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The Northeast Utilities System

APR 16 1998

Docket No. 50-423
B17115

US Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Millstone Nuclear Power Station Unit No. 3
Response to Request For Additional Information
Erosion of Cement From The Underlying Porous Concrete Drainage System

By a letter dated February 24, 1998, the NRC staff transmitted two (2) questions to Northeast Nuclear Energy Company (NNECO) regarding issues related to the Millstone Unit No. 3 Containment Basemat Concrete. Accordingly, in Attachment 2, NNECO hereby submits our response to those questions.

Additional information is being provided in the form of three attachments to facilitate review and closure of this issue. Attachment 3 provides a review of the background and correspondence history pertaining to this issue. Attachment 4 contains an update on the status of preceding commitments relevant to this topic. Attachment 5 contains a copy of the recently approved 10CFR50.59 evaluation. This evaluation supports statements contained in our response. Attachment 6 provides a copy of the Construction Technology Laboratories (CTL) report which supports the conclusions contained within the attached 10CFR50.59 evaluation.

NNECO's commitments in response to this issue are contained within Attachment 1.

Should you have any questions regarding this submittal, please contact Mr. David Smith at (860) 437-5840.

Very truly yours,
NORTHEAST NUCLEAR ENERGY COMPANY

BY: *M L Bowling*
Martin L. Bowling
Millstone Unit No.2 Recovery Officer

Attachments (6)

1. NNECO's Commitments In Response To The Request For Additional Information Erosion Of Cement From The Underlying Porous Concrete Drainage System
2. Response to Request For Additional Information: Erosion of Cement From The Underlying Porous Concrete Drainage System
3. Historical Review of Erosion Of Cement From Porous Concrete Sub-Foundation
4. Commitment Status for Erosion Of Cement From Porous Concrete Sub-Foundation
5. Safety Evaluation S3-EV-9700574, Rev. 1, Containment Structure Porous Concrete Drainage System
6. Construction Technology Laboratories (CTL) report: "Exmination of Concrete Cores Millstone III Subcontainment Porous Concrete"

cc: H. J. Miller, Region 1 Administrator
W. D. Travers, Ph.D., Director Special Projects
A.C. Cerne, Senior Resident Inspector, Millstone Unit No. 3
J. W. Andersen, NRC Project Manager, Millstone Unit No. 3

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Attachment 1

Millstone Nuclear Station Unit No. 3
NNECO's Commitments In Response To The
Request For Additional Information
Erosion Of Cement From The Underlying Porous Concrete Drainage System

April 1998

Enclosure 1
List of Regulatory Commitments

The following table identifies those actions committed to by NNECO in this document. Please notify the Manager - Regulatory Compliance at the Millstone Nuclear Power Station Unit No. 3 of any questions regarding this document or any associated regulatory commitments.

Number	Commitment	Due
B17115-01	Monitoring of the HAC porous concrete and portland cement porous concrete groundwater chemistry to confirm the sub-containment chemical and environmental conditions.	On a yearly basis.
B17115-02	Measuring of the white residue / mass loss of calcium-alumina in the ESF sumps.	Semi-annually,
B17115-03	Inspection of the sub-containment drainage piping in the ESF sumps.	On a yearly basis.
B17115-04	Containment structure settlement monitoring.	Once every 2 years.

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Attachment 2

Millstone Nuclear Station Unit No. 3
Response to
Request For Additional Information
<u>Erosion of Cement From The Underlying Porous Concrete Drainage System</u>

April 1998

Responses
Request For Additional Information
Erosion Of Cement From Porous Concrete Sub-foundation

Question 1:

For each of the five effects considered in the safety evaluation Section (1.2) , the licensee chooses to extract conclusions from the various reports by its consultants, rather than discussing the applicable portions (test results, results of investigations, expert opinions, etc..) of the reports as the basis for certain conclusions. As such, it is difficult for the staff to determine what in the contractors reports the licensee utilized in making final conclusions. Please provide a safety assessment which the staff can utilize in making a safety judgment regarding the current condition and the future expectations regarding the containment structure's ability to perform its design function. Include the actions (periodic inspections, settlement monitoring, sump residue monitoring, etc...) planned to monitor future conditions.

Response 1:

The original safety evaluation S3-EV-9700574 dated December 18,1997 was revised to include additional technical details in various sections to support the stated conclusions [Attachment 5- Safety Evaluation Rev.01 dated 3/25/98].

Initially, a test program was conducted at Alden Research Laboratories on porous concrete mock-ups to improve our understanding of the porous concrete behavior under simulated conditions. The primary objectives of the previous Phase I, II and III test programs were to determine the reasons for the observed white residue collected in the ESF sumps and its associated impact on the integrity of the subcontainment porous concrete materials. Construction Technology Laboratories (CTL) subsequently performed a technical investigation (1) to determine the reasons for formation of the white deposits, (2) to establish a root cause mechanism for deterioration of the sub-base concrete, as reflected in the degradation of the mock-up specimens, and (3) to provide an estimate of the residual strength of the in-situ porous concrete. Based on the CTL investigation completed in April 1997, the primary concern identified was with the integrity of the High Alumina Cement (HAC) porous concrete. The Phase III mock-up tests were performed to determine the long-term effects of groundwater exposure on the residual strength of the porous concrete. Application of the test data and strength model to the structure in the field was considered problematic, since the mock-up tests did not take into account the chemical dissolution mechanism for the HAC porous concrete. Furthermore, there was no reliable data for the in-situ strength of the HAC porous concrete. Due to these uncertainties, extrapolation of the test data to longer time periods was not warranted. It is noted that usable qualitative data was developed by the Phase I, II and III test programs which was instrumental in understanding the complex reactions in the as-built structure.

It was concluded that the prior Phase I, II and III programs were not representative of the construction materials and practices utilized during original construction as well as the subcontainment conditions at Millstone Unit-3. In the aggregate, these difficulties made a quantitative translation of the mock-up strength data to the Millstone Unit-3 situation tenuous. Given the uncertainties in the prior test program, it was recommended that cores be obtained from the actual structure and tested to confirm the potential degradation mechanism(s) and the in-situ compressive strength of the HAC porous concrete.

