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November 27, 1996

Docket No. 50-423

B15985

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

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

By letter dated October 18, 1996, the NRC staff transmitted nine (9) requests to Northeast Nuclear Energy Company (NNECO) regarding issues related to the Millstone Unit 3 Containment Basemat Concrete. Accordingly, in Attachment 1 to this letter, NNECO hereby submits its response to the requests defined in the letter. NNECO's commitments associated with this letter are provided in Attachment 5.

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

Very truly yours,

NORTHEAST NUCLEAR ENERGY COMPANY

John Paul Cowan
Recovery Officer
Millstone Unit 3

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Attachments (5)

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

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Attachment 1

Millstone Nuclear Station Unit 3
Response to Request For Additional Information On Erosion of Cement From The Underlying Porous Concrete Drainage System, Millstone 3

November 1996

REQUEST 1

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

RESPONSE 1

This response is divided into three portions, one for each phase of the testing.

PHASE I

PURPOSE OF PHASE I TESTING

The Phase I test was designed to assist in an understanding of the residue phenomena emanating from under the Millstone 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.

MOLD CONSTRUCTION/MATERIALS

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) Portlant 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.

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

White residue similar to that from the Containment underdrain system was collected in the two layered test molds.

No white residue leached out from the single layer mold

Some of the core samples were damaged during the coring process in the double layer mold and could not be tested for compressive strength.

Core samples were successfully removed from the single layer test mold.

CONCLUSION

A more representative test was required for any conclusions related to the affects on the porous concrete to be reached.

A complete copy of the Phase I test results is included as Attachment 2.

PHASE II

PURPOSE OF PHASE II TESTING

The Phase II test was designed to study any effects on the porous concrete that may be occurring due to removal of the concrete laitance or concrete washout, and to evaluate the potential for cement erosion to occur as a result of the hydraulic pressure. The test molds for Phase II were constructed to be more representative of the actual geometry of the Containment underdrain system, such that some correlation could be made with respect to the effect on the porous concrete layers.

MOLD CONSTRUCTION/MATERIALS

A total of three test molds were constructed in the Phase II test. Mold A 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 and a 2 inch layer of calcium aluminate mortar was used to seal the top. Molds B & C consisted of 10 inches of Portland cement based porous concrete and a 9 inch layer of calcium aluminate cement based porous concrete separated by a rubber membrane protected by a 2 inch thick Portland cement seal mortar. A 2 inch layer of calcium aluminate mortar was used to seal the top of the mold. The molds were provided with inlet orifices in the side forms to allow the introduction of water, and an internal perforated drain pipe for removal of the water. The rubber membrane and seal

mortar were intentionally breached to provide a flow path through the encapsulated layer of porous concrete which simulates the leaking containment structure membrane.

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.

HYDRAULIC TESTING

Water was applied to the test mold through the inlet orifices on the side of the test mold at a water pressure of 5 psi. This water then passed through the intentionally breached rubber membrane and seal mortar. The water is removed from the media through the embedded perforated drain pipes. The mold was subjected 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 subjected to a 30 day hydraulic test at the same applied hydraulic pressure.

TEST RESULTS

The average of the laboratory cured Portland and calcium aluminate cylinders prepared at the time of the placement were 2152 psi at 28 days and 1787 psi at 28 days respectively.

The average of the unconfined compressive strength cores from mold A, after hydraulic testing, were 1094 psi for Portland cement and 1119 psi for calcium aluminate cement.

The average of the unconfined compressive strength cores from mold B, after hydraulic testing, were 1355 psi for Portland cement and 1394 psi for calcium aluminate cement.

The average strength of the unconfined compressive strength cores from mold C, after hydraulic testing, were 1531 psi for Portland cement and 1263 psi for calcium aluminate cement.

OBSERVATIONS

No variation in compressive strength porous concrete samples with respect to location of water flow was observed.

Residue similar to that from the Containment underdrain system was collected.

Some of the test samples were damaged during the coring process and could not be tested for compressive strength.

A complete copy of the Phase II test results is included as Attachment 3.

PHASE III

Note: As previously committed in Reference 3 the results of Phase III testing are scheduled to be completed and forwarded to NRC by the end of 1996. Where available the data has been provided here, in a preliminary form. This data will be confirmed, observations assembled and conclusions drawn as part of the final report.

PURPOSE OF PHASE III TESTING

The purpose of the Phase III test is two fold. One objective is to study the long term effects that water flow creates on the porous concrete strength, and the second purpose is to test the Portland concrete on top of the test mold to determine if there is any impact on the Containment mat. The concrete representing the mat is placed on top of the porous concrete mold similar to the design condition. This testing is 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 and simultaneously 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. Core and cylinder samples were tested for compressive strength at predetermined intervals.

MOLD CONSTRUCTION/MATERIALS

CEMENT

PORTLAND CEMENT
Portland Cement is Type II (low Alkali) conforming to ASTM C150.

Cement Properties (Mill Test Report)

SiO_2, percent	20.7
Al_2O_3, percent	4.7
Fe_2O_3, percent	3.1
CaO, percent	63.4
MgO, percent	3.4
SO_3, percent	3.1
Na_2O, percent	0.58
Ignition Loss, percent	0.8
Insoluble Residue, percent	0.23

Physical

Fineness, Blaine m^2/kg	367
Time of Setting(VICAT)	
Initial (minutes)	110
Final (minutes)	230
Air Content, percent	6.3
Compressive Strength	
at 3 days (psi)	3840
7 days (psi)	4820
28 days (psi)	6250

CALCIUM ALUMINATE CEMENT

Chemical Properties (Mill Test Report)

AL_2O_3, + TiO_3, percent	50.22
CaO, percent	35.83
SiO_2, percent	7.11
Fe_2O_3, percent	5.49
MgO, percent	0.50
SO_3, percent	0.46
Ignition Loss, percent	0.39

Physical Properties

Time of setting (VICAT), ASTM C403:	
Initial hours: min.	2.38
Final hrs: min.	3.38
Fineness, Blaine m^2/kg	331
Compressive Strength, at 24 hours,ASTM C109 (Mpa)	39.5

AGGREGATE

COARSE

Coarse aggregates were obtained from the Wauregan Quarry, owned and operated by Tilcon Connecticut Incorporated. The # 4, # 57, & # 67 gradations are in accordance with ASTM C33 and C136. Table 1 shows the gradation analysis of these aggregates.

FINE

Fine aggregates were Millbury Sand from Concrete Service Company, no gradation analysis was performed.

CONCRETE MIXES

Mix A - Porous Concrete with Portland Cement Type II, quantities per cubic yard

Cement, pounds/sacks	560/5.96
Coarse Aggregate #57, pounds	2670
Water to Cement Ratio (maximum)	0.384

Mix B - Porous Concrete with Calcium Aluminate Cement, quantities per cubic yard

Cement, pounds/sacks	560/5.96
Coarse Aggregate #57, pounds	2670
Water to Cement Ratio (maximum)	0.320

Mix C - Mortar Seal with Calcium Aluminate Cement, quantities per cubic yard

Cement, pounds/sacks	900/9.57
Coarse Aggregate #57, pounds	2757
Water to Cement Ratio (maximum)	0.439

Mix D - Mortar with Portland Cement Type II, quantities per cubic yard

Cement, pounds/sacks	900/9.57
Coarse Aggregate #57, pounds	2757
Water to Cement Ratio (maximum)	0.439

Mix E - Containment Foundation with Portland Cement Type II, quantities per cubic yard (10 foot thick mat)

Cement, pounds/sacks	500/5.32
Fine Aggregate, pounds	1315
Coarse Aggregate #4, pounds	752
Coarse Aggregate #67, pounds	1127
Percent Air Admixture	3 to 6
Water to Cement Ratio (maximum)	0.532

MEMBRANE

The membrane consists of two layers of waterproof membrane installed as recommended by the membrane manufacturer.

FORMS

The concrete forms and boundaries for the water separations consist of poly coated plywood for waterproofing.

WATER

The water used for the concrete batching and curing were tested and found to be free of unacceptable quantities of oils, acids, alkalides, salts and organic materials in accordance with ASTM C94. The results of the chemical analysis are presented in Table 2.

DESCRIPTION OF TEST MOLD

The test mold 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 has been intentionally eliminated.

The cross section of the mold in the area of the membrane consists of: the bottom form; a 10 inch layer of Mix A Portland cement porous concrete; the waterproof membrane; a two inch layer of Mix D Portland cement seal mortar; the 9 inch layer of Mix B calcium aluminate cement porous concrete; a 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 the rubber membrane, the Mix D mortar on top of the membrane and the Mix E 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. Details of the test mold are shown in Figure 1(a-c).

MOLD CONSTRUCTION

Table 3 includes the placement schedule of each layer of porous concrete and seal mortar. The number of days indicated in the table between pours are the conservatively selected curing days before the placement of the next pour.

POROUS CONCRETE MIX A (Portland cement)

Mix A was placed in a 10 inch thick layer of porous concrete on top of the bottom of the mold form. The concrete was consolidated by the rodding method to represent a density of approximately 118 to 131 pcf. This concrete layer was wet cured for 5 days prior to further construction activities.

MEMBRANE

Two layers of waterproof membrane were placed on top of the Mix A. The membrane extends to the top of the mold, such that it encases subsequent layers of the concrete.

MORTAR MIX D (Portland cement)

Mix D was placed in a two inch layer on top of the waterproof membrane as protection for the subsequent concrete placement. This mortar was cured for a minimum of 48 hours prior to further construction activities.

FLOW PATH

As a flow path for subsequent testing, the rubber membrane and Mix D are intentionally breached at the predetermined locations of subsequent core-bore samples.

POROUS CONCRETE MIX B (calcium aluminate cement)

Mix B is placed in a 9 inch thick layer of porous concrete on top of the waterproof membrane. The concrete was consolidated by rodding to represent a density of approximately 118 to 131 pcf. This concrete was cured by applying a thin spray of water at the top surface to remove the heat. This process was continued for 24 hours after initial set of the porous concrete.

MORTAR MIX C (calcium aluminate cement)

Mix C is placed in a two inch layer on top of the 9 inch layer of porous concrete. This mortar was cured similar to Mix B for 7 days prior to further construction activities.

STRUCTURAL CONCRETE MIX E

Mix E was placed in a 12 inch layer on top of the 2 inch layer of calcium aluminate cement mortar. An additional sister mold, measuring 3 feet x 3 feet x 12 inches high, of Mix E was also constructed from the same batch of concrete, and maintained separate from the mockup (Figure 2). The sister mold was constructed in a wooden form carefully constructed to be free from any calcium

aluminate cement products. Both sections of Mix E concrete were wet cured for 7 days prior to any flow testing. Five concrete test cylinders were made at the time of the placement in accordance with ASTM C31.

HYDRAULIC TESTING

The Sequence of the Flow Testing is as follows:

CYCLE 1

1. The 6 inch diameter inlet # 2, the 6 inch diameter outlet #1, and the two 1 inch diameter drain orifices are closed, (refer to Figure 1).

2. The 6 inch diameter outlet # 2 is maintained open.

3. The inflow of water is regulated through the 6 inch diameter inlet # 1.

4. The water is stopped for 7 days and the mold is drained through the two 1 inch diameter orifices located at the far end of the mold.

5. Core samples are removed from the mold in the sequence identified in the results section.

6. Cored holes are filled with crushed stone.

7. The water flow is restarted in the reverse direciion in the sequence outlined below:

   Close inlet # 1
   Close outlet # 2 and the two drain orifices
   Open outlet # 1
   Regulate the water flow for 21 days
   Stop the water for 7 days and drain the mold for the coring operation.

8. Continue the same cycle for the duration of the testing. The rate of flow of water through the test mold for the first twelve months is presented in Table 4*.

* The information provided in Table 4 was previously submitted to the NRC in Reference 19, (October 10, 1996, Response for Additional Information), however the data had two errors. Corrections have been made to the Total Flow in the tenth month as well as the total flow for the year.

RESULTS

TEST CYLINDERS

PORTLAND CEMENT POROUS CONCRETE (Mix A) AND CALCIUM ALUMINATE POROUS CONCRETE (Mix B)

Laboratory Cured Test Samples

Five (5) test cylinders measuring 6 inches x 12 inches high, were made from concrete Mix A (Portland cement porous concrete) and also from Concrete Mix B (calcium aluminate cement porous concrete) at the time of placement into the test mold. These cylinders were cured in a laboratory fog room for Mix A, and water misted for 24 hours for Mix B. Two cylinders from each mix were tested at 7 days and the remaining 3 cylinders were tested at 28 days. Table 8 shows the cylinders weighed between 127 to 130 pcf. The cylinders cast from Portland cement had an average unconfined compressive strength of 2130 psi at 7 days and 2357 psi at 28 days, about an 11% increase in strength. Where as the porous concrete containing calcium aluminate cement, with an average weight of 129 pcf had an average unconfined compressive strength of 2367 psi, and no strength gain was evident after 7 days.

PORTLAND CEMENT CONCRETE (Mix E)

Laboratory Cured Test Samples

Five 6 inch diameter by 12 inch high cylinders were prepared for compression testing from Mix E, in accordance with ASTM C31 and C39, at the time of concrete placement in the mold. After laboratory curing, two cylinders were tested for compressive strength at 28 days and three cylinders were tested at 56 days. At 150 pcf density of the cylinders, the average unconfined compressive strength was determined to be 4935 psi and 5257 psi corresponding to the age of 28 and 56 days respectively. The results are included in Table 5.

CORE BORE SAMPLES FROM THE MOCK-UP MOLD

PORTLAND CEMENT POROUS CONCRETE (Mix A)

Table 7 show the average unconfined compressive strength of the core samples taken at the end of each hydraulic flow cycle. In the 12 month test, the Portland cement based porous concrete maintained its strength without any degradation. The minimum tested strength of 1570 psi occurred at the end of 3rd cycle and a maximum tested strength of 1887 psi occurred at the end of the 11th cycle.

CALCIUM ALUMINATE POROUS CONCRETE (Mix B)

Table 6 shows the average unconfined compressive strength of the core samples taken at the end of each hydraulic flow cycle. The strength of the cores varies with the duration of water flow. An average unconfined compressive strength of 1333 psi occurred at the end of the 1st cycle. The successive specimen strength varied with respect to the first month samples. An average maximum strength of 1667 psi occurred at the end of the 5th cycle, which is approximately a 25% increase in strength. The minimum tested strength of 877 psi occurred at the end of 10th cycle, which is approximately a 34% below the initial strength, and approximately a 47 % below the maximum strength.

PORTLAND CEMENT CONCRETE (Mix E)

After being exposed to a continuous flow of water for 24 hours a day and 21 days, the following core samples have been extracted at the specified time intervals. The cores from the test slabs (both the test mold and sister mold), were tested for unconfined compressive strength at 40 days, 60 days and 98 days after construction. The location of these core samples are shown in plan view, Figure 1a.

At 40 days; Two cores located at C-6 and E-6,
At 60 days; Two cores located at D-7 and E-7,
At 98 days; Two cores located at C-8 and E-8

The average compressive strength values of the cored samples have been summarized in Table 5. The 60 day average strength of 4925 psi corresponds to a core density of 149 pcf, with water flow.

<u>CORE BORE SAMPLES FROM THE SISTER MOLD PORTLAND CEMENT CONCRETE (Mix E)</u>

Concrete Mix E in the sister mold was constructed and cured similar to the mock-up but it was not subjected to either water flow or contact with calcium aluminate cement. Two sets of two 5.72 inch diameter core samples were removed from the 3 foot x 3 foot x 12 inch high sister mold. A set of two cores were removed from locations SM-1 and SM-2 at 40 days, and a second set of two cores were removed from locations SM-3 and SM-4 at 60 days (Figure 2). The samples were then tested for unconfined compressive strength. A 60 day average compressive strength of 4695 psi was achieved, at a core density of 148.5 pcf. Table 5 summarizes the test data for the sister mold samples.

OBSERVATIONS

PORTLAND CEMENT POROUS CONCRETE (Mix A) AND CALCIUM ALUMINATE CEMENT POROUS CONCRETE (Mix B)

The observations for this portion of the test are in the process of being assembled, and will be provided in the final Phase III test report.

PORTLAND CEMENT (Mix E)

During the 21 day flow test into the mold, close observations were made regarding white residue.

Upon core sample removal all cores were inspected for their structural integrity and sound appearance. No visual differences were noted between the cores from the slab on top of the calcium aluminate cement mortar mock-up, and the cores removed from the sister mold.

The 3 foot x 3 foot x 12 inch thick concrete slab on top of the mock-up with water flow remained in position until the end of the sixth month. The slab was removed with little effort. When removed, the concrete slab showed lack of bonding to the seal mortar at the interface. The impression at the interface was smooth with any adverse affect between the cements limited to the face of the surfaces.

CONCLUSIONS

PORTLAND CEMENT POROUS CONCRETE (Mix A) AND CALCIUM ALUMINATE CEMENT POROUS CONCRETE (Mix B)

The conclusions for this portion of the test are in the process of being assembled, and will be provided in the final Phase III test report. The results of the Phase III test have been factored into the operability determination contained in Reference 2.

PORTLAND CEMENT (Mix E)

The Containment structure is designed for the loads and load combinations presented in the Millstone 3 FSAR Section 3.8.1.3.1. The allowable stresses are in accordance with ACI 318-71. Mix E was used to construct the mock-up of the Containment mat slab interface with the calcium aluminate cement layer below the Containment mat.

From Table 5, it can be seen that there is a close correlation among 60 day strength of the concrete samples cored out either from the mock-up mold subjected to water flow or from the sister mold which was not subjected to the water flow. The variation in strength is insignificant and their value, to a degree is influenced by their densities. This indicates there has been no degradation of the concrete as a result of the exposure to the calcium aluminate concrete and the water flow . In addition when all cores were removed from the mock-up slab and inspected, as well as from the sister mold, the concrete integrity was intact with no visual difference. Therefore it can be concluded from the mock-up test that the Containment mat concrete containing Portland cement has not experienced any decrease in strength as a result of interacting with the porous concrete layer containing calcium aluminate cement.

Even though lack of bond at the mating surfaces of Containment mat slab with the porous concrete layer was observed in the mockup testing, this is not expected to have

any adverse impact on the structural integrity of the Millstone 3 Containment basemat, as discussed in the response to Request 3.

REQUEST 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.

RESPONSE 2

(1) Portlant Cement

A comparison of the strength of cores samples representing the Containment basemat is included in Table 5. This table compares the strength of core samples exposed to water flow to samples removed from the sister mold which, was not exposed to water flow, and to laboratory cured cylinders.

(2) High Alumina Cement Concrete

Further explanation is contained in the Phase III portion of the response to Request 1 using cycle number 1 for the baseline strength.

REQUEST 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.

RESPONSE 3

The impact of the lack of bond at the interface of the Containment Structure foundation structural concrete and the porous concrete layer containing calcium aluminate cement are addressed in Reference 13. This calculation addresses two aspects related to the loss of bond: (1) The ability to transfer vertical loads across the interface of the Containment foundation and the porous concrete, and (2) The ability to transfer the horizontal shear force from a seismic event across the interface of the Containment foundation and the porous concrete.

Section 3.8 of the Millstone 3 FSAR provides the applicable load combinations for the design of the Containment Structure. Load combination No. 9 Abnormal/Extreme Environmental 1.0D + 1.0L + 1.0Pa + 1.0Ta + 1.0SSE + 1.0Ra is considered the limiting load combination for this condition. The SSE case includes loads from both the vertical and horizontal excitations acting simultaneously. The loads at this location are:

1.0D + 1.0L + 1.0Pa + 1.0Ta + 1.0Ra	= 155,617 kips ↓
SSE Vertical Force	= 29,087 kips ↑
SSE Horizontal Force	= 55,152 kips

The impact of the lack of bond is summarized below:

(1) Vertical direction

The net vertical force from this load combination is 126,530 kips in compression resulting from a vertically upward SSE force and the resulting downward force from the remainder of the loads. No bond between the Containment Structure foundation and the porous concrete layer is required to transfer this net compression load.

(2) Horizontal Direction

For the horizontal direction the load transfer can be accomplished by friction resulting from the net vertical downward load of 126,530 kips at this interface. In the condition of concrete to concrete the coefficient of friction (μ) of 0.6, and a interface reduction factor (γ) of 0.8 is used to account for the porous concrete interface with the normal weight structural concrete, per ACI 318-89 Chapter 11.

Net Compressive Force (N) = 126,530 kips
Frictional Coefficient (μ) = 0.6
Reduction Factor (γ) = 0.8
Resisting Capacity ($\mu\gamma N$) = 60,734 kips
Horizontal SSE Force = 55,152 kips

Margin of Safety 60,734/55,152 = 1.10

In summary, during an SSE event there is sufficient net compressive force which produces enough frictional resistance to transfer the inertia loads without crediting any bond at the interface of Containment Structure foundation and the porous concrete.

REQUEST 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.

RESPONSE 4

In preparation of the responses for Reference 1, project specification 2199.141-281 "Mixing and Delivering of Concrete" (Reference 10) was reviewed. This specification indicates that concrete mix 302 is a 3000 psi at 60 day mix. A review of the actual pour records indicate that the laboratory cylinders were tested at 28 days and had an average strength of 4451 psi.

REQUEST 5

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

RESPONSE 5

The particle size distribution for (1) the calcium aluminate cement used in the Phase III mock-up test and (2) the Portland cement type II of a representative sample has been provided in Attachment 4. The particle size distribution for the porous concrete aggregate is similar to that presented in Table 1 for the # 57 aggregate. The grain size distribution of the residue removed from the sumps was previously provided in Reference 1. We do not believe that a direct comparison of these particle sizes is appropriate, since the calcium aluminate residue is removed from the Containment structure foundation in a ground water solution. It appears that once the water enters the sumps in the Engineered Safety Features Building the residue crystallizes from solution and the particle sizes may be different in this state.

REQUEST 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 8,700 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.

RESPONSE 6

The operability determination referenced intentionally assumed conservative hypothetical scenarios to maximize the potential loss of cement emanating from the porous concrete layers. This was partially due to uncertainties in the total amount of residue that may have been removed from the Containment foundation. We recognize that it may not be possible to receive such large amounts of water if the drainage pipes were even partially full, but since the amount of data available on the residue is limited we provided the conservative approximations. As mentioned in response to question IV in Reference 1 some of the variability in the amount of residue collected is explained by the duration between the sump cleanings. Since this time frame was not constant, variability in the data would be expected.

With the average of 80 pounds of dry weight of residue being received in the sump each year, an estimate of 100 pounds per year may be more reasonable, considering small amounts of residue may have passed through the underdrain sumps in solution and some residue may be retained under the Containment foundation. Based on the data to date, we believe that the 100 pounds per year accumulation of residue is the most reasonable for prediction of future quantities.

REQUEST 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.

RESPONSE 7

In this hypothetical scenario a total of five areas were considered to have degraded in a 5 foot diameter pattern. Four of the areas considered were at intersections of the drainage pipe sections, and the fifth was at the centerline of the Containment Structure. The 10 foot thick containment mat was determined to have sufficient structural rigidity to redistribute vertical loads over the hypothetical gaps without any impact on the Containment mat qualification. This scenario was based on engineering judgment considering the classical load distribution method by shear transfer mechanism of the vertical load from the mid plane of the mat section to the bottom porous concrete support. Industry practice indicates a 45 degree shear angle for load distribution in normal weight concrete is appropriate. Conservatively using a 30 degree distribution as a lower bound from the vertical plane a gap of approximately 5.77 feet could be predicted, which bounds the conservative gap of 5 feet.

Alternately this has been verified by computing the rigidity of the Containment Mat by employing the classical method of Beams on Elastic Foundations, as proposed in Reference 18. Here it is proposed that the limits of the variable λL can be used to determine the rigidity. If λL is less than $\pi/4$ then in local areas the bending is not influenced by the subgrade stiffness.

$$\lambda = \sqrt[4]{\frac{k}{4D}} \qquad D = \frac{Eh^3}{12(1-\nu^2)} \qquad L = \frac{\pi}{4}\frac{1}{\lambda}$$

Where:

D = Flexural Rigidity of the Mat
h = Thickness of the Mat
k = Porous Concrete Spring Stiffness
E = Modulus of Elasticity of the structural concrete
L = Rigid Length of the Beam

Containment Mat Parameters

$h = 10\,feet \quad f_c' = 3000\,psi$

$E_C = 2.9x10^6\,psi$

$\nu = 0.167$

$$I = \frac{h^3}{12(1-\nu^2)} = 85.72\,ft^4$$

Porous Concrete Parameters

Total thickness of the two layers is 19 inches (1.583 feet).
Minimum average monthly unconfined compressive strength from the Phase III mockup test was 877 psi (Table 6).

