pool. Three such examinations have occurred to date. The purpose of this effort is to determine the effects of prolonged water penetration and erosion damage on the Boraflex panel material. This data will be used to support the EPRI database for Boraflex damage.

Also, silica concentration measurements from the Millstone Unit No. 2 spent fuel pool are shown in Figure 2. The data is remarkably constant over several years. The lack of significant increase in silica implies little change in the Boraflex dissolution rate over the years.

In summary, data from these monitoring programs indicate the physical condition of the Boraflex panels in the Millstone Unit No. 2 fuel storage pool are within the expected physical condition of panels with similar exposure as described in References 1 and 2. Shrinkage induced gaps have been found, and this is the only significant degradation

of the Boraflex at this time. Dissolution damage is not believed to be of significance at this time based on direct visual observation and neutron attenuation measurements of heavily irradiated in-service Boraflex panels taken from the Millstone Unit No. 2 spent fuel pool. Neutron attenuation testing of 5 samples from taken from an in-service Boraflex panel did not show any significant Boron-10 areal density difference from the original boraflex. Silica measurements in the spent fuel pool over several years have also been very steady, which implies little change in the Boraflex dissolution rate.

Maintaining 5 Percent Subcritical Margin

Maintaining a minimum 5 percent subcritical margin in the spent fuel storage racks which contain Boraflex panels is assured by performing conservative analytical calculations which determine the maximum storage pool reactivity, and verification that the physical characteristics of the Boraflex panels are within the assumptions made in the analysis.

The current approved criticality analysis was submitted to the NRC in 1992 (reference 6). The criticality analysis was performed by HOLTEC International.

Key assumptions in that analysis include:

- Maximum reactivity fuel (4.5 w/o fresh U-235 fuel) in 3 out of 4 configuration in Region B of the SFP. The 4th location is empty and blocked.
- Maximum reactivity fuel (consistent with burnup/enrichment curve) in a 4 out of 4 configuration in Region A of the SFP.
- No boron in the pool water
- Highest reactivity water temperature for the pool water
- No credit for radial leakage
- No credit for absorption in the assembly structures.
- No credit for any burnable absorber in the fuel
- 4% axially random Boraflex gaps due to shrinkage (5.65 inch gaps)
- 4% Boraflex width shrinkage penalty

The final reactivity of the pool (K-effective) was the calculated reactivity plus the following:

- Calculational uncertainty based on the analytical method
- Allowance for mechanical tolerances

This analysis provided for a design value of K-effective below 0.95. This criticality analysis calculated a maximum K-effective value of 0.938 including all tolerances and uncertainties for Region A, and a maximum K-effective value of 0.925 including all tolerances and uncertainties for Region B.

The Boraflex degradation observed to date is due to shrinkage induced Boraflex gaps. The criticality evaluation of record (ref. 6) allows for up to 5.65 inch gaps in every Boraflex panel to be randomly distributed in axial location. Blackness testing to date has not identified any Boraflex panel that has exceeded the gap size limit, and the measured axial gap distribution has continued to be random through the 3 blackness testing campaigns. The most recent blackness testing shows the largest known gap in the pool to be less than 2 inches.

Dissolution damage is not believed to be of significance at this time based on direct visual observation and neutron attenuation measurements of heavily irradiated in-service Boraflex panels taken from the Millstone Unit No. 2 spent fuel pool. Neutron attenuation testing of 5 samples from taken from an in-service Boraflex panel did not show any significant B-10 areal density difference from the original boraflex. Silica measurements in the spent fuel pool over several years have also been very steady, which implies little change in the Boraflex dissolution rate. Therefore since no significant Boraflex dissolution has occurred yet, no significant reactivity loss has occurred.

While not specifically accounted for in the criticality analysis of record, there is sufficient margin in the criticality analysis to accommodate at least 10% uniform thinning (dissolution) of the Boraflex. This is because there is margin to the 0.95 K-effective limit. As discussed above, the maximum K-effective values for Region A and B respectively are 0.938 and 0.925, including all tolerances and uncertainties This amount of margin left to the K-effective limit is sufficient to accommodate at least 10% uniform thinning (dissolution) of the Boraflex. This provides adequate margin to ensure that dissolution damage will not cause criticality limits to be exceeded.

In summary, the Millstone Unit No. 2 racks are currently maintaining a subcritical margin of 5 percent reactivity in unborated water. The only degradation observed to date in the actual Boraflex panels is shrinkage induced gaps which are already accounted for in the criticality analysis. Three Blackness testing campaigns have confirmed the assumptions in the criticality analysis with regard to gaps. Coupon testing is of limited use at this time due to the boraflex erosion observed in the coupon vent holes. Dissolution damage is not believed to be of significance at this time based on direct visual observation and neutron attenuation measurements of heavily irradiated in-service Boraflex panels taken from the Millstone Unit No. 2 spent fuel pool. The existing criticality analysis has sufficient margin to accommodate at least 10% uniform thinning (dissolution) of the Boraflex, should such dissolution begin to be observed.

Generic Letter Question

Submit to the NRC a description of any proposed actions to monitor or confirm that this 5 percent criticality margin can be maintained for the lifetime of the storage racks and describe what corrective actions could be taken in the event it cannot be maintained.

Response

To maintain 5 percent criticality margin in the spent fuel pool, the physical condition of the Boraflex panels must be verified to be within the assumptions in the criticality analysis. The monitoring programs which verify this are discussed next.

Monitoring for Boraflex Gaps

Blackness testing is used to verify that the actual Boraflex gap sizes are bounded by the criticality analysis. A summary of the Boraflex Blackness testing program to date for Millstone Unit No. 2 is provided in Attachment 2-2. NNECO plans on continuing to perform blackness testing at periodic intervals for Millstone Unit No. 2, for as long as Boraflex is credited in the criticality analysis. Performing blackness testing will ensure that the gap assumptions in the criticality analysis (reference 6) are confirmed by the actual gap measurements.

Monitoring for Boraflex Dissolution Damage

Monitoring for Boraflex dissolution damage is performed by 3 methods, Boraflex coupon testing, use of EPRI's RACKLIFE program to project dissolution damage based on measured Spent Fuel Pool Silica concentrations, and removal of the poison boxes to directly measure Boraflex dissolution damage, if necessary.

