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The Northeast Utilities System

February 28, 1997
Docket No. 50-423
B16298

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

Millstone Nuclear Power Station Unit No. 3
Evaluation of Phase III Containment Basemat Mock-up Testing Report -
Millstone Unit No. 3

As a follow-up to a letter dated December 31, 1996, NNECO provides in Attachment 2, an engineering evaluation of the Phase III Containment Basemat Mock-Up Testing Report. NNECO's commitments associated with this letter are provided in Attachment 1.

Should you have any questions or require additional information please contact Mr. James M. Peschel at (860) 437-5840.

Very truly yours,

NORTHEAST NUCLEAR ENERGY COMPANY

M.H. Brothers
Vice President - Millstone Unit No. 3

Attachments

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

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Docket No. 50-423
B16298

Millstone Nuclear Power Station Unit No. 3

Evaluation of Phase III Containment Basemat Mock-up Testing Report -
Millstone Unit No. 3
NNECO's Commitments

February 1997

Enclosure
List of Regulatory Commitments

The following table identifies those actions committed to by NNECO in this document. Any other actions discussed in the submittal represent intended or planned actions by NNECO. They are described to the NRC for the NRC's information and are not regulatory commitments. Please notify the Manager - Nuclear Licensing at the Millstone Nuclear Power Station Unit No. 3 of any questions regarding this document or any associated regulatory commitments.

Commitment		Committed Date or Outage
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

Docket No. 50-423
B16298

Millstone Nuclear Power Station Unit No. 3

Evaluation of Phase III Containment Basemat Mock-up Testing Report -
Millstone Unit No. 3

February 1997

Abstract:

The mock-up of Millstone Unit No. 3 containment mat/porous concrete, is an engineering study of tests conducted at Alden Research Laboratory (ARL), in an effort to obtain a better understanding of the white residue effluent collected at the Engineered Safety Features (ESF) sumps which collect water from the porous layer. The mock-up testing program encompassed three phases of testing and each was intended to simulate the response of the containment basemat when exposed to flowing water. The Phase I mock-up test did not represent "as-built" conditions of the porous concrete drainage system, but the testing molds were constructed by deliberately creating adverse conditions of the porous media to flowing water. This resulted in collection of white residue similar to what is being observed at the ESF sumps. Where as in Phase II, most elements of "as-built" conditions were incorporated into the construction of mock-up test molds and were subjected to water flow through a series of intentional ruptures in the rubber membrane created to simulate the water flow underneath the mat. This also resulted in collection of white residue similar to that observed at the ESF sumps. The chemical analysis of residues collected at the mock-up testing and also at the ESF sumps are similar in chemical oxides of similar weights. Since the Phase II test was limited to thirty (30) days of waterflow, Phase III mock-up testing was initiated to determine the impact of prolonged flow of water on the porous concrete's structural integrity. The primary purpose of the Phase III test program was to simulate long-term porous concrete degradation through accelerated erosion by subjecting the molds to higher flow of water. After fifteen (15) months of conducting the water flow test the results indicate some decline in compressive strength with respect to age in the calcium aluminate cement porous concrete layer. There is no conclusive evidence that the portland based porous concrete is affected by the hydraulic process.

OVERVIEW OF MOCK-UP TESTING PROGRAM

Phase I Testing

The Phase I test was designed to assist in an understanding of the residue phenomena emanating from under the Millstone Unit No. 3 containment structure. The mock-up test molds were intentionally constructed differently than the field conditions, by elimination of some of the intermediate layers, as a conservative model of the containment structure with a breached membrane. In addition during the concrete placement, the objective was to loosely place the concrete to maximize the voids between the aggregate which would provide the worst case for potential accumulation of laitance and concrete washout from the aggregate surface due to the hydrodynamic force of the introduced water.

A total of three test molds were constructed in the Phase I test. One mold consisted of a 9 inch thick single layer of calcium aluminate based porous concrete sandwiched between (1) portland cement based mortar at the bottom, and (2) calcium aluminate cement based mortar on top. The other two molds consisted of 10 inches of portland cement based porous concrete and a 9 inch layer of calcium aluminate cement based porous concrete, placed directly on top of the portland cement based porous concrete. The top of the mold was sealed with a calcium aluminate cement based mortar layer. The molds were provided with inlet orifices on the side forms to allow for the introduction of water, and two 6 inch diameter internal perforated drain pipes installed in the top porous concrete layer for removal of the water.

The materials and mix proportions of the concrete and mortar mixes duplicated the original construction mixes to the extent possible, including procurement of aggregate from one of the quarries used during original plant construction. The molds were cured for 7 days prior to hydraulic testing.

Water was applied laterally to the test mold through the inlet orifices on the side of the test mold at a hydraulic pressure of 22 psi, and removed from the media through the embedded perforated drain pipes. The mold was subject to four 8 hour tests, during which any residue emanating from the test mold was filtered and collected. After the completion of the 8 hour tests, the test mold was subject to a 30 day hydraulic test at the same applied pressure.

Observations:

1) The white residue leached out from the test mold during the seven (7) day curing period.

2) Residue was also collected during the period of water flow.

3) The core samples from the test mold could not be recovered for compression testing from both of the porous concrete layers containing two types of cements.

4) The test molds produced residue both for the water flow condition as well as under stagnant wet condition.