$\gamma = 110\,pcf$

$f_c' = 877\,psi$

$E_C = \gamma^{1.5} 33\sqrt{f'_c} = 1.12x10^6 = 162{,}355\,ksf$ (Reference 15)

$$k = \frac{AE}{l} = \frac{(1)162{,}355}{1.583} = 102{,}540\,k/ft$$

From Reference 13 the following values have been computed:

$D = 35{,}798{,}381\,kft^2$

$\lambda = 0.164$

$L = 4.8\,feet$

From this it can be stated that the 10 foot thick reinforced concrete mat would behave as rigid to a gap up to approximately 5 feet and the load path would be in the shear transfer mode.

REQUEST 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.

RESPONSE 8

The response to this request is included in the response to Request 9.

REQUEST 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.

RESPONSE 8 & 9

Permanent benchmarks have been installed on the Containment exterior shell since plant construction. These benchmarks have been periodically monitored since installation for any signs of Containment settlement. The latest survey results have been previously reported in Reference 2, and no differential settlement has been observed to date. Periodic monitoring of these benchmarks will continue as part of our Condition Monitoring of Structures for compliance with the Maintenance Rule.

Visual inspections will be performed to monitor potential settlement of the containment internal structure. This monitoring will be included in our existing program for Condition Monitoring of Structures in compliance with the Maintenance Rule. A baseline inspection will be completed in our present outage and subsequent inspections will be completed each refueling outage.

REFERENCES:

1. Northeast Utilities Letter B15803 to NRC, dated July 12, 1996, Pertinent Information Related to the Issue of Erosion of Cement from the Millstone Unit No. 3 Containment Mat.

2. Northeast Utilities Letter B15825 to NRC, dated August 1, 1996, Additional Information Related to the Issue of Cement from the Millstone Unit No. 3 Containment Mat.

3. Northeast Utilities Letter B15850 to NRC, dated August 9, 1996, Additional Information Related to the Issue of Cement from the Millstone Unit No. 3 Containment Mat.

4. NRC Letter TAC No. M96402 to Northeast Utilities, dated October 18, 1996, Request for Additional Information, Erosion of Cement from the Porous Concrete Drainage System Millstone Unit 3.

5. Alden Research Laboratory Report No. 178-92/M295F-R Revision 1, dated November 1996, Phase I Porous Concrete Mock-up Testing for Millstone Unit 3.

6. Alden Research Laboratory Report No. 161-93/M295F-R Revision 1, dated November 1996, Phase II Porous Concrete Mock-up Testing for Millstone Unit 3.

7. NUSCO Specification SP-CE-354, Revision 1, Porous Concrete Mock-up Testing (Phase I), dated March 10, 1992.

8. NUSCO Specification SP-CE-363, Porous Concrete Mock-up Testing (Phase II), dated February 18, 1993.

9. NUSCO Specification SP-M3-CE-0001, Revision 1, Porous Concrete Mock-up Testing Phase III with Containment Mat Concrete, dated December 2, 1994

10. Stone and Webster Specification 2199.141-281 Revision 1, with Addendum 1, dated February 14, 1984, Mixing and Delivering Concrete.

11. Stone and Webster Calculation 12179-NS(B)-025, Millstone 3 Seismic Analysis of the Reactor Containment.

12. Stone and Webster Calculation 12179-NS(B)-002, Millstone 3 Containment Structure Static Analysis and Design.

13. NUSCO Calculation 96-ENG-1263C3, Response to NRC inspector Findings, dated June 6, 1996.

14. Millstone 3 FSAR Section 3.7, Seismic Design, and Section 3.8 Design of Structures.

15. ACI 318-1989 Building Code Requirements for Reinforced Concrete.

16. ACI 349-1980, Code Requirements for Nuclear Safety Related Concrete Structures.

17. Roarks Formulas for Stress and Stress and Strain, 6th Edition.

18. Foundation Analysis and Design, by Joseph E. Bowles, 2nd Edition, McGraw Hill Publication,1968.

19. Northeast Utilities Letter B15934 to NRC, dated October 10, 1996, Additional Information Related to Millstone Unit No. 3 Containment Mat.

TABLE 1

MP3 CONTAINMENT MAT POROUS CONCRETE PHASE III MOCK-UP TEST

GRADATION ANALYSIS OF COARSE AGGREGATES

ASTM DESIGNATION: ASTM C33 and C136

RESULTS

SAMPLE	No. 67	No. 57	No. 4
Retained on 1 1/2 inch sieve, (percent)	-	-	0
1 inch sieve	-	-	58
3/4 inch sieve	1	4	96
1/2 inch sieve	34	47	99
3/8 inch sieve	77	82	99
#4 sieve	98	96	99
#8 sieve	99	97	100
Fineness Modulus	6.76	6.82	7.94

The gradation distribution of the 3 samples meet the requirements of ASTM C33-92a for concrete aggregates.

TABLE 2

MP3 CONTAINMENT MAT POROUS CONCRETE
PHASE III MOCK-UP TEST

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 samples analyses are well within the limits of ASTM C94-92a requirements for ready-mixed wash water as presented in Table II of that Standard.

TABLE 3

MP3 CONTAINMENT MAT POROUS CONCRETE PHASE III MOCK-UP TEST

CONCRETE PLACEMENT SCHEDULE

DATE	MIX PLACEMENT	REMARKS
MAY 11, 1995	Place Mix A	10 inch thick Portland cement porous concrete
MAY 16, 1995	Place Mix D	2 inch thick Portland cement seal mortar on the membrane
MAY 18, 1995	Place Mix B	9 inch thick calcium aluminate cement porous concrete
MAY 25, 1995	Place Mix C	2 inch thick calcium aluminate cement seal mortar
JUNE 1, 1995	Place Mix E	12 inch thick structural concrete with Portland cement representing the 10 foot thick containment mat, and also constructed in a 3 foot x 3 foot x 1 foot thick sister mold.
JUNE 8, 1995	N/A	Water flow test started

TABLE 4

MP3 CONTAINMENT MAT POROUS CONCRETE
PHASE III MOCK-UP TEST

FLOW TEST
(based on a 24 hour 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

TOTAL 7,947,072 GALLONS/YEAR

TABLE 5

MP3 CONTAINMENT MAT POROUS CONCRETE
PHASE III MOCK-UP TEST

UNCONFINED COMPRESSIVE STRENGTH STRUCTURAL CONCRETE
(MIX E)

DESCRIPTION OF TEST	LAB CURED CYLINDERS *NO WATER FLOW*		CORES FROM MOCK-UP SLAB *WITH WATER FLOW*			CORES FROM SISTER MOLD *NO WATER FLOW*	
AGE OF TEST (in days)	28	56	40	60	98	40	60
CORE DIAMETER (inches nominal, 12 inches high)	6	6	5.72	5.72	5.72	5.72	5.72
AVERAGE DENSITY (pcf)	150	150	151.5	149	152	151	148.5
AVERAGE COMPRESSIVE STRENGTH (psi)	4935	5257	5335	4925	5260	4640	4695

From the above table it can be concluded:

1. The compressive strengths are in very close agreement.
2. The strength variations are insignificant and related to the density of the specimens.
3. The presence of water flow has no effect on the strength and the integrity of the core samples removed from the mock-up slab.
4. In three months of water flow there is no degradation of concrete strength observed.

TABLE 6
MP3 CONTAINMENT MAT POROUS CONCRETE
PHASE III MOCK-UP TEST
UNCONFINED COMPRESSIVE STRENGTH CALCIUM ALUMINATE POROUS CONCRETE
(MIX B)

Age Of The Tests (Months)	Sample Location	Density (pcf)	Strength (PSI)	Ave. Density	Ave. Strength (PSI)
1	1C	120	1420.		
	1E	119	1200.		
	1G	122	1380.	120	1333.
2	2C	115	1020.		
	2E	122	1390.		
	2G	122	1440.	120	1283.
3	3C	115	1220.		
	3E	114	1370.		
	3K	125	1760.	118	1450.
4	4D	118	1310.		
	4E	122	1970.		
	4H	118	1510.	119	1597.
5	5D	118	1650.		
	5E	122	1910.		
	5H	122	1440.	120	1667.
6	6C	120	1010.		
	6E	118	1170.		
	6K	127	1730.	122	1303.
7	7D	115	1110.		
	7F	123	2340.		
	7H	121	1480.	120	1643.
8	8C	119	1170.		
	8F	118	1130.		
	8K	120	1390.	119	1230.
9	9C	118	1120.		
	9E	113	840.		
	9G	115	1050	115	1003.
10	10C	115	850.		
	10E	116	840.		
	10G	119	940.	117	877.
11	11D	115	1050.		
	11E	112	730.		
	11G	118	960.	115	913.
12	12E	114	860.		
	12F		untestable		
	12K	120	1150.	117	1005.

Note:

1. The average strength of the 3 test samples showed a net gain in strength for the first 5 months and a decline in compressive strength for the next 7 months.
2. The maximum increase in strength from month one is approximately 25%, and the maximum decrease in strength from month one is approximately 34%, occurred in 10th month of the flow test.
3. Refer to Figure 1a for Test Sample Coordinates.

TABLE 7
MP3 CONTAINMENT MAT POROUS CONCRETE
PHASE III MOCK-UP TEST
UNCONFINED COMPRESSIVE STRENGTH PORTLAND CEMENT POROUS CONCRETE
(MIX A)

Age Of The Tests (Months)	Sample Location	Density (pcf)	Strength (PSI)	Ave. Density	Ave. Strength (PSI)
1	1C	123	1490.		
	1E	124	1550.		
	1G	125	1750.	124	1597.
2	2C	126	1640.		
	2E	129	1790.		
	2G	124	1350.	126	1593.
3	3C	123	1620.		
	3E	124	1640.		
	3K	124	1450.	124	1570.
4	4D	128	1900.		
	4E	128	1620.		
	4H	126	1690.	127	1737.
5	5D	126	1890.		
	5E	125	1850.		
	5H	126	1740.	126	1827.
6	6C	126	1710.		
	6E	123	1820.		
	6K	123	1470.	124	1667
7	7D	123	1600		
	7F	127	1970.		
	7H	122	1540.	124	1703
8	8C	125	1810.		
	8F	125	1910.		
	8K	108	1220.	119	1647
9	9C	126	1910.		
	9E	125	1560.		
	9G	126	1520.	125	1663
10	10C	126	1570.		
	10E	127	1640.		
	10G	128	1740.	127	1650
11	11D	127	1940.		
	11E	129	2020.		
	11G	126	1700.	127	1887
12	12E	127	1750.		
	12F	127	1920.		
	12K	122	1390.	125	1687

Note:

1. The average strength of the three test samples from the 1st month to the 12th month showed no loss of strength.
2. The maximum increase in strength from month one is approximately 19%, occurred in 11th month, and the maximum decrease is about 1.5% occurred in the 3rd month.
3. Refer to Figure 1a for Test Sample Coordinates.

TABLE 8

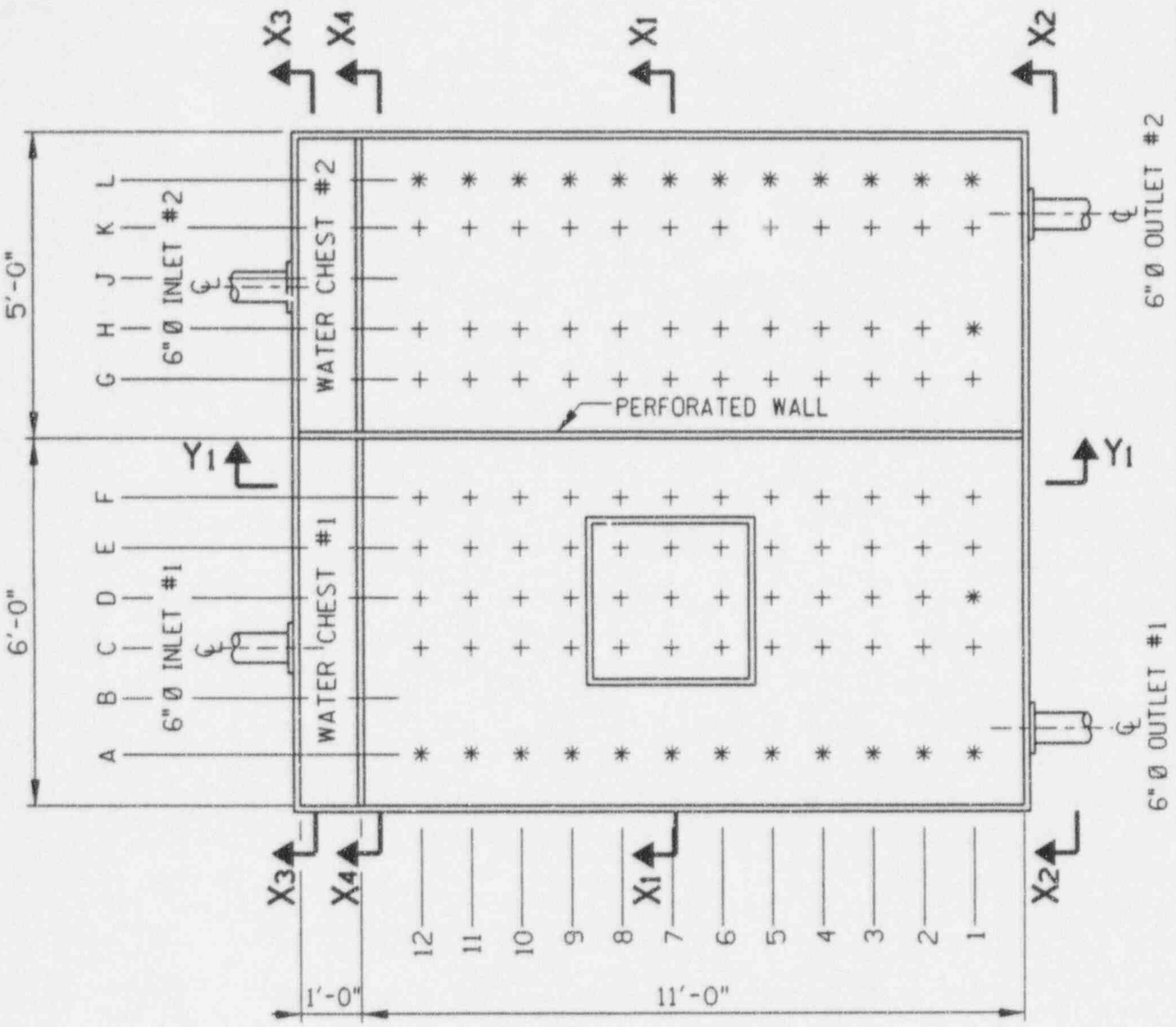
MP3 CONTAINMENT MAT POROUS CONCRETE
PHASE III MOCK-UP TEST

UNCONFINED COMPRESSIVE STRENGTH POROUS CONCRETE LABORATORY CYLINDERS

DIMENSIONS: 6" x 12" High Cylinders				
Description of Test	**Mix A (Portland)**		**Mix B (Calcium)**	
Age of Test (Days)	7	28	7	28
Average Density (pcf)	127.5	127.7	129.	129.3
Average Compressive Strength (psi)	2130.	2357.	2505.	2367.0

Note:

1. Mix A - Porous Concrete with Portland Cement, shows an 11% increase in strength fro day 7 to 28.
2. Mix B - Porous Concrete with Calcium Aluminate Cement, shows no strength increase after 7 days.



PLAN VIEW

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

* - INDICATES THE POSITION OF PERFORATED METAL CAGES.

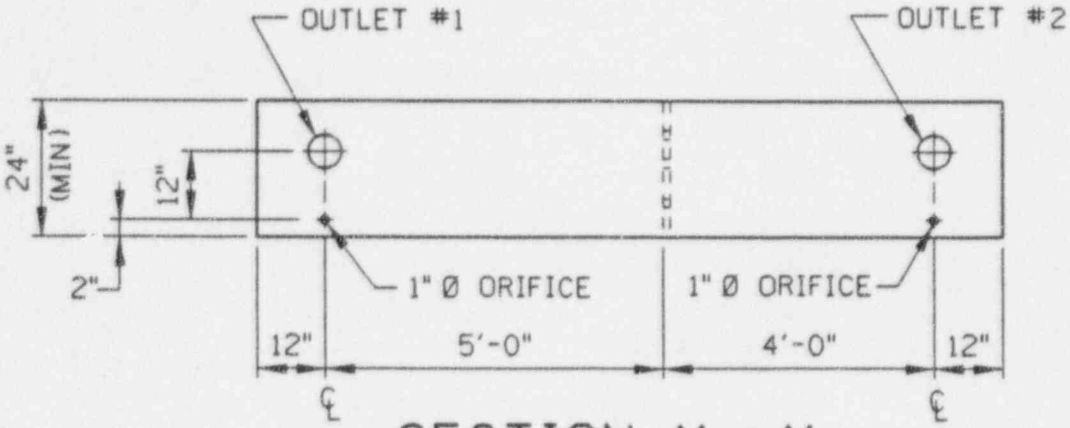
P.A.*	NO.	DATE	REVISIONS	BY	CHK.	APP.	APP.

Northeast Utilities System

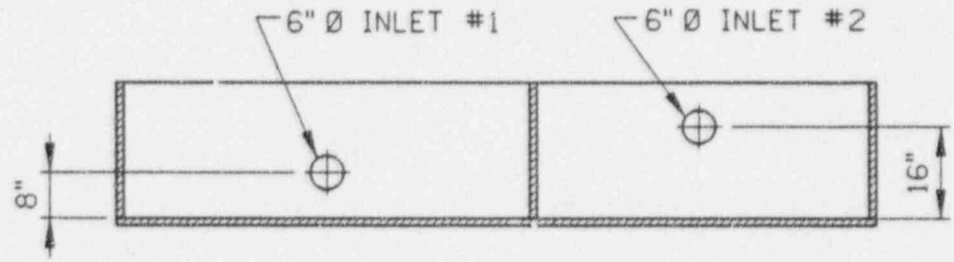
FOR MILLSTONE NUCLEAR POWER STATION UNIT 3

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

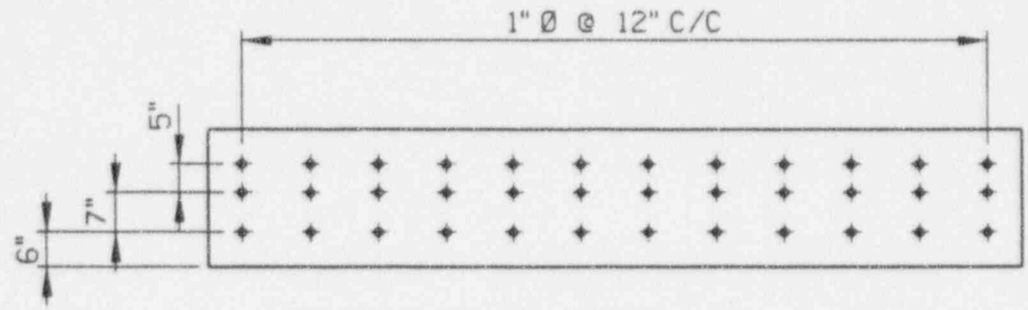
BY K.FULLER	CHKD.	APP.	APP.
DATE 8-6-96	DATE	DATE	DATE
SCALE N.T.S	DWG. NO.	FIGURE 1a	
P.A.*			



SECTION X_2-X_2



SECTION X_3-X_3



SECTION Y_1-Y_1 (ELEVATION)

PERFORATED WALL

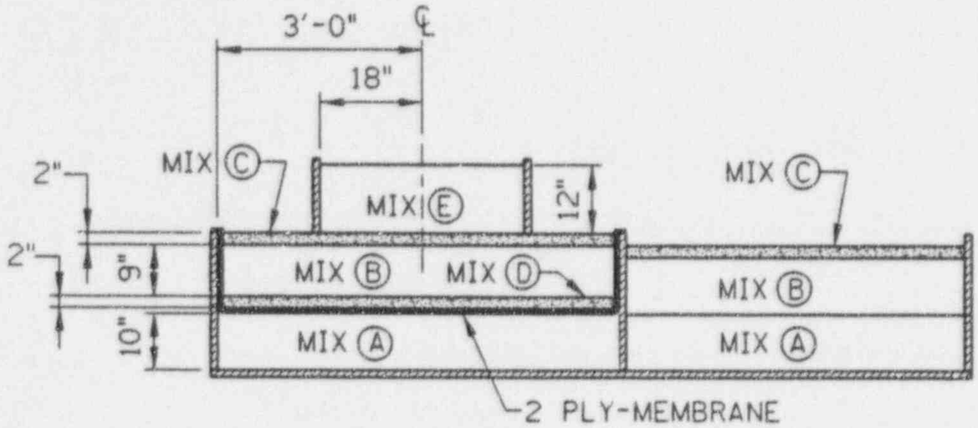
M/✓	P.A.#	NO.	DATE	REVISIONS	BY	CHK.	APP.	APP.

Northeast Utilities System

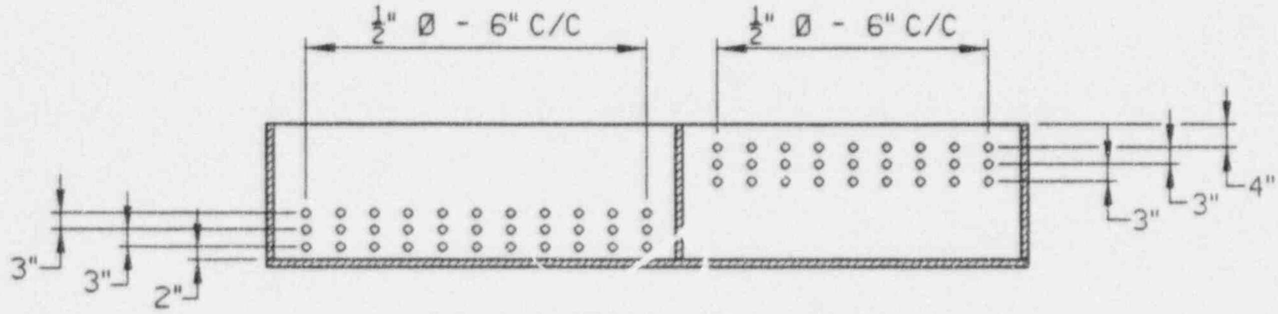
FOR MILLSTONE NUCLEAR POWER STATION UNIT 3

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 $X_4 - X_4$

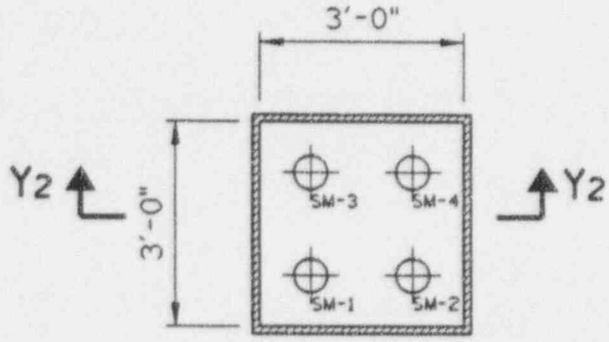
M/F ✓	P.A.#	NO.	DATE	REVISIONS	BY	CHK.	APP.	APP.

Northeast Utilities System

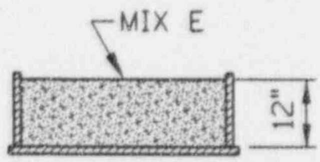
FOR MILLSTONE NUCLEAR POWER STATION UNIT 3

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.* ———			

Docket No.50-423
B15985

Attachment 2

Millstone Nuclear Station Unit 3

Phase I Test Report
Millstone 3 Erosion of Cement From The Porous Concrete Drainage System

November 1996

POROUS CONCRETE MOCK-UP TESTING
FOR MILLSTONE UNIT 3
WATERFORD, CONNECTICUT

By

Dean K. White

Sponsored by

NORTHEAST UTILITIES SERVICE COMPANY

ALDEN RESEARCH LABORATORY, INC.