Boraflex Coupon Testing

The value of future coupon tests will be diminished due to the presence of the eroded Boraflex material in the coupon vent holes. However, it is currently planned to continue the coupon program, to monitor the remaining Boraflex in the coupons. Should the coupons reach a point where their value is not relevant to understanding what is happening to the Boraflex in the racks, Boraflex from the actual racks (poison box removal) may be removed for examination, instead of the coupons. A summary of results from 4 irradiated coupon tests are shown in Attachment 2-1. A fifth coupon test is planned for 1996.

EPRI RACKLIFE computer program

Currently, evaluation of the EPRI RACKLIFE computer program is being performed with the expectation to predict the future amount of Boraflex dissolution of individual panels in the Millstone Unit No. 2 fuel storage pool. RACKLIFE uses the measured Silica concentrations in the spent fuel pool (see Figure 2 for Millstone Unit No. 2), along with rack dimensions, pool dimensions, fuel inventory and chemistry information to determine Boraflex dissolution damage. The RACKLIFE program also provides a fuel management tool which will allow evening out the gamma doses to individual Boraflex panels, thus minimizing overall degradation of the Boraflex racks. Given that the future amount of Boraflex dissolution can be determined, the reactivity loss due to dissolution can be calculated, and the useful lifetime of the Boraflex racks can be predicted.

Removal of poison boxes from the spent fuel pool

Should the Boraflex coupons or RACKLIFE program not be definitive for determination of dissolution damage, an additional method is possible. The Millstone Unit No. 2 Boraflex fuel storage rack monitoring program is unique in that poison boxes from the storage racks can (and have been) removed and subjected to examination and measurement. This makes possible, if needed, the capability to select and remove Boraflex panels to quantify the dissolution damage for validation of the criticality analysis.

Corrective actions in the event criticality margin cannot be maintained.

Should any significant degradation of the Boraflex be identified in the future, there are measures which could be taken to assure acceptable safety margins can be maintained. These include administrative controls on fuel loadings and usage, not crediting Boraflex material in the criticality analysis, use of additional fixed poisons, or fuel pool re-racking. Millstone Unit No. 2 has the additional option of replacing poison boxes without having to remove storage racks from the pool.

Calculations are currently under way to evaluate using fuel burnup credit instead of Boraflex credit for some of the Boraflex racks. This is the preferred approach for corrective action, should the required criticality margin not be maintained. Also, calculations are in progress to determine what poison box replacement or re-racking would be necessary to replace those Boraflex cells where fuel burnup credit is not possible due to the need to accommodate fresh fuel or highly reactive fuel storage.

Generic Letter Question

Describe the results from any post operational blackness testing and state whether blackness testing, or other in-situ tests or measurements, will be periodically performed.

Response

Blackness testing has been the primary means used to assess gap formation and degradation in the Boraflex panels. Blackness testing has been periodically performed to evaluate gap formation in the Millstone Unit No. 2 Boraflex panels, and will continue to be performed periodically in the future, for as long as Boraflex is credited in the criticality analysis. Blackness Testing has shown that the Boraflex has suffered from shrinkage induced gaps typical of what would be expected from that described in EPRI reports (reference 1 and 2). Three campaigns of blackness testing have been performed for the Millstone Unit No. 2 racks. The largest known gaps are less than 2 inches in height, and the gaps are randomly distributed in the axial direction. Some larger gaps (2.9 inches and 2.2 inches) were found in the second blackness test campaign. However, the poison boxes containing the gaps greater than 2 inches were removed for examination, and replaced with new (spare) poison boxes. Blackness testing has been performed at least once on 185 of the 384 cells which contain Boraflex. Many of these 185 tested locations have had blackness testing performed 2 or 3 times. Attachment 2-2 summarizes the blackness test results.

Overall, the results of the three blackness test measurements were as expected and fully consistent with trends seen in panels with similar exposure in terms of gap formation and shrinkage. The blackness testing measurements performed to date have supported that the physical condition of the Boraflex panels is within the bounds of the criticality analysis.

Generic Letter Question

Chronological trends of pool reactive silica levels, along with the timing of significant events such as refuelings, pool silica cleanups, etc., should be provided. Implications of how these pool silica levels relate to Boraflex performance should be described.

Response

Chronological spent storage pool reactive silica concentration data for the Millstone Unit No. 2 pool is provided in Figure 2. Data is provided for the period 4/91 through 5/95, with significant events noted. Spent fuel storage pool silica levels for Millstone Unit No. 2 have tended to be steady over several years at values of between 1.0 to 2.0

ppm. This is very low by industry standards for PWR's. This low silica level is similar to the Haddam Neck Plant, which does not have Boraflex in the spent fuel pool. Also of note is the fact that the Millstone Unit No. 2 silica levels have been relatively constant over several years, indicating very little change in degradation of the Boraflex racks. This implies very little interaction between the spent fuel pool water and the Boraflex.

However, because the Boraflex racks are such an enormous source of silica, it difficult to draw a conclusion based on silica levels alone. Other factors such as amount of Boraflex, pool size, fuel inventory and demineralizer characteristics make conclusions or comparisons difficult. The RACKLIFE program was developed to consider all of these characteristics to determine how much Boraflex dissolution is occurring. The tracking of silica does provide a relative indication for a specific spent fuel pool of relative Boraflex degradation in the racks. Based on the data observed to date, no indication of severe degradation or rapidly increasing degradation has been observed. The observed rates of silica increase during the operating cycles appear to be very low for Millstone Unit No. 2 relative to that observed in other PWR's.

Currently, evaluation of the EPRI RACKLIFE computer program is being performed with the expectation to predict the future amount of Boraflex dissolution of individual panels in the Millstone Unit No. 2 fuel storage pool.

Attachment 2-1
Coupon Surveillance Program Summary
Millstone Unit No. 2

Surveillance Coupon- General

The coupon system consists of an assembly which contains 14 surveillance coupons. The Boraflex surveillance coupons consist of a sample of about 3 inches in length, 2.75 inches in width and 0.11 inches in thickness. The coupon is sandwiched between two stainless steel plates which are .033 inches thick. A 3/8 inch diameter vent hole is located in the center of each plate. The surveillance coupon assembly is placed between fuel assemblies, such that the gamma dose received by the surveillance system exceeds the dose received by Boraflex material in the racks.