It was decided in April 1997 to obtain actual HAC porous concrete cores from the containment structure to establish conclusively any potential degradation mechanisms and the in-place compressive strength capacity of the HAC porous concrete material. The HAC porous concrete cores were extracted from the ESF building foundation in October 1997. The HAC porous concrete of the ESF Building foundation is representative of the subcontainment HAC porous concrete based on a technical evaluation confirming the similarities of the as-constructed and post construction conditions below the ESF mat and the containment mat. Therefore, the 1997 technical investigations including the core boring test program and evaluation of samples from the ESF Building supersedes the previous Phase I, II and III investigations and results provided to you in prior submittals.

In summary, the primary focus of the 1997 investigations was to perform a comprehensive evaluation of the containment basemat issues based primarily on the analysis and testing of representative insitu HAC porous concrete materials samples. The results and findings derived from the 1997 investigations constitute the primary technical basis for the safety evaluation S3-EV-9700574 dated December 18,1997.

As part of the ESF core boring program, two standpipes were installed in the ESF building foundation that provide direct access one to the HAC porous concrete and the other to the portland cement porous concrete layers. Based on the evaluations completed in December 1997, the following monitoring actions are planned in the future:

1. Monitoring of the HAC porous concrete and portland cement porous concrete groundwater chemistry on a yearly basis to confirm the subcontainment chemical and environmental conditions;

2. Measuring of the white residue / mass loss of calcium-alumina in the ESF sumps semi-annually;

3. Inspection of the subcontainment drainage piping in the ESF sumps on a yearly basis;

4. Containment structure settlement monitoring once every 2 years.

Question 2:

The porous concrete media under the ESF building (where the test cores were taken), is not subject to the same type of construction sequences, seal construction, sustained water flow, and stress gradients as the porous media under the containment structure. Discuss what, if any, factors were used to account for such differences in the tested parameters.

Response 2:

Prior to core boring in 1997, a technical evaluation was conducted to confirm that the HAC porous concrete core samples from the ESF building foundation are representative of the subcontainment HAC porous concrete conditions The evaluation considered the original as-constructed conditions and the post-construction conditions including potential degradation mechanisms and the chemical and environmental conditions below the ESF building and the containment structure.

The inputs for the as constructed conditions were obtained from the original Architect Engineer (Stone & Webster), while the potential post-construction degradation mechanisms were established by CTL based on the investigation completed in April 1997. The major conclusions from the technical evaluation are summarized below:

1. The HAC porous concrete layer below the ESF mat and the containment mat is constructed as part of one homogenous uniform horizontal subcontainment drainage system. The location of the cores is in a section of the ESF building HAC porous concrete layer which is in essence a part of a containment pour which extends into the ESF building by design.

2. The construction processes and materials, and the conditions in which the HAC porous concrete material was placed under both the ESF building mat and the containment mat were determined to be very similar. Therefore, the concrete characteristics of the HAC porous concrete layer under the ESF building mat are representative of the material that existed under the containment mat upon completion of the construction activities. A finite

element heat transfer analysis was performed and confirmed that the thermal conditions in the wet HAC porous concrete layer under the ESF mat and the containment mat were similar due to the heat of hydration from the portland cement concrete basemat. There is one minor difference in construction, since a PC mortar was used between the top of the HAC porous concrete and the containment mat while an HAC mortar was used at the same location below the ESF mat. However, it is noted that the same material combination(PC mortar/HAC porous concrete) exists in the ESF building on the bottom of the HAC porous concrete layer. Given the inherent porosity of the of the HAC porous concrete layer, the PC mortar to HAC porous concrete materials under both the ESF building and the containment mat are exposed to the same chemical and environmental conditions. This supports the assumption that the ESF cores will provide representative information regarding the PC mortar to HAC porous concrete conditions below the containment mat.

3. The potential degradation mechanisms for the HAC porous concrete were determined to be primarily conversion and high-pH dissolution of the HAC cement paste. Considering the continuous groundwater infiltration and porous concrete porosity, the HAC porous concrete layer below the ESF and containment mat has been submerged at a steady-state temperature of 65-68 F since construction. Consequently, the potential for continued conversion of the HAC paste is considered to be the same under both the ESF and containment mat.

The groundwater in the HAC porous concrete layer is considered to be relatively stagnant based on the low migration velocity. Stagnation provides for diffusion and equilibration of the groundwater and its chemical content throughout the HAC porous concrete layer. Consequently, the potential for high-pH dissolution of the HAC paste is considered to be the same under both the ESF and containment mat. In general, the conditions in the HAC porous concrete layer are expected to be quite homogeneous for the majority of the HAC porous concrete layer with the possible exception close to locations of groundwater inleakage and the drainage pipes.

Three 6-inch HAC porous concrete cores were subjected to confined compression strength testing in order to determine the compressive strength capacity and the compressibility of the in-situ HAC porous concrete. Because of potential concerns that the HAC porous concrete might have significantly less strength when wet than when dry, each HAC core was tested in a wet condition. Although each specimen was tested to failure, the reported compressive strength was limited to the linear stress-strain response of the specimen. The average confined compressive strength of the in-situ HAC porous concrete was determined to be 2,850 psi which well exceeds the containment structure design loading requirements of 215 psi associated with

SSE loading. The established strength capacity of the HAC porous concrete envelopes the maximum design stress gradients in the containment structure.

Based on the above, it is concluded that the as-constructed conditions in the HAC porous concrete layer under the ESF building and the containment structure are very similar and that the HAC porous concrete layer below the ESF mat and the containment mat is subject to the same post-construction chemical and environmental conditions. Furthermore, the locations of the core samples were away from the drainage pipes and the ESF sumps to the extent possible and as close as possible to the containment structure to ensure that the most representative materials data is obtained for assessment of the subcontainment HAC porous concrete layer. Therefore, the core samples from the ESF building are considered to be representative for the general assessment of the subcontainment mat HAC porous concrete materials.