5) The leaching of white residue was assessed to be from both porous concrete layers, and when both porous concrete layers were exposed to a wet environment.

Conclusion:

The Phase I mock-up testing provided valuable information regarding the potential conditions resulting in a white residue. However, the data is not considered as representative of actual conditions for the following reasons:

1) Loosely placed concrete.

2) Each layer was cured only two (2) days before the placement of the next layer.

3) Porous layers were subjected to a 22 psi hydrodynamic water pressure on green concrete, which is not an "as-built" condition.

4) Not including the rubber membrane and the 2-inch mortar on top does not reflect "as-built" conditions.

Because of the above, a more representative test was required to simulate the "as-built" conditions under long term exposure, thus, a Phase II mock-up test was initiated immediately thereafter.

Phase II Testing

The Phase II test was designed to study any effects of water flow on the porous concrete that may be occurring due to removal of the concrete laitance or cement washout and to evaluate the potential for cement erosion to occur as a result of the hydraulic pressure.

Each element of the "as-built" condition of the containment substructure, including the rubber membrane and seal mortars between the two porous concrete layers were included in the construction of the mock-up test molds. The only difference was the substitution of the porous concrete drainage pipe with PVC piping. The method of concrete placement, consolidation, installation of the containment underdrain system, and the water leakage in the membrane were simulated to the extent possible, such that some correlation could be made with respect to the effect on the porous concrete layers.

As part of the Phase II mock-up test, three test molds were constructed. In the sequence of construction of the porous concrete layers, a minimum of seven (7) days was allowed to cure the concrete before placing the next layer, with an additional seven (7) days of curing totaling fourteen (14) days was allowed to age the concrete to attain full strength before hydraulic testing. In the hydraulic testing, water was introduced laterally into the test mold at a pressure of approximately 5 psi for thirty (30) days.

Observations:

1) After thirty (30) days of waterflow, no variation in compressive strengths of porous concrete samples was observed with respect to the location of water flow. The compressive strength is directly correlated and proportional to the density of the core samples. Out of seventy (70) core samples extracted from the test molds and tested, a maximum density of 123 pcf correlated to a compressive strength of 1620 psi and a minimum density of 110 pcf correlated to a compressive strength of 820 psi.

2) Residue was collected in all three molds during the curing period and as well as during water flow conditions.

3) Some of the test samples from the calcium aluminate cement porous concrete layer were damaged during the coring process and could not be tested for compressive strengths.

4) Also observed during coring operation was a lack of bonding between the calcium aluminate cement porous concrete and the portland cement mortar.

The need for an additional phase of testing was identified to address the long term effects of the water flow on the strength of porous concrete, as well as to study the interface effects of the calcium aluminate cement porous concrete layer with the containment mat of portland cement structural concrete.

Phase III Testing

The purpose of the Phase III test was two fold. One objective was to study the long term effects that the water flow creates on the porous concrete strength. The second purpose was to test the portland cement concrete placed on top of the test mold, to determine, if there is any impact on the containment mat containing portland cement due to the interfacing with the porous concrete containing calcium aluminate cement. The concrete representing the mat is placed on top of the porous concrete mold similar to the design condition. This testing was completed by subjecting the test mold to water flow and periodically removing core samples for compressive strength testing. Similarly for the concrete representing the containment basemat, cores were periodically removed from the mold and also simultaneous core samples were removed from a sister mold which was not exposed to the porous concrete or water flow. Laboratory cured cylinder samples were also cast during the concrete placement into the mold. Cores and cylinder samples were tested for compressive strength at predetermined intervals.

Mold Construction Materials

Number 57 Aggregate:

The Number 57 coarse aggregate used in the porous concrete slab was procured from Tilcon Connecticut, Inc., the operators of the Wauregan Quarry, which was one of the sources of the coarse aggregate for the Millstone Unit No. 3 during the original construction. Table No. 1 provides the gradation analysis of the representative samples done in 1975 and also the analyses performed on samples used in the Phase II and Phase III mock-up testing. It was recognized that it would not be possible to obtain a sample of crushed stone that "exactly" matches the gradation and angularity used during construction. The aggregate used in Phase II and Phase III have a slightly different gradation, but meet the ASTM C33 gradation requirements for Number 57 aggregate and were suitable for mock-up testing.

Cements:

Table Number 2 included the percentage contents of oxides extracted from the Mill Test Reports for the cements used in Phase II and Phase III mock-up testing and compared with the oxides of the contents of the representative cement samples used in the original construction of the porous concrete. All oxides are within the range values of the ASTM requirements and were certified to be suitable for the mock-up testing with the exception of 3.1% content of SO_3 (procured) which is about 0.1% higher than the 3.0% maximum recommended.

Water:

Water chemistry listed in Table No. 3, was certified to be suitable for concrete mixing as well as for the hydro test of the mock-up mold.

Concrete Mixes:

Concrete mix proportions and the construction sequence of each layer of placement and the details of mix designations that are identified in Figure 1c, are described in the Phase III porous concrete mock-up testing report prepared by Alden Research Laboratory, Inc. (ARL) and submitted to the Staff on December 31, 1996. All mix designs used in Phase III mock-up testing are in accordance with the original construction specification "Mixing and Delivering Concrete", Stone and Webster Specification 2199.141-281, Revision 1.