Solving Flow Problems Since 1894

178-92/M295F-R

November 1992

Revised - November 1996

Solving Flow Problems Since 1894

ALDEN RESEARCH LABORATORY, INC.
30 SHREWSBURY STREET, HOLDEN, MASSACHUSETTS 01520
TELEPHONE 508-829-4323 • FAX (508) 829-5939

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FOR MILLSTONE UNIT 3
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30 Shrewsbury Street

Holden, MA 01520

Revised and Reprinted at ARL - November 1996

TABLE OF CONTENTS

INTRODUCTION

This report covers all work conducted under Northeast Utilities Specification SP-CE-354 both by the Alden Research Laboratory, Inc. (ARL) and its subcontractor, Trow Protze Consulting Engineers (TP). All technical matters related to the project were coordinated with Mr. K. Lakshmipathiah of Northeast Utilities Service Company (NU).

SCOPE OF WORK

The ARL and its subcontractor were to provide all the necessary materials, equipment, and technical requirements for the construction of three (3) porous concrete test slabs and for testing of the test slabs to evaluate potential cement erosion resulting from the flow of water through the porous concrete.

CONSTRUCTION OF APPARATUS

Three (3) concrete test slabs were constructed. One (1) test slab was a single layer while two (2) test slabs were double layers. The wooden forms built to contain the test slabs were heavily reinforced to minimize deflection.

The 6 x 10 foot form for the single layer slab was 13 inches high to accommodate a 9 inch layer of porous concrete between two 2 inch layers of grout. One 10 foot long side of the form contained groups of one quarter inch holes to introduce water into the test slab. The holes were drilled over size, and a plastic sleeve was pressed into each hole to insure uniformity. The single layer test slab contained two 6 inch perforated plastic drainage pipes to collect the water introduced through the one quarter inch holes. The drainage pipes contained four (4) rows of five eighths inch diameter holes spaced 3 inches center to center. The rows of holes were located at 2 o'clock, 4 o'clock, 8 o'clock, and 10 o'clock around the pipe. Figure 1 is the plan of the single layer test slab.

The two double layer test slab forms were 6 x 10 feet x 21 inches high. These forms contained a 9 inch layer of porous concrete on top of a 10 inch layer of porous concrete. A 2 inch layer of grout was on top of the 9 inch layer of porous concrete. One 10 foot long side of the form contained groups of one quarter inch holes to introduce water into the test slab. The holes were drilled over size, and a plastic sleeve was pressed into each hole to insure uniformity. The double layer test slabs contained two 6 inch perforated plastic drainage pipes in the 9 inch porous concrete layer to collect the water introduced through the one quarter inch holes. The drainage pipes contained four rows of five eighths inch diameter holes spaced 3 inches center to center. The rows of holes were located at 2 o'clock, 4 o'clock, 8 o'clock, and 10 o'clock around the pipe. Figure 2 is the plan of the double layer test slab. A partially filled two layer slab is shown in Figure 3.

Water was supplied to the boxes through pumps capable of developing 50 feet of head of water (22 psig) discharge pressure at the slab. Flow from the pump was introduced into a manifold where smaller lines carried flow to each of the one quarter inch holes. A calibrated pressure gauge was located on the manifold and a valve on the inflow to the manifold was provided to regulate pressure.

Water discharging from the drainage pipes was collected in a settling box and the residue washed from the slab was recovered by filtering the water from the box using a 5 micron filter. For the tests of 8 hour duration, all water was filtered. For the 30 day test, only the residue in the box at the conclusion of the test was collected.

PROCUREMENT AND TESTING OF MATERIALS

The ASTM #57 coarse aggregate to be used in the porous concrete slabs was procured from Tilcon Connecticut, Inc., the quarry providing the coarse aggregate to the Millstone Plant during the original construction. Review of the gradation logs for the original aggregate, aggregate being shipped from the quarry today and a sieve analysis of the aggregate actually used for this

test showed that the aggregate used in the test was similar to the aggregate used at Millstone and was within the ASTM specifications for #57 aggregate, see Appendix A.

The calcium aluminate cement was produced by the Lehigh Portland Cement Company of Gary, Indiana at the Buffington Plant. The mill test report indicates that the cement meets the requirements of Section 8.3 of the NU Specifications. In addition, TP conducted check tests of the Lumnite cement which confirm the mill test report. Both the mill test report and the check tests conducted by TP are in Appendix A.

The Portland Cement Type II produced by the LaFarge Corporation Northeast Cement Plant complies with current ASTM C-150 as well as A.A.S.H.T.O. M-85 specifications called for in Section 8.2 of the NU Specifications, see Appendix A.

The concrete used in the test slabs required careful preparation of transit mixing equipment since Calcium Aluminate Cement is not in common usage (all local concrete plants use Portland Cement). Concern for the possible contamination of Calcium Aluminate Cement with Portland Cement prompted tests on how the initial setting time of Calcium Aluminate Cement was effected by Portland Cement contamination. The results of these tests indicated that contamination up to 10% did not significantly effect the setting time of Calcium Aluminate Cement. The results of these tests are shown in Appendix A.

BATCHING AND PLACING OF CONCRETE

The test slabs contained very small quantities of concrete and to better control the batching process, the minimum batch sizes was set at 3 cubic yards of concrete. The mix designs were based on this yardage and can be found in Appendix B. The mixes containing Portland Cement were batched at the transit mix batch plant and sent to the site with only a small fraction of the water requirement added at the plant. The remaining water was added at the site and carefully controlled to produce the proper consistency. The mixes containing Calcium Aluminate Cement

only added the aggregate at the transit mix batch plant and the cement was added at the site by the bag to minimize the potential of rapid setting of the concrete in the truck mixing drum. Water was added at the site and carefully controlled to produce the proper consistency. Due to the stiffness of the mixes using the #57 aggregate slump was not sufficient to determine the proper water content. The mix was inspected visually for the consistency of the concrete paste on the aggregate.

The preparation of each concrete and grout mix was monitored by TP inspectors, both at the concrete batch plant and during placement. Reporting of these inspections is contained in Appendix C.

DESCRIPTION OF WORK

Three (3) test slabs were constructed. Two (2) slabs contained two layers of porous concrete. The lower layer was 10 inches thick, made with Portland Cement Type II and the upper layer was 9 inches thick, made with Calcium Aluminate Cement (Lumnite Cement). A 2 inch thick grout layer (sand cement mix) made with Lumnite Cement was used to seal the top. The third slab contained a single porous concrete layer 9 inches thick, made with Lumnite Cement and placed on a 2 inch thick layer of grout made using Portland Cement Type II. A 2 inch thick grout layer made with Lumnite Cement was also used to seal the top of the single layer slab.

To preserve porosity as called for in section 10.3.1.1 of the specifications (Ref. 1), the porous concrete layers were compacted in 4 to 5 inch layers by walking on the concrete ("booting"). Each layer of concrete placed in the slab was allowed to cure 48 hours before the next layer was placed. The concrete placing schedule is shown in Table 1.

TABLE 1

CONCRETE PLACING SCHEDULE

DAY	TWO LAYER MOLDS	ONE LAYER MOLD
1	10" Portland concrete	2" Portland grout
3	9" Lumnite concrete*	9" Lumnite concrete*
5	2" Lumnite grout	2" Lumnite grout

* Layer containing 6" drain pipes.

In the two layer slabs only, within 24 hours of the pour the perforated drain pipes were cleaned out and the recovered concrete residue was weighed and analyzed.

The single layer slab and one of the double layer slabs were cured for 7 days before being pressurized with water. The remaining double layer slab was cured for 30 days and is being stored for future testing.

After 7 days of curing, water was applied to one hole in group A in each of the slabs. Four 8 hour tests were conducted in each slab using this hole. The scope of work was modified to use only one hole of the original four holes labeled as holes A for the 8 hour test series. Water was introduced at a pressure of 22 psig (50 feet of water) and allowed to flow for 8 hours. All water collected from the 6 inch perforated pipes was filtered and the residue collected, dried, and weighed. Samples of the residue were analyzed to determine the type of cement.

In the two layer slab, one hole of group B was opened and four 8 hour tests were conducted with a single hole in both groups A and B open to water at a pressure of 22 psig. As was the case for hole A, only one of four holes labeled holes B was open for the 8 hour test series. All

water collected from the 6 inch perforated pipes was filtered, and the residue collected, dried, and weighed. Samples of the residue were analyzed to determine the type of cement.

At the conclusion of the 8 hour testing sequence, both molds were subject to a 30 day test with all holes open. This included four holes for holes A and four holes for holes B plus all holes labeled C. The water exiting the 6 inch perforated pipes discharged into a settling box that was inspected for residue five times a week. The residue was collected at the end of the test.

LABORATORY CERTIFICATION

The latest CCRL (Cement and Concrete Reference Laboratory) certification for the laboratory of TP is in Appendix D.

SUMMARY OF TEST RESULTS

AGGREGATE VOIDS

The volume of the voids in the Tilcon #57 coarse aggregate was 46%. The volume of the voids in the Mix B laboratory prepared sample was 32.7%, in the test cylinders prepared when Mix B was placed, the volume of the voids was 30%, and the volume of the voids in cores removed from the single layer slab was 33.5%. The volume of the concrete paste is approximately 16% of the total volume which accounts for the difference in the volume of the voids in the aggregate compared to the volume of the voids in the concrete. Void ratio test results are in Appendix E. The variation in the volume of the voids in the mixes may have some influence on the compressive strength of the concrete.

TEST CYLINDERS

Six (6) test cylinders were made from concrete Mix A (Portland cement porous concrete) and six (6) test cylinders were made from concrete Mix B (Lumnite porous concrete) at the time of pouring. In addition, three (3) test cylinders were made in the TP laboratory using Lumnite cement and Tilcon crushed stone (Mix B). The laboratory cylinders were kept in the laboratory fog room and were tested at 28 days. The cylinders made at the time of the pour remained at the site for three (3) days and then were held in the laboratory fog room. Two (2) cylinders from each mix were tested at 7 days, 14 days, and 28 days. The average 28 day strength of the three Mix B (Lumnite cement) laboratory cylinders was 1,310 psi. The average strengths of the two Mix B cylinders from the pour broken at 7 days, 14 days, and 28 days were 985 psi, 1,035 psi, and 1,060 psi, respectively. The increase in strength from the 7 day strength to the 28 day strength was approximately 8% for Mix B. There were no laboratory cylinders made from Mix A (Portland cement). The average strengths of the two Mix A cylinders from the pour broken at 7 days, 14 days, and 28 days were 470 psi, 480 psi, and 565 psi, respectively. The increase in strength from the 7 day strength to the 28 day strength was approximately 20% for Mix A. The test reports are contained in Appendix F.

The residue in the 6 inch drain lines of the two layer slabs was removed 24 hours after placement of the porous concrete layer. The residue samples were weighed and the chemical content analyzed. The pipes of the 7 day cure two layer slab contained 33.07 grams of material. This material consisted of dry concrete particles and small pieces of cement coated aggregate. The size of the aggregate was limited by the diameter of the holes in the drain pipe. The pipes of the 28 day cure two layer slab contained 9.70 grams of material. This material was similar to that found in the other slab. The report on the chemical content of the residue is in Appendix G.

FLOW TESTING

At the conclusion of the 7 day curing period, both the single layer slab and one of the two layer slabs were introduced to flowing water at a pressure of 22 psi for a series of tests, each 8 hours in duration. The water which circulated through the slabs was filtered through a 5 micron filter upon leaving the slab. The residue was dried and weighed. During each test, the flow rate was measured. The weights and flow rates are shown in Tables 2 and 3.

TABLE 2

SINGLE LAYER SLAB RESIDUE WEIGHT AND FLOW RATE

TEST	WEIGHT grams	FLOW gpm	DESCRIPTION
1	4.84	*	Gray Powder
2	23.30	4.94	Gray Powder
3	11.27	6.66	Gray Powder
4	11.62	3.50	Gray Powder

* Flow not measured.

TABLE 3

DOUBLE LAYER SLAB RESIDUE WEIGHT AND FLOW RATE

HOLE A ONLY

TEST	WEIGHT grams	FLOW gpm	DESCRIPTION
1	120.35	*	White Residue
2	52.26	1.35	White Residue
3	49.19	1.36	White Residue
4	47.59	0.88	White Residue

HOLES A & B

TEST	WEIGHT grams	FLOW gpm	DESCRIPTION
1	69.37	8.20	White Residue
2	91.87	8.26	White Residue
3	60.26	8.43	White Residue
4	53.22	8.12	White Residue

* Flow not measured.

During the curing process, a white residue leached from both of the two layer slabs. This material deposited on the wooden box and on the floor any where the curing water went, see Figure 4. In the case of the single layer slab, no such white residue leached from the slab. When the flowing water was introduced into the slabs, the two layer mold produced a similar appearing white residue which was filtered out and collected as the material tabulated above. The single layer slab did not produce any white residue. The material washed from the single

layer mold was more granular and gray in color. The results of the chemical analysis to determine the type of cement contained in the residue is in Appendix H.

At the conclusion of the 8 hour tests, both slabs were tested for 30 days introducing water through all holes shown in Figures 1 and 2. The rate of flow through the slabs was measured during the test period. The average flow through the single layer mold was 50 gpm. There was a decreasing trend in flow from a high of about 64 gpm to a low of 40 gpm. The average flow through the double layer mold was 140 gpm, and there was no trend of increasing or decreasing flow. No material was found in the water discharging from either mold.

REVISED

The two layer mold that did not undergo flow testing was cured by remaining flooded for approximately 28 days. The curing water level was maintained at the top of the Lumnite cement grout layer. Only enough water was added to make up for leakage and evaporation. The water that leaked from the mold deposited a white residue on the wooden mold, the building floor and on the surface any standing water. At the conclusion of the curing period and after the curing water leakage had evaporated 15 pounds, dry weight, of the white residue were removed from the outside surface of the mold and from the floor. During curing, no special precautions were taken to ensure that the residue transported by the leaking curing water was all captured. Some leaking curing water did run into the building floor drain system while the remainder evaporated on the floor. It is estimated that roughly 70 percent of the residue transported by the leaking curing water was collected in the weighed sample.

CORE TESTING

After the 30 day test period, twelve (12) 4 inch diameter cores were taken from each slab at the locations shown in Figures 1 and 2. Eight (8) of the cores were broken in compression and four (4) cores were split in the longitudinal direction. The coring operation was successful in the single layer slab. The compression tests of the single layer slab cores ranged from a high of 600 psi to a low of 440 psi with the average for 7 test of 520 psi. This average strength is

approximately one half the 28 day strength of the test cylinders for Mix B. Since there appears to be no correlation of compressive strength with location within the slab, i.e., some cores were exposed to flowing water and others were not, the reduced strength does not appear to be related to the flowing water. Other factors, such as curing and density of the mix may account for the differences. If the compressive strength of the cylinders made at the time of the pour of Mix B is compared with the strength of the laboratory test specimens, it can be seen that the cylinders made at the time Mix B was poured broke at 1,060 psi while the laboratory test cylinders broke at 1,310 psi. A discussion of the relative strengths of the cylinders and the cores is in Appendix I.

In the double layer slab, the cores broke under the drilling action. Increasing the core diameter to 6 inches did not prevent the cores from breaking. Anticipating that this might happen, 6 inch diameter steel perforated cages were placed in the slabs during the pour, see Figure 3. These cages were extracted from the slab by cutting an 8 inch core around the cage and breaking away the slab. Three of the cages were cut away from the concrete in an attempt to produce specimens for testing. The bond of the concrete, however, was not strong enough to hold the aggregate together when the cages were removed and only one specimen from each layer was recovered for testing. The two recovered cores were used to conduct split tensile strength tests. The Mix A (Type II) broke at 17 psi while the Mix B (Calcium Aluminate) broke at 40 psi. The Mix B specimen strength was much lower than the average of the single layer slab split tensile strength tests. Since the compression test could not be conducted, specimens contained in the remaining cages were tested in a confined compression test by sealing the specimen in a rigid steel cylinder using leadite and an impermeable barrier to keep the leadite out of the voids in the concrete. The confined compression tests were made on four (4) specimens measuring both loading and deflection. Each specimen contained equal lengths of Mix A and Mix B concrete. The results of the confined compression tests are shown in Figures 5 through 8. The compression tests indicated that at loadings ranging from 385 psi to 654 psi, the specimens began to compress rapidly due to breaking of the bond and rearrangement of the aggregate. Examination of one of the confined compression test specimens after testing showed that there

was more aggregate destruction in Mix A with Type II cement than in Mix B with Calcium Aluminate cement. The laboratory test reports for the two layer slab are presented in Appendix J.

REFERENCE

1. Northeast Utilities Service Company Specification SP-CE-354; Specification for Porous Concrete Mock-up Testing; January 8, 1992; Revision 1, March 9, 1992.