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Attachment 3

Millstone Nuclear Station Unit No. 3

Historical Review of
Erosion Of Cement From Porous Concrete Sub-Foundation

April 1998

Historical Review of Erosion Of Cement From Porous Concrete Sub-Foundation

Background

The containment structure at Millstone Nuclear Power Station Unit 3 (MNPS-3) has a 3.05-meter [10-foot] thick reinforced-concrete basemat founded on rock. Between the foundation rock surface and the underside of the basemat are several layers of different materials. These layers consist of (1) a 25.4-cm [10-inch] thick leveling layer of porous concrete made of coarse aggregates and portland cement, (2) a 0.16-cm [~1/16th inch] thick butyl rubber waterproofing membrane, (3) a 5.08-cm [2-inch] thick portland cement mortar seal, (4) a second layer of 22.86-cm [9-inch] thick porous concrete made of coarse aggregates and calcium aluminate (high-alumina) cement, and (5) a thin mortar seal (consisting of calcium aluminate cement and sand) or portland cement mortar seal on the top of the upper layer of the porous concrete. In the upper porous concrete layer, 15-cm [6-inch] diameter porous concrete pipes are installed to collect and drain ground water which may seep down along the periphery of the containment wall. The collected water drains into two sumps inside the Engineered Safety Features (ESF) Building.

This issue of cement erosion from the porous concrete drainage system was identified in 1987, upon examination of the accumulated sludge in the two lower drain sumps in the ESF Building. Efforts to follow up on and resolve this concern were documented in NRC Inspection Reports 50-423/94-11 and 50-423/96-04, dated May 27, 1994, and June 6, 1996, respectively.

The main concern has been the adequacy of the porous media to transfer the containment loads to the bedrock. The unexpected erosion of the high-alumina cement also gave rise to another concern regarding a potential for interaction between the concrete of the foundation basemat that contains portland cement and the high-alumina cement of the sub-foundation in the presence of underground water.

To address these concerns, strength tests on cores obtained from mockup tests that simulated accelerated degradation of the porous concrete were performed. This testing was conducted in three (3) phases. An overview of the mock-up testing program was provided in Attachment 1 to a letter entitled "Millstone Nuclear Power Station Unit No. 3, Evaluation of Phase III Containment Basemat Mock-up Testing Report -Millstone Unit No. 3," (B16298), dated February 28, 1997.

Through the Phase I mock-up testing, it was learned that the two cements i.e., portland cement type II and the calcium aluminate cement in porous concrete layers result in collection of white residue and the indication of a loss of strength either by allowing the water flow or by keeping the porous concrete layers submerged with stagnating water. In the Phase II mock-up testing, it was learned that cross flowing two layers with two types of cements produced the white residue deposits after allowing the water to flow for thirty (30) days while maintaining the structural integrity of the porous concrete layers.

The confined and unconfined compressive strength performed during the Phase III mock-up testing showed that there is some degree of erosion of cement and apparent corresponding decline in compressive strength. The erosion of the cement as a result of water flow was determined to be insignificant.

With the assistance of Construction Technology Laboratories (CTL), a technical investigation was subsequently performed. Based on the CTL investigation, completed in April 1997 the primary concern identified was with the integrity of the High Alumina Cement (HAC) porous concrete. This investigation also concluded that the prior Phase I, II and III programs are not considered to be representative of the construction materials and practices utilized during original construction as well as the sub-containment conditions at Millstone Unit-3. Taken all the mock-up issues in total, a quantitative translation of the mock-up strength data to the Millstone Unit-3 situation would have been tenuous. Furthermore, there was no reliable data for the in-situ strength of the HAC porous concrete. Due to these uncertainties, extrapolation of the test data to longer time periods was not warranted. However, usable qualitative data was developed by the Phase I, II and III test programs which was instrumental in understanding the complex reactions in the as-built structure.

Given the uncertainties in the prior test program, it was recommended that cores be obtained from the actual structure and tested to confirm the potential degradation mechanism(s) and the in-situ compressive strength of the HAC porous concrete. As a result, HAC porous concrete cores were extracted from the porous concrete layers under the ESF building foundation in October 1997 to establish conclusively any potential degradation mechanisms and the in-place compressive strength capacity of the HAC porous concrete material. The ESF building foundation HAC porous concrete was determined to be representative of the sub-containment HAC porous concrete based on a technical evaluation which confirmed the similarities of the as-constructed and post construction conditions below the ESF mat and the containment mat. Therefore, these technical investigations including the core boring test program and evaluation of samples from the actual structure supersede the previous Phase I, II and III investigations and results provided in prior submittals.

Regulatory Correspondence

During the period from August 1 to August 5, 1994, an inspection at Millstone Nuclear Station Unit No. 3 (MP3), focusing on the subsurface drainage system under the containment structure of MP3, was conducted by the Nuclear Regulatory Commission (NRC) Staff to assure the continued integrity and stability of this structure. The results of this inspection were reported on August 11, 1994 in Inspection Report (IR) 50-423/94-21 (A11790). The inspection concluded that the technical investigation, analysis and evaluation of the degradation and erosion of the porous concrete was incomplete in that:

1. The test and evaluation of the interface between the high alumina cement and the porous concrete and portland cement structural concrete in the Containment base mat had not been completed, and;

2. Dynamic behavior of the Containment structure during seismic events, either due to high pore pressure because of the clogged drainage system, or due to changes on the normal (vertical loads) and seismic vibration, and its effect on the bearing capacity of the remaining course aggregate, had not been evaluated, and;

3. The effect of high/low tides in Long Island Sound on the drainage/seepage under the containment has not been investigated and evaluated.

It was also noted in IR 50-423/94-21 that additional efforts were continuing or were being planned for further investigations and tests. It also concluded that this condition had no immediate safety concern regarding the stability of Containment.