It should be noted that in a previous submittal, dated November 26, 1996, on this subject data, on page 6, of Attachment 1, the concrete mixes contained several discrepancies. For Mix B, the water/cement ratio (lb. per lb. maximum) should have

been 0.384 versus the value 0.320 provided. Additionally for Mix C and D the reference should have been to fine aggregate versus coarse aggregate.

Description of Test Mold

The test mold (see Figure 1a-c) represents a typical cross section of the containment porous concrete and basemat. It has nominal dimensions of 11 feet by 11 feet with an inlet water reservoir constructed at the water inlet end and outlet pipes at the discharge end of the mold. One half of the mold contains a rubber membrane similar to the actual containment layers and in the other half of the mold the rubber membrane had been intentionally eliminated.

The cross section of the mold in the area of the membrane consists of the bottom form, 10 inch layer of Mix A portland cement porous concrete, waterproof membrane, a two inch layer of Mix D portland cement seal mortar, 9 inch layer of Mix B calcium aluminate cement porous concrete, two inch layer of Mix C calcium aluminate cement seal mortar and a 12 inch layer of Mix E portland cement structural concrete on top. The cross section in the portion without the rubber membrane is similar except that the rubber membrane, the Mix D mortar on top of the membrane and the Mix E structural concrete have been omitted. The center wall of the mold as well as the inlet end wall have been provided with perforations to allow water entrance. One inch diameter orifices are provided for draining of the mold prior to the coring operations. The details of the test mold are shown in Figure 1a-c.

Hydraulic Testing:

In Phase III mock-up testing, the test mold, (Figure 1a), was designed such that the water flow should have access between two portions of the mold by cross flow from portland cement porous concrete to calcium aluminate cement porous concrete layers or vice versa. This was accomplished by cycles of allowing the water entering through inlet No. 1 and by exiting out of the mold from the outlet No. 2. In the second cycle by allowing the water to pass through inlet No. 2 and exit the water from outlet No. 1. The quantity of the water flow was regulated such that the water flow on the mold was just touching the interface of the structural concrete placed on top of the calcium aluminate cement mortar. Here one (1) cycle of flow defined the flow of water for twenty-four (24) hours a day for twenty-one (21) days in a one month period. The rate of flow for the fifteen (15) months is presented in Table No. 4. A total of about 9.5 million gallons of water was passed through the mold in a fifteen (15) month period to simulate the long-term effects (approximately twenty-five (25) years) through accelerated erosion.

Residue Collection:

The test program did not call for collecting residue from the water, but observations of the sump and the floor where water evaporated indicated that there was no residue being washed from the mold. Since the white residue was collected in Phase I and

Phase II mock-up testing, chemical analysis was performed and compared with the residue collected at the ESF sumps. Table No. 5 is a tabulation of the major oxides.

PHASE III MOCK-UP TESTING

Summary of Results:

This section addresses only the porous concrete strengths and does not address the interface impact of the containment mat structural concrete containing portland cement with the porous concrete drainage layer containing calcium aluminate cement in presence of flowing water. This aspect of the issue has been addressed and submitted to the Staff as response to Question No. 1 in NNECO's November 26, 1996 letter. Therefore, the results of porous concrete layers are summarized below:

1) Unconfined Compressive Strength:
(Reference Figure 1a for the Test Sample Coordinates)

Table No. 6 shows the average unconfined compressive strength of the core samples taken at the end of each water flow cycle for a duration of fifteen (15) months. The compressive strengths of core samples from the portland cement porous concrete were all well above the design requirements of 1000 psi with no evidence of significant deterioration as a result of the hydraulic testing.

The unconfined compressive strength of the core samples (Table No. 6) extracted from the calcium aluminate cement porous concrete indicated a loss of density after the end of the first (1st) cycle of waterflow and loss of compressive strength after the fifth (5th) cycle of waterflow. The average strength of the three (3) test samples showed a net gain in strength for the first five (5) months of about 25% of the first (1st) month and a maximum loss of strength of about 34% occurred in tenth (10th) month. The maximum loss of relative density between the end of the first (1st) cycle to the end of thirteenth (13th) is about 4%, and a maximum loss of strength of about 30%, occurred between the second (2nd) and fourteenth (14th) cycle of water flow.

2) Confined Compressive Strength:

Table No. 7 shows the average confined compressive strength of core samples taken at the end of each hydraulic flow cycle. The core samples after the thirteenth (13th), fourteenth (14th) and fifteenth (15th) flow cycle were extracted from the test mold at locations adjacent to the first (1st), second (2nd) and third (3rd) locations.

The first twelve (12) months of the test, the portland cement porous concrete confined compressive strength of the cores had considerable variation. The maximum strength seen in period twelve (12) is 8% higher than that in first (1st)

period, and the minimum strength in period five (5) is approximately 34% lower than that in the first (1st) period. Where as the confined compressive strength of core samples from that of calcium aluminate cement, for the first (1st) twelve (12) months showed a maximum gain in period five (5) of about 8% higher than the first (1st) period, followed by a decline in strength from the sixth (6th) period to the twelve (12th) period. A 23% decrease in strength was observed from first (1st) period to the twelve (12th) period.

Observations:

1) Core samples were successfully removed from both the porous concrete layers containing portland cement and calcium aluminate cement.

2) Some core samples were separated at the interface of two cements indicating loss of bond.

3) Apparent reduction in density and in compression strength was observed in the calcium aluminate cement porous concrete layer from the core samples and a loss of strength from the core samples towards the water inlet.