Surveillance Coupon Examination 1

Reference:
Report 70385-9351-Q-013, "Examination of Spent Fuel Rack Surveillance Capsule #2 from Millstone Unit No. 2," J. S. Glazman, Combustion Engineering, October 29, 1987.

Rack Surveillance Capsule #2 was the first surveillance capsule removed. Surveillance Capsule #1 is a control sample. Capsule #2 received exposure from 5/28/86 to 4/28/87. The Boraflex material became significantly harder, more fragile and stiffer. Minor changes in dimensions and neutron absorptivity were noted.

Surveillance Coupon Examination 2

Reference:
Report 70385-9351-Q-018, "Examination of Spent Fuel Rack Surveillance Capsule #3 from Millstone Unit No. 2," J. S. Glazman, Combustion Engineering, May 4, 1990.

Exposure from 5/28/86 to 6/14/89.

Neutron attenuation results show 1.43% less neutron absorbent than reference sample (#1).

Coupon #3 ability to absorb neutrons was basically equal to #2.

Some graying of the Boraflex material in the vent hole area was observed.

General conclusions

- Shrinkage expected based on BISCO testing.
- Material is getting harder making it more susceptible to cracking.
- Neutron absorptivity trending slightly downward.
- Capsules have greater ratio of exposed surface then does actual panels in the rack so results may not be directly applicable.

Surveillance Coupon Examination 3

Reference:
Report 70385-9351-Q031, Revision 1, "Examination of Spent Fuel Rack Surveillance Capsule #4 from Millstone Unit No. 2," J. S. Glazman, Combustion Engineering, August 30, 1989.

Exposure 5/28/86 to 6/14/89

Continued graying of Boraflex material in vent hole area was observed

Other conclusions same as for coupon #3, with no additional findings.

Surveillance Coupon Examination 4

Reference:
Report 70385-9351-Q064, "Examination of Spent Fuel Rack Surveillance Capsule #5 from Millstone Unit No. 2," J. S. Glazman, Combustion Engineering, March 21, 1991.

Exposure from 5/28/86 to 7/20/90 (1514 days)

No Boraflex was found in the vent hole area of coupon. Also the thickness of the Boraflex had been reduced over an area about 1 inch away from the center of the hole. The remaining Boraflex material was undamaged. The expected cause was flow erosion. Flow patterns were observed to be present inside the capsule. It was also observed that all of the remaining coupons in the spent fuel pool had similar erosion holes.

Neutron attenuation measurements showed a decrease in the neutron absorptivity in the coupon tested, with the cause due to erosion of the neutron absorbing material in the vent hole.

Other general conclusions the same as for Coupons #3 and #2.

Note: As result of the missing Boraflex in the coupon vent hole, visual inspections were performed on 24 Boraflex panels in the actual racks, which had similar vent holes. This inspection showed that there was no evidence of similar erosion in the vent holes of the actual racks.

Table 1 below shows a summary of the results for Coupons 2-5.

Table 1 Summary of the results for Millstone 2 Coupons 2-5

Test	Coupon 2	Coupon 3	Coupon 4	Coupon 5
Time in Pool (Days)	335	569	1113	1514
	% change			
Neutron Attenuation	-4.5 %	-6.9%	-2.4%	-4.9%*
Length	-0.186%	-1.31%	-1.55%	-2.23%
Width	+0.02%	-1.10%	-1.36%	-0.46%
Thickness	+2.62%	+2.30%	+1.30%	+1.74%
Weight	+0.28%	-0.52%	-0.46%	-1.28%

* Coupon 5 neutron attenuation value from measurements which tried to eliminate the effects of the Boraflex missing from the vent hole.

Coupon 1 is the unirradiated archive sample. There is an ongoing shrinkage in the length and width, as shown above. The thickness increase is believed to be due to water absorption. The decrease in weight in coupon 5 is due to the loss of Boraflex material from the vent hole area.

Attachment 2-2
Summary of Blackness Testing
Millstone Unit No. 2

Blackness Testing (First campaign)

Reference:
Holtec report HI-90535, "Blackness Testing of Boraflex in Selected Cells of the Spent Fuel Storage Racks of Millstone Unit No. 2," Stanley E. Turner, Holtec International, October, 1990.
8/23/90 to 8/29/90 HOLTEC performed testing.

Results:

105 cells tested out of a total of 384 cells in Region A & B which contain Boraflex.
A total of 420 Boraflex panels were tested.
45 of 420 panels had gaps.
3 (of the 45) had 2 gaps.
1.8 inches was largest gap, 1.4 inches was the second largest gap.
Both of the above gaps were in storage cell D-9.

The cause of the gaps was suspected to be gamma radiation induced shrinkage.

Blackness Testing (Second campaign)

Reference:
Holtec report HI-91737, "Blackness Testing of Boraflex in Selected Cells of the Spent Fuel Storage Racks of Millstone Unit No. 2," Stanley E. Turner, Holtec International, January, 1992.

10/15/91 HOLTEC performed testing

Results:

141 cells tested out of a total of 384 cells in Region A & B which contain Boraflex
A total of 564 Boraflex panels were tested.
This campaign retested all cells that had gaps in Test #1.
This campaign retested some cells which did not have gaps from Test #1, and tested some cells which previously had not been tested.

The test results indicate that gap growth has been experienced in the cell locations previously identified to have gaps. Additionally, new gaps have appeared in cells where no gaps were previously encountered. Finally, some gaps are present in the cells which were tested for the first time.

Some additional information;

38% of cells tested had gaps (30% in Campaign #1).
The average gap size was similar to Campaign #1(.83 inches vs .76 inches).
For gaps measured in campaign 1, the average increase in gap size was about 20%. The largest gap was in cell location J-9 (2.8 inches), which was not tested in Campaign #1.
The largest gap from Campaign #1 (D-9) went from 1.8 inches to 2.2 inches.
Of the 35 locations with no gaps from Campaign #1, only 1 had a gap. The number of Boraflex panels with more than 1 gap increased from 3 in the first campaign to 5 in this campaign.
The axial location of Boraflex gaps tended to be random.

The cause of the gaps was suspected to be gamma radiation induced shrinkage.

<u>Blackness Testing (Third Campaign)</u>

Reference:
Holtec Report HI-96153, "Blackness Testing of Boraflex in Selected Region-1 Cells of the Millstone-2 Spent Fuel Storage Racks," Stanley E. Turner, June, 1996.