A letter entitled "Millstone Nuclear Power Station, Unit No. 3, Response To Inspection Report 50-423/94-21, Erosion Of Cement From The Millstone Unit No. 3 Containment Mat" (B15008), dated October 14, 1994, provided a response within Attachment 1 which included an assessment of the issue and plans with milestones for resolution of the concern. The response included plans to continue mock-up testing to determine the effect of high alumina cement in the porous concrete on the portland cement within the structural concrete. Additionally, it stated the intent to conduct a study, utilizing 4 inch bore holes, to determine the effect, if any, of Long Island Sound tidal variations.

On February 29, 1996, an update was provided to the Staff in a letter entitled "Millstone Nuclear Power Station, Unit No. 3, Update On Erosion Of Cement From The Millstone Unit No. 3 Containment Mat."(B15519). This correspondence reported that there had been no discernible trend in concrete strength reduction as a result of the water flow introduced into the Phase III test molds. It also reported that there would be a delay in the completion of some previous commitments and that a study to determine the correlation between surface rainfall data, Long Island Sound tidal levels, and the quantity of water removed from the containment underdrain sump would be undertaken in lieu of a study utilizing 4 inch bore holes.

On May 6, 1996 the NRC completed an inspection at Millstone Units 1, 2, & 3. The results of this inspection were reported in "NRC Combined Inspection Reports 50-245/97-05; 50-336/97-05; 50-423/97-05 and Notice of Violation" (A12863), dated June 6, 1997. During the seven weeks encompassed by this inspection, one of the items that was addressed was Inspection

Follow-up Item (IFI) 50-423/94-11-09 concerning the erosion/leaching of cement from the nine inch (9") thick porous concrete installed for drainage under the containment base mat for Unit 3. This condition had been previously documented in NRC Inspection Reports 50-423/96-11 and 50-423/96-21, and information that had been submitted to the Commission in letters dated October 10, 1994 and February 29, 1996. In paragraph E8.1 of the Combined Inspection, the NRC Staff requested that Northeast Nuclear Energy Company (NNECO) provide an assessment of certain issues concerning the concrete under the Millstone Unit No. 3 Containment basemat. Specifically, the Staff requested that NNECO provide:

1. An assessment of a discrepancy between the bearing load value listed in the UFSAR and the actual peak load calculated (URI 423/96-04-13),

2. A response to a question regarding the validity and use of the UFSAR value in designing safety-related structures (URI 423/96-04-14),

3. A formal update of the operability of the containment system that addresses the extension schedule (URI 423/96-04-15).

During a meeting held on July 1, 1996 at the Millstone Site, the NRC staff made an informal request for pertinent information on a series of topics related to the issue of erosion of porous concrete under the Millstone Unit 3 Containment basemat. This request was answered in a letter entitled "Millstone Nuclear Power Station, Unit No. 3, Pertinent Information Related To The Issue Of Erosion Of Cement From The Millstone Unit No. 3 Containment Mat" (B15803), dated July 12, 1997. Attachment 1 to this correspondence provided information that responded fully to the staff's request. Attachment 2, titled "1991 Chemical Analysis of Sump Residue," presented information related to the debris found in the MP3 Engineered Safety Features Building sump. Attachment 3, titled "1996 Chemical Analysis of Sump Residue and Water," contained the results of the analysis of the samples removed from the Millstone 3 containment sump and mock-up samples. Attachment 4, titled 'Technical Data on Porous Wall Concrete Drainage Pipes," presented technical information regarding the six inch (6") diameter porous concrete drain pipes.

The response to the NRC Staff's request of June 6,1996 was provided in a letter entitled "Millstone Nuclear Power Station, Unit No. 3, Additional Information Related To The Issue Of Erosion Of Cement From The Millstone Unit No. 3 Containment Mat" (B15825), dated August 1, 1997. Attachment 1 to this letter provided the results of the assessment of the Unit 3 containment bearing load, and the results of the review that confirmed that other building bearing loads in Unit 3 had been appropriately addressed. The results of a review of the validity and significance of Final Safety Analysis Report (FSAR) Table 2.5.4-23, which provides the bearing capacity of major structures were also provided in Attachment 1. Attachment 2, contained an update of the operability of the Unit 3 containment.

During a teleconference on August 2,1996, the NRC Staff requested that test results of one aspect of the porous concrete mock-up testing be provided. Specifically, the Staff requested the results of the mock-up test conducted to determine the impact on the simulated containment basemat concrete at the interface with the nine inch porous concrete layer. These results were provided as Attachment 1to a letter entitled "Millstone Nuclear Power Station, Unit No. 3, Additional Information Related To The Issue Of Cement From The Millstone Unit No. 3 Containment Mat" (B15850), dated August 9, 1997. Within this attachment it was stated that a mockup test had been performed at Alden Research Laboratory that was intended to duplicate the response of the containment basemat when exposed to water flow and assess the response of porous concrete when subjected to water flow. It also included the interface between the structural concrete and the porous concrete. The results of the compression tests ands visual examinations did not reveal any degradation of the structural basemat as a result of the water flow through the test slab.

The letter entitled "Millstone Nuclear Power Station Unit 3, Additional Information Related to Millstone Unit No. 3 Containment Mat," dated October 10, 1997, forwarded five tables and four figures that had been referenced in Attachment 1 to "Millstone Nuclear Power Station, Unit No. 3, Additional Information Related to the Issue of Cement from the Millstone Unit No. 3 Containment Mat," dated August 9, 1996 but which had inadvertently not been included in the transmittal.

By a letter dated October 18, 1996 (A13073), the NRC staff transmitted nine (9) requests to Northeast Nuclear Energy Company (NNECO) regarding issues related to the Millstone Unit 3 Containment Basemat Concrete. These questions were:

1. Provide a complete description and findings from Phase I, Phase II, and Phase III (to the extent available) mockup testing.

2. Reference 3 describes the Phase III mock-up test as related to the study of interaction between the calcium aluminate concrete, and the portland cement concrete of the basemat. Provide the information regarding the relative deterioration of the two concrete types by comparing the 60-day strengths of (1) portland cement mold before and after the test, and (2) that for the high alumina cement concrete. Comparisons with the specified strengths (as shown in the Conclusion) is inappropriate.