FIGURES

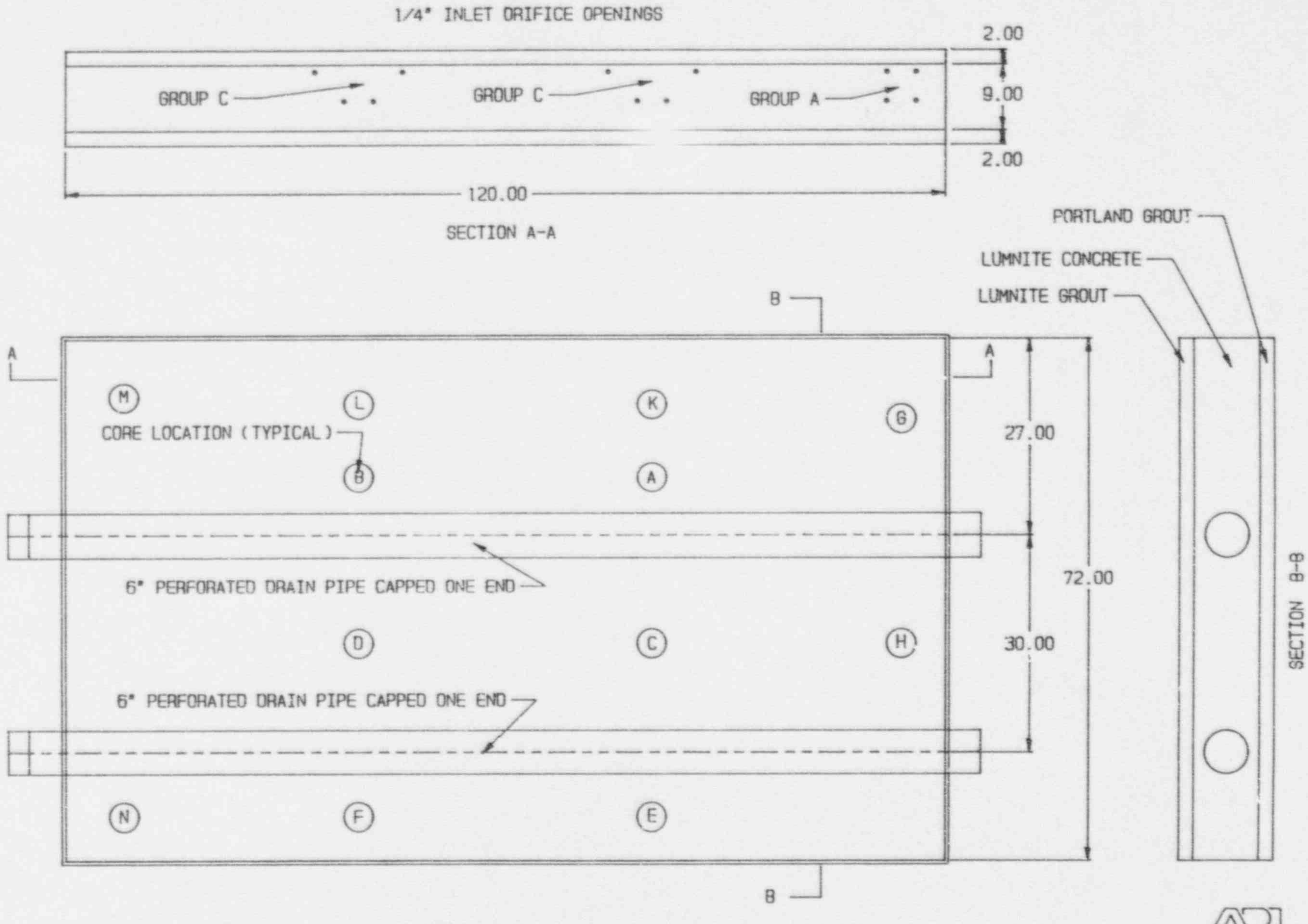

FIGURE 1 SINGLE LAYER SLAB PLAN VIEW

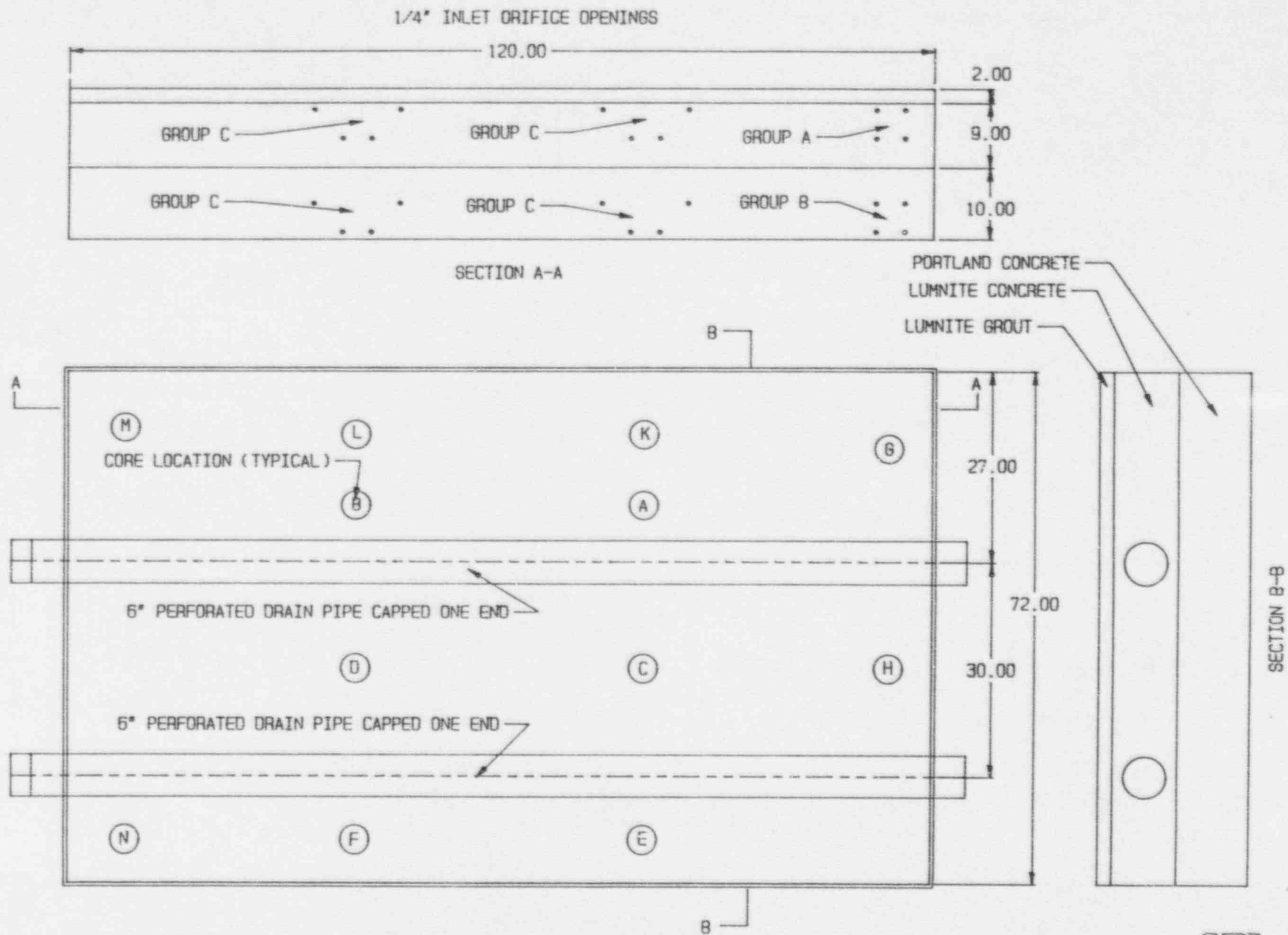

FIGURE 2 DOUBLE LAYER SLAB PLAN VIEW

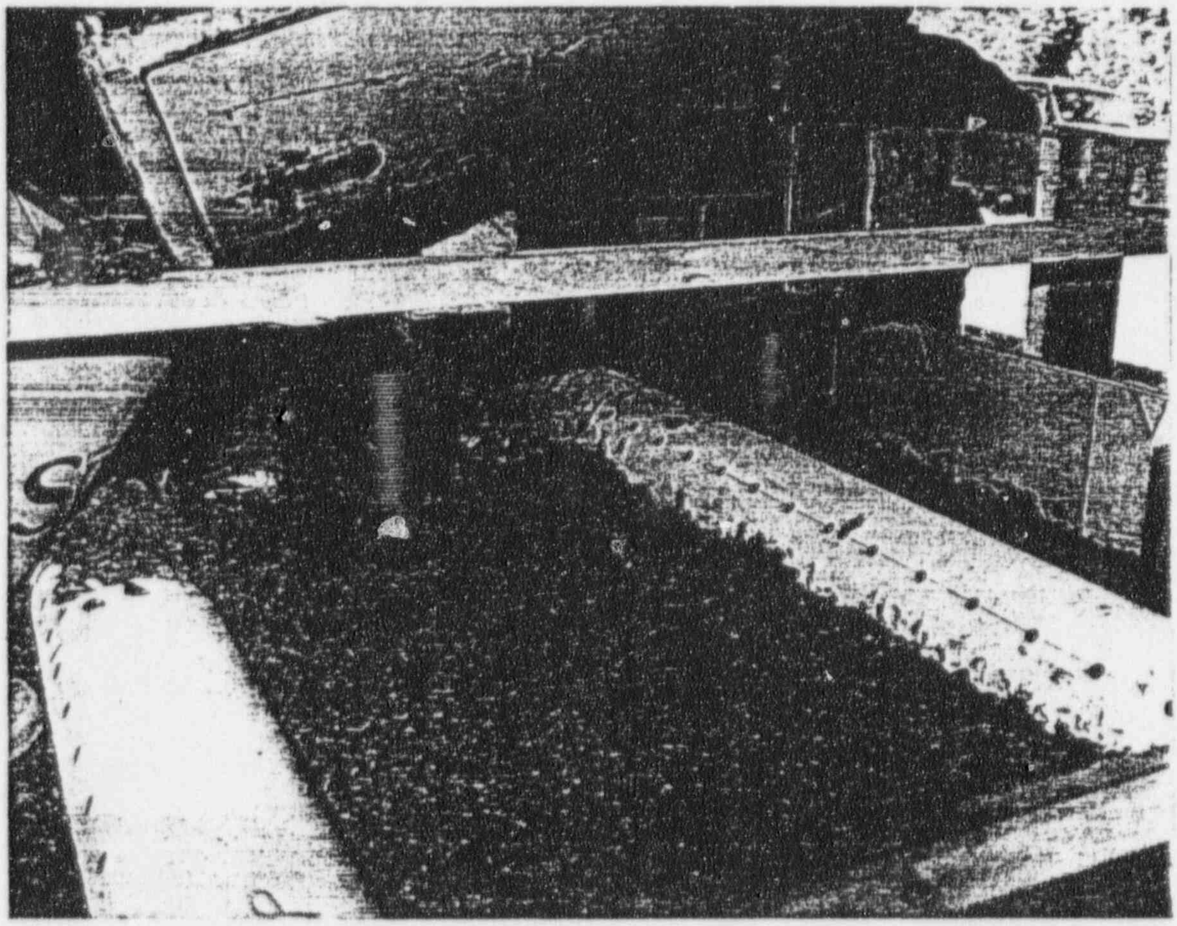

FIGURE 3 TWO LAYER SLAB CONSTRUCTION

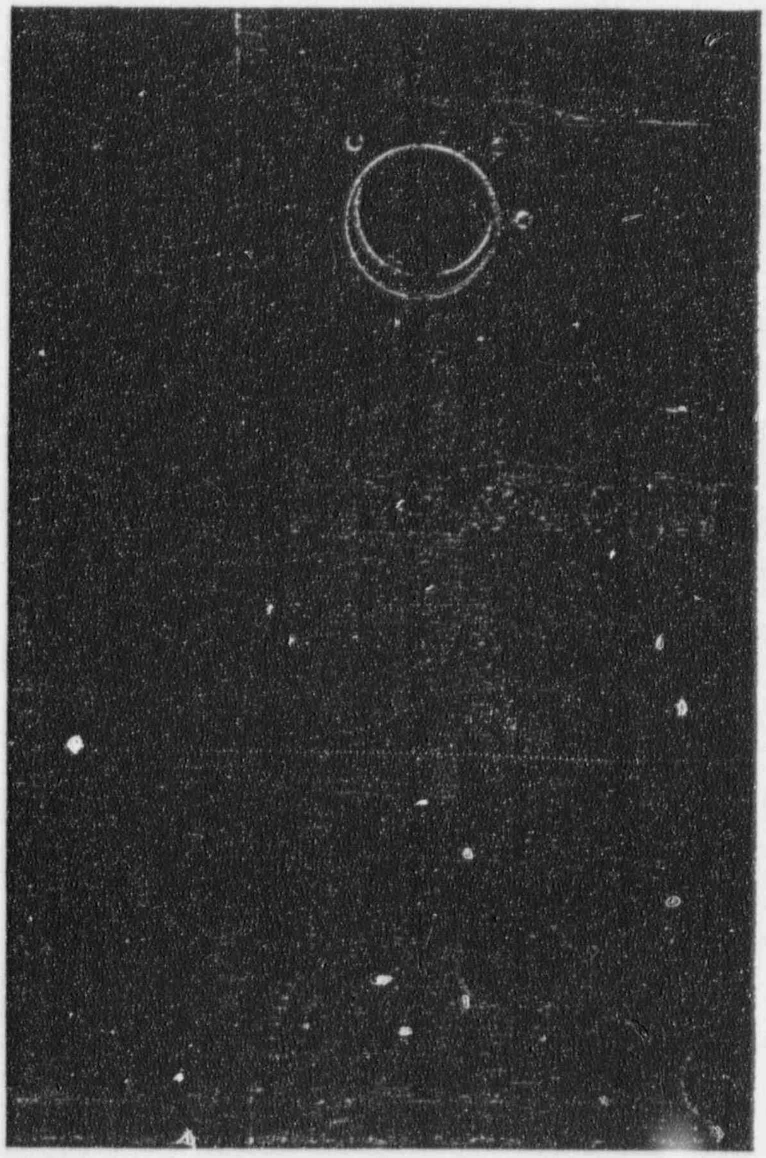

FIGURE 4 WHITE RESIDUE FROM TWO LAYER SLAB

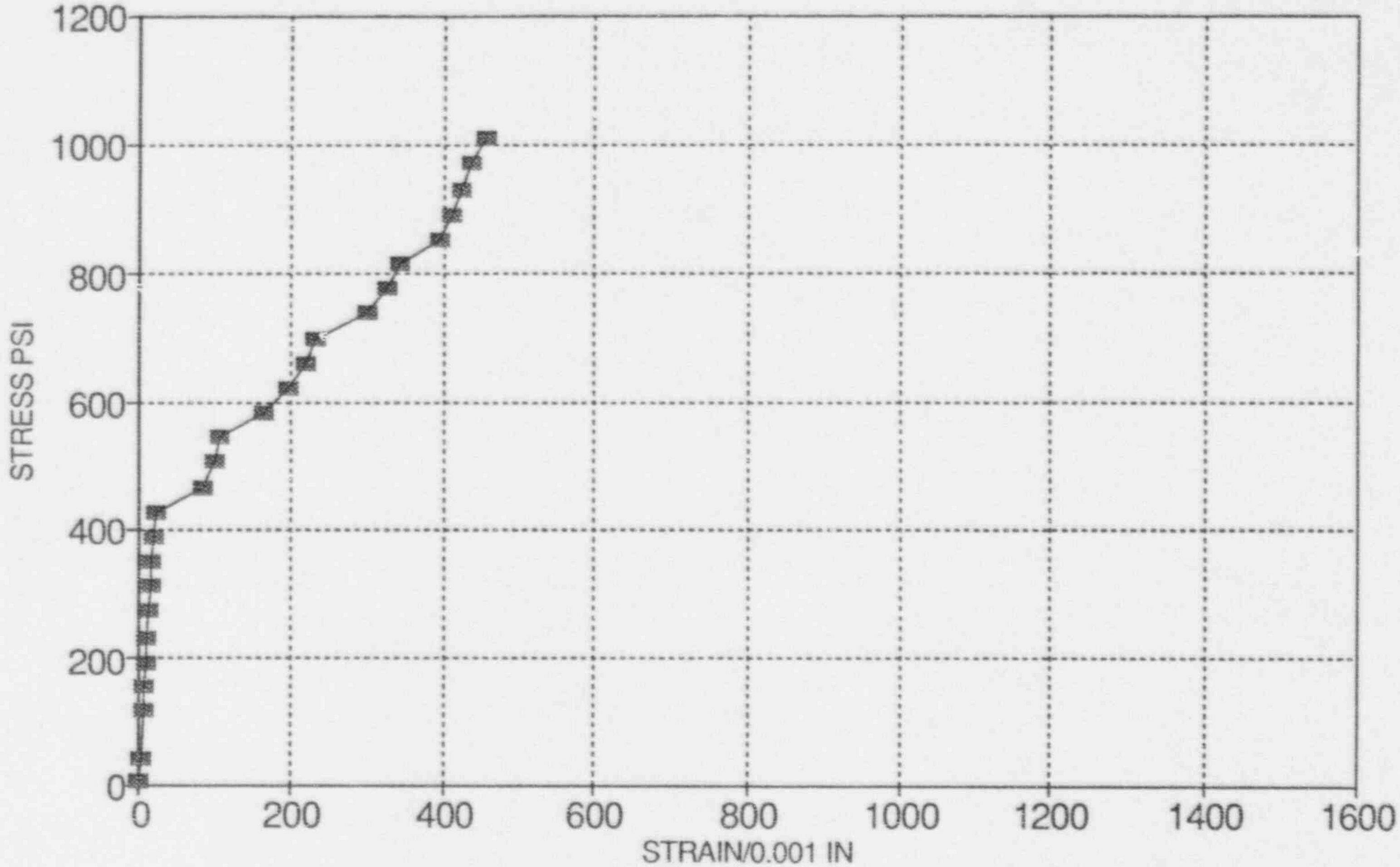

FIGURE 5 CONFINED COMPRESSION TEST SAMPLE D

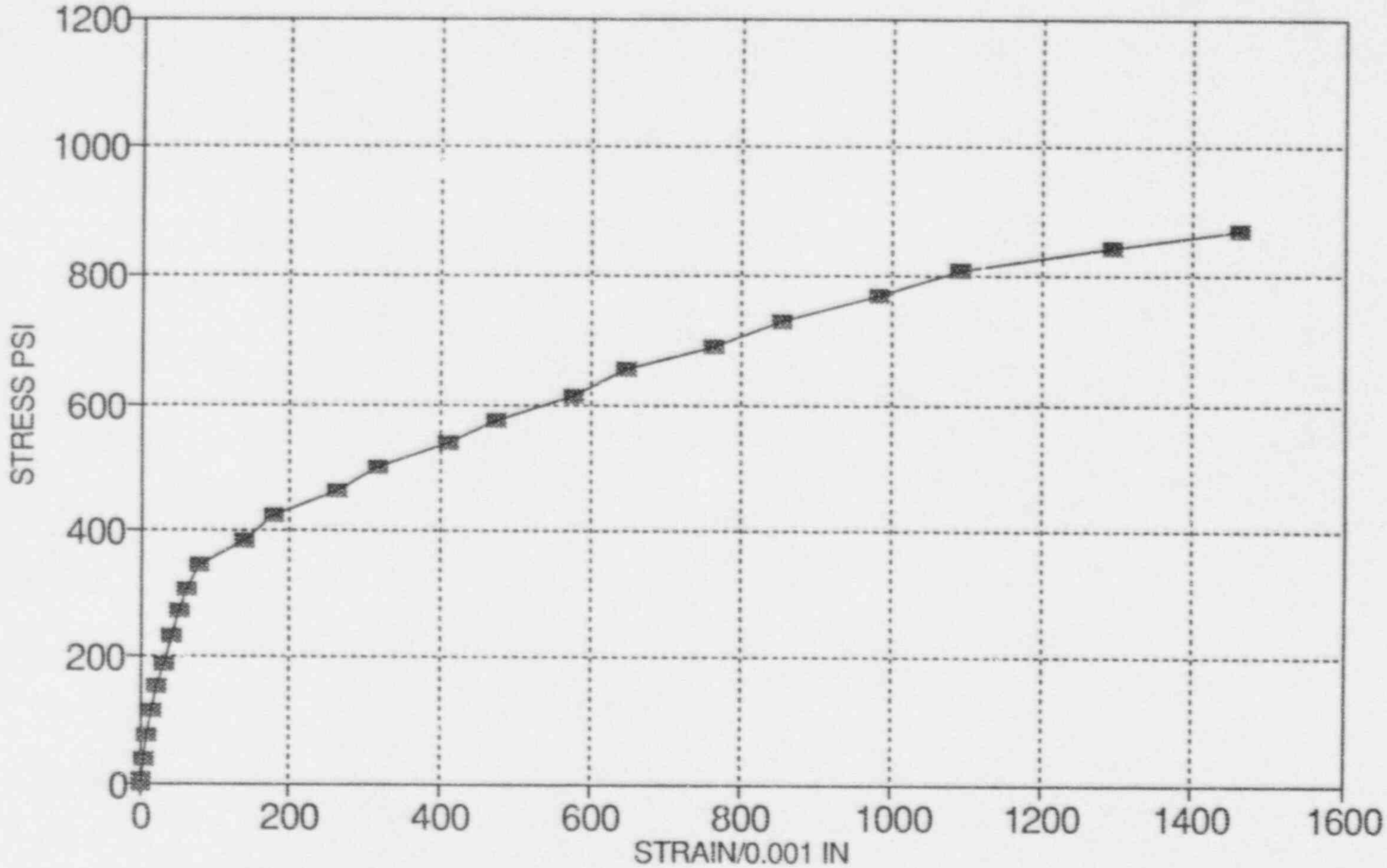

FIGURE 6 CONFINED COMPRESSION TEST SAMPLE B

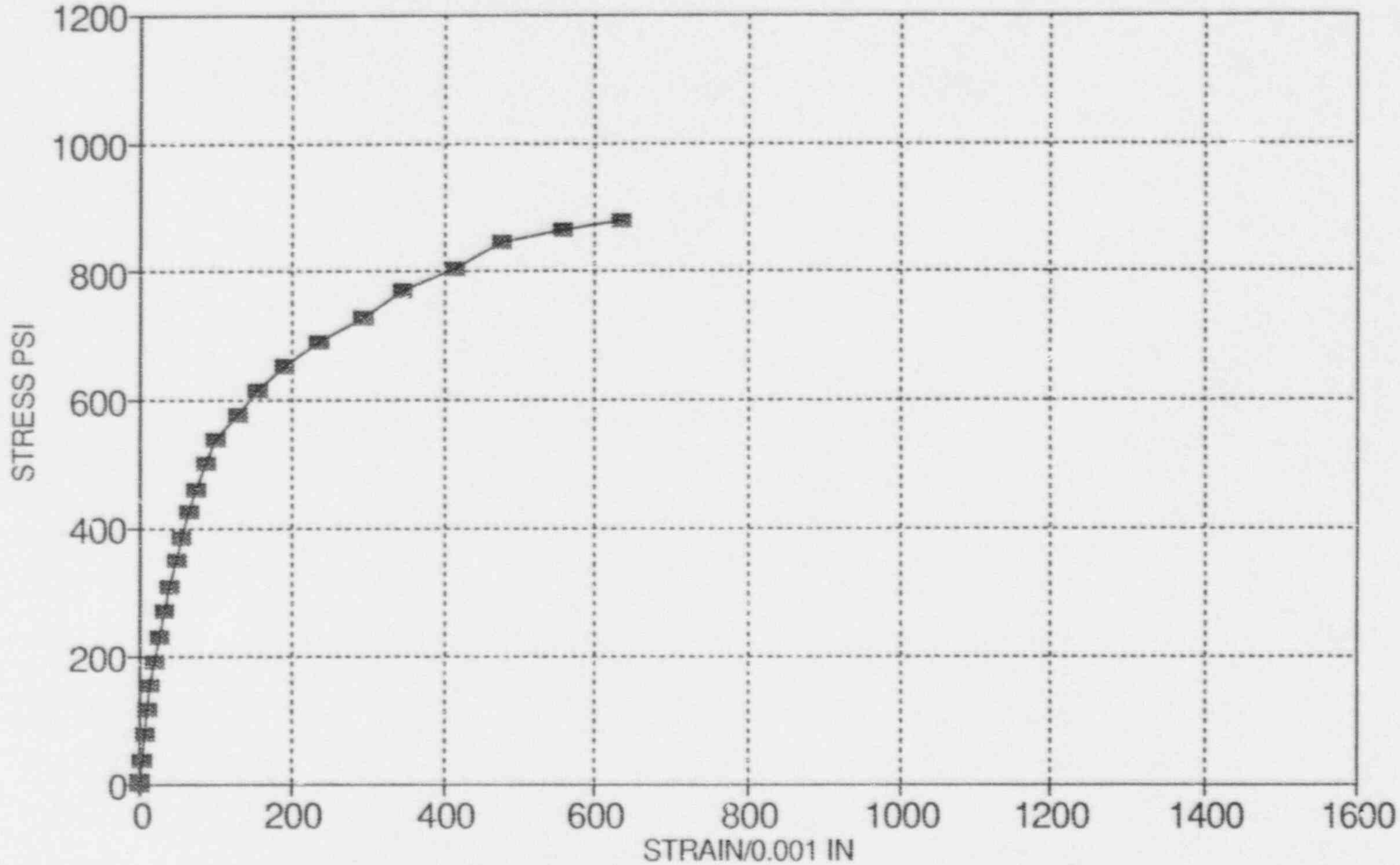

FIGURE 7 CONFINED COMPRESSION TEST SAMPLE F

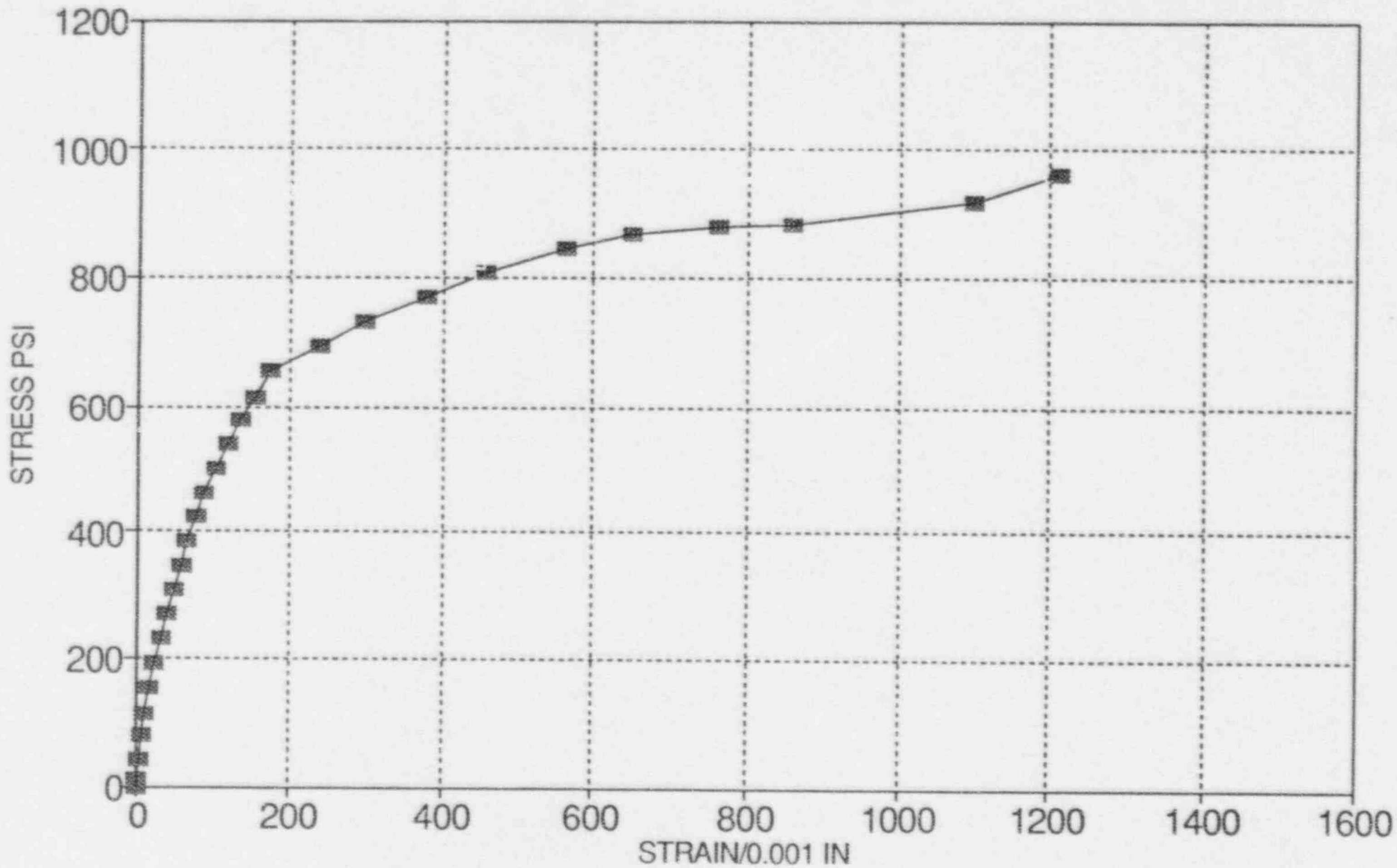

FIGURE 8 CONFINED COMPRESSION TEST SAMPLE H

APPENDIX A

MATERIAL SPECIFICATIONS AND DOCUMENTATION

SIEVE ANALYSIS OF #57 AGGREGATE FROM ORIGINAL CONSTRUCTION
% PASSING

SAMPLE DATE	SIEVE SIZE 1-1/2	1	1/2	#4	#8	#200
2/27/75	100.0	99.0	41.0	6.0	4.0	
2/28/75	100.0	99.0	37.0	5.0	3.0	
3/3/75	100.0	98.0	26.0	4.0	3.0	
3/5/75	100.0	99.0	30.0	2.0	2.0	
3/4/75	100.0	100.0	44.0	3.0	2.0	0.9
3/7/75	100.0	100.0	36.0	3.0	2.0	0.6
3/7/75	100.0	100.0	40.0	4.0	2.0	0.9
3/21/75	100.0	100.0	49.0	5.0	3.0	
3/26/75	100.0	99.0	42.0	5.0	3.0	
3/27/75	100.0	98.0	31.0	2.0	2.0	
3/29/75	100.0	99.0	41.0	5.0	3.0	
3/31/75	100.0	100.0	49.0	8.0	5.0	1.2
4/1/75	100.0	99.0	40.0	5.0	3.0	
4/2/75	100.0	99.0	37.0	4.0	2.0	
4/7/75	100.0	97.0	36.0	5.0	3.0	1.2
AVG	100.0	99.1	38.6	4.4	2.8	

RECENT TILCON CRUSHED STONE GRADATIONS
% PASSING

SAMPLE DATE	SIEVE SIZE 1	3/4	1/2	3/8	#4	F.M.
4/7/92	100.0	90.2	37.0	9.8	1.6	
4/8/92	100.0	90.0	37.3	10.7	1.2	
4/6/92	100.0	85.9	35.9	9.4	1.2	
4/6/92	100.0	90.9	39.1	11.2	0.6	
4/3/92	100.0	89.5	37.1	10.1	2.1	
4/2/92	100.0	93.2	44.3	13.7	1.8	
3/30/92	100.0	86.0	32.3	7.0	1.1	
3/31/92	100.0	83.7	24.5	12.0	1.6	
AVG	100.0	88.7	35.9	10.5	1.4	7.0
MIN	100.0	83.7	24.5	7.0	0.6	7.1
MAX	100.0	93.2	44.3	13.7	2.1	6.9
#57 ASTM	95-100	70-85	25-60	15-25	0-10	7.0

NU/Concrete GEH, DKW, JL

Trow Protze Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

FAXMITTAL

TROW PROJECT NO TP-04518-A DATE 6-2-92

TO: COMPANY: Alden Research Laboratory, INC.

FAX NUMBER: 1-508-829-5939

TOTAL NUMBER OF PAGES (including this one) 1

ATTENTION: Mr. Dean K. White, P.E.