Testing was performed 5/6/96 through 5/9/96

Results:

89 cells were tested, 64 had measurable gaps and 25 had no gaps.
Of the 64 cells with gaps

134 total gaps were measured
83 of the 134 gaps were measured to be less than 1.0 inch.
41 of the 134 gaps were measured to be in the range of 1.0 to 1.5 inches
10 of the 134 gaps were measured to be in the range 1.6 to 1.9 inches

Additional information:
Gaps found in Campaign #2 and retested in Campaign #3 had increased in size.
Cells D9 and J9 had their poison boxes replaced between Campaign 2 and 3. The replacement panels for cells D9 and J9 had no gaps.

There were no gaps as large as the gaps found in Campaign #2, The largest gaps measured in Campaign 3 were 1.9 inches in cells J8 and P11. The Boraflex gap found in cell J8 went from 1.5 inches in campaign 2 to 1.9 inches in campaign 3. The Boraflex gap found in cell P11 went from 1.3 inches in campaign 2 to 1.9 inches in campaign 3.

Distribution of Boraflex gaps was random in the axial direction.

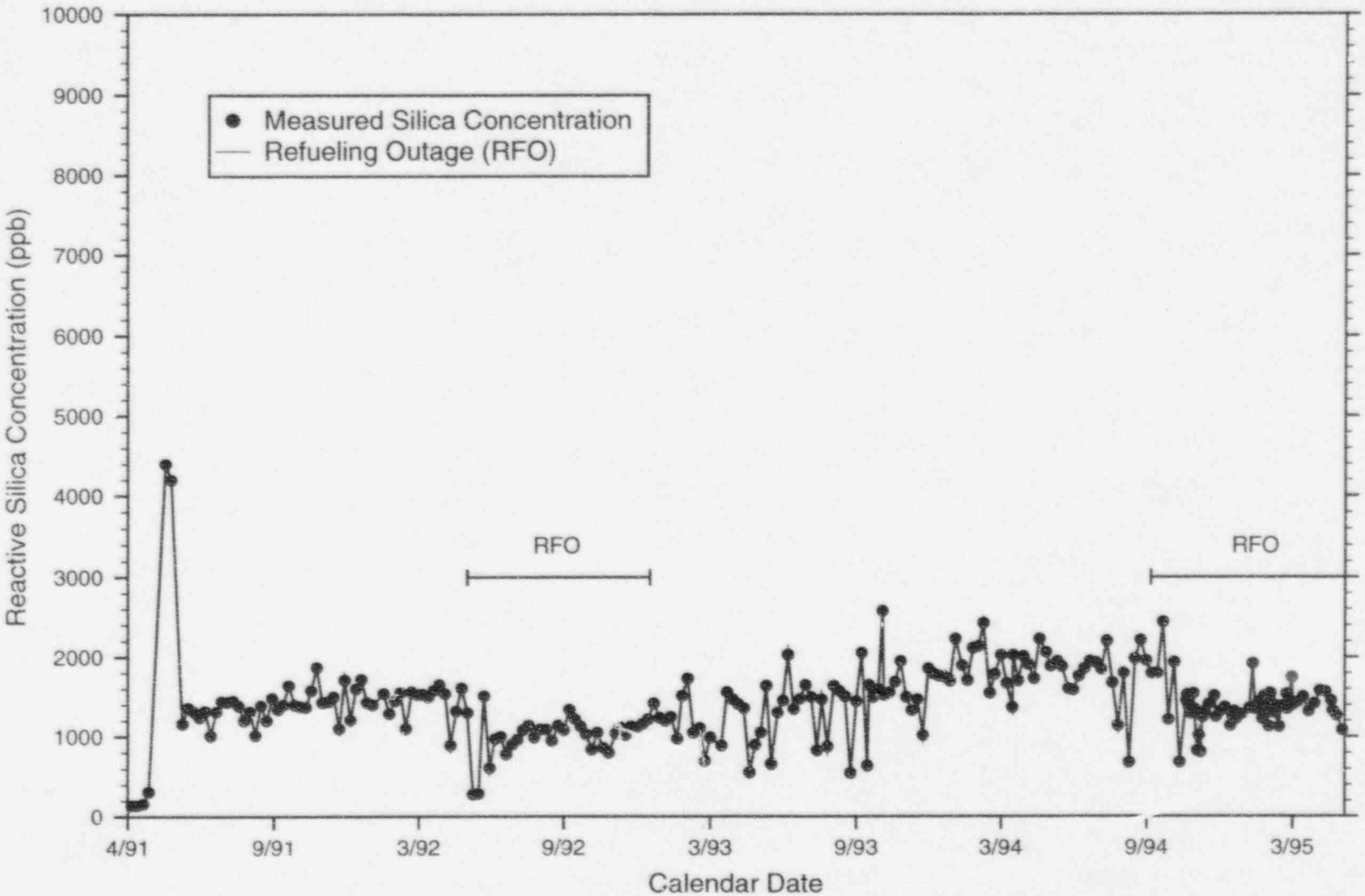
Attachment 2-3
Summary of Boraflex Panel Removal Examination
Millstone Unit No. 2

Reference:
Report No. NET-043-M2, "Millstone Unit No. 2 Boraflex Panel Inspection: East and West Panels from Cell D-9," Northeast Technology Corp., March 25, 1992.

In late 1991 and early 1992, the poison box was removed from cell D-9 for visual observation and to confirm the results of the blackness testing program. A Boraflex panel in cell location D-9 had the largest known Boraflex gap from Blackness campaign 2. The poison box panels were dismantled to allow visual examination of the Boraflex. The observed gap locations and gap sizes in the Boraflex panels confirmed the Blackness Testing results. Some end shrinkage was noted. Total panel shrinkage (gaps plus end shrinkage) was found to be 1.6% (east panel) and 1.9% (west panel), substantially less than the 4% shrinkage assumed in the criticality analysis. Some areas of local Boraflex erosion were noted. At the ends of the panel, the Boraflex exhibited some residual flexibility. At the center of the panel, it was harder and pressing on it caused it to crack. Inspection of the Boraflex edges show a few examples of "burn-through" from fabrication. It is postulated that the welding tool "wandered" from its intended track when the cells were assembled causing it to burn-through the stainless steel and Boraflex. These "burn through" areas were small in size and would have insignificant reactivity effect.