3. The Phase III mock-up test also indicated that there was a complete lack of bond between the portland cement concrete mold (representing the basemat concrete), and the calcium aluminate concrete of the test mold. Provide information regarding the consequences of the lack of bond on the load transfer to the foundation, and on the dynamic behavior of the structure.

4. UFSAR Section 3.8.1.6.1. states, "In general, concrete mixes were of a 28-day strength of 3,000 psi unless otherwise specified by the Engineer." However, in response to question I.1 (Ref. 1), the strength of the containment basemat concrete is indicated as 3,000 psi at 60-days. Provide information on what was really used. If available, provide information regarding the strength of lab-cured and field-cured cylinders taken from the basemat concrete during construction. This information is useful in comparing the degradation effects, if any, with the results of the mock-up tests.

5. Provide a relationship between the grain size distribution of the sump slurry (Attachment 3, Ref. 1), and the finer particles and cement particulate in the porous concrete layers. This information is useful in understanding and predicting the ability of the erosion process to continue.

6. An Operability Determination (OD) has been provided in Attachment 2 to Reference 2. In item F.1a, a gross assumption has been made that the full 800 feet of drainage pipes are filled with eroded cement. Figure II.2-3 attached to Reference 1 shows the daily count of the total amount of water collected in the sumps in the year 1994. The peak flow shown is about 6,700 gallons of water per day. Such a large flow is not feasible if the pipes were even half filled with the hardened cement. There is a vast uncertainty in estimating the yearly accumulation of dry weight of the cement residue. Based on the results of the mock-up tests and other information (e.g., the latest estimate of 1996 cement residue), provide one reasonable scenario in your OD that can be compared against future accumulation of cement slurry in the sumps.

7. Four additional hypothetical scenarios have been postulated in the OD (Attachment II, Ref. 2). In the evaluation of each scenario, a statement is made at the end of the evaluation, "The containment mat has sufficient rigidity to span over these hypothetical gaps without any impact on the mat qualification." The results of the calculations, if any, have not been provided. Provide the results of the calculations (stresses and deflections) for the fourth scenario (where a 5-foot diameter gap has been assumed) considering the gap to be under the heavily loaded area, for example, under the fully loaded crane wall, or reactor (primary shield) wall.

8. Erosion of cement from the porous concrete layers is continuing, and it is necessary to monitor the movement of the foundation basemat under heavily loaded areas of the basemat (e.g. crane wall and primary shield wall). Provide information regarding your plans for monitoring the settlements under such areas.

9. The effects of uniform and differential settlements could be monitored by inspecting the surface conditions of the walls near discontinuities, and pipe alignments around piping penetrations in the containment wall, crane wall, and the primary shield wall. Provide your plans to implement augmented inspections for this purpose.

The letter entitled "Millstone Nuclear Power Station Unit 3, Response to Request for Additional Information On Erosion of Cement from the Underlying Porous Concrete Drainage System, Millstone 3 (B15985)," dated November 26, 1996, provided responses to these nine questions in Attachment 1. This response also contained three (3) new commitments relative to the Containment base mat issue (B15985-01 through 03).

In a letter entitled "Millstone Nuclear Power Station Unit 3, Response to Request for Additional Information on Erosion of Cement from the Underlying Porous Concrete Drainage System" (B16111) dated December 31, 1996, Attachment 2 provided the Phase III Containment Basemat Mock-Up Testing Final Report as closure to a commitment contained in the letter dated November 26, 1996 (B15985-01).

By letter dated February 28, 1997 (B16298), an engineering evaluation of the Phase III Containment Basemat Mock-Up Testing Report for Millstone Unit 3 was provided to the NRC. The mock-up testing performed at the Alden Research Laboratory (ARL) was an effort to obtain a better understanding of the cement erosion observed from under the containment foundation basement. This letter contained one (1) new commitment (B16298-01).

On March 19, 1997, members from NRR toured the mock-up at Alden Research Laboratory. During the tour and follow-up discussions, many of the questions the NRC had concerning the mock-up testing and the monitoring of the Millstone Unit 3 basemat were addressed. During these discussions, several reports were mentioned which the NRC requested for review in a letter dated April 11, 1997 (A13279). Specifically, they requested that the root cause analysis and residual strength assessment, the porous concrete materials properties evaluation, and the containment structure seismic assessment be submitted by the end of April 1997.

In Information Notice 97-11 "Cement Erosion From Containment Sub-foundations At Nuclear Power Plants", dated March 21, 1997, the NRC staff concluded, on the basis of a review of all the available information, that there was no immediate safety concern at Millstone Point Unit 3 (MP3) because only an insignificant amount of cement is estimated to have possibly eroded from the porous concrete sub-foundation since the plant was built in 1975, and because no adverse consequences of the cement erosion are either predicted or have been observed at the plant. On the basis of the staff's preliminary assessments of MP3, the **staff found that there was no immediate generic or plant-specific safety concern related to the porous concrete sub-foundations below the containment basemat at nuclear power plants**. However, the NRC Staff stated its intent to continue evaluating the potential long-term impact of erosion of high-alumina cement at MP3.

The reports requested on April 11, 1997 (A13279), were provided in a letter entitled "Millstone Nuclear Power Station Unit 3, Response to Request for Additional Information on Erosion of Cement from the Underlying Porous Concrete Drainage System, Millstone Unit No. 3" (B16403), dated April 30, 1997. Specifically, the Staff had requested copies of the following reports: the root cause analysis and residual strength assessment, the porous concrete materials properties evaluation, and the containment structure seismic assessment. These reports were provided as Attachment 2 to this letter. The root cause analysis and residual strength assessment were contained in the Construction Technologies Laboratory (CTL) report dated, April 11, 1997. The porous concrete materials properties evaluation was contained in Section 4 of the GEI Consultants, Inc. (GEI) report, dated March 14, 1997, and the containment structure seismic assessment was contained in Section 3 of the same GEI report, dated March 14, 1997.