SUBJECT: Gradation of Tilcon Stone

FROM: Herman G. Protze

TROW PROTZE

COMMENTS:

1"	100%
3/4	72
1/2	27
3/8	6
#4	1
F.M.	7.21

NOTED JUN 1

This grading is better than previous samples.

Original Will Be Sent to you_____ Yes - Courier Yes - Mail (No) Later

If you do not receive the total number of pages indicated above, or if these pages are unclear, please call Trow Protze at 617-332-8460.

MILL TEST REPORT

LEHIGH PORTLAND CEMENT CO.

BUFFINGTON PLANT — GARY, INDIANA

CONSIGNEE: Kesseli + Morse ADDRESS: Attn. Bob Kesseli

DATE SHIPPED: ______

CEMENT TYPE: LUMNITE TRUCK/CAR NUMBER ______

PHYSICAL TEST DATA:

FINENESS, BLAINE, (m^2/kg)	354
INITIAL SET VICAT (hr:min)	08:03.
COMPRESSIVE STRENGTH ASTM C-109, 24 HOURS (psi)	6556

CHEMICAL ANALYSIS:

SILICA, % SiO_2	6.12
ALUMINA, % Al_2O_3	52.99
IRON OXIDE, % Fe_2O_3	5.30
CALCIUM OXIDE, % CaO	34.11
MAGNESIA, % MgO	0.78
SULPHUR TRIOXIDE, % SO_3	0.34
LOSS ON IGNITION, %	0.33

WE WARRANT THAT TEST RESULTS SHOWN WERE OBTAINED USING GENERALLY ACCEPTED LABORATORY PRACTICES, INCLUDING ASTM METHODS AND PROCEDURES WHERE APPLICABLE.

DATE: 4/13/92 QUALITY CONTROL SUPERVISOR: [signature]

NU/Concrete

gen/file sent DKW

Trow Protze Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A

April 15, 1992

Alden Research Laboratory, Inc.
30 Shrewsbury Street
Holden, MA 01520

Attn: Mr. Dean K. White, P.E.

Porous Concrete
Mock-Up Testing

Gentlemen:

This will confirm that the Lumnite Cement mill test report, dated 4/13/92, indicates that this cement fully satisfies the Northeast Utilities specification dated January 14, 1992. Inquiry No. CB0-636, page 3 of 13 for calcium-aluminate cement, chemical and physical properties.

Yours very truly,

TROW PROTZE

Herman G. Protze

Herman G. Protze, P.E.

1-Alden

Ref. No. 92C-476

NOTED AF

CHECK TESTS OF LUMNITE CEMENT

Normal Consistency	26.8%
Initial Set (Vicat Needle)	6 hours 54 min.
Compressive Strength, 24 hours	4360 psi
	4120
	4150
	4210

These tests confirm those by the Lehigh Portland Cement Co.

Herman G. Protze

NU/concrete GEH, JL, DKW

Trow Protze Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A

May 21, 1992

Alden Research Laboratory, Inc.
30 Shrewsbury Street
Holden, MA 01520

Attn: Mr. Dean K. White, P.E.

Time of Set Tests
Lumnite & Type II Cements

Gentlemen:

We have made some time of set tests on Lumnite Cement contaminated with varying amounts of normal type II cement using such combinations as could occur in a transit mixer truck. The samples were stored in laboratory air at 73°F, 65% RH during the test period.

Lumnite Cement	Type II Addition	Distilled Water	Initial Set
200 gm	0%	50cc	7 Hours
200 "	1	50	7 "
200 "	2	50	7 "
200 "	3	55	7 "
200	10	60	6 "

The tests were carried out essentially in conformity with ASTM Methods C191. These results indicate that it would take a major amount of contamination of normal Portland cement to cause excessively quick setting of concrete containing Lumnite cement. Hence, we expect no problems during casting of the test boxes. However, the writer will maintain sharp consciousness during the casting process and be ready to dump the involved concrete should any unexpected rapid setting start to occur.

Sincerely yours,

TROW PROTZE

Herman G. Protze

Herman G. Protze, P.E.

1-Alden
1-DeFalco
Ref. No 92C-669

NOTED MAY

LAFARGE CORPORATION

Northeast Cement

CEMENT TEST REPORT

St-Constant Plant
Cement test report

Date: May 25, 1992

Period covered : May 11- 17, 1992

Identification: Moderate, Type II Cement

Physical tests :

Spec.Surf. (Blaine) :		3350	cm2/g
Fineness (Sieve) 45 um :		86.7	%passing
Initial setting time :		145	minutes
Final setting time :		260	minutes
Autoclave Expansion :		0.01	%
Air content of mortar :		8.1	%
Compressive strength at :	3 days :	3250	psi
	7 days :	4000	psi
April 6 - 12	28 days :	5410	psi

Chemical tests :

Silica (SiO_2):	21.2	%
Alumina (Al_2O_3):	4.6	%
Iron Oxide (Fe_2O_3) :	3.2	%
Calcium Oxide (CaO) total :	62.9	%
Calcium Oxide (CaO) free :	0.9	%
Sulphur Trioxide (SO_3) :	2.7	%
Magnesium Oxide (MgO) :	2.5	%
Alkali equivalent (Na_2O) :	0.84	%
Loss on ignition :	1.0	%
Insoluble Residue :	0.3	%

Potential Compounds :

C3A:	7	%
C4AF:	10	%
C3S:	51	%
C2S:	22	%

REFERENCE SPECIFICATIONS

This cement complies with current ASTM C-150, for both type I and II, as well as A.A.S.H.T.O. M-85 specifications

Herman G. Protzo

Certified Joanne Leclerc

Joanne Leclerc
Quality Control Jr. Eng.

APPENDIX B
CONCRETE BATCH WEIGHTS

ACTUAL BATCH WEIGHTS EMPLOYED

June 8

Grout Mix D (3 cu.yds.)		Concrete Mix A (4.5 cu.yds.)	
Type II cement	2940 lb.	Type II cement =	2012 lb
Sand 6360 + 4%	6614	Stone 11870+2% =	12107 lb
Water (201) Actual:	100+20+5 gal.	Water (79) Actual: 40+10+5+2+1 gal	
Slump	2" Max	Consistency:	Slightly sticky; not runny (glossy)

June 10	Do Not Use This	Use 2 Batches
Concrete Mix B	(6.0 cu.yds)	6.3 cu.yd. total
CaA1 Cement	2682 lbs = 28.5 sacks	15 sacks (1410 lb)
Stone 17010+2%	17350 "	9135 lb
Water (105) gal	-	22+5+3+1+1 gal 20+5+2+1+2+1+1
Consistency	Slightly sticky, not runny (Glossy)	

June 12	Do Not Use This	Use
Grout Mix C	(3 cu.yds.)	2.98 c.y.
CaA1 Cement	2940 lb = 31 1/4 sacks	2914 (31 sacks)
Sand 6360+4%	6614	6561
Water (201) gal	-	116+2+1+1*
Slump	2" Max	

*Molds 2,3 at 2" slump. Mold 1 @ 5" slump

Do not Use All the Water

Bring slumps to the conditions indicated

APPENDIX C
CONCRETE CONTROL

FIELD BATCH DATA

6-8-92 Grout Mix D	Northeast type II Cement	
	into one mold (#1)	
	batched	10:15
	arrive job	11:15
	completed	12:00
	water	100+20+5 gal.
6-8-92 Concrete Mix A	Northeast type II Cement	
83°F Mix	into two molds (#2,3)	
	batched	1:20
	arrive job	2:10
	completed	3:30
	water	40+10+5+2+1 gal
6-10-92 Concrete Mix B	Calcium Aluminate Cement	
	into two molds (#1,2)	
Total time cement in mixer 1:45 Hr.	batched	7:50
	arrive job	8:30
	cement @ site	8:40-8:45
	start deposit	9:00
	end deposit	10:00 & 10:30
	water	22+5+3+1+1 = 32 gal
Dumped when started to stiffen rapidly.		
6-10-92 Concrete Mix B	Calcium Aluminate Cement	
	into two molds (#2,3)	
Total time cement in mixer 1:10 Hr.	batched	11:15
	arrive job	11:55
	cement @ site	11:57 - 12:00
	start deposit	12:20
	end deposit	12:30 & 1:10
	water	20+5+2+1+2+1+1=32 gal
Dumped @ 1:15 when started to stiffen very rapidly. Truck was hot; stayed in sun between loads at plant		
6-12-92 Grout Mix C	Calcium Aluminate Cement	
	into three molds (#2,3,1)	
Total time cement in mixer 50 min.	batched	8:20
	arrive job	8:58
	cement @ site	9:00-9:10
	Deposit #2	9:10-9:20
	" #3	9:28-9:33
	" #1	9:35-9:40
	Water	116+2+1+1

Slumps #2-2"; #3-1 1/2"; #1-5" (too wet)

Trow Protze Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A

June 16, 1992

ALDEN RESEARCH LABORATORY, INC.
HOLDEN, MASSACHUSETTS

INSPECTION OF CONCRETE
TEST SAMPLES FOR NORTHEAST UTILITIES
MILLSTONE UNIT 3
WATERFORD, CT

REFERENCE NUMBER	92C-831	
DATE OF INSPECTION	June 8, 1992	
BATCH CONTROL	See Appended Log Sheet	
TEST SPECIMENS	Series No.	1A-H
	Class, psi	Mix A Mix D
	Load No.	2
	Slump, in	Zero
PLACEMENT OF	Concrete Mix A Northeast Type II cement in lower 10" area of boxes 2 and 3	

REMARKS The writer performed plant inspection of batching of concrete for the subject project. This work was done at the North Grafton Plant of the Emaral Concrete Company. The work consisted of the following:

Visually examined sand and coarse aggregate for cleanliness and gradation.
Sampled sand for laboratory analysis.
Determined moisture content of sand and Tilcon Connecticut crushed stone.
Verified cleanliness of truck mixer before grout was batched and before Mix A was batched.
Established Grout and Mix A batch weights.
Established batching sequence for Mix A (1/2 stone, cement, 1/2 stone).
Checked weigh boxes for cleanliness.
Checked scales for zero readings during empty weigh boxes.
Witnessed scales while each load was batched.
Recorded relevant data and wrote inspection tickets.
Followed load of grout to site for consistency control.
Followed load of Mix A to site for consistency control and fabrication of test specimens.

The work was satisfactorily carried out. The grout was mixed and placed at 2" slump in Box #1 (Mix D). It was brought to proper slump at the site by additions of 20+5 gallons of water to the load. Mix A concrete was placed into Boxes #2 and 3. 40 gallons of water was added at the plant and another 10 gallons were added at the site to provide a wet sticky mix that adhered to the stone thoroughly without any dripping. During filling of the lower 10" of forms B and C another 5+2+1 gallons were added as needed to keep the consistency uniform.

CONCRETE CONTROL FOR ALDEN RESEARCH LABORATORY LOG SHEET 1
HOLDEN, MASSACHUSETTS

LOCATION OF PLACEMENT: NorthEast Utilities Research Models, 1, 2, 3 — June 8, 1992

TYPICAL BATCH QUANTITIES

Vendor	Emaral	
Plant	North Grafton (Dauphinais)	
Mix No.	D	A
Class Concrete, psi	-	-
Time	10:15AM	1:20PM
Size Load, Cu.Yd.	3	4.5
Cement, lb	2980	2012
Fine Agg "	6678	-
Coarse Agg "	-	12107
Water Added, gal	100+25	40+18
Moisture in FA,%	5.0	-
Moisture in CA,%	-	2.0
W/C Ratio, gal/sack	5.0	3.5
Admixture	None	None

ANALYSIS OF AGGREGATES

Sieve	Millbury Sand	Sieve	Tilcon Stone
#4	0%	1 1/2"	
8	10	1	0%
16	31	3/4	28
30	53	1/2	73
50	76	3/8	94
100	92	#4	99
F.M.	2.62	F.M.	7.21
Organic	0+		0+

MISCELLANEOUS INFORMATION

Weather	Cloudy, 72-84°F
Cement Brand	Northeast type II
No. Loads Inspected	2
Inspection Ticket Nos.	HGP5904-5905
C.Y. Inspec. this date	7.5(1-3.0; 2-4.5)
C.Y. Inspec. to date	7.5
Plant Inspection Time	5 1/2 hour (9:00 - 1:30PM + travel)
Plant Inspector	E.S. Van Buren

REMARKS

Equipment satisfactory and clean
Scales checked during batching
Aggregates satisfactory
Special Items: Mixer washed with gravel and water after grout mix and at end of day.

HERMAN G. PROTZE, INC., NEWTON HIGHLANDS, MASS.

CONCRETE CONTROL

DATE 6-8-92

CLIENT [illegible]
PROJECT No.east Utilities

ARRIVE 9⁰⁸
DEPART

ASSIGNED START TIME 9⁰⁰
ACTUAL JOB RELEASE 3³⁰.

PLANT Emaral - No. East [illegible]
OPERATOR
INSPECTOR [illegible]
SCALE CHECK

WEATHER

CEMENT NoEast II
CAR NO Truck 6/5

ASSIGNMENT
- Grout Mix D - 3cy
Cover Mix A - 4.5 c.y
TF 04518

LOAD	TICKET	CY	TRUCK	TIME	CLASS	Ct	FA	CA	WATER PLANT+JOB	ADMIXES	TOTAL CY	REMARKS
1	5904	3	133	10:15	Grout	2980	6678	—	100+5	x	3.0	Sand 5%
2	5905	4.5	133	1:20	Mix A	2012	—	12107		x	4.5	

[illegible]

Stone 2%

TP 04518

1 A-H
2:40 PM
@ 86°F
83°F
Zero

6678
[illegible]
278
[illegible]
[illegible]

70 Jaconnet Street
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Trow Protze Consulting Engineers

Project No. TP-04518-A

June 16, 1992

ALDEN RESEARCH LABORATORY, INC.
HOLDEN, MASSACHUSETTS

INSPECTION OF CONCRETE
TEST SAMPLES FOR NORTHEAST UTILITIES
MILLSTONE UNIT 3
WATERFORD, CT

REFERENCE NUMBER	92C-832	
DATE OF INSPECTION	June 10, 1992	
BATCH CONTROL	See Appended Log Sheet	
TEST SPECIMENS	Series No.	2A-H
	Class, psi	Mix B
	Load No.	1
	Slump, in	Zero
PLACEMENT OF	Concrete Mix B Calcium Aluminate/Stone mix in boxes 1,2 and 3 to 2" below top surface.	

REMARKS The writer arrived at Emaral-Dauphinais, North Grafton plant and met with Mr. Stephen Charist. We discussed the intended mix for this day's placement. The writer then inspected the interior of the transit mixer drum and approved it for use. (Documents herewith). We then witnessed the batching of coarse aggregate and water, and followed the truck to the site where the Lumnite calcium-aluminate cement was introduced into the mixer.

Mr. Herman G. Protze, P.E., of our office, was present at the site and assisted in final water adjustments of the mix to produce the desired consistency for use. This consisted of a sticky mix of cement plus water adhering to the coarse aggregate.

Placement operations began with the discharge of the mix from the truck's chutes into five-gallon pails; then the mix was spread for half the total thickness, followed by tamping into place by booting. Then the forms were filled level to 2" below the top of each box, tamped into place by booting and screeded exactly level at 2" below the top surface of the form.

The writer obtained a representative sample from the middle of the first load of concrete and fabricated eight 6x12" test specimens following the normal method of rodding, etc., per ASTM.

As placement continued it became necessary several times to add a gallon or two or more of water to the mix. Before completion of the load we made a decision to discard the remaining mix and prepare a second load.

The writer then inspected the mixer drum for post-placement cleanliness prior to returning to the plant to witness the next batch.

At the plant after further cleaning of the mixers drum, we again inspected the drum for pre-batch cleanliness followed by the introduction of coarse aggregate and water.

The writer again returned to the site and assisted our Mr. Protze in thc inspection of the placement of this load.

At this time we made preparations to transport the eight test specimens, fabricated by us on June 8, 1992, to our laboratory for testing at various ages.

Upon completion of placement operations we assisted in attempts to clean the mixer drum. Inadequate quantities of water were immediately available at the site; therefore, final cleaning was to take place at the plant. The writer then followed the mixer truck back to the plant where approximately two cubic yards of 1 1/2" nominal size aggregate and much water were deposited into the mixer.

After continued clean-out procedures were employed the driver climbed into the mixer drum to discover that significant amounts of the mix had adhered to the drum face and the edge of the mixer blades. We then discussed this matter with Mr. George DeFalco, Jr. of Emaral and concluded that additional cleaning efforts were required. These would be carried out the following day, in preparation for the Lumnite grout mix intended for placement on June 12, 1992.

We then left the plant without signing off the post placement clean-out inspection slip.

CONCRETE CONTROL FOR ALDEN RESEARCH LABORATORY HOLDEN, MASSACHUSETTS

LOG SHEET 2

LOCATION OF PLACEMENT: NorthEast Utilities Research Models, 1, 2, 3

June 10, 1992

TYPICAL BATCH QUANTITIES

Vendor	Emaral
Plant	North Grafton (Dauphinais)
Mix No.	B
Class Concrete, psi	-
Time	7:50AM and 11:15AM
Size Load, Cu.Yd.	3.15
Cement, lb	1410 (15 sacks)
Fine Agg "	-
Coarse Agg "	9135
Water Added, gal	22+10
Moisture in FA,%	-
Moisture in CA,%	2.0
W/C Ratio, gal/sack	3.1
Admixture	None

MISCELLANEOUS INFORMATION

Weather	Fair, 72-84°F
Cement Brand	Lumnite, Calcium Aluminate
No. Loads Inspected	2
Inspection Ticket Nos.	HGP 2057-2058
C.Y. Inspec. this date	6.3
C.Y. Inspec. to date	13.8
Plant Inspection Time	10 hours (7:00 - 3:00PM + travel)
Plant Inspector	Steven Harvey

REMARKS

Equipment clean and suitable
Scales checked before and during batching
Aggregates satisfactory
Special Items: Mixer drum inspected for cleanliness prior to and after each use.
Cement batched @ site by the sack

June 10, 1992

CLIENT ALDEN RESEARCH LABORATORY
PROJECT HOLDEN, MASSACHUSETTS
ARRIVE 7:00 AM
DEPART 3:00 PM
ASSIGNED START TIME 7:00
ACTUAL JOB RELEASE 3:00
PLANT Emaral - Dauphinais N Grafton
OPERATOR Robert Lavallee / Joe Magliaro
WEATHER Fair, 72°F
ASSIGNMENT 6 yds Special mix
INSPECTOR Steven Harvey
CEMENT Luminite Lehigh- Calcium Aluminate
SCALE CHECK Before & During
CAR NO

.D	TICKET	CY	TRUCK	TIME	CLASS	Ct	FA	CA	WATER PLANT+JOB	ADMIXES	TOTAL CY	REMARKS
	02057	3	133	7:50 + 8:40	470	N/A	3045		22 + 10	None	3	Ct added @ site
	02058	3	133	11:15 + 11:55	"	"	"		20 + 12	"	6	" " "

Trow Protze Consulting Engineers

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Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A June 16, 1992

ALDEN RESEARCH LABORATORY, INC.
HOLDEN, MASSACHUSETTS

INSPECTION OF CONCRETE
TEST SAMPLES FOR NORTHEAST UTILITIES
MILLSTONE UNIT 3
WATERFORD, CT

REFERENCE NUMBER	92C-833
DATE OF INSPECTION	June 12, 1992
BATCH CONTROL	See Appended Log Sheet
TEST SPECIMENS	None made this date
PLACEMENT OF	Topping grout, Mix C to top-off boxes 1, 2 and 3.

REMARKS We reported to the Emaral-Dauphinais North Grafton plant and thoroughly inspected the interior of the mixer drum. Mr. Stephen Charist of Emaral and the writer both signed off the pre-batch inspection documents, separately herewith. The previous day Mr. Protze, of our office, and Mr. DeFalco of Emaral discussed measures to assist in the prevention of the mix adhering to the interior of the mixer drum. It was determined that the batching operation would take place at the Emaral-DeFalco, Millbury Street plant. This selection was due to the water temperatures being considerably lower at Millbury Street (52°F) than at Grafton. The writer followed the truck from North Grafton to Millbury Street where we then witnessed the weighing and metering of the desired quantities of Fine Aggregate and water and subsequent introduction into the mixer.

The writer then followed the truck to the site where again we witnessed the introduction of Lumnite-Calcium Aluminate cement, into the mixer. After mixing the constituents, we assisted our Mr. Protze in the inspection of placement of the mix. We also assisted your staff in placement and consolidation of the mix.

Upon completion of placement operations, the remainder of the load was dumped at the site. The writer returned to the North Grafton plant where the drum was cleaned in the same manner as previously described. We inspected the thoroughly cleaned mixer drum interior and then Mr. Charist and the writer signed off the post placement documents, see attached copies. The drum was thoroughly clean.

CONCRETE CONTROL FOR ALDEN RESEARCH LABORATORY
HOLDEN, MASSACHUSETTS

LOG SHEET 3

LOCATION OF PLACEMENT: NorthEast Utilities Research Models, 1, 2, 3

June 12, 1992

TYPICAL BATCH QUANTITIES

Vendor	Emaral
Plant	Millbury Street (DeFalco)
Mix No.	C
Class Concrete, psi	-
Time	8:20AM
Size Load, Cu.Yd.	2.98
Cement, lb	2914
Fine Agg "	6561
Coarse Agg "	-
Water Added, gal	116+4
Moisture in FA,%	5.0
Moisture in CA,%	-
W/C Ratio, gal/sack	5.7
Admixture	None

MISCELLANEOUS INFORMATION

Weather	Fair, 64-75^{o}F
Cement Brand	Lumnite Calcium Aluminate
No. Loads Inspected	1
Inspection Ticket Nos.	2059
C.Y. Inspec. this date	2.98
C.Y. Inspec. to date	16.8
Plant Inspection Time	6 1/2 hours (7:00 - 11:30AM + travel)
Plant Inspector	Steven Harvey

REMARKS

Equipment clean and well maintained
Scales checked before and during batching
Aggregates clean and well graded
Special Items: Cement batched @ site. Mixer drum clean before and after cleaning with gravel and water.

HERMAN G. PROTZE, INC., NEWTON HIGHLANDS, MASS.

CONCRETE CONTROL

DATE June 12, 1992

CLIENT ALDEN RESEARCH LABS

PROJECT HOLDEN, MASSACHUSETTS

ARRIVE 7:00/9:00

DEPART 10:35/11:30

ASSIGNED START TIME 7:00

ACTUAL JOB RELEASE 11:30

PLANT EMARAL - Millbury St.

OPERATOR Richard DiRenzo

INSPECTOR Steven Harvey

SCALE CHECK Before & During

WEATHER Fair, 64°F

CEMENT Lumnite Lehigh - Calcium Aluminate

CAR NO

ASSIGNMENT

2.98 yds Grout Mix "C"

LOAD	TICKET	CY	TRUCK	TIME	CLASS	Ct	FA	CA	WATER PLANT+JOB	ADMIXES	TOTAL CY	REMARKS
1	02059	2.98	133	8:20/9:05	-	979*	2201	N/A	116 + 3	None	2.98	Ct Batched @ site

APPENDIX D

CONCRETE TESTING LABORATORY INSPECTION REPORT

C

[illegible]

[illegible]

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, MD 20899

[illegible] CONCRETE REFERENCE [illegible]

NISTIR [illegible]

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, MD 20899

CEMENT AND CONCRETE REFERENCE LABORATORY
AT THE
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(301) 975-6704

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COMMITTEE C-9 ON CONCRETE AND
CONCRETE AGGREGATES
AMERICAN SOCIETY FOR TESTING AND MATERIALS

August 27, 1991

INTRODUCTION TO REPORT ON INSPECTION OF CONCRETE TESTING LABORATORY

This report covers an inspection, designated Inspection No. S-970, which was performed by a representative of the Cement and Concrete Reference Laboratory in the concrete testing laboratory of Trow-Protze, Consulting Engineers, at Newton Highlands, Massachusetts, on July 3, 1991.

The report has one, two or three parts, depending on the scope of the inspection. Part I covers the inspection of concrete testing facilities; Part II, when included, covers the inspection of aggregate testing facilities; and Part III, when included, covers the inspection of the testing facilities for concrete reinforcing bars.

Each part has three sections. The first section describes the scope of the inspection. The second section contains a summary of the findings. The third section contains a series of footnotes in which departures from specification requirements, mechanical deficiencies in apparatus, and other important matters are covered in detail. In addition, there is a closure.