It is estimated that the Boraflex in location D-9 had received approximately 2×10^{10} rads, and should therefore be in a nearly saturated condition. Observations from the poison box destructive examinations revealed that the boraflex had not yet reached its "saturated" condition (the point at which it will no longer continue to shrink with exposure to radiation).

Figure 2
Measured Spent Fuel Pool Reactive Silica Concentration versus Time
Millstone Unit Number 2



Docket No. 50-423
B15928

Attachment 3

Millstone Nuclear Power Station, Unit No. 3

Response to NRC Generic Letter 96-04

October 1996

Millstone Nuclear Power Station, Unit No. 3
Response to NRC Generic Letter 96-04

Generic Letter Question

Provide an assessment of the physical condition of the Boraflex, including any deterioration, on the basis of current accumulated gamma exposure and possible water ingress to the Boraflex and state whether a subcritical margin of 5 percent can be maintained for the racks in unborated water. Monitoring programs or calculational models in effect or being developed, or an estimation of anticipated concerns based on the specific rack design, are considered an appropriate basis for this response.

Response

Description of Boraflex Racks

The Millstone Unit No. 3 spent fuel storage racks were designed and fabricated by Westinghouse. The Millstone Unit No. 3 storage racks are a "flux trap" design, where water is between the adjacent cells to provide thermalization of neutrons for capture by the poison panels. The structure of the individual cells at Millstone Unit No. 3 are of a "wrapper" type design. The Boraflex panels are attached to the outside of the cell box and a thin stainless steel wrapper is used to enclose the Boraflex material on the box structure. The design of the Millstone Unit No. 3 racks is such that the Boraflex panels are not highly susceptible to water ingress and are not rigidly restrained, which allows shrinkage with less susceptibility to cracking.

Irradiated fuel was first placed in the spent fuel storage racks in 1987. The current configuration of the Millstone Unit No. 3 fuel storage pool contains two regions which accommodate 756 fuel storage locations. The racks are divided into 2 regions, designated region 1 and 2. Region 1 can accommodate up to 5 w/o U-235 fresh fuel in a 3-out-of-4 configuration with the fourth location blocked. Region 2 can accommodate fuel in a 4 out 4 configuration, provided that fuel enrichment/burnup limits are met. Both Region 1 and 2 have physically identical racks, all of which have Boraflex panels.

Physical Condition of the Racks

The physical condition of the Boraflex panels in the spent fuel storage pool for Millstone Unit No. 3 is determined from monitoring programs consisting of coupon surveillances, blackness testing and pool reactive silica concentration data.

The Boraflex panels at Millstone Unit No. 3 have received a gamma dose to date averaging about 7.5×10^9 rads, with a peak panel dose of about 3.5×10^{10} rads.

Boraflex coupon testing to date has generally shown no significant material loss, or loss of Boron-10 neutron attenuation capability. Results from 5 irradiated coupon tests are described in Attachment 3-1.

A noteworthy item from Boraflex coupon testing in general, is the brittleness of the irradiated Boraflex material. Calculations were performed to assess whether the Boraflex material for Millstone Unit No. 3 would be able to maintain its reactivity function during a seismic event. These calculations have shown that the Boraflex may not be able to maintain its integrity during a seismic event, and this was prompt reported to the NRC in September 1996 in accordance with 10CFR50.72 reporting requirements. Additional information was provided to the NRC in the LER 50-423/96-033 (reference 11).

Blackness Testing has shown that the Boraflex has suffered from shrinkage induced gaps typical of what would be expected from that described in EPRI reports (reference 1 and 2). Two campaigns of blackness testing have been performed for the Millstone Unit No. 3 racks. The largest known gaps are less than 4 inches in height, and the gaps are randomly distributed in the axial direction. Attachment 3-2 summarizes the blackness test results.

Also, silica concentration measurements from the Millstone Unit No. 3 spent fuel pool are shown in Figure 3. The data seems typical of many plants for increasing silica trends as a function of time.

In summary, data from these monitoring programs indicate the physical condition of the Boraflex panels in the Millstone Unit No. 3 fuel storage pool are within the expected physical condition of panels with similar exposure as described in References 1 and 2. Shrinkage induced gaps have been found, and this is the only significant degradation of the Boraflex at this time. Dissolution damage to the Boraflex is not believed to be of any significance yet, since the coupon samples do not show any significant dissolution damage or significant loss of neutron attenuation ability. Calculations have shown that the Boraflex, due to its brittleness after radiation exposure, may not be able to maintain its integrity during a seismic event, and this was prompt by reported to the NRC in September 1996.

Maintaining 5 Percent Subcritical Margin

Maintaining a minimum 5 percent subcritical margin in the spent fuel storage racks which contain Boraflex panels is assured by performing conservative analytical calculations which determine the maximum storage pool reactivity, and verification that the physical characteristics of the Boraflex panels are within the assumptions made in the analysis.

The current criticality analysis was performed in 1993 (reference 9). The criticality analysis was performed by Westinghouse. A summary of this criticality analysis was provided to the NRC in reference 10.

Key assumptions in that analysis include:

- Maximum reactivity fuel (5.0 w/o fresh U-235 fuel) in 3 out of 4 configuration in Region 1 of the SFP. The 4th location is empty and blocked.
- Maximum reactivity fuel (consistent with burnup/enrichment curve) in a 4 out of 4 configuration in Region 2 of the SFP.
  - No boron in the pool water
- Highest reactivity water temperature for the pool water
- No credit for radial leakage
- No credit for absorption in the assembly structures
- 4% axially random Boraflex gaps due to shrinkage (5.65 inch gaps)
  - 4% Boraflex width shrinkage penalty
  - No credit for any burnable absorber in the fuel
- The minimum Boraflex panel thickness and poison loading

The final reactivity of the pool (K-effective) was the calculated reactivity plus the following:

- Calculational uncertainty based on the analytical method
- Allowance for mechanical tolerances

This analysis provided for a design value of K-effective below 0.95. The maximum k-effective from all configurations analyzed was .9355, including uncertainties and tolerances.

The Boraflex degradation observed to date is due to shrinkage induced Boraflex gaps. The criticality analysis of record (ref. 9) allows for up to 5.65 inch gaps in every Boraflex panel to be randomly distributed in axial location. Blackness testing to date has not identified any Boraflex gaps which exceeded the assumed gap size, and the measured axial gap distribution has continued to be random based on the 2 blackness

testing campaigns. The most recent blackness testing shows the largest known gap in the pool to be less than 4 inches.