The NRC staff reviewed the information and requested further clarification by a letter titled "Request For Additional Information Regarding Erosion Of Cement From Porous Concrete Sub-foundations (TAC No. M96452)," dated June 16, 1997 (A13338). In this letter, the NRC staff transmitted eight questions regarding issues related to the containment basemat concrete. These questions were:

1. Construction Technology Laboratory (CTL) has performed a detailed evaluation and attempted to identify the potential causes of: (i) the erosion of high alumina cement (HAC) from the upper porous concrete layer and, (ii) the leaching of alkalis from the lower portland cement concrete layer. However, it has neglected to consider one important aspect of erosion that is specific to the site condition. During the placement of the portland cement concrete basemat, the HAC porous concrete and the seal coat were subjected to water accumulation and high heat of hydration (necessary conditions for high rate of conversion). Conversion of HAC is likely to have started from that point on. Neglecting this initial condition is likely to yield an erroneous estimate of the degree of conversion and reduction in the compressive strength.

Explain how this aspect of the porous concrete degradation is considered in your assessment.

2. In CTL Report, CTL Project No. 050943, "Investigation of Possible Deterioration of Porous Concrete - Millstone No. 3 Nuclear Reactor," Construction Technology Laboratories, Inc., April 11, 1997., CTL emphasized a need to have representative porous concrete cores from the structure before it could provide a realistic assessment of the actual condition of the concrete (degree of conversion of high alumina concrete, effect of alkalis, reduction in compressive strength, etc.). Provide information regarding this planned activity, and the results of CTL's final assessment.

3. In the settlement analysis (Section 4 of GEI Report, GEI Project 96199, "Porous Concrete Investigation, Millstone Unit 3, Waterford, Connecticut," GEI Consultants, Inc., March 14, 1997.), GEI Consultants, Inc. (GEI) hypothesizes that all cements are lost prior to placing the static loading of the containment structure. This is a highly unrealistic initial condition. Discuss how you plan to use CTL's assessment with GEI's techniques to obtain a realistic assessment of the settlement of the containment structure.

4. CTL has made a rough first order estimate that the compressive strength of the HAC porous concrete will be reduced by 380 psi in the next 5 years. Explain if, and how, you accounted for this strength loss in your final assessment of the foundation behavior (e.g., in the estimate of moments and shears in the foundation basemat caused by uniform and differential settlements).

5. Section 4.3.2 (GEI Report, GEI Project 96199, "Porous Concrete Investigation, Millstone Unit 3, Waterford, Connecticut," GEI Consultants, Inc., March 14, 1997.) states the EQE International, Inc. (EQE), determined a maximum compressive stress of about 7.4 ksf on the porous concrete layer due to vertical seismic acceleration and due to overturning. Provide the minimum compressive stress and discuss whether or not there is any loss of contact on the circumference of the basemat.

6. Section 4.4 (GEI Report, GEI Project 96199, "Porous Concrete Investigation, Millstone Unit 3, Waterford, Connecticut," GEI Consultants, Inc., March 14, 1997.) states that total settlement of the 19-inch-thick porous concrete layer due to complete loss of cement, static loading by the containment, and seismic loading (under safe shutdown earthquake) is estimated to be about 1.7 inches. Does your estimate of settlements consider the effect of saturation of the crushed stone with water? What is the estimated maximum differential settlement of the basemat due to the factors mentioned in 3b and 3c above, and what are the consequences of such differential settlement?

7. In conjunction with the assessment of settlements that could have occurred (prior to placement of the Initial Structural Integrity Testing (ISIT) markers), and future prediction (including that under the postulated seismic event), provide a discussion of actions that you would take to ensure the integrity of the safety-related structures, systems and components affected by the potential settlement. Such actions may include monitoring of differential settlements, identifying critical areas where differential settlements need to be monitored, etc.

8. The sketch of the Reactor Building structural model shown in Figure 3.4 (GEI Report, GEI Project 96199, "Porous Concrete Investigation, Millstone Unit 3, Waterford, Connecticut," GEI Consultants, Inc., March 14, 1997.) shows different notations for some of the structural elements from those shown in Figure 3.7B-9 of the Final Safety Analysis Report (FSAR). Explain the differences, if any, between the structural element models used in the FSAR and in the current soil-structure interaction analysis (GEI Report, GEI Project 96199, "Porous Concrete Investigation, Millstone Unit 3, Waterford, Connecticut," GEI Consultants, Inc., March 14, 1997.).

Accordingly, the response to the questions were provided in Attachment 1 to "Millstone Nuclear Power Station, Unit No. 3 Response to the Request for Additional Information on Erosion of Cement From the Underlying Porous Concrete Drainage System" (B16566), dated July 16, 1997. This letter contained five (5) new commitments (B16566-01 through 05).

The schedule for the completion of the commitments contained on the letter of July 16, 1997 (B16566) was subsequently modified by two letters entitled "Millstone Nuclear Power Station, Unit No. 3, Revised Schedule to Commitments in Response to the Request for Additional Information on Erosion of Cement From the Underlying Porous Concrete Drainage System" (B16774 & B16816), dated September 30, 1997 and November 21, 1997, respectively. Additionally, completion of the preliminary structural assessment of the containment basemat considering postulated strength loss in the HAC porous concrete layers was reported in the letter of September 30, 1997. Completion of the coring and in situ testing was subsequently reported in the letter of November 21, 1997.

In the initial response to Request For Additional Information Regarding Erosion Of Cement From Porous Concrete Sub-foundations (TAC No. M96402)," dated June 16, 1997 (A13338) response to some of the questions was deferred until a final assessment of the results from the core boring and testing could be completed. Following completion of the high alumina cement (HAC) core boring, testing and final assessment, Attachment 2 to a letter entitled "Millstone Nuclear Power Station Unit No. 3, Response to Request For Additional Information On Erosion of Cement From The Underlying Porous Concrete Drainage System" (B16925), dated December 19, 1997, provided the response to the remaining questions.