4) No white residue was observed during the fifteen (15) month duration of water flow, instead a light brownish paste coating on the aggregate was observed during the coring operation from the calcium aluminate cement porous concrete starting after the fifth (5th) cycle of the test program.

Discussion of Test Results:

In the strength evaluation of concrete structures, the strength of concrete is measured in terms of the ultimate compressive strength of concrete and it shall be based on compressive strength tests of concrete cylinders prepared as prescribed in ACI 318-89, Section 5.6-2. The cylinders for strength tests shall be molded and laboratory cured in accordance with the "Practice For Making and Curing Concrete Test Specimens In The Field" (ASTM C31) and tested in accordance with "Test Method For Compressive Strength of Cylindrical Concrete Specimens" (ASTM C39).

ASTM C31 recommends that the compressive strength specimens shall be cylinders of concrete cast and hardened in an upright position with a length equal to twice the diameter. The standard specimen shall be the 6 inch by 12-inch cylinder.

In compliance with the ACI codes, the unconfined compressive strength is considered the minimum compressive strength for the porous concrete. The results in Table No. 6 indicate a minimum compressive strength of 1440 psi for the portland cement porous concrete and 877 psi for the calcium aluminate porous concrete was considered as the minimum strength.

Conclusions:

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 wet by 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.

Leaching of white residue was not observed during the fifteen (15) months flow of water in Phase III mock-up testing. This is most likely attributed to the curing of the concrete layers during the construction of test molds. The core samples were extracted for compression testing at the end of each cycle of flow test. The confined and unconfined compressive strength results (Table Nos. 6 & 7) show there is some degree of erosion of cement and apparent corresponding decline in compressive strength.

Table No. 8 shows the comparison of test results, i.e., densities/compressive strength of two samples located next to each other but taken twelve (12) months apart. The sample tested at the thirteenth (13th) cycle was taken next to the sample taken after the first (1st) cycle of waterflow. Similarly the fourteenth (14th) and the fifteenth (15th) samples cored out from the test mold adjacent to the second (2nd) and third (3rd) sample locations. The impact of twelve (12) month water flow into the mock-up test mold follows:

<u>Portland Cement Porous Concrete</u>

After twelve (12) months of waterflow into the test mold there is a loss of about 1.2% weight density of cores taken at the end of the thirteenth (13th), fourteenth (14th) & fifteenth (15th) cycles as compared to the first (1st), second (2nd) and third (3rd) cycles. Correspondingly there was a 3.4% decline in the compressive strength of the core samples taken at the same period of time. This indicates that there is a small degree of erosion of cement due to high flow of water which is insignificant.

<u>Calcium Aluminate Cement Porous Concrete</u>

The erosion of calcium aluminate cement from the porous concrete due to the high flow of water is more aggressive than the erosion from the portland cement porous concrete. A 2.4 % loss of relative density from the core samples between first (1st), second (2nd) and third (3rd) core samples compared to the thirteenth (13th), fourteenth (14th) and fifteenth (15th) cycles.

However, a loss relative of about 11% relative compressive strength was observed on the core samples taken at the same time period. This indicates that the calcium aluminate cement is more susceptible for a prolonged duration of waterflow.

The above conclusions are based on the following factors:

1. Intentionally imposed high flow water conditions on the construction of mock-up Test molds which do not reflect all aspects of actual flow conditions of the porous concrete drainage system underneath the containment mat.

2. Large quantities of water flowing through the test molds causing loss of strength due to erosion of cement resulting in loss of bonding effect.

3. The residue collected as oxides could be from both layers of porous concrete and correlates to some degree with the oxides contained in the white residue collected at the ESF sumps.

In an effort to have a better understanding of the process of porous concrete degradation mechanism, additional evaluations of the degradation mechanism are being performed by the Construction Technology Laboratories (CTL). In addition to testing the porous concrete cores and the white residue samples from the mock-up test, the water samples from around the containment (before entering into the foundation level), as well as white residue and water samples at the ESF sumps will be evaluated for a mass balance assessment. This effort is expected to determine the residual strength of the porous concrete at the present time and also estimate the residual strength at future dates.

PHASE III MOCK-UP TESTING

Table No. 1

Number 57 Aggregates Gradation Analysis
% Passing by Weight

		SIEVE SIZE							
	SAMPLE	**1½"**	**1"**	**3/4"**	**½"**	**3/8"**	**# 4**	**# 8**	
DATE									
1975	Aggregate used in the original construction (Representative)	100	99.1	-	38.6	-	4.4	2.8	-
1993	Phase II Mock-Up Testing	-	100	97	51	24	3	-	-
1995	Phase III Mock-Up Testing	-	100	96	53	18	4	3	
	ASTM C33	100	95-100	-	25-60	-	0-10	0-5	-
The aggregate gradation of the original construction and the aggregate used in the Phase II and Phase III mock-up testing meets ASTM C33 requirement.									