Dissolution damage to the Boraflex is not believed to be of any significance yet, since Boraflex coupon testing to date has generally shown no significant material loss, or loss of Boron-10 neutron attenuation capability. Attachment 3-1 provides a more detailed summary of coupon testing to date. Therefore, since no significant Boraflex dissolution has occurred yet, no significant reactivity loss has occurred.

While not specifically accounted for in the criticality analysis of record, there is sufficient margin in the criticality analysis to accommodate at least 10% uniform thinning (dissolution) of the Boraflex. As discussed above, the maximum K-effective values for Region 1 and 2 was 0.9355, including all tolerances and uncertainties. This amount of margin left to the 0.95 K-effective limit is sufficient to accommodate at least 10% uniform thinning (dissolution) of the Boraflex.

In summary, the Millstone Unit No. 3 racks are currently maintaining a subcritical margin of 5 percent reactivity in unborated water. The only degradation observed to date is through shrinkage induced gaps which are already accounted for in the criticality analysis. Two Blackness testing campaigns have confirmed the assumptions in the criticality analysis with regard to gaps. Dissolution is not believed to be a factor yet based on coupon testing. The existing criticality analysis has sufficient margin to accommodate at least 10% uniform thinning (dissolution) of the Boraflex, should such dissolution begin to be observed.

Generic Letter Question

Submit to the NRC a description of any proposed actions to monitor or confirm that this 5 percent criticality margin can be maintained for the lifetime of the storage racks and describe what corrective actions could be taken in the event it cannot be maintained.

Response

To maintain 5 percent criticality margin in the spent fuel pool, the physical condition of the Boraflex panels must be verified to be within the assumptions in the criticality analysis. The monitoring programs which verify this are discussed next.

Monitoring for Boraflex Gaps

Blackness testing is used to verify that the actual Boraflex gap sizes are bounded by the criticality analysis. A summary of the Boraflex Blackness testing program to date

for Millstone Unit No. 3 is provided in Attachment 3-2. As discussed later in this response, NNECO intends to discontinue credit for Boraflex as a neutron absorber for Millstone Unit 3, when additional racks containing a different neutron poison are placed in the spent fuel pool. Because the testing to date has shown that the Millstone Unit No. 3 Boraflex shrinkage/gaps are behaving in an expected manner based on EPRI data, further blackness testing is not planned unless there is a delay in the re-rack of the Millstone Unit No. 3 spent fuel pool.

Monitoring for Boraflex Dissolution Damage

Monitoring for Boraflex dissolution damage is intended to be performed by 2 methods, Boraflex coupon testing, and use of EPRI's RACKLIFE program to project dissolution damage based on measured Spent Fuel Pool Silica concentrations.

Boraflex Coupon Testing

Boraflex coupon testing to date has shown no significant material loss, or loss in Boron-10 neutron absorption capability. Results from 5 irradiated coupon tests are shown in Attachment 3-1. Periodic Coupon testing will continue until Boraflex is no longer credited in the criticality analysis.

EPRI RACKLIFE computer program

Currently, evaluation of the EPRI RACKLIFE computer program is being performed with the expectation to predict the future amount of Boraflex dissolution of individual panels in the Millstone Unit No. 3 fuel storage pool. RACKLIFE uses the measured Silica concentrations in the spent fuel pool (see Figure 3 for Millstone Unit No. 3), along with rack dimensions, pool dimensions, fuel inventory and chemistry information to determine Boraflex dissolution damage. The RACKLIFE program also provides a fuel management tool which will allow evening out the gamma doses to individual Boraflex panels, minimizing overall degradation of the Boraflex racks. Given that the future amount of Boraflex dissolution can be determined, the reactivity loss due to dissolution can be calculated, and the useful lifetime of the Boraflex racks can be predicted.

Corrective actions in the event criticality margin cannot be maintained.

A spent fuel pool re-rack is currently planned for Millstone Unit No. 3 during the latter portion of operating cycle 7. Millstone Unit No. 3 is currently in cycle 6. At that time it is planned to end credit for Boraflex in the Millstone 3 spent fuel pool. Any remaining Boraflex racks would use fuel burnup credit to compensate for taking no Boraflex credit. New storage racks would be added to the pool (which use a different neutron poison) to accommodate fresh fuel or highly reactive fuel.

Should any significant degradation of the Boraflex be identified in the interim time period before Boraflex credit is eliminated, there are measures which could be taken to assure acceptable safety margins can be maintained. These include administrative controls on fuel loadings and usage, additional credit for fuel burnup, or the addition of other fixed neutron poisons.

Generic Letter Question

Describe the results from any post operational blackness testing and state whether blackness testing, or other in-situ tests or measurements, will be periodically performed.

Response

Blackness testing is the primary means used to assess gap formation and degradation in the Boraflex panels.

Blackness Testing has shown that the Boraflex has suffered from shrinkage induced gaps typical of what would be expected from that described in EPRI reports (reference 1 and 2). Two campaigns of blackness testing have been performed for the Millstone Unit No. 3 racks. The largest known gaps are less than 4 inches in height, and the gaps are randomly distributed in the axial direction. Attachment 3-2 summarizes the blackness test results.

Overall, the results of the first two measurements were as expected and fully consistent with trends seen in panels with similar exposure in terms of gap formation and shrinkage. The blackness testing measurements performed to date have supported that the physical condition of the Boraflex panels is within acceptable bounds of the criticality analysis.

As discussed earlier, NNECO intends to discontinue credit for Boraflex as a neutron absorber for Millstone Unit No. 3, when additional racks containing a different neutron poison are placed in the spent fuel pool. Because the testing to date has shown that the Millstone Unit No. 3 Boraflex shrinkage/gaps are behaving in an expected manner based on EPRI data, further blackness testing is not planned unless there is a delay in the re-rack of the Millstone Unit No. 3 spent fuel pool.

Generic Letter Question

Chronological trends of pool reactive silica levels, along with the timing of significant events such as refuelings, pool silica cleanups, etc., should be provided. Implications of how these pool silica levels relate to Boraflex performance should be described.