Several pieces of apparatus in the laboratory have been assigned CCRL identification numbers. Some of these numbers are listed in the summary and footnote sections.

In the interest of brevity, any minor adjustments of apparatus which may have been made while the inspection was in progress have not been mentioned. When necessary, additional explanatory information about the inspection will be furnished in separate correspondence.

Information concerning the qualifications of supervisory personnel is included where appropriate.

Unless otherwise indicated, the specifications and methods of test to which references are made are standards of the American Society for Testing and Materials.

Copies of this report, or parts thereof, are not to be used for promotional purposes.

PART I: INSPECTION OF CONCRETE TESTING FACILITIES

DESCRIPTION OF INSPECTION

The inspection of concrete testing facilities was designed to include an examination of the apparatus prescribed for use in the methods of test for concrete indicated in Section 7.2 of ASTM C1077; a review of the laboratory's quality assurance system; an examination of the apparatus or procedures prescribed in any optional test methods presented for inspection; and an observation of several of the procedures used in the testing of concrete.

The ASTM Standards on which the work was based are as follows: C31-90, C39-86, C138-81, C143-90, C172-90, C173-78, C231-89, C470-87, C511-85, C617-87, C1077-90, E4-89, and E171-82.

Apparatus

Tamping Rods (C143)

The 5/8-inch diameter tamping rods which were immediately available for use in various rodding operations were checked for conformance to the design and dimensional requirements of C143.

Slump Cones (C143)

Each slump cone presented for inspection was checked for conformance to the design and dimensional requirements of C143, and the physical condition was observed.

Unit Weight Apparatus (C138)

The capacity of each scale or balance used in determining the unit weight of plastic concrete was recorded, and the accuracy checked for conformance to the requirements of Section 4.1 of C138. The design, dimensions, and physical condition of each unit weight measure presented for inspection was checked for conformance to the requirements of Section 4.4; a check was made to determine if the required flat strike-off plate was available; and inquiry was made as to whether the measure had been calibrated in accordance with Section 5.

Apparatus for Air Content of Plastic Concrete (Volumetric Method) (C173)

The design of each air meter used in determining the air content of concrete by the volumetric method was checked for conformance to the design requirements of C173, and observations were made to determine that the necessary funnel, strike-off bar, metal measuring cup, syringe, pouring vessel, tamping rod, trowel, and scoop were on hand.

Apparatus for Air Content of Plastic Concrete (Pressure Method) (C231)

The design of at least one of the air meters used in determining the air content of freshly mixed concrete by the pressure method was checked for conformance to the design requirements of C231, and observations were made to determine that the necessary trowel, syringe, tamping rod, mallet, strike-off bar, and pouring vessel were on hand.

Compression Test Apparatus (C39, C470 and C617)

Apparatus used in making compressive strength tests of concrete not covered elsewhere in this report includes the cylinder molds and vibrators used in fabricating specimens, the capping equipment and materials used to obtain smooth load bearing surfaces on specimens, and the compression machine in which specimens are tested.

Cylinder Molds. - Cylinder molds are classified according to intended use as reusable molds and single-use molds. Where reusable molds were employed, the design, dimensions, and watertightness of several molds considered to be typical of those used by the laboratc [illegible] were checked for conformance to the requirements of C470. Where single-use molds were employed, the design, dimensions, and water absorption characteristics of several molds considered to be typical of those used by the laboratory were checked for conformance to the specification.

Vibrators. - Each vibrator used in consolidating test specimens made from low-slump concrete was checked for conformance to the requirements for such devices set forth in Section 4.5 of C31.

Capping Equipment and Materials. - The apparatus and material used in capping concrete cylinders were checked for conformance to the requirements of C617, with particular attention being given to the dimensions, planeness, surface condition, and thickness of capping plates; and to the preparation and use of the capping material. In addition, the planeness of the caps on several specimens was checked.

Compression Machine. - Unless otherwise noted, only one testing machine was inspected. During this inspection, several of the more important mechanical and design features were noted; the design, dimensions, and surface planeness of bearing blocks used in testing concrete cylinders were checked for conformance to the requirements of C39; and the accuracy of load indication was verified.

The verification tests were made using force measuring instruments calibrated at the National Institute of Standards and Technology. In these tests, each load indicator was set at the zero position customarily employed by the laboratory. Test loads were approached by increasing the load from a lower load as specified in Method E4; the force-measuring instrument and the machine were individually operated as is considered to be good practice; and all load readings were corrected for differences between the test temperature and the temperature at which the instrument was calibrated.

Facilities for Curing Test Specimens (C31 and C511)

An investigation was made to determine if storage facilities for curing of concrete test specimens were available. Each tank or moist room used for curing compression specimens were then checked for conformance to the requirements of C511.

During the examination, temperature and relative humidity readings were taken as appropriate to determine if the curing environment conformed to the requirements of applicable standards; an observation was made to determine if all specimens in storage had free water on the entire surface area; and a check was made to determine if each unit was equipped with thermostatic temperature control and with a recording thermometer as required by C511. In addition, it was asked if the water in each tank was saturated with lime, and the state of cleanliness of the water and the condition of the interior surfaces of the tank were noted.

Miscellaneous

The temperature of the air in the laboratory was checked for conformance with the range (20° to 30°C) set forth in E171.

The containers and packing materials which the laboratory prescribes for use in transporting cylinders were inspected for obvious deficiencies.

A check was made to determine if the laboratory had been supplied with a copy of the latest edition of the ASTM Book of Standards pertaining to the testing of concrete.

Optional Methods

At the discretion of the laboratory, selected optional test methods as set forth in Section 7.3.1 of C1077 may be presented for inspection. If presented, the inspection of these test methods for concrete may consist of an examination of prescribed equipment, specified procedures, or both, as the individual test method should warrant.

The apparatus examined and the procedures observed for any optional test method presented by the laboratory were checked for compliance with the referenced specification.

Quality Assurance System

Written records maintained by the laboratory and reviewed for compliance with C1077 included the following: an inventory of equipment and its required calibrations; personnel training and performance evaluations, including relevant certifications; general laboratory practice for fabrication, transfer and testing of concrete specimens; and test reports conforming to the requirements of Section 9.4. It was also ascertained whether the laboratory was under the technical direction of a registered engineer.

Procedures

The concrete testing procedures which were observed and discussed during the inspection were as follows: Sampling Freshly Mixed Concrete, Slump of Concrete, Unit Weight Test, Air Content Test (Volumetric Method), Air Content Test (Pressure Method), and Determination of the Compressive Strength of Molded Concrete Cylinders. The review of the strength test covered fabrication of cylinders, capping, storage after capping, measurement before testing, and testing. The laboratory's conformance to specified procedures was as indicated in the summary of findings.

All departures noted were reviewed in detail with laboratory personnel with particular attention being given to those matters described in the footnote section.

Inspection No. S-970
Concrete - 5

SUMMARY OF FINDINGS

Inspection Item	Apparatus	*Status
1.	Tamping Rod(s)	See footnote (a)
2.	Slump Cone(s)	Satisfactory
3.	Unit Weight Apparatus	
a.	Scale or Balance	Satisfactory
b.	Unit Weight Measure(s)	See footnote (b)
c.	Accessory Apparatus	Satisfactory
4.	Air Content Apparatus (Volumetric)	
a.	Air Meter(s)	Satisfactory
b.	Accessory Apparatus	Satisfactory
5.	Air Content Apparatus (Pressure)	
a.	Air Meter(s)	Satisfactory
b.	Accessory Apparatus	See footnote (c)
6.	Compression Test Apparatus	
a.	Cylinder Molds:	
	(1) Reusable Molds	- - - - - - - - -
	(2) Single-use Molds	Satisfactory
b.	Vibrator(s)	Satisfactory
c.	Capping Equipment and Materials:	
	(1) Capping Equipment	See footnote (d)
	(2) Capping Material	Satisfactory
	(3) Planeness of Caps	Satisfactory
d.	Compression Testing Machine:	
	(1) Maker: Baldwin	
	(2) Serial No.: 482195 (3) Capacity: 300,000 lbf	
	(4) Accuracy of Indication:	
	(a) Range: 300,000 lbf From: 50,000 to 200,000 lbf	Satisfactory
	(b) Range: 50,000 lbf From: 6,000 to 45,000 lbf	Satisfactory
	(c) Range: ____ From: ____ to ____	- - - - - - - - -
	(d) Range: ____ From: ____ to ____	- - - - - - - - -
	(e) Range: ____ From: ____ to ____	- - - - - - - - -
	(f) Range: ____ From: ____ to ____	- - - - - - - - -
	(5) Mechanical Condition	See footnote (e)
	(6) Design	Satisfactory
	(7) Bearing Blocks for Cylinders	Satisfactory
e.	Additional Compression Machines	None

*Entry covers availability, physical condition, and/or conformance to specification requirements. Where reference is made to a footnote in which one or more deficiencies are described, it may be concluded that the item or items in question were judged to be satisfactory in all respects other than as described in the footnote.

1/91

Inspection Item	*Status
7. Curing Facilities	
a. Moist Air Storage Facilities........................	See footnote (f)
b. Water Storage Facilities............................	- - - - - - - - -
8. Miscellaneous	
a. Temperature of Air in Laboratory....................	Satisfactory
b. Specimen Shipping Containers........................	Satisfactory
c. Additional Observations of Interest to Laboratory.....	None
d. Qualifications of Supervisory Personnel..............	See attachment
9. Optional Methods....................................	None
10. Quality System	
a. Organization..	See footnote (g)
b. Human Resources.....................................	See footnote (g)
c. Operations..	See footnote (g)
d. Quality Assurance...................................	See footnote (g)
e. Equipment...	See footnote (g)

Procedures

Test	Method Reference	Technique in Exact Agreement With Standard Practice
Sampling Freshly Mixed Concrete.......	C172-90	See footnote (h)
Slump of Concrete....................	C143-90	Yes
Unit Weight of Concrete..............	C138-81	Yes
Air Content (Volumetric Method).......	C173-78	Yes
Air Content (Pressure Method).........	C231-89	See footnote (i)
Compression Test:		
a. Fabrication of Cylinders..........	C31-90	Yes
b. Capping of Cylinders..............	C617-87	Yes
c. Storage After Capping.............	C617-87	Yes
d. Measurement Before Testing........	C39-86, C617-87.....	See footnote (j)
e. Testing of Cylinders..............	C39-86	Yes

FOOTNOTE SECTION

Tamping Rods:

(a) The small tamping rods examined were not 3/8 inch in diameter as required. These rods were subsequently replaced during the inspection.

Unit Weight Apparatus (C138-81):

(b) The top rim of the one-third cubic foot unit weight measure was not plane to 0.01 inch as required. This measure was replaced with an apparatus that conformed to the requirements of C138.

Air Content Apparatus (Pressure Method) (C231-89):

(c) The calibration vessel used with the Type A apparatus, which was designed to be placed in the meter during calibration, was found not to comply with the requirement that its inside depth be 1/2 inch less than that of the bowl.

Capping Equipment and Materials (C617-87):

(d) Four capping plates, designed for use in capping 4 x 8 inch cylinders, were checked and all were found not to conform to the requirement of C617 that the alignment device be located so that no cap will be off-centered on a test specimen by more than 1/16 inch.

Compression Testing Machine (C39-86 and E4-89):

(e) The maximum hands with which the 300,000-lbf and 50,000-lbf dials were equipped were checked and found not to be in satisfactory operating condition. It was recommended that the necessary repairs be made.

Facilities for Curing Test Specimens (C511-85):

(f) It was noted that several of the specimens in storage were not in a surface moist condition as required by C511, and it was recommended that several of the spray nozzles be redirected in an effort to correct this deficiency.

Quality System (C1077-90):

(g) No documentation or records pertaining to the quality system of the laboratory, as set forth in ASTM Standard Practice C1077, were presented for inspection.

Procedures:

(h) Sampling Freshly Mixed Concrete (C172-90): The concrete was sampled at only one interval, rather than at two or more intervals from the middle portion of the discharge batch as specified.

(i) Air Content Test (Pressure Method) (C231-89): It was understood that an aggregate correction factor had not been determined for the aggregates and that no aggregate correction factor was used in determining the air content of the concrete.

(j) Measurement before Testing (C39-86 and C617-87): It was understood that the laboratory did not check the planeness of caps at intervals that would include the minimum prescribed in C617.

PART II INSPECTION OF AGGREGATE TESTING FACILITIES

DESCRIPTION OF INSPECTION

The inspection was designed to include an examination of the apparatus prescribed for use in the methods of test for concrete aggregates listed in ASTM C1077; a review of the apparatus or procedures prescribed in any optional test methods presented for inspection; and an observation of several of the procedures used in the testing of concrete aggregates.

The ASTM Standards on which the work was based are as follows: C33-90, C40-84, C117-87, C127-88, C128-88, C136-84, C566-89, C702-87, C1077-90, D75-87, E11-87 and E171-87.

Apparatus

Drying Apparatus

The physical condition of the apparatus used in drying samples of aggregates for testing purposes was observed, and a check made to determine if the operating temperature was being maintained at less than 115°C.

Sample Splitters (C702)

The apparatus available for use in reducing field samples of aggregates to testing size was checked for conformance to the design requirements of C702, and its physical condition was observed. Note was taken as to whether the laboratory had at least one riffle sampler with no less than twelve chutes 1/2 inch in width for use with fine aggregate, and one riffle sampler with no less than 8 chutes of the appropriate chute width for use with coarse aggregate.

Sieves (E11)

The physical condition of each sieve presented for inspection was noted, and a check made to determine if the size of opening was marked on the side as required by E11.

With the exception of such omissions as may be set forth in the footnote section, the group of sieves presented for inspection contained one or more of each of the sieves with nominal openings ranging from 52 to .150 mm listed by size or number in C33, and one or more of each of the sieves listed by size or number in the various methods of test to which reference is made in this report. The particular sizes and numbers are: 2 in., 1 1/2 in., 1 in., 3/4 in., 1/2 in., 3/8 in., No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, and No. 200.

Mechanical Sieving Apparatus

The physical condition of each mechanical sieving device presented for inspection was noted.

Balances

The requirements for balances to which reference is made during the inspection were derived from a number of sources.

A sensitivity requirement of 0.01 g is believed to be applicable to balances with capacities of less than 1000 g (Reference: Method D854). A basic maintenance tolerance (0.1 percent of the test load) considered to be appropriate for equal-arm balances used in the testing of aggregates (Reference: Method C136) is given in Paragraph T.3.2 of the Scales Section of the 1986 Edition of NIST Handbook 44. Tolerances believed to be applicable to the accuracy of indication of the direct-reading dials with which some small balances are equipped are given in Paragraph T.3 of the Weights Section of Handbook 44.

Sensitivity requirements for balances with capacities of 1000 g or more are found in Methods C127 and C128. The basic maintenance tolerance to which reference is made above is applicable. A tolerance of ± 0.2% for the accuracy of indication of beams or dials on balances which are so equipped is suggested by information given in Paragraph T.3.1. of the Scales Section of Handbook 44.

Each balance with a rated capacity of less than 1000 g presented for inspection was tested for conformance to the selected sensitivity requirement at zero load. When of the two-pan, equal-arm type, it was subsequently tested for conformance to the selected accuracy requirement at its maximum capacity. When of the single-pan type, the accuracy of indication of the direct-reading indicating system was subsequently tested for conformance to the selected tolerances at 50, 100, 200, 500 and 700 g as appropriate for the capacity of the system.

Each balance with a capacity of 1000 g or more presented for inspection was tested for conformance to the selected sensitivity requirements at 500, 1000, and 2000 g, as appropriate for the capacity. When of the two-pan, equal-arm type, it was subsequently tested for conformance to the selected accuracy requirement at the said three test points, and the dial or beams, if any, were tested separately for accuracy of indication at five points over their respective capacities. When of the single-pan type, the accuracy of indication of the direct-reading indicating system was subsequently tested for conformance to the selected tolerance at five points over the capacity of the system, or to 10,000 g, whichever was the lesser.

Testing Weights

All metric weights presented for inspection were checked for conformance to the maintenance tolerances for metric weights specified in Paragraph T.3 of the Weights Section of the 1986 Edition of NIST Handbook 44. When the weights in a set were within the specified limits and were suitably stored, each storage container was assigned a CCRL identification number.

Organic Impurities Apparatus (C40)

The glass bottles, the reagent, and the color standards used in testing for organic impurities in sands were checked for conformance to the requirements of C40.

Apparatus for Specific Gravity and Absorption of Fine Aggregate (C128)

Observations were made to determine if one or more pieces of each item of equipment (pycnometer, conical mold, and tamping rod) needed to determine the specific gravity and absorption of fine aggregates in accordance with the requirements of C128 were available for use and in good physical condition.

Apparatus for Specific Gravity and Absorption of Coarse Aggregate (C127)

Each basket used for holding samples of coarse aggregate during the specific gravity determination was checked for conformance to the requirements of C127, each suspending apparatus was examined, the capacity of each balance being used in conjunction with the foregoing items was noted, and a check was made on the temperature of the immersion water.

Sample Containers for C117 and C566

The size, physical condition, and shape of the pans used in the test for determining fine materials in aggregate (C117), and in the test for determining the total moisture content by drying (C566) were observed.

Miscellaneous

The temperature of the air in the laboratory was measured at random for comparison with the range for room temperatures (20° to $30^{\circ}C$) set forth in E171.

The containers used for transporting samples of aggregate to the laboratory were checked for cleanliness and to determine if they were so made that there would be no loss of fines during shipment.

A check was made to determine if the laboratory had been supplied with a copy of the latest edition of the ASTM Book of Standards pertaining to the testing of concrete aggregates.

Optional Methods

At the discretion of the laboratory, selected optional test methods as set forth in Section 7.3.1.2 of C1077 may be presented for inspection. If presented, the inspection of these test methods for concrete aggregates may consist of an examination of prescribed equipment, specified procedures, or both, as the individual test method should warrant.

The apparatus examined and the procedures observed for any optional test method presented by the laboratory were checked for compliance with the referenced specification.

Procedures

The concrete aggregate procedures which were observed and discussed during the inspection were as follows: Minus No. 200 Wet Sieving, Organic Impurities Test, Sieve Analysis of Aggregates, Specific Gravity and Absorption of Fine and Coarse Aggregate, Moisture Content by Drying, and Reducing Field Samples to Testing Size.

The laboratory's conformance to specified procedures was as indicated in the summary of findings. All departures noted were reviewed in detail with laboratory personnel with particular attention being given to those matters described in the footnote section.

SUMMARY OF FINDINGS

Inspection Item	*Status
1. Drying Apparatus	
a. Oven(s):	
(1) Maker: Quincy ID No. 15744B	Satisfactory
(2) Maker: Laboratory design ID No. - - - -	Satisfactory
(3) Maker: ______ ID No. ______	- - - - - - - - -
b. Hot Plate(s): Number Inspected: 0	- - - - - - - - -
2. Sample Splitter(s)	
a. For Coarse Aggregates:................................	See footnote (a)
b. For Fine Aggregates:................................	See footnote (a)
3. Sieves	
a. Number Inspected: 27	Satisfactory
b. Missing Sizes or Numbers:..............................	None
4. Mechanical Sieving Apparatus	
(1) Maker: Gilson ID No. 11306	Satisfactory
(2) Maker: Tyler ID No. 3227	Satisfactory
(3) Maker: ______ ID No. ______	- - - - - - - - -
5. Balances	
(1) Maker: Mettler Capacity: 2400 g CCRL No.: S-4811	Satisfactory
(2) Maker: Mettler Capacity: 12 kg CCRL No.: S-4812	Satisfactory
(3) Maker: Mettler Capacity: 12 kg CCRL No.: S-4813	Satisfactory
(4) Maker: ______ Capacity: ______ CCRL No.: ______	- - - - - - - - -
6. Testing Weights	
(1) CCRL No.: S-4810 No. Weights Checked 13	Satisfactory
(2) CCRL No.: ______ No. Weights Checked ______	- - - - - - - - -
(3) CCRL No.: ______ No. Weights Checked ______	- - - - - - - - -

*Entry covers availability, physical condition, and/or conformance to specification requirements. Where reference is made to a footnote in which one or more deficiencies are described, it may be concluded that the item or items in question were judged to be satisfactory in all respects other than as described in the footnote.

Inspection Item	*Status
7. Organic Impurities Apparatus	Satisfactory
8. Specific Gravity and Absorption Apparatus (F.A.) ...	Satisfactory
9. Specific Gravity and Absorption Apparatus (C.A.) ...	Satisfactory
10. Sample Containers	
a. For Minus No. 200 Sieve Test - C117	Satisfactory
b. For Test for Total Moisture Content by Drying - C566	Satisfactory
11. Miscellaneous	
a. Temperature of Air in Laboratory	Satisfactory
b. Sample Shipping Containers	Satisfactory
c. ASTM Standards	Satisfactory
d. Additional Observations of Interest to Laboratory ..	See footnote (b)
12. Optional Methods..................................	None

Procedures

Test	Method Reference	Technique Agrees with Standard Practice
Minus No. 200 Wet Sieving	C117-87............	Yes
Organic Impurities Test...............	C40-84.............	Yes
Sieve Analysis of Aggregates..........	C136-84............	Yes
Specific Gravity and Absorption:		
a. Fine Aggregate..................	C128-88............	Yes
b. Coarse Aggregate................	C127-88............	Yes
Moisture Content by Drying............	C566-89............	Yes
Reducing Field Samples................	C702-87............	Yes

FOOTNOTE SECTION

Sample Splitters (C702-87):

(a) It was understood that the laboratory used the quartering method for reducing field samples of aggregate to testing size.

Miscellaneous:

(b) No equipment for the testing of steel reinforcing bars was presented for inspection; therefore, with reference to paragraph two of the Introduction, this report has only two parts.

ADDENDUM

The Cement and Concrete Reference Laboratory has been in existence since 1929. In April of that year, a Research Associate Program, known as the Cement Reference Laboratory, was established at the National Institute of Standards and Technology (formerly the National Bureau of Standards) under the sponsorship of Committee C-1 on Cement of the American Society for Testing Materials. The principal responsibility of the CRL was to promote uniformity in the testing of hydraulic cements through the inspection of laboratories.

In 1948, the first steps were taken in a gradual expansion of the field work to include some of the more important procedures used in the testing of concrete. On March 1, 1958, the resulting new inspection service was made available to any interested concrete testing laboratory within the prescribed areas of operation, and shortly thereafter Committee C-1 invited Committee C-9 to become a joint sponsor. The invitation was accepted and on July 1, 1960, the name "Cement and Concrete Reference Laboratory" was adopted in recognition of the new arrangement.

At the time of the redesignation, a joint C-1, C-9 Subcommittee on the Cement and Concrete Reference Laboratory, consisting of seven representatives of each of the parent committees, was created to work with the National Institute of Standards and Technology in administering the CCRL program. The new administrative plan perpetuated the earlier arrangements whereby selected representatives of the Federal Agencies, materials producers, construction and design firms, and national associations, who furnish either financial or technical assistance, participate in the direction of the activity through membership on the supervising ASTM Subcommittee.

As of January 1, 1991, organizations who were furnishing financial or technical support were as follows:

Federal:
Federal Highway Administration
National Institute of Standards and Technology
U.S. Army Corps of Engineers

Non-Federal:
American Concrete Institute
ASTM
National Ready Mixed Concrete Assn.
National Aggregates Association
Portland Cement Association
W. R. Grace and Company

CLOSURE

This inspection was performed by the writer. While the work was in progress, many of the details covered by this report were discussed with laboratory personnel. At the conclusion of the inspection the special work sheets, on which all observations were recorded, were made available for review by members of the laboratory staff, and all of the entries thereon were discussed in detail.

Testing equipment that was used during the inspection to make temperature determinations, to determine compliance of selected apparatus to specified weights, and to verify the accuracy of indication of compression testing machines is identified as follows:

Thermometers	:	CCRL Nos. S33, S32, C164, C189 and C169
Test Weights	:	NIST Nos. 172810 and 163683
Proving Rings	:	Serial Nos. 585, 4893 and 3374B

It is recommended that this report be compared with the report of the preceding inspection which was made in March 1989.

This report is not to be used for advertising, publication, or promotional purposes.