As part of the Millstone Restart Assessment Plan Significant Item List No.12 review, the NRC staff reviewed the safety evaluation, "Containment Structure Porous Concrete Drainage System." Based on a review of the December 19, 1997 letter, and the safety evaluation, the NRC requested additional information in a letter titled "Request For Additional Information Regarding Erosion Of Cement From Porous Concrete Sub-foundation (TAC No. M96402)," dated February 24, 1998. Specifically, the Staff transmitted two (2) questions regarding issues related to the containment basemat concrete. These questions were:

1. For each of the five effects considered in the safety evaluation (Section 1.2), the licensee chooses to extract conclusions from various reports by its consultants, rather that discussing the applicable portions (test results, results of investigations, expert opinions, etc.) of the reports as the basis for certain conclusions. As such, it is difficult for the staff to determine what in the contractor's reports the licensee utilized in making final conclusions. Please provide a safety assessment that the staff can utilize in making a safety judgment regarding the current condition and the

future expectations regarding the containment structure's ability to perform its design function. Include the actions (periodic inspections, settlement monitoring, sump residue monitoring, etc.) planned to monitor future conditions.

2. The porous concrete media under the engineering safety features building (where the test cores were taken), is not subject to the same type of construction sequences, seal construction, sustained waterflow, and stress gradients as the porous concrete media under the containment structure. Discuss what, if any, factors were used to account for such differences in the tested parameters.

On March 30, 1998 a letter titled "Millstone Nuclear Power Station Unit No. 3, Notification of Revised Commitment Regarding Erosion of Cement from the Underlying Porous Concrete Drainage System (TAC No. M96402)," (B17131) retracted a commitment to submit an amendment request for the MP3 Technical Specifications to include the limits and frequency for measuring the maximum Containment Building settlement (total), differential settlement (tilt) and penetration differential settlement. This commitment was made in "Millstone Nuclear Power Station, Unit No. 3 Response to the Request for Additional Information on Erosion of Cement From the Underlying Porous Concrete Drainage System" (B16566), dated July 16, 1997. With this correspondence one commitment was opened to discuss planned monitoring of future conditions of the containment basemat structure in the response to "Request For Additional Information Regarding Erosion Of Cement From Porous Concrete Sub-foundation (TAC No. M96402)," dated February 24, 1998.

Attachment 4

Millstone Nuclear Station Unit No. 3
Commitment Status for
Erosion Of Cement From Porous Concrete Sub-Foundation

April 1998

Commitment Source	Commitment	Due Date	Status
B15008	Evaluate the potential chemical reaction between high alumina cement and the portland cement structural concrete .	1st quarter 1996	**This was superseded by B15519-01**
B15008	Address the long term effects of the water flow on the concrete by conducting a series of compressive tests of the core samples for a period of 6 - 12 months.	1st quarter 1996	**This was superseded by B15519-01**
B15008	The forces on the Containment foundation will be evaluated for the loads as defined in the Unit 3 FSAR Section 3.8.5 "Foundations" and NUREG-800 Standard Review Plan Section 3.8.1-II(3), (4) "Design and Analysis Procedure," and Section 3.8.5-II(3), (4) "Design and Analysis Procedure," and Section 3.8.5-II(3), (4), (5), "Structural Acceptance Criteria."	1st quarter 1996	**Completed** "Millstone Nuclear Power Station, Unit No. 3, Additional Information Related To The Issue Of Erosion Of Cement From The Millstone Unit No. 3 Containment Mat" (B15825), dated August 1, 1997. Attachment 1 to this letter provided the results of the assessment of the Unit 3 containment bearing load, and the results of the review that confirmed that other building bearing loads in Unit 3 had been appropriately addressed.
B15008	The net normal force on the aggregate of the porous concrete will be determined to assess the effect on the bearing capacity of the remaining course aggregate.	1st quarter 1996	**Completed** "Millstone Nuclear Power Station, Unit No. 3, Additional Information Related To The Issue Of Erosion Of Cement From The Millstone Unit No. 3 Containment Mat" (B15825), dated August 1, 1997. Attachment 1 to this letter provided the results of

Commitment Source	Commitment	Due Date	Status
			the assessment of the Unit 3 containment bearing load, and the results of the review that confirmed that other building bearing loads in Unit 3 had been appropriately addressed.
B15008	Conduct a study, utilizing 4" bore holes, to determine the effect, if any, of Long Island Sound tidal variations.	1st quarter 1996	**This was superseded by B15519**
B15008	A program will be instituted to monitor ESF pump operation time.	1st quarter 1996	**This was superseded by B15519**
B15519-01	The completion of the Phase III testing and a complete report with the detailed test parameters and results for the NRC's review is now targeted for December 1996.	December 1996	**This was superseded by B15985-1**
B15519	A study to determine the correlation between surface rainfall data, Long Island Sound tidal levels, and the quantity of water removed from the containment underdrain sump would be undertaken.	December 1996	**Completed** Contained within Attachment 1 to a letter entitled "Millstone Nuclear Power Station, Unit No. 3, Additional Information Related To The Issue Of Erosion Of Cement From The Millstone Unit No. 3 Containment Mat" (B15825), dated August 1, 1997 was HYDROLOGICAL DATA - MILLSTONE 3. This data contained the results of the study correlating surface rainfall data, Long Island Sound tidal levels, and the quantity of water removed from the containment.

Commitment Source	Commitment	Due Date	Status
B15985-1:	A final report detailing the results of the Phase III Mock-up Testing will be provided to the NRC.	December 31, 1996	**Completed** A final report detailing the results of the Phase III Mock-up Testing was provided in Attachment 2 to "Millstone Nuclear Power Station Unit 3, Response to Request for Additional Information on Erosion of Cement from the Underlying Porous Concrete Drainage System," dated December 31, 1996.
B15985-2:	Periodic monitoring of permanent benchmarks on the Containment exterior, for any settlement, will be included in NNECO's program for Condition Monitoring of Structures for compliance with the Maintenance Rule.	June 30, 1997	**Completed** The requirement for "Periodic monitoring of permanent benchmarks on the Containment exterior, for any settlement," was incorporated in Engineering Procedure, "MP3 Condition Monitoring of Structures" (EN31098)
B15985-3:	Visual inspections to monitor for potential settlement of the containment internal structure will be included in NNECO's program for Condition Monitoring of Structures for compliance with the Maintenance Rule.	June 30, 1997	**Completed** The requirement for "Visual inspections to monitor for potential settlement of the containment internal structure" was incorporated in Engineering Procedure, "MP3 Condition Monitoring of Structures" (EN31098)