Response

Chronological spent storage pool reactive silica concentration data for the Millstone Unit No. 3 pool is provided in Figure 3. Data is provided for the period 4/91 through 5/96, with significant events noted. Spent fuel storage pool silica levels for Millstone Unit No. 3 have tended to increase over the years, with levels currently at about 6 to 7 ppm. Because the Boraflex racks are such an enormous source of silica, it is difficult to draw a conclusion based on silica levels alone. Other factors such as amount of Boraflex, pool size, fuel inventory and demineralizer characteristics make conclusions or comparisons difficult. The RACKLIFE program is needed to consider all of these characteristics to determine how much Boraflex dissolution is occurring. The tracking of silica does provide a relative indication for a specific spent fuel pool of relative Boraflex degradation in the racks. Based on the data observed to date, no indication of severe degradation or rapidly increasing degradation has been observed. The observed rates of silica increase during the operating cycles appears to be similar to that observed in most other PWR's.

Currently, evaluation of the EPRI RACKLIFE computer program is being performed with the expectation to predict the future amount of Boraflex dissolution of individual panels in the Millstone No. 3 fuel storage pool

Attachment 3-1
Coupon Surveillance Program Summary
Millstone Unit No. 3

Surveillance Coupons-general

The Millstone 3 surveillance coupons are shaped like tensile specimens. The following measurements are made: Physical observation, neutron attenuation tests, weight and dimensional checks and Shore A hardness tests.

Surveillance Coupon Examination 1

Reference:
"Examination of the Millstone 3 Boraflex Surveillance Coupons Short Term No. 1 (EM89)," S. E. Turner, NUSERTEC, August 3, 1989.

Three coupons were removed from the Millstone Unit No. 3 spent fuel pool.
No significant degradation was observed.

Noticeable taper and usually smooth areas suggest coupon under compression during in-pool irradiation.

No significant loss of neutron absorptivity based on neutron transmission tests (the results were similar to archive sample results).

No abnormalities, coupons fully hard (Shore A of 100)

Estimated dose 1 to 2 x 10^9 Rads based on density measurements.

Surveillance Coupon Examination 2

Reference:
Holtec Report HI-91683, "Examination of Millstone-3 Boraflex Surveillance Coupons Summary Report No. 2," Stanley E. Turner, Holtec International, September 3, 1991.

Three coupons were removed from the Millstone Unit No. 3 spent fuel pool.

The estimated dose that the coupons were exposed to was 5 x 10^9 Rads based on physical properties.

The edges of the Boraflex were still sharply defined.

Shore A measurements indicate the Coupons are fully hard.

Neutron attenuation measurements continue to show no loss in absorption properties.

Appearance of several small cracks on the coupons are evident.

Surveillance Coupon Examination 3

Reference:
Holtec Report HI-93996, "Examination of Millstone-3 Boraflex Surveillance Coupons Summary Report No. 3," Stanley E. Turner, Holtec International, May, 1993.

Three coupons were removed from the Millstone Unit No. 3 spent fuel pool.

Estimated dose was 1×10^9 Rads based on physical properties.

Shore A measurements indicate the Coupons are fully hard

Neutron attenuation measurements continue to show no loss in absorption properties, relative to archive samples.

Several large cracks found in coupons (first sighting)

Surveillance Coupon Examination 4

Reference:
Holtec Report HI-941229, "Examination of Millstone-3 Boraflex Surveillance Coupons Summary Report No. 4," Stanley E. Turner, Holtec International, October, 1994.

Three coupons were removed from the Millstone Unit No. 3 spent fuel pool.

Shore A measurements indicate the Coupons are fully hard

Neutron attenuation measurements continue to show no loss in absorption properties, relative to archive samples.

Average measured specific gravity suggests Boraflex has almost reached saturation dose where no further changes in physical properties would be expected.

Numerous small cracks found in coupons.

Surveillance Coupon Examination 5

Reference:
Holtec Report HI-961483, "Examination of Millstone-3 Boraflex Surveillance Coupons Summary Report No. 5," Stanley E. Turner and Walter Mitchell III, Holtec International, April, 1996

Three coupons were removed from the Millstone Unit No. 3 spent fuel pool.

Shore A measurements indicate the Coupons are fully hard.

Neutron attenuation measurements continue to show no loss in absorption properties relative to archive samples.

Average measured specific gravity suggests Boraflex has almost reached saturation dose where no further changes in physical properties would be expected.

Numerous small and large cracks were found in the coupons.

A summary of the neutron attenuation measurements is shown below in Table 2 for the 5 coupon tests.

Table 2 Summary of the results for Millstone Unit No. 3 Coupons 1-5

	Coupon 1	Coupon 2	Coupon 3	Coupon 4	Coupon 5
Test Coupon Measured Boron - 10 areal density	.0241	.0233	.0218	.0244	.0237
Archive Coupon Measured Boron - 10 areal density	Value Not Reported	Value Not Reported	.0220	.0245	.0243

Values shown are in grams Boron-10 per square centimeter (areal density). The criticality analysis uses the minimum areal density of .020 gms B-10/cm^2. Even though there is some variation of the above measured areal density values, it can be readily seen that for a given areal density measurement that the irradiated coupons give B-10 areal density values very close to the unirradiated archive samples.

Attachment 3-2
Summary of Blackness Testing
Millstone 3

Blackness Testing (First campaign)

Reference:
Holtec Report HI-92869, "Blackness Testing of Boraflex in Selected Cells of the Millstone-3 Spent Fuel Storage Racks," Stanley E. Turner, July, 1992.

Performed May 18-22, 1992.

Results

Blackness testing was conducted on 62 cells out of 756 total cells.
Assessment of 232 Boraflex panels was performed
19 Boraflex gaps were identified in 16 cells.
The 19 identified gaps had an average gap size was 1.5 inches.
The largest Boraflex gap size was 3.5 inches.
A high percentage of gaps(3 out of 4) were 1 inch or larger
Blackness tests typically reveal some small gaps, however, there was no indication of small gaps in this test.
The Boraflex Gaps appear to be randomly distributed axially.
Several Boraflex panels started 3 to 4 inches higher in elevation than the other panels.
This implied some amount of shrinkage from the bottom up.

Blackness Testing (Second campaign)

Reference:
Holtec Report HI-951257, "Blackness Testing of Boraflex in Selected Spent Fuel Storage Rack Cells of the Millstone 3 Nuclear Station," Walter E. Bustynowicz, February, 1995.

Performed November 14-18, 1994

Results:

Blackness testing was conducted on 69 cells out of 756 total cells. Most of the cells tested were the same cells as the first campaign.
Assessment of 257 Boraflex panels was performed. 31 Boraflex gaps were identified.