PHASE III MOCK-UP TESTING

Table No. 2

CEMENTS OXIDE FROM THE MILL TEST REPORTS IN PERCENT

COMMODITY	CEMENTS	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O
Phase II Mock-Up Testing (1993)	Portland Type II (LeHigh Portland Cement Co.)	21.5	4.5	2.9	63.8	2.2	2.5	0.48	0.09
	Calcium Aluminate (LeHigh Portland Cement Co.)	6.25	50.93	7.28	34.16	0.65	0.38	-	-
Phase III Mock-Up Testing (1995)	Portland Type II (Blue Circle Cement)	20.7	4.7	3.1	63.4	3.4	3.1	-	0.58
	Calcium Aluminate (LeHigh Portland Cement Co.)	7.11	50.22	5.49	35.83	0.50	0.46	-	-
Original Construction (1975)	Portland Type II (Representative)	21.04	4.88	3.00	63.37	3.21	2.89		
	Calcium Aluminate (Representative)	7.5	47.2	7.5	34.2	0.85	2.1		
ASTM Requirements	Portland Type II (C150)	20.0(min)	6.0(max)	6.0(max)		6.0(max)	3.0(max)		
	Calcium Aluminate (C114)	10.0(max)	42.0(min)	18.0(max)	38.0(max)	-	-		

NOTE: The cements procured for the original construction and the cements used in the mock-up testing are closely comparable and meet the requirements of ASTM with the exception of SO_3, portland cement supplied by Blue Circle Cement used in Phase III. Mock-up test results indicated 0.1% higher than the 3.0% max required by ASTM C150.

PHASE III MOCK-UP TESTING

Table No. 3

MP3 CONTAINMENT MAT POROUS CONCRETE

CHEMICAL ANALYSIS OF WATER

SOURCE

SPECIMEN A: WELL WATER FROM ALDEN RESEARCH LAB
SPECIMEN B: BATCH WATER FROM CONCRETE SERVICES INC.

TEST PROCEDURE

1. STANDARD METHODS FOR EXAMINATION OF WATER AND WASTE WATER. APHA-AWWA-WPCF, 17TH EDITION, 1989

2. METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES. EPA 600/4-82-055, 1983

RESULTS

DESCRIPTION	SPECIMEN A (expressed in ppm)	SPECIMEN B (expressed in ppm)
ACIDITY	7	7
ALKALINITY	7	94
SOLIDS (includes salts)	70	180
ORGANIC (3.0% NaOH)	None	None
OILS & GREASE	None	None

The water sample analysis is well within the limits of ASTM C94-92a requirements for ready-mixed wash water as presented in Table II of that Standard.

PHASE III MOCK-UP TESTING

Table No. 4

MP3 CONTAINMENT MAT POROUS CONCRETE
PHASE III MOCK-UP TEST
FLOW TEST
(based on a 24 hr. day for 21 days in a one month period)

MONTH	GALLONS/MINUTE	GALLONS/MONTH
1	32.0	967,680
2	26.9	813,456
3	18.5	559,440
4	29.7	898,128
5	21.6	653,184
6	21.9	662,256
7	16.6	501,984
8	18.0	544,320
9	21.6	653,184
10	19.0	574,560
11	18.0	544,320
12	19.0	574,560
13	17.0	514,080
14	17.0	514,080
15	18.0	544,320

TOTAL = 9,519,552 GALLONS

PHASE III MOCK-UP TESTING

Table No. 5

CHEMICAL ANALYSIS OF THE RESIDUES

	ABB CE XRF (RESULTS)		Mock-Up I Report	Mock-Up II Report	
	ESF (Sumps)	Mock-Up I			
SiO2	0.2	0.2	7.43	1.27	
Al2O3	10.9	17.5	10.5	4.34	
Fe2O3	1.8	0.1	-	1.06	
CaO	43.3	43.4	-	29.33	

Note: The predominant chemical oxides of the residue samples collected at ESF sumps and from mock-up testing as analyzed by ABB-CE are comparable to those results published in the mock-up test reports.

PHASE III MOCK-UP TESTING

Table No. 6

UNCONFINED COMPRESSIVE STRENGTH POROUS CONCRETE

	PORTLAND CEMENT		CALCIUM ALUMINATE CEMENT	
FLOW PERIOD	Core Samples Average Values		Core Samples Average Values	
	Density (pcf)	Strength (psi)	Density (pcf)	Strength (psi)
1	124.0	1597	120.4	1333
2	126.4	1593	119.7	1283
3	123.9	1570	117.6	1450
4	127.3	1737	119.1	1597
5	125.7	1827	120.7	1667
6	123.8	1667	121.7	1303
7	123.6	1703	119.6	1643
8	119.2	1647	118.8	1230
9	125.2	1663	115.4	1003
10	126.8	1650	116.6	877
11	127.1	1887	115.2	913
12	125.2	1687	116.8	1005
13	121.9	1497	115.1	1517
14	124.1	1440	117.4	897
15	123.6	1660	116.4	1207

PHASE III MOCK-UP TESTING

Table No. 7

CONFINED COMPRESSIVE STRENGTH POROUS CONCRETE

	CORE SAMPLES (1) PORTLAND CEMENT		CORE SAMPLES (2) CALCIUM ALUMINATE CEMENT	
FLOW PERIOD	*DENSITY (PCF)*	*STRENGTH (PSI)*	*DENSITY (PCF)*	*STRENGTH (PSI)*
1	121.6	2352	117.8	1901
2	125.8	1764	120.9	1607
3	125.8	1921	122.0	1646
4	125.7	1783	122.4	1470
5	122.3	1548	122.4	2058
6	123.8	2185	120.6	1979
7	123.7	2019	120.0	1842
8	124.8	2332	119.7	1587
9	123.2	1862	119.7	1391
10	123.6	1764	120.0	1293
11	125.8	2254	119.1	1489
12	124.2	2548	118.3	1470
13	122.8	1568	118.0	1352
14	126.1	1626	119.8	1392
15	123.2	1666	118.7	1411

(1) The confined compressive strength of the core samples taken from the portland cement porous concrete is somewhat erratic in spite of nearly no loss of density, with an exception of the 13th to 15th flow periods.