Commitment Source	Commitment	Due Date	Status
B16298-1	Perform a study of test samples associated with the Millstone Unit No. 3 porous concrete to better understand the degradation mechanism.	July 30, 1997	**Completed** Based on the completion of the CTL investigation which is summarized in report CTL Project number 050943 "Investigation of Possible Deterioration of Porous Concrete - Millstone No. 3 Nuclear Reactor," dated April 11,1997. The report addressed all commitments as noted below: 1. Evaluation of well waters outside containment. 2. Analyses of ESF sump residues and liquid samples. 3. Estimation of residual strength and prediction correlations including test results. 4. Evaluations of possible porous concrete degradation mechanisms. A copy of the report was submitted to the NRC on April 30, 1997. In a letter entitled "Millstone Nuclear Power Station Unit 3, Response to Request for Additional Information on Erosion of Cement from the Underlying Porous Concrete Drainage System, Millstone Unit No. 3" (B16403).

Commitment Source	Commitment	Due Date	Status
B16566-1	Address in Unit 3's final assessment the potential effect of conversion during placement on the high alumina cement (HAC) porous concrete degradation.	December 19, 1997	**Complete** "Millstone Nuclear Power Station, Unit No. 3 Revised Schedule to Commitments in Response to the Request for Additional Information on Erosion of Cement From the Underlying Porous Concrete Drainage System (B16816 & B16774), dated November 21, 1997, September 30, 1997, respectively, provided revised schedules for commitments in Northeast Nuclear Energy Company (NNECO) letter B16566. The commitment schedule for performance of high alumina cement (HAC) core boring and to provide a final assessment by November 21, 1997, was deferred to December 19, 1997. These letters affirmed that a final assessment based on the results from the coring and testing would be performed. "Millstone Nuclear Power Station Unit No. 3, Response to Request For Additional Information On Erosion of Cement From The Underlying Porous Concrete Drainage System" (B16925), dated December 19, 1997 provided in Attachment 2 the results of the high alumina cement (HAC) core boring, testing and the final assessment.

Commitment Source	Commitment	Due Date	Status
B16566-2	Perform HAC core samples in the ESF sump area base slab and test water environments to provide a more accurate assessment of the current condition of the HAC.	December 19, 1997	**Completed** "Millstone Nuclear Power Station, Unit No. 3 Revised Schedule to Commitments in Response to the Request for Additional Information on Erosion of Cement From the Underlying Porous Concrete Drainage System (B16816 & B16774), dated November 21, and September 30, 1997, respectively, provided revised schedules for commitments in Northeast Nuclear Energy Company (NNECO) letter B16566. The commitment schedule for performance of high alumina cement (HAC) core boring and to provide a final assessment by November 21, 1997, was deferred to December 19, 1997. "Millstone Nuclear Power Station Unit No. 3, Response to Request For Additional Information On Erosion of Cement From The Underlying Porous Concrete Drainage System" (B16925), dated December 19, 1997 documented the completion of this commitment in Attachment 2.

Commitment Source	Commitment	Due Date	Status
B16566-3	Address in the final assessment the consequences of potential strength loss in the HAC porous concrete layer.	December 19, 1997	**<u>Complete</u>** "Millstone Nuclear Power Station, Unit No. 3 Revised Schedule to Commitments in Response to the Request for Additional Information on Erosion of Cement From the Underlying Porous Concrete Drainage System (B16816 & B16774), dated November 21, and September 30, 1997, respectively, provided revised schedules for commitments in Northeast Nuclear Energy Company (NNECO) letter B16566. The commitment schedule for performance of high alumina cement (HAC) core boring and to provide a final assessment by November 21, 1997, was deferred to December 19, 1997. "<u>Millstone Nuclear Power Station Unit No. 3, Response to Request For Additional Information On Erosion of Cement From The Underlying Porous Concrete Drainage System</u>" (B16925), dated December 19, 1997 documented the completion of this commitment.

Commitment Source	Commitment	Due Date	Status
B16566-4	Address in the final assessment the actual consequences of maximum expected differential settlement.	December 19, 1997	**Complete:** "Millstone Nuclear Power Station, Unit No. 3 Revised Schedule to Commitments in Response to the Request for Additional Information on Erosion of Cement From the Underlying Porous Concrete Drainage System (B16816 & B16774), dated November 21, and September 30, 1997, respectively, provided revised schedules for commitments in Northeast Nuclear Energy Company (NNECO) letter B16566. The commitment schedule for performance of high alumina cement (HAC) core boring and to provide a final assessment by November 21, 1997, was deferred to December 19, 1997. "Millstone Nuclear Power Station Unit No. 3, Response to Request For Additional Information On Erosion of Cement From The Underlying Porous Concrete Drainage System" (B16925), dated December 19, 1997 documented the completion of this commitment in Attachment 2.

Commitment Source	Commitment	Due Date	Status
B16566-5	Submit an amendment request for the Millstone Unit 3 Technical Specifications to include the limits and frequency for measuring the maximum Containment Building settlement (total), differential settlement (tilt) and penetration differential settlement.	March 31, 1998	**Retracted** "Millstone Nuclear Power Station Unit No. 3, Notification of Revised Commitment Regarding Erosion of Cement from the Underlying Porous Concrete Drainage System (TAC No. M96402)" (B17131), retracted the commitment to submit an amendment request for the MNPS-3 Technical Specifications. This retraction was based on the results of analysis of core samples from the basemat supports and the final assessment of this analysis.
B17131-01	Discussion of planned monitoring of future conditions of the containment basemat structure will be included by NNECO in a response to a more recent request for information from the NRC Staff, of February 24, 1998.	April 10, 1998	**Complete** The information satisfying this commitment is contained in Attachments 1 and 2 to this letter (B17115).