CEMENT AND CONCRETE REFERENCE LABORATORY

Paul C. Burns

Paul C. Burns
Inspector

Report Approved By:
Raymond M. Kolss

SUMMATION OF QUALIFICATIONS OF MANAGERIAL AND SUPERVISORY PERSONNEL
(Reference: Section 6, ASTM Specification C1077)

Name of laboratory: Trow-Protze, Consulting Engineers

Location : 70 Jaconnet Street, Newton Highlands, MA 02161

Director of Inspection and Testing Services

Name and title : Herman G. Protze, P.E.
Mailing address: 24 Greystone Road
Dover, MA 02030

Full time employee of laboratory?.. yes
Registered engineer?.. yes
Number of years experience in inspection and testing of construction materials.. 53

Supervising Laboratory Technician

Name and title : Edgar S. Van Buren
Mailing address: 23 Hadley Road
Framingham, MA 01701

Number of years of experience performing tests on construction materials?... 34

Supervising Field Technician

Name and title : Edgar S. Van Buren
Mailing address: 23 Hadley Road
Framingham, MA 01701

Number of years of inspection experience in kind of work involved on construction projects?.................................... 45

Foregoing entries certified to be correct.

Signature: Herman G. Protze
Title : Executive Engineer

Date July 3, 1991

SUMMATION OF QUALIFICATIONS OF MANAGERIAL AND SUPERVISORY PERSONNEL
(Reference: Section 6, ASTM Specification C1077)

Name of laboratory: Trow-Protze, Consulting Engineers

Location : 70 Jaconnet Street, Newton Highlands, MA 02161

Director of Inspection and Testing Services

Name and title : Herman G. Protze, P.E.
Mailing address: 24 Greystone Road
Dover, MA 02030

Full time employee of laboratory?.................................. yes
Registered engineer?.................................. yes
Number of years experience in inspection and testing of
construction materials.................................. 53

Supervising Laboratory Technician

Name and title : Edgar S. Van Buren
Mailing address: 23 Hadley Road
Framingham, MA 01701

Number of years of experience performing tests
on construction materials?.................................. 34

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Name and title : Edgar S. Van Buren
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Framingham, MA 01701

Number of years of inspection experience in kind of work
involved on construction projects?.................................. 45

Foregoing entries certified to be correct.

Signature: Herman G. Protze
Title : Executive Engineer

Date July 3, 1991

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The Cement and Concrete Reference Laboratory has been in existence since 1929. In April of that year, a Research Associate Program, known as the Cement Reference Laboratory, was established at the National Institute of Standards and Technology (formerly the National Bureau of Standards) under the sponsorship of Committee C-1 on Cement of the American Society for Testing Materials. The principal responsibility of the CRL was to promote uniformity in the testing of hydraulic cements through the inspection of laboratories.

In 1948, the first steps were taken in a gradual expansion of the field work to include some of the more important procedures used in the testing of concrete. On March 1, 1958, the resulting new inspection service was made available to any interested concrete testing laboratory within the prescribed areas of operation, and shortly thereafter Committee C-1 invited Committee C-9 to become a joint sponsor. The invitation was accepted and on July 1, 1960, the name "Cement and Concrete Reference Laboratory" was adopted in recognition of the new arrangement.

At the time of the redesignation, a joint C-1, C-9 Subcommittee on the Cement and Concrete Reference Laboratory, consisting of seven representatives of each of the parent committees, was created to work with the National Institute of Standards and Technology in administering the CCRL program. The new administrative plan perpetuated the earlier arrangements whereby selected representatives of the Federal Agencies, materials producers, construction and design firms, and national associations, who furnish either financial or technical assistance, participate in the direction of the activity through membership on the supervising ASTM Subcommittee.

As of January 1, 1991, organizations who were furnishing financial or technical support were as follows:

Federal:
Federal Highway Administration
National Institute of Standards and Technology
U.S. Army Corps of Engineers

Non-Federal:
American Concrete Institute
ASTM
National Ready Mixed Concrete Assn.
National Aggregates Association
Portland Cement Association
W. R. Grace and Company

APPENDIX E
VOID RATIO TESTS

VOID RATIO TESTS

Laboratory Voids within compacted coarse aggregate * 46,46,46%; aver 46% = Va

Laboratory Voids within rodded Mix B concrete * 33,33,32%; aver 32.7% = Vc

46.0 - 32.7 equals 13.3% less voids

Mix B for one cylinder:

Aluminous Cement	1363 grams equiv. to 447 lb
Tilcon Aggregate	8647 " " " 2835 "
Water	442 " " " 17.5 gal

1363 gm cement in cylinder batch

$$\frac{1363}{3.14 \times 62.5 \times 453} = 0.0153 \text{ cu.ft. of cement}$$

$$\frac{442}{453 \times 62.5} = \underline{0.0156 \text{ cu.ft. of water}}$$

Total 0.0309 cu.ft. of cement paste

Volume of cylinder mold equals 0.1963 cu.ft.

13.3% of 0.1963 = 0.0261 cu.ft.

0.0261 is 85% of 0.0309

This is a reasonable check for this size test specimen.

Also the yield of cement + water to produce cement paste is not quite equal to the sum of the two individual volumes.

NOTE: Field cylinders Reference Number 92L-439AB
Exhibit Vc void ratios of 30% and 30%.

Here Va-Vc = 46.0 - 30.0 equals 16% less voids
Then translating (as above) 16.0% of 0.1963 = 0.0314 cu.ft. voids
Thus voids 0.0314 are 1.6% greater than 0.0309 cu.ft. of cement paste

Hence, it appears that average voids Vc in the stone and aluminous cement + water mixture varies somewhat dependent upon gradation and compaction of the mixture in the cylinder and at times does approach the original volume of the plain aggregate voids minus the volume of the cement paste.

*As determined by filling voids with water.

APPENDIX F
TEST OF CONCRETE SPECIMENS

RECEIVED NU/Concrete GEH JL DKW

JUL 16 1992

Trow Protze ARL Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A

July 6, 1992

TEST OF LABORATORY SPECIMENS

CLIENT ALDEN RESEARCH LABORATORY, INC., HOLDEN, MASSACHUSETTS
PROJECT FABRICATION OF POROUS CONCRETE MOCK-UP SLABS FOR NORTHEAST UTILITIES SERVICE COMPANY, WATERFORD, CT

Reference Number	92L-394ABC		
Date Made	6-4-92 by us		
Source	Laboratory Trial Mixture		
Class Concrete	Mix B		
Water Cement Radio	3.3 gals/sack (0.30)		
Cubic Yards	1.0		
Cement	447 lbs Lumnite (calcium aluminate)		
Coarse Aggregate	2835 lbs. Tilcon 3/4" Crushed stone		
Water	16.0 gals. total (excluding absorption)		
Admixture	None		
Air Temperature	75°F, 65%RH		
Concrete Temperature	73°F		
Slump	Zero		
Workability	None		
Appearance	Satisfactory, glistening, sticky		
Storage	Laboratory fog room		
Date of Test	7-2-92		
Age of Test	28 days		
Specimen Number	1A	1B	1C
Dimensions	6x12"	6x12"	6x12"
Density lbs/cu.ft.	117	117	119
Voids	33%	33%	32%
Compressive Strength	1350	1390	1190
Remarks	Strength low but acceptable		

Respectfully Submitted,
TROW PROTZE
Herman G. Protze
Herman G. Protze, P.E.

2-Alden

NOTED JUL 16 G.E.L.

Trow Protze Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A

June 17, 1992
June 24, 1992
July 15, 1992

TEST OF CONCRETE SPECIMENS

CLIENT ALDEN RESEARCH LABORATORY, INC., HOLDEN, MASSACHUSETTS
PROJECT FABRICATION OF POROUS CONCRETE MOCK-UP SLABS FOR NORTHEAST UTILITIES SERVICE COMPANY, WATERFORD, CT

Reference Number	92L-439ABCDEF
Date Received	6-12-92
Date Sampled	6-10-92 by us
Location Used	Box 1 and upper layer in Box 2
Truck Number	DeFalco 133
Load Number	1-inspected by us
Ticket Number	HGP 2057/Emaral 48834
Class Concrete	Mix B
Cubic Yards	3.15
Cement	1410 lbs. (15 sacks) Calcium Aluminate Lumnite
Fine Aggregate	None
Coarse Aggregate	9135 lbs. Tilcon, Conn. 3/4" Crushed stone
Water	3.3 gallons/sack
Admixture	None
Time Sampled	9:20AM
Weather	Fair, 72°F
Mix Temperature	75°F
Slump	Zero
Entrainted Air	Voids 30% and 30% respectively
Appearance	Satisfactory, glistening, sticky
Storage	With models, then laboratory fog room

Date of Test	6-17-92		6-24-92		7-8-92	
Age of Test	7 days		14 days		28 days	
Specimen Number	2A	2B	2C	2D	2E	2F
Dimensions	6x12"	6x12"	6x12"	6x12"	6x12	6x12
Density lbs/cu.ft.	116	115	116	116	116	118
Compressive Strength	980psi	990psi	980	1090	1070	1050
Remarks	Strength low; no gain with time					

Respectfully Submitted,
TROW PROTZE
Herman G. Protze

2-Alden

Trow Protze Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A

June 16, 1992
June 24, 1992
July 14, 1992

TEST OF CONCRETE SPECIMENS

CLIENT ALDEN RESEARCH LABORATORY, INC., HOLDEN, MASSACHUSETTS
PROJECT FABRICATION OF POROUS CONCRETE MOCK-UP SLABS FOR NORTHEAST UTILITIES SERVICE COMPANY, WATERFORD CT

Reference Number	92L-438ABCDEF
Date Received	6-10-92
Date Sampled	6-8-92 by us
Location Used	Bottom layer in Molds #2&3
Truck Number	DeFalco 133
Load Number	2-inspected by us
Ticket Number	HGP 5905
Class Concrete	Mix A
Cubic Yards	4.5
Cement	2012 lbs. Northeast Type II
Fine Aggregate	None
Coarse Aggregate	12107 lbs. Tilcon, Conn. 3/4" Crushed stone
Water	3.5 gallons/sack
Admixture	None
Time Sampled	2:40PM
Weather	Cloudy, 86°F
Mix Temperature	83°F
Slump	Zero
Entrainted Air	Voids 35% and 34% respectively
Appearance	Satisfactory for the project
Storage	With models, then laboratory fog room

Date of Test	6-15-92		6-22-92		7-6-92	
Age of Test	7 days		14 days		28 days	
Specimen Number	1A	1B	1C	1D	1E	1F
Dimensions	6x12"	6x12"	6x12"	6x12"	6x12"	6x12"
Density lbs/cu.ft.	108	110	108	111	111	112
Compressive Strength	440psi	500psi	440psi	520psi	560psi	570psi
Remarks	Strength poor; little gain with age					

Respectfully Submitted,
TROW PROTZE

Herman G. Protze

2-Alden

APPENDIX G
CEMENT RESIDUE ANALYSIS

NU/Concrete Gen, UL, DKW

RECEIVED

OCT 26 1992

ARL, INC.

Trow Protze Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A **October 21, 1992**

Alden Research Laboratory, Inc.
30 Shrewsbury Street
Holden, MA 01520

Cement Washout Analyses
Northeast Utilities Service Company
Millstone Unit #3
Waterford, Connecticut

Attn: Mr. Dean White, Project Engineer

Gentlemen:

We enclose herewith the analyses of the two samples of cement residue received by us in September.

It appears that 30% or less of the SiO_2 derives from the calcium aluminate cement, and the remainder from the type II. It appears that 10% or less of the Al_2O_3 derives from the type II cement and the remainder from the calcium aluminate. It appears that 50% or less of the Fe_2O_3 derives from the type II cement and the remainder from the calcium aluminate cement. The analyses of the virgin cements were approximately as follows:

	Type II	Calalum
SiO_2	20.0% min	6.1%
Al_2O_3	6.0 max	53.0
Fe_2O_3	6.0 ,max	5.3

The variations of the constitutional solubility is a function of time and relative solubility of each theoretical compound.

Yours very truly,

TROW PROTZE
Herman G. Protze
Herman G. Protze, P.E.

Ref. No. 92C-337A,B
1-White

Samples	--	Two samples of cement residue identified as: - A, 92C-337A, 30-day cure, 2 layer mold, Pipes A and B, Material in pipe per section 12.1.1 - B, 92C-337B, 7-day cure, 2 layer mold, Pipes A and B, Material in pipe per section 12.1.1
Test Procedure	--	ASTM: C 114 on sub #80 portions
Results	--	The following data have been obtained:

Sample Mark	A	B
SiO_2, %	14.9	11.2
Al_2O_3, %	40.8	44.2
Fe_2O_3, %	5.4	4.4

APPENDIX H
CEMENT WASHOUT ANALYSIS

RECEIVED NU/Concrete GKH, JL, DKW

AUG 14 1992

Trow Protze Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A August 12, 1992

Alden Research Laboratory, Inc.
30 Shrewsbury Street
Holden, MA 01520

Attn: Mr. Dean White, Project Engineer

Tests for Presence of Cement Washout
Northeast Utilities Service Company
Millstone Unit 3
Waterford, Connecticut

Gentlemen:

The tests of the six residue cement samples submitted by you on July 21 have been completed in accordance with Section 12.0 of the project specifications (Procedure for Mock-up Tests). The samples were identified as follows:

A	First 8 hour test,	Residue	1 Layer Mold
B	Fourth " "	"	1 " "
C	First " "	Hole A	2 " "
D	Fourth " "	Residue	2 " "
E	Test 1, Holes A&B	2 layer mold	Filter #30
F	Test 4, " "	2 " "	

The samples were first tested for moisture content with the following results:

A	B	C	D	E	F
1.2%	3.4%	2.7%	1.5%	5.5%	3.5%

The samples were then analyzed chemically in conformity with standard methods of analysis per ASTM-C-114. The following results were obtained:

Sample	SiO_2	Al_2O_3
A	13.3%	6.0%
B	11.3	4.7
C	0.5	17.1
D	1.5	7.5
E	4.8	8.0
F	13.2	19.7

The previous tests on the cements employed in this investigation exhibited the following constitutions: *

Compound	Type II	CaA1
SiO_2	21.2%	6.1%
Al_2O_3	4.6	53.0
CaO	62.9	34.1

From the above information we have computed how much type II and calcium aluminate cement each residue contains:

Sample	Residue Content
A	10:1 Type II and CaA1 cement
B	13:1 " " "
C	Essentially all CaA1 cement (Large SiO_2 loss)
D	1:4 Type II and CaA1 cement
E	1-0.7 Type II and CaA1 cement
F	1-0.6 Type II and CaA1 cement

These results appear unusual (particularly for samples A and B where the only type II cement available was in the base seal mortar). The type II cement is slower in attaining strength than the rapid calcium aluminate cement. Results C,D,E,F are more reasonable due to the location of the exit sampling holes.

Yours very truly,

TROW PROTZE

Herman G. Protze

Herman G. Protze, P.E.

Ref.No.92S-279

* See Appendix A.

APPENDIX I

SINGLE LAYER SLAB CONCRETE STRENGTH

RECEIVED NU/Concrete GEN, DKW, JL

AUG 27 1992

Trow Protze Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A

August 19, 1992

Alden Research Laboratory, Inc.
30 Shrewsbury Street
Holden, MA 01520

Attn: Mr. Dean White, Project Engineer

Tests of Concrete Cores
Northeast Utilities Service Company
Millstone Unit 3
Waterford, Connecticu

Gentlemen:

We made the compression and split tensile tests of the cores recently drilled from the test panel shown in "Fig.2" of your test instruction sheets. The cores were received on August 10 and the tests were conducted on August 13 at an age of 9 weeks after time of fabrication. The lower layer of Type II cement mortar separated from the cores during coring and the upper layer of calcium aluminate cement mortar was then sawed off of all test specimens. The compression test specimens of calcium aluminate cement concrete were capped normally with leadite and tested in accordance with ASTM Methods C39. The split tensile specimens were tested flatwise with 1/8" wooden strips on top and bottom sides per ASTM C496. One specimen was saved without testing, which Dr. Lakshmipathiah took with him on his visit of August 19, 1992.

Compression Tests

Specimen	Dia	Capped Length	Density	Compress Strength
A1	3.69"	8.72"	114 pcf	540 psi
B1	"	8.62	116	600
C1	"	Saved for review		
D1	"	7.90	110	440
E1	"	7.65	108	440
F1	"	8.30	110	540
G1	"	8.05	110	500
H1	"	7.72	110	580

Split Tensile Strength Tests

Specimens	Dia"	Sawed Length	Density	Split Tensile Strength	Fractured Aggregate
K1	3.69	7.75"	114 pcf	87 psi	10%
L1	"	8.00	114	106	15
M1	"	7.30	109	70	15
N1	"	7.80	105	44	10

All strength results were very low due to the porous nature (high voids) of the concrete. The densities of typical samples drilled from the test box tabulated above and described in Fig. 2 of the instruction sheets varied from 105 to 116 pcf (averaging 111 pcf). Consolidation of the porous concrete in the test boxes was attained by walking on the concrete at half and full depth ("booting").

The strengths of companion test cylinders (Ref. No. 92L-439EF) averaged 1060 psi at 28 days because those samples were better compacted (averaging 117 pcf) and were not affected by possible reduction in bond by flowing water as in the core concrete. Earlier test of similar cylinders made in a laboratory trial mixture by us Ref.No. 92L-394ABC (averaging 117.7 pcf) exhibited an average strength of 1310 psi with the still less voids. The split tensile results were also very low and variable due to the high and variable voids ratio compared with normal concrete specimens containing sand mortar to fill the voids and increase the bond.

We understand that the voids in the concrete in the parent structure are significantly less than those described herein due to greater compaction of the site concrete by vibration and perhaps as well, due to use of a more uniform stone gradation than the gap gradation (with less fines) employed in this study as shown on page 2 of Appendix C in our report dated June 19, 1992.

Yours very truly,

TROW PROTZE

Herman G. Protze

Herman G. Protze, P.E.

Ref. No. 92C-1164B

1-Alden

APPENDIX J
DOUBLE LAYER SLAB CONCRETE STRENGTH

NU/Concrete GEN, UL, SJW

RECEIVED
OCT 13 1992
ARL, INC.

Trow Protze Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A

October 9, 1992

ALDEN RESEARCH LABORATORY, INC.
HOLDEN, MASSACHUSETTS

SPLIT TENSILE TESTS
SAMPLES FROM SPECIMEN 1K

REFERENCE NUMBER 92S-353

DATE OF TEST October 9, 1992

APPROXIMATE AGE 4 months

METHOD Sample K from the first double mold described in Fig. 1, Sect. 1-1 of the Specifications for Porous Concrete Mock-Up Testing transmitted on January 14, 1992 was supplied by you in the perforated metal mold. Sample K was sawed in half diametrically at the intersection of the type II and calcium aluminate cement concretes. They were each then cut into 8" lengths and the metal enclosures were carefully removed.

Each specimen was then individually subjected to a careful split tension test in accordance with ASTM C-496-90, until failure.

RESULTS

Sample	Type II	Cal. Aluminate
Load	1300 lbs	3000 lbs
Stress	17 psi	40 psi

Both samples crumbled at maximum load, breaking bond between the pieces of coarse aggregate and causing small chips on contact areas. Approximately 20% of aggregate in the failed area was chipped in each sample. There was no shinyness in aggregate in each case.

REMARKS The test results are very low. We shall withhold further testing until you advise us as to the disposition of remaining test specimens.

Respectfully submitted,
Herman G. Protze
Herman G. Protze, P.E.

2-Alden

RECEIVED
SEP 18 1992
ARL, INC.
Gen, SKN, UL
NU/Concrete

Trow Protze Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A

September 14, 1992

Alden Research Laboratory, Inc.
30 Shrewsbury Street
Holden, MA 01520

Concrete Core Strain Test
Northeast Utilities Service Company
Millstone Unit #3
Waterford, Connecticut

Attn: Mr. Dean White, Project Engineer

Gentlemen:

On September 3, 1992, (at an average age of 12 weeks after casting) we tested Sample D as removed from the first of two test panels shown in "Fig. 1." of your test instruction sheets. This sample including the perforated steel form was removed by you from the in-place concrete casting and delivered to us on August 14.

The sample was free of cement mortar etc., on the outside of the perforated steel jacket. The sample was sawed by us to provide flat ends perpendicular to the axis at a total length of 14 5/8 inches, with equal lengths of the type II cement concrete (Mix A) and calcium aluminate cement concrete (Mix B) in the sample. The sample diameter was slightly less than 6". A layer of thin rice paper was fastened around the perforated cylinder by us to prevent intrusion of the capping compound described below.

A 7" I.D. steel pipe, 13 5/8" long with 3/8" walls (provided by you with ends machined square to its axis) was placed over the test sample centered lengthwise and diametrically. The lower gap was caulked with flexible pipe caulking and the circular gap was slowly filled with leadite capping compound to avoid "piping" and assure a completely filled area. Both ends of the sample were then capped with leadite flat and perpendicular to the sample. The total length of the sample + capping was 14 3/4". The outside edges of the capping compound did not touch the steel pipe.

After several days (on September 3, 1992) the sample was tested in our 300,000 lb. hydraulic Baldwin-Southwark testing machine recently verified for test accuracy. Two Ames dials (reading directly in 0.001" and accurate to 0.0001") were arranged on diametrically opposite locations to read changes in length of the interior concrete at each load application. The outside steel tube was

supported on three steel nuts to prevent disloging, because the pipe was free to move due to the shrinkage of the leadite during hardening. There was approximately a half a thousandth of an inch freedom between the leadite and the pipe.

The test data are appended hereto. On the first test ("Run No. 1") we could hear aggregate breakage starting at 10,000 lb. load. At 10,000 lb and after all subsequent load applications, aggregate breakage continued; this required bringing a given load somewhat higher than the desired load so that after the aggregate splintered the recorded load became stable as noted. At 17,900 lbs. a definite "yield point" was reached. Run No. 1, was stopped at 25,000 lbs (962 psi) load.

At the end of Run No. 1, the load was removed, and then loading was repeated (starting at the new zero) to 20,000 lb. Note that the deflection from zero to 10,000 lb. was approximately 9% greater than with Run No. 1. Then the latter curve continued almost as a straight line to 20,000 lb (quite different from Run No. 1 whose deflections were greater due to continued aggregate breakage, which did not occur again).

After this 20,000 lb. test, the nuts supporting the steel restraining pipe were changed to thin wooden strips.

Run No. 3 was a duplicate of Run No. 2. Note that total squeeze at 10,000 lb. was 45% greater than with Run No. 1.

Run No. 4 was another duplicate. Here there was more aggregate breakage from 16,900 to 18,000 lbs and the total squeeze at 10,000 lbs. was 50% greater than with Run No. 1.

In examining the test specimen after the fourth test we noted that aggregate breakage involved moderate chipping of numerous pieces of the coarse aggregate. There was more aggregate destruction in Mix A with the type II cement than in Mix B with calcium aluminate cement.

We await your instructions regarding further tests of remaining samples.

Yours very truly,

TROW PROTZE

Herman G. Protze, P.E.