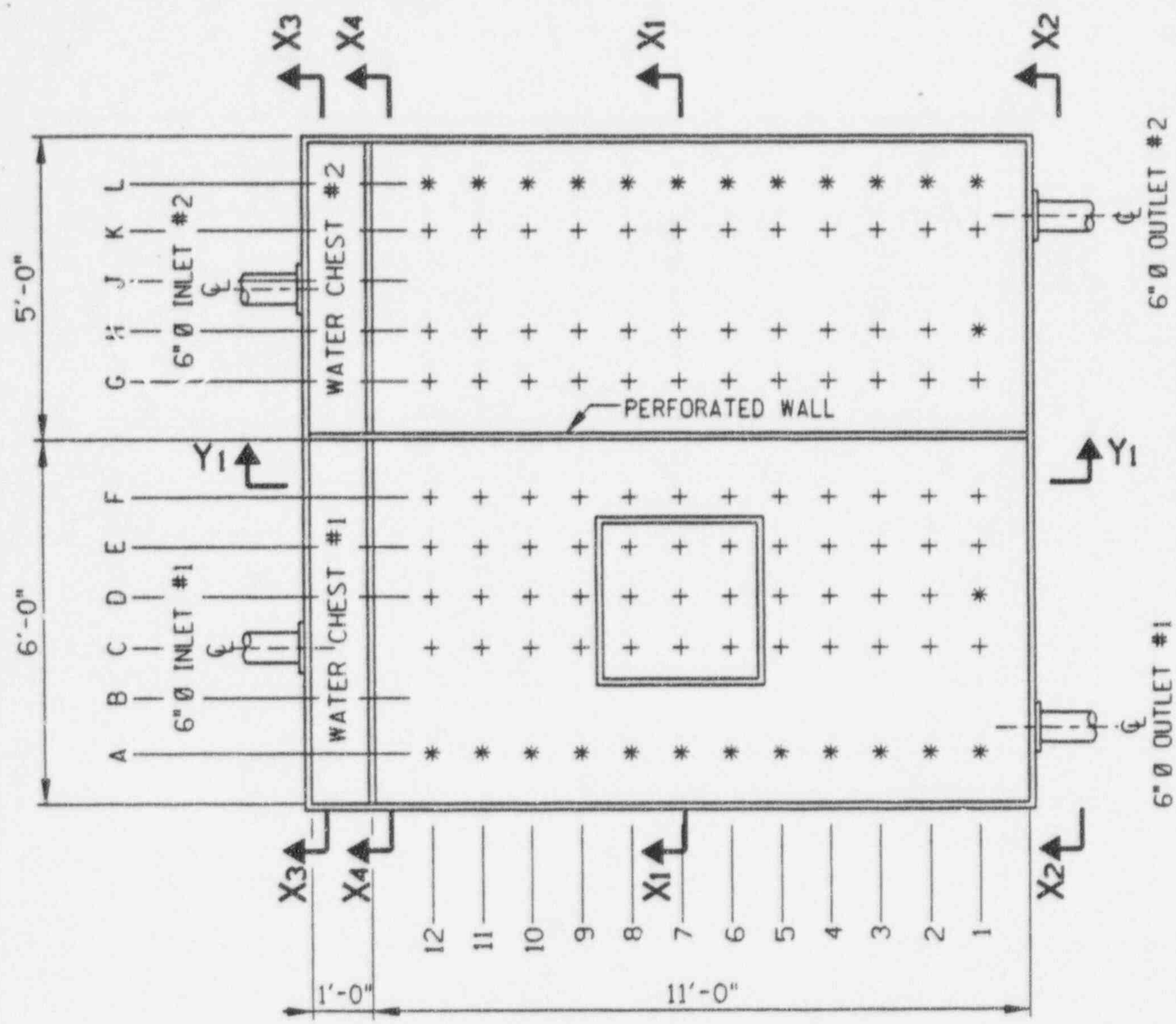
(2) The confined compressive strength of the core samples taken from the calcium aluminate cement porous concrete show a loss of strength and density with age.

PHASE III MOCK-UP TESTING

Table No. 8
PHASE III POROUS CONCRETE
UNCONFINED COMPRESSIVE STRENGTH vs. TEST PERIOD

PERIOD	PORTLAND CEMENT Average Values		CALCIUM ALUMINATE Average Values	
1st Cycle	*DENSITY (PCF)*	*STRENGTH (PSI)*	*DENSITY (PCF)*	*STRENGTH (PSI)*
End of 1st	124.0	1597	120.4	1333
End of 13th	121.9	1497	115.1	1517
% Change from 1st	(-) 1.7%	(-) 6.3%	(-) 4.4%	(+) 13.8%
2nd Cycle	*DENSITY (PCF)*	*STRENGTH (PSI)*	*DENSITY (PCF)*	*STRENGTH (PSI)*
End of 2nd	126.4	1593	119.7	1283
End of 14th	124.1	1440	117.4	897
% Change from 2nd	(-) 1.8%	(-) 9.6%	(-) 1.9%	(-) 30%
3rd Cycle	*DENSITY (PCF)*	*STRENGTH (PSI)*	*DENSITY (PCF)*	*STRENGTH (PSI)*
End of 3rd	123.9	1570	117.6	1450
End of 15th	123.6	1660	116.4	1207
% Change from 3rd	(-) 0.2 %	(+) 5.7%	(-) 1.0%	(-) 16.8%

Note: After 12 months of net water flow, there is an indication of loss in density and compressive strength.