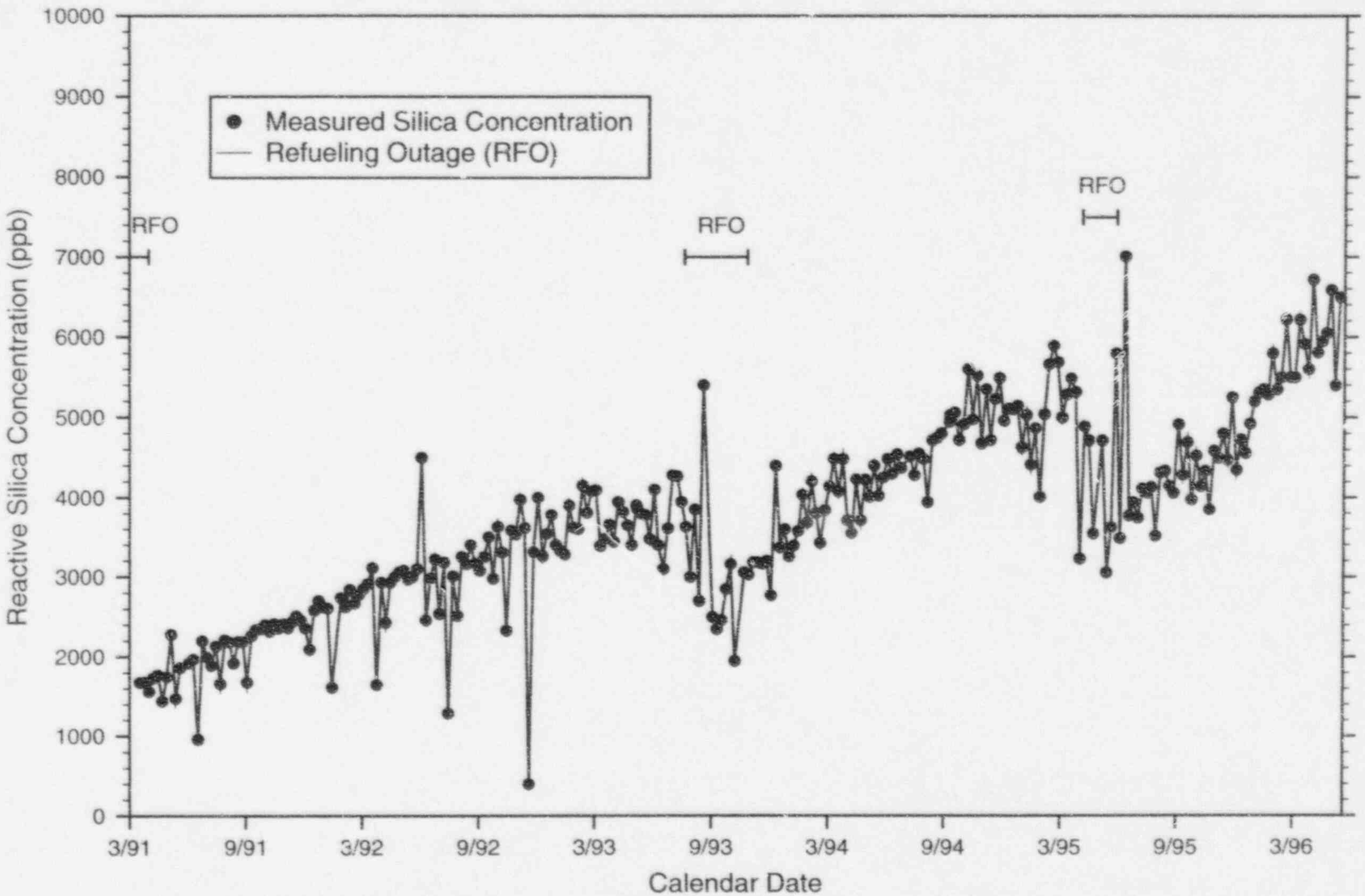
The 31 identified gaps had an average size of 1.1 inches. This average gap size is smaller than campaign 1 because additional small gaps were found in the second campaign.

The largest Boraflex gap size was 3.1 inches.

The Boraflex Gaps appear to be randomly distributed axially

Both the number and size of gaps continue to increase and it is postulated that 4.5 to 5.0 inches may be saturation gap size.

Figure 3
Measured Spent Fuel Pool Reactive Silica Concentration versus Time
Millstone Unit Number 3



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2 EPRI Report TR=103300, "Guidelines for Boraflex Use in Spent-Fuel Storage Racks," February, 1993.

3 Letter, E. J. Mroczka, to USNRC, "Information on Proposed Spent Fuel Rack Modifications," May 5, 1988, B12844.

4 Letter, F. R. Dacimo to USNRC, "Millstone Nuclear Power Station, Unit No. 1 proposed Technical Specification Revision Fuel Storage," May, 1996, B15683.

5 Letter, T. C. Feigenbaum to USNRC, "Millstone Nuclear Power Station, Unit No. 1, Response to Request for Additional Information, Fuel Storage Amendment, B15807, August 1996.

6 Letter, J. F. Opeka to USNRC, "Millstone Nuclear Power Station, Unit No. 2 Proposed Revision to Technical Specifications Spent Fuel Pool Reactivity," April 16,1992, B14102.

7 Letter from, D.B. Osborne (USNRC) to J.F. Opeka (NNECO), "Issuance of Amendment No. 109", dated January 15, 1986.

8 Northeast Technology Report NET-043-M2, "Millstone Unit No. 2 Boraflex Panel Inspection: East and West Panels from Cell D-9," March 25, 1992.

9 "Millstone Unit 3 Spent Fuel Rack Criticality Analysis with Boraflex Shrinkage and Gaps", Westinghouse Nuclear Fuel Division, January, 1993.

10 Letter, E. A. DeBarba to USNRC, "Millstone Nuclear Power Station, Unit No. 3 Spent Fuel Pool Boraflex Blackness Testing," April 30, 1993, B14308.

11. M. H. Brothers letter to the USNRC, "Licensing Event Report 96-033-00," dated October 7, 1996.

12. J. W. Andersen letter to T. C. Feigenbaum, "Issuance of Amendment (TAC No. M95372)," dated October 4, 1996.