PLAN VIEW

\+ - INDICATES THE LOCATION OF 6" Ø CORE BORES.

* - INDICATES THE POSITION OF PERFORATED METAL CAGES.

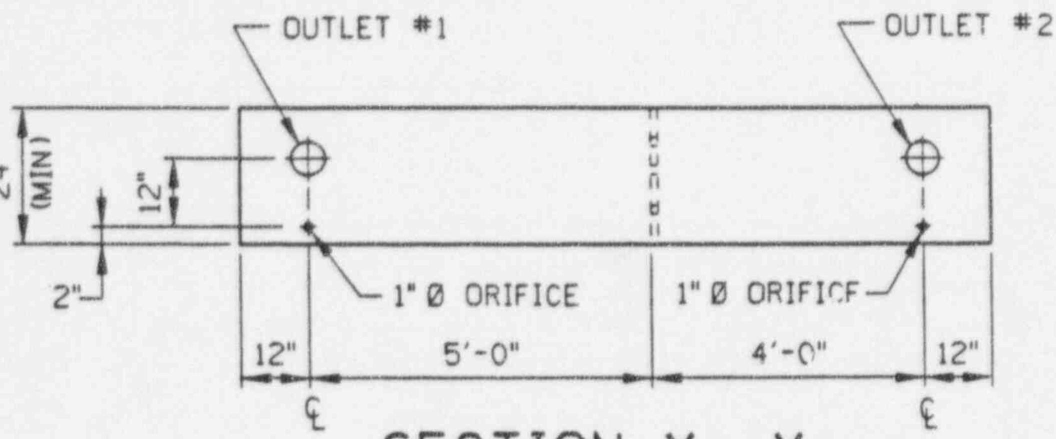
Northeast Utilities System

FOR MILLSTONE NUCLEAR POWER STATION UNIT 3

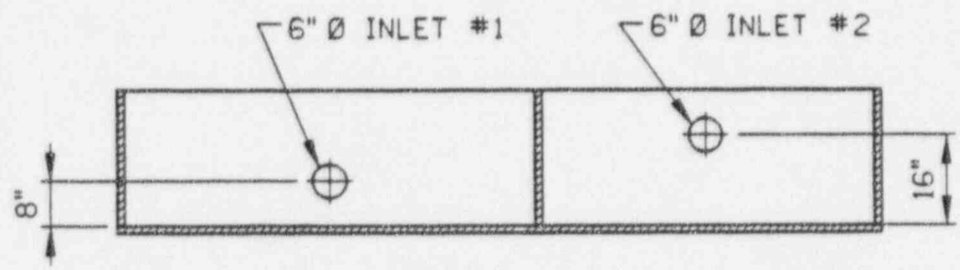
TITLE POUROUS CONCRETE MOCK UP TEST TESTING MOLD - PHASE III

BY K.FULLER	CHKD.	APP.	APP.
DATE 8-6-96	DATE	DATE	DATE
SCALE N.T.S	DWG. NO.	FIGURE 1a	
P.A.#			

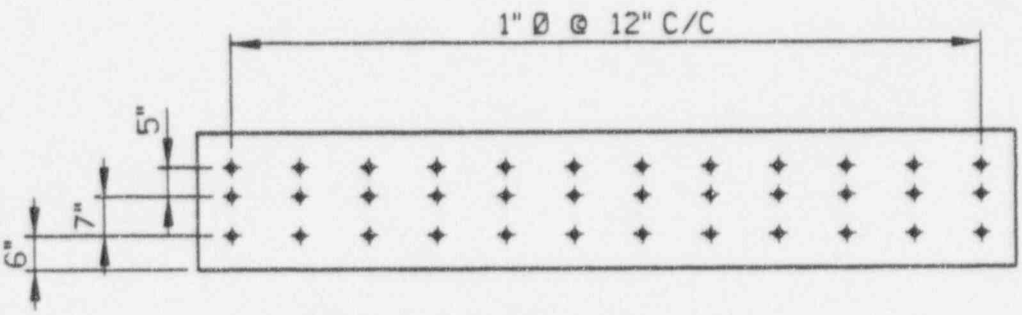
P.A.#	NO.	DATE	REVISIONS	BY	CHK.	APP.	APP.



SECTION X_2-X_2



SECTION X_3-X_3



SECTION Y_1 -Y_1 (ELEVATION)

PERFORATED WALL

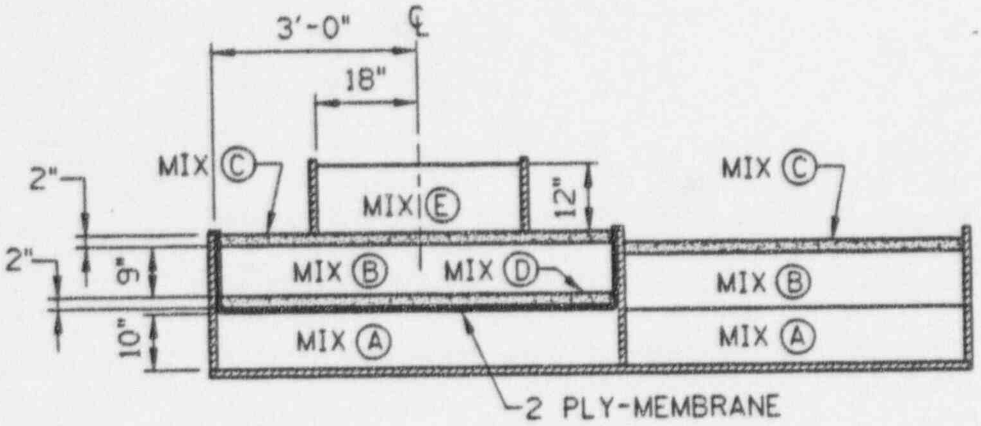
MF	P.A.#	NO.	DATE	REVISIONS	BY	CHK.	APP.	APP.

Northeast Utilities System

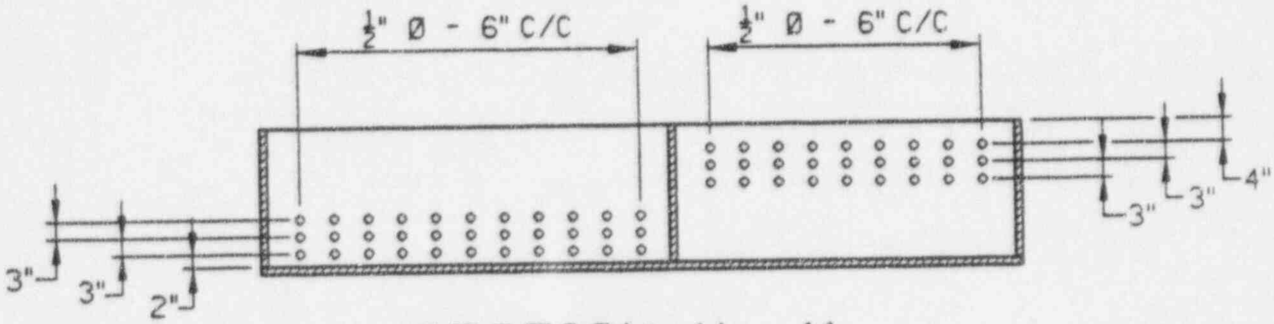
FOR MILLSTONE NUCLEAR POWER STATION UNIT 3

TITLE
POUROUS CONCRETE MOCK-UP TEST
TESTING MOLD - PHASE III

BY K.FULLER	CHKD.	APP.	APP.
DATE 8-6-96	DATE	DATE	DATE
SCALE N.T.S	DWG. NO.	FIGURE 1b	
P.A.# ———			



SECTION $X_1 - X_1$



SECTION $X_4 - X_4$

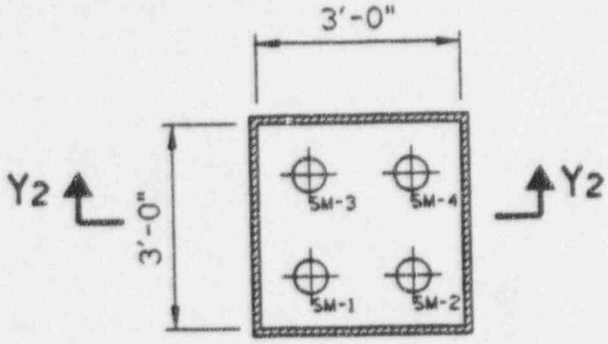
	P.A.*	NO.	DATE	REVISIONS	BY	CHK.	APP.	APP.

Northeast Utilities System

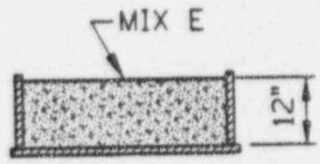
FOR MILLSTONE NUCLEAR POWER STATION UNIT 3

TITLE POUROUS CONCRETE MOCK-UP TEST TESTING MOLD - PHASE III

BY K.FULLER	CHKD.	APP. / APP.
DATE 8-6-96	DATE	DATE / DATE
SCALE N.T.S	DWG NO.	FIGURE 1c
P.A.*		



PLAN



SECTION Y_2 - Y_2

NOTE:

⌖ LOCATION OF CORE SAMPLES.

SM-1 & SM-2 - COMP. TEST @ 40 DAYS

SM-3 & SM-4 - COMP. TEST @ 60 DAYS

CONCRETE MIX DESIGN "E"
MIN DESIGNED COMP. STRENGTH

fc' = 3000 PSI @ 60 DAYS

MF	P.A.*	NO.	DATE	REVISIONS	BY	CHK.	APP.	APP.

Northeast Utilities System

FOR MILLSTONE NUCLEAR POWER STATION UNIT 3

TITLE POUROUS CONCRETE MOCK-UP TEST SISTER MOLD - PHASE III

BY K.FULLER	CHKD.	APP.	APP.
DATE 8-6-96	DATE	DATE	DATE
SCALE N.T.S	DWG NO. FIGURE 2		
P.A.* ———			