Ref. No. 92C-1343
2-White

Run No. 1

Center Load		Change in Length		
lbs	psi	L	R	AV.
Zero	0	0	0	0
200	8	1	1	1
1000	38	4	4	4
2000	77	6	6	6
3000	115	8	8	8
4000	154	10	10	10
5000	192	12	12	12
6000	231	14	13	13.5
7000	269	15	15	15
8000	308	17	17	17
9000	346	19	19	19
10,000	385	22	22	22
11,000	423	75	91	83
12,000	462	78	119	98.5
13,000	500	81	131	106
14,000	539	136	192	164
15,000	577	170	225	197.5
16,000	615	193	248	220.5
17,000	654	206	261	233.5
18,000	692	272	328	300
19,000	731	298	352	325
20,000	769	317	370	343.5
21,000	808	368	422	395
22,000	846	383	438	410.5
23,000	885	397	451	424
24,000	923	410	462	436
25,000	962	430	482	456
✓	✓	✓	✓	✓

Run No. 2

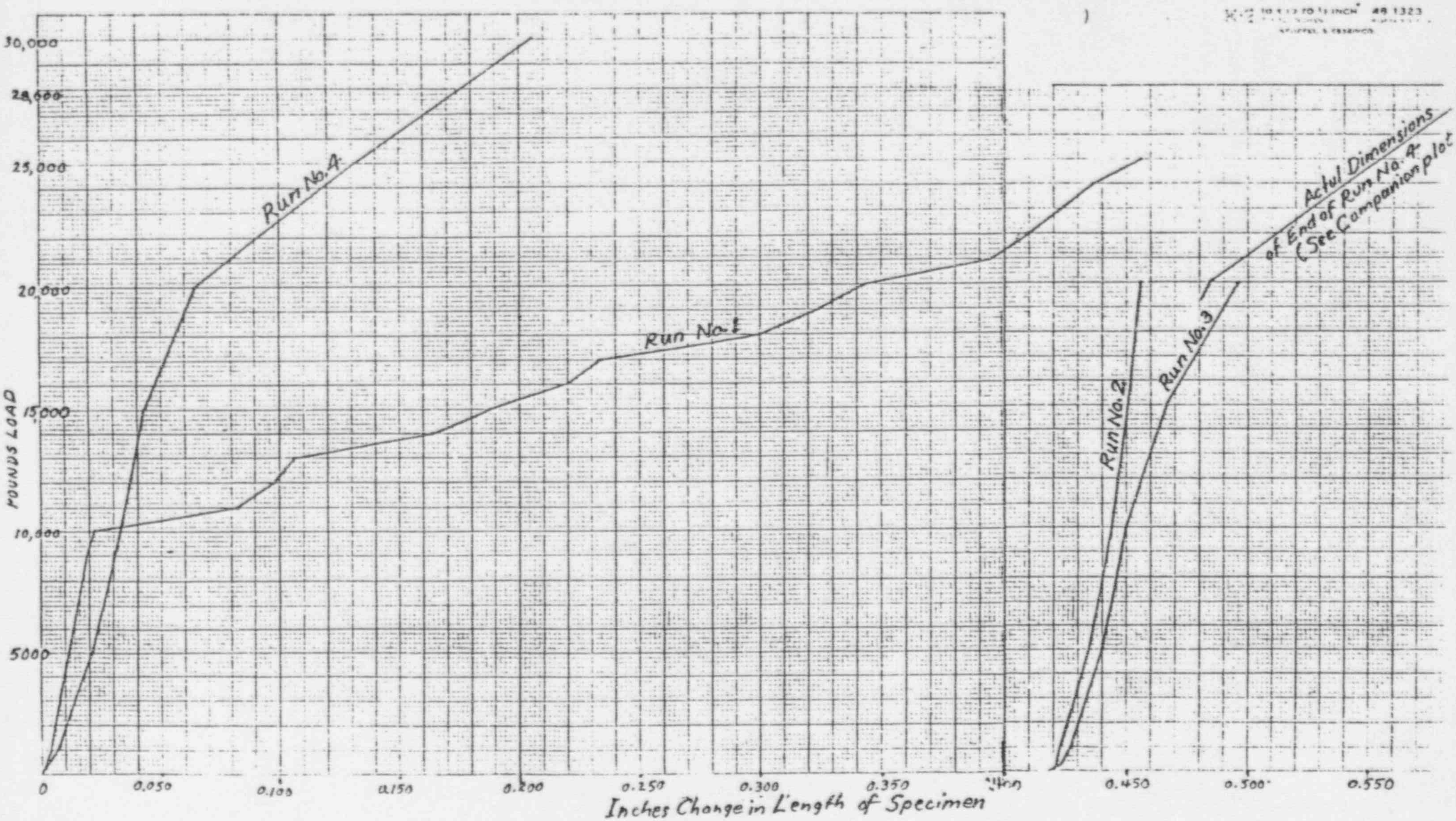
Center Load		Change in Length		
lbs	psi	L	R	AV.
Zero	0	395	445	420
200	8	396	446	421
1000	38	398	449	423.5
5000	192	410	460	435
10,000	385	419	469	444
15,000	577	425	476	450½
17,000	653	427	478	452½
20,000	769	431	482	456½
✓	✓	✓	✓	✓

Run No. 3

Zero	0	395	441	418
200	8	399	446	422½
1000	38	404	450	427
5000	192	417	463	440
10,000	385	428	472	450
15,000	577	447	486	466½
20,000	769	456	537	496½
✓	✓	✓	✓	✓

Run No. 4

Zero	0	0	0	0
200	8	1	1	1
1000	38	7	6	6½
5,000	192	23	19	21
10,000	385	35	31	33
15,000	577	44	41	42½
20,000	769	63	66	64½
25,000	962	123	140	131½
30,000	1154	186	224	205
✓	✓	✓	✓	✓



30,000
25,000
20,000
15,000
10,000
5000
POUNDS LOAD
Run No. 4
Run No. 1
Run No. 2
Run No. 3
Actul Dimensions of End of Run No. 4 (See Companion plot
0
0.050
0.100
0.150
0.200
0.250
0.300
0.350
.400
0.450
0.500
0.550
Inches Change in Length of Specimen

RECEIVED   NU| Concrete   GEH| file cc JL DKW

SEP 30 1992

ARL, INC.

Trow Protze Consulting Engineers

70 Jaconnet Street
Newton Highlands, MA 02161

Tel.: (617) 332-8460
FAX: (617) 332-3914

Project No. TP-04518-A **September 30, 1992**

Alden Research Laboratory, Inc.
30 Shrewsbury Street
Holden, MA 01520

Concrete Core Strain Tests
Northeast Utilities Service Company
Millstone Unit #3
Waterford, Connecticut

Attn: Mr. Dean White, Project Engineer

Gentlemen:

On September 25, 1992, (at an average age of 15 weeks after casting) we tested Samples B, F, H as removed from the first of two test panels shown in "Fig. 1." of your test instruction sheets. These samples including the perforated steel forms were removed by you from the in-place concrete casting and delivered to us on August 14.

As described for the first Sample D in our report of September 14, 1992, (Ref.No.92C-1343), the appearance of these new samples were similar to those the prior sample. Dimensions were the same as previously. Area of the concrete in the cage of the test sample again was 26.0 square inches.

These three samples were tested in the same general manner as previously described with the following differences:

A. Thin strips of soft wood on edge were used to support the encompassing steel cylinder instead of the previous steel nuts.

B. Each specimen was "massaged" twice from zero load to 10,000 lbs prior to conducting the formal stress/strain test to significantly reduce the amount of hysteresis loop.

C. Only one detailed sequence of loading was made on each specimen after massaging. (A short-form secondary rerun at large load increments was made on each sample after the formal run. You will note that again there is no relation between the original and secondary runs).

Aggregate chipping and load fluctuations occurred with the various specimens as follows:

Sample B	9900 lbs	load fluctuations and aggregate popping
	11000	more popping
	17700	small fractures and fluctuations
	20500	fluctuations of load
	21000	cracking, long holding of load
	22600	cracking, maximum load
Sample F	14900 lbs	big pop and load loss to 7000
	17700	fluctuations in loading
	22700	load fluctuation
	22900	maximum load
Sample H	18000 lbs	fluctuations in load
	18900	end of fluctuations
	25000	stopped loading; no popping

See appended data sheets and plots.

Yours very truly,

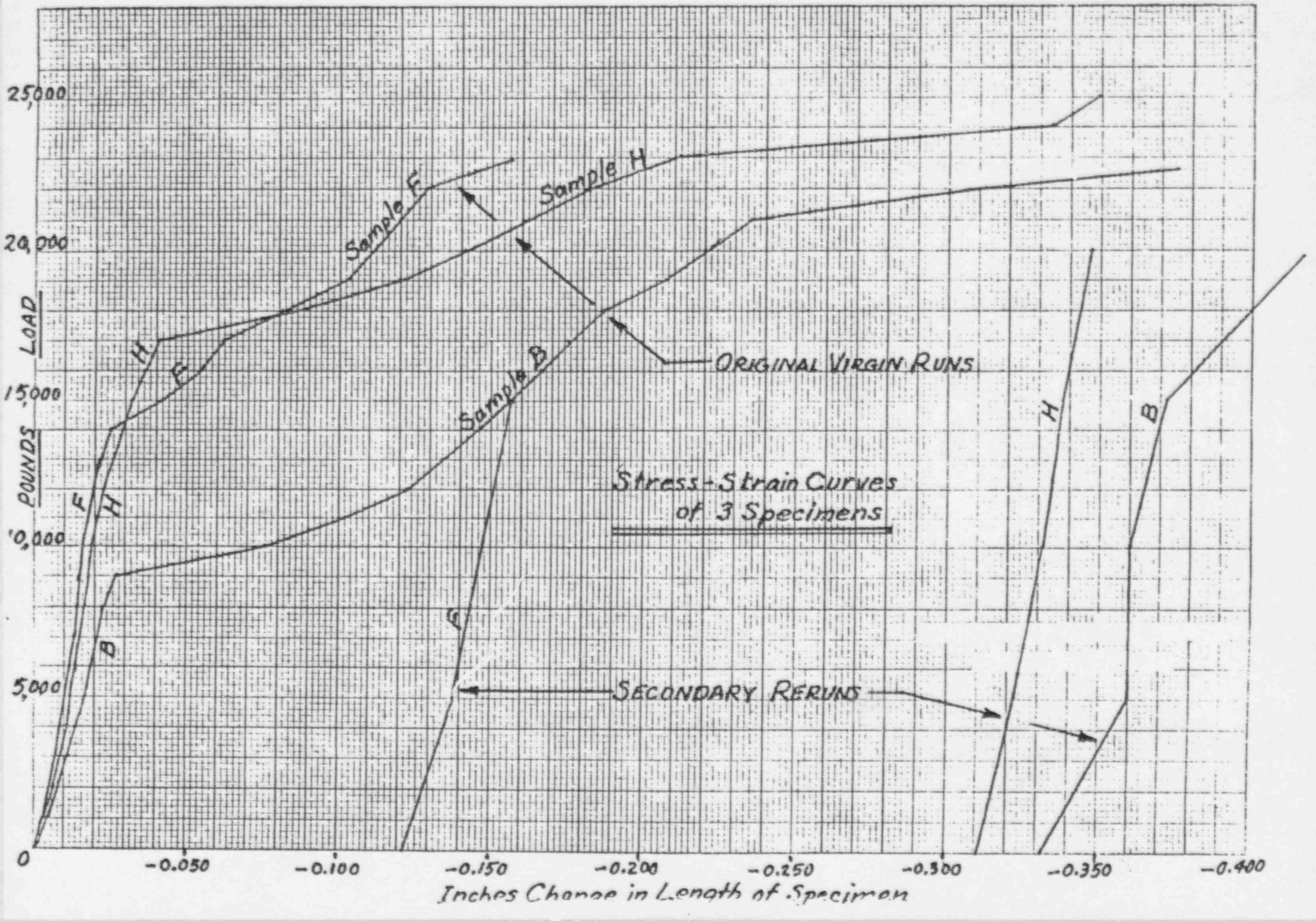
TROW PROTZE

Herman G. Protze, P.E.

Ref. No. 92C-1390
2-White

Applied Center Load		CHANGE IN LENGTH - - 0.001 INCHES								
		Sample B			Sample F			Sample H		
lbs.	psi	L	R	Av.	L	R	Av.	L	R	Av.
Zero	0	0	0	0	0	0	0	0	0	0
200	8	2	1	2	1	0	1	1	1	1
1000	38	6	3	5	4	2	3	4	3	4
2000	77	9	6	8	6	4	5	6	6	6
3000	115	12	9	11	8	6	7	9	8	9
4000	154	16	12	14	9	8	9	11	10	11
5000	192	18	15	17	10	9	10	12	12	12
6000	231	20	17	19	12	11	12	14	14	14
7000	269	23	19	21	13	12	13	15	15	15
8000	308	25	21	23	14	13	14	16	17	17
9000	346	28	25	27	15	15	15	17	18	18
10,000	385	76	75	76	16	16	16	18	19	19
11,000	423	103	101	102	17	18	18	20	21	21
12,000	462	123	123	123	19	20	20	22	23	23
13,000	500	134	134	134	21	23	22	25	26	26
14,000	539	146	146	146	24	26	25	28	29	29
15,000	577	156	157	157	40	43	42	31	33	32
16,000	615	165	166	166	50	59	55	35	37	36
17,000	654	174	176	175	56	68	62	40	42	41
18,000	692	185	188	187	69	92	81	87	85	86
19,000	731	207	206	207	90	116	103	121	119	120
20,000	769	213	227	220	101	123	112	141	140	141
21,000	808	224	247	236	105	134	120	162	162	162
22,000	846	290	333	312	114	144	129	178	185	182
22,600	869	352	398	375	-	-	-	-	-	-
22,900	881	✓	✓	✓	140	173	157	-	-	-
23,000	885						✓	206	217	212
24,000	923							322	345	334
25,000	962							337	361	349
Zero	0	316	348	332	106	136	121	306	316	311
5,000	192	354	365	360	122	153	138	317	326	322
10,000	385	344	375	360	131	162	147	326	335	331
15,000	577	355	389	372	141	172	157	333	342	338
19,800	761	395	438	417	-	-	-	-	-	-
20,000	769	-	-	-	-	-	-	341	352	347
Zero	0	362	393	378	112	141	127	310	312	311

KEUFFEL & ESSER CO.



Docket No.50-423
B15985

Attachment 3

Millstone Nuclear Station Unit 3

Phase II Test Report
Millstone 3 Erosion of Cement From The Porous Concrete Drainage System

November 1996

POROUS CONCRETE MOCK-UP TESTING
FOR MILLSTONE UNIT 3
WATERFORD, CONNECTICUT

By
Dean K. White

Sponsored by
NORTHEAST UTILITIES SERVICE COMPANY

ALDEN RESEARCH LABORATORY, INC.
Solving Flow Problems Since 1894

161-93/M295F-R

November 1993
Revised - November 1996

POROUS CONCRETE MOCK-UP TESTING
FOR MILLSTONE UNIT 3
WATERFORD, CONNECTICUT

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November 1993
Revised - November 1996

ALDEN RESEARCH LABORATORY, INC.
30 Shrewsbury Street
Holden, MA 01520

TABLE OF CONTENTS

INTRODUCTION

This report covers all work conducted under Northeast Utilities Specification SP-CE-363, Supplement to SP-CE-354 by both the Alden Research Laboratory, Inc. (ARL) and its subcontractor, Trow Protze Consulting Engineers (TP). All technical matters related to the project were coordinated with Mr. K. Lakshmipathiah of Northeast Utilities Service Company (NU). Work under this specification has been subject to the independent review of Harstead Engineering Associates, Inc.

SCOPE OF WORK

The ARL and its subcontractor were to provide all the necessary materials, equipment, and technical requirements for the construction of three porous concrete test molds and for testing of the test molds to evaluate potential cement erosion resulting from the flow of water through the porous concrete.

CONSTRUCTION OF APPARATUS

Three concrete test molds were constructed. One test mold was a double layer mold with no membrane between the layers of porous concrete while two test molds were double layer molds with a membrane between the two layers of porous concrete. The wooden forms built to contain the test molds were heavily reinforced to minimize deflection.

The 6 x 10 foot form for the double layer mold without the membrane was 21 inches high to accommodate a 9 inch layer of porous concrete on top of a 10 inch layer of porous concrete. A two 2 inch layers of grout was placed on top of the 9 inch layer of porous concrete. One 10 foot long side of the form contained groups of one quarter inch holes to introduce water into the test mold. The holes were drilled over size, and a plastic sleeve was pressed into each hole to insure uniformity. Each test mold contained two 6 inch perforated plastic drainage pipes in the 9 inch (top) layer of porous concrete to collect the water introduced through the one quarter inch holes. The drainage pipes contained four rows of five eighths inch diameter holes spaced 3

inches center to center. The rows of holes were located at 2 o'clock, 4 o'clock, 8 o'clock, and 10 o'clock around the pipe. Figure 1 is the plan of the test mold without the membrane.

The forms for the two test molds with the membranes were 6 x 10 feet x 23 inches high. These forms contained a 10 inch layer of porous concrete using Portland cement covered by a membrane that was intentionally punctured at several locations. A 2 inch layer of grout using Portland cement was placed on top of the membrane and holes were formed in the grout above the location of each hole in the horizontal portion of the membrane. A 9 inch layer of porous concrete using Calcium Aluminate cement was placed on top of the grout. A 2 inch layer of grout using Calcium Aluminate cement was placed on top of the 9 inch layer of porous concrete. One 10 foot long side of the form contained groups of one quarter inch holes to introduce water into the test mold. The holes were drilled over size, and a plastic sleeve was pressed into each hole to insure uniformity. The test molds with the membrane also contained two 6 inch perforated plastic drainage pipes in the 9 inch porous concrete layer to collect the water introduced through the one quarter inch holes. The drainage pipes contained four rows of five eighths inch diameter holes spaced 3 inches center to center. The rows of holes were located at 2 o'clock, 4 o'clock, 8 o'clock, and 10 o'clock around the pipe. Figure 2 and 3 are the plans of the test molds with the two configurations of membrane. A partially filled mold is shown in Figure 4.

Water was supplied to the mold boxes through a single pumping system capable of providing sufficient flow and pressure to the three test molds. Flow from the pump was introduced into a manifold where smaller lines carried flow to each of the one quarter inch holes. A calibrated pressure gauge was located on the manifold and a valve on the inflow to the manifold was provided to regulate pressure.

Water discharging from the drainage pipes was collected in a settling box and the residue washed from the mold was recovered by filtering the water from the box using a 5 micron filter. For

the tests of 8 hour duration, all water was filtered. For the 30 day test, only the residue in the box at the conclusion of the test was collected.

PROCUREMENT AND TESTING OF MATERIALS

The ASTM #57 coarse aggregate to be used in the porous concrete slabs was procured from Tilcon Connecticut, Inc., the operators of the Wauregan Quarry which provided the coarse aggregate to the Millstone Plant during the original construction. Review of the gradation logs for the original aggregate and aggregate being shipped from the quarry today indicated that the present day Tilcon Stone from the Wauregan Quarry should meet the ASTM #57 aggregate specifications and be similar to the material used at Millstone. A sieve analysis of a 300 pound sample of the aggregate obtained from the quarry in April 1993 also indicated that the aggregate would meet specifications, see Appendix A, page A1. Tests of the aggregate delivered to the concrete batch plant for the pouring of the concrete on June 16, 1993 indicated that the material gradation lacked fines and therefore was slightly outside of the ASTM #57 specifications, see Appendix A, page A2. The aggregate, however, was considered acceptable by NU and was used to conduct the test program.

The calcium aluminate cement was produced by the Lehigh Portland Cement Company of Gary, Indiana at the Buffington Plant. The mill test report indicates that the cement meets the requirements of Section 8.3 of the NU Specifications. The mill test report is in Appendix A, page A3.

The Portland Cement Type II produced by the LaFarge Corporation Northeast Cement Plant complies with current ASTM C-150 as well as A.A.S.H.T.O. M-85 specifications called for in Section 8.2 of the NU Specifications, see Appendix A, page A4.

Water chemistry at both the concrete batch plant and ARL were tested per ASTM requirements for batch water and curing water. The water analysis is shown in Appendix A, page A5.

The concrete used in the test slabs required careful preparation of transit mixing equipment since Calcium Aluminate Cement is not in common usage (all local concrete plants use Portland Cement). Concern for the possible contamination of Calcium Aluminate Cement with Portland Cement prompted tests to determine how the strength of the concrete is effected by the contamination of one cement with the other. Porous concrete mixes were prepared with 100% Portland Cement, 100% Calcium Aluminate Cement, a 10% Portland Cement to 90% Calcium Aluminate Cement mix, and a 10% Calcium Aluminate Cement to 90% Portland Cement mix. An 18 inch diameter by 12 inch high mold and three six inch cylinders were cast from each mix. The molds and all cylinders were rodded to achieve maximum density. The concrete mix proportions are shown in Appendix A, page A6. Results of the testing of the cores and cylinders are shown in Appendix A, page A7. The void ratios and the densities of the specimens were very consistent indicating that the compactive effort was well controlled. The Lumnite Cement concrete showed a greater decreased in strength when mixed with 10% Portland Cement (20% decrease) than did the Portland cement concrete mixed with 10% Lumnite Cement (9% decrease).

In addition to the testing of laboratory prepared mixes of porous concrete five mixes of cement paste and five mixes of cement mortar were made with varying amounts of Portland Cement and Calcium Aluminate Cement. Three inch diameter cylinders were prepared from each mix. Compressive strength tests were conducted on the cylinders after 28 days of curing. The results of these tests are shown in Appendix A, page A8.

The Lumnite Cement paste strength was reduced approximately 58% when 10% Portland Cement was added while the Portland Cement paste strength was reduced approximately 19% when 10% Lumnite Cement was added. When there were equal parts of Portland Cement and Lumnite Cement the strength was approximately 17% of the average of the unmixed strengths.

The motar mixes indicated that when Lumnite Cement motar has 10% Portland Cement added the strength is decreased only 6% while when Portland Cement motar has 10% Lumnite Cement

added the strength decreases 12%. When the motar was prepared with equal parts of Lumnite Cement and Portland Cement the strength was approximately 27% of the average of the unmixed strengths.

BATCHING AND PLACING OF CONCRETE

The test molds contained very small quantities of concrete and to better control the batching process, the minimum batch sizes was set at 3 cubic yards of concrete. The mix designs were based on this yardage. The mixes containing Portland Cement were batched at the transit mix batch plant and sent to the site with only a small fraction of the water requirement added at the plant. The remaining water was added at the site and carefully controlled to produce the proper consistency. The mixes containing Calcium Aluminate Cement, only added the aggregate at the transit mix batch plant and the cement was added at the site by the bag to minimize the potential of rapid setting of the concrete in the truck mixing drum. Water from the batch plant was added at the site and carefully controlled to produce the proper consistency. Due to the stiffness of the mixes using the #57 aggregate slump was not sufficient to determine the proper water content. The mix was inspected visually for the consistency of the concrete paste on the aggregate.

The preparation of each concrete mix and each grout mix was monitored by TP inspectors, both at the concrete batch plant and during placement. Reporting of these inspections is contained in Appendix B, pages B1 through B4.

DESCRIPTION OF WORK

Three test molds containing two layers of porous concrete were constructed. Two molds labeled Mold "B" and Mold "C", see Figures 2 and 3, respectively, contained a water proof membrane and a 2 inch thick layer of Portland Cement grout (sand cement mix) between the two layers of porous concrete. Each membrane was intentionally punctured at certain locations by cutting a

3" long by 1/8" wide slit. An opening was left in the grout layer where it covered a slit in the membrane, Figures 5 and 6 show the location of these slits for Mold "B" and Mold "C", respectively. The lower layer of porous concrete was 10 inches thick, made with Portland Cement Type II and the upper layer of porous concrete was 9 inches thick, made with Calcium Aluminate Cement (Lumnite Cement). A 2 inch thick grout layer (sand cement mix) made with Lumnite Cement was used to seal the top. The third mold labeled Mold "A" was similar to the other two molds described above with the exception of the water proof membrane and the 2 inch grout layer between the two layers of porous concrete, i.e., the two porous concrete layers were poured one on top of the other with nothing in between, see Figure 1.

The porous concrete layers were co pacted in 3 to 4 inch layers by rodding to produce a concrete of a density similar to that produced in the concrete laboratory while making the trial mixes. Each layer of concrete placed in the mold was allowed to cure according to the concrete placing schedule is shown in Table 1.

TABLE 1

CONCRETE PLACING SCHEDULE

DAY	MOLD WITH MEMBRANE	MOLD WITHOUT MEMBRANE
1	10" Porous Portland	10" Porous Portland
6	2" Portland grout	No Activity
8	9" Porous Lumnite*	9" Porous Lumnite*
15	2" Lumnite Grout	2" Lumnite Grout
22	Hydraulic Testing	Hydraulic Testing

* Layer containing 6" drain pipes.

In Molds "A" and "B" only, immediately prior to water tests the perforated drain pipes were cleaned out and the recovered concrete residue was weighed and analyzed.

After the 7 day curing period of the Lumnite Grout seal, water was applied to one hole in hole group A in Mold "A" and one hole in hole group B of Molds "B" and "C". Four 8 hour tests were conducted in each mold using these holes. Water was introduced at a pressure of approximately 5 psig (11.5 feet of water) and allowed to flow for 8 hours. All water collected from the 6 inch perforated pipes was filtered and the residue collected, dried, and weighed. Samples of the residue were analyzed to determine the type of cement.

During the second group of four eight hour tests in Mold "A", one hole in each of hole groups A and B was open and in Molds "B" and "C", one hole of hole group B was open. All water collected from the 6 inch perforated pipes was filtered, and the residue collected, dried, and weighed. Samples of the residue were analyzed to determine the type of cement.

At the conclusion of the 8 hour testing sequence, all molds were subject to a 30 day test with all holes open. This included four holes for holes A and four holes for holes B plus all holes labeled C. The water exiting the 6 inch perforated pipes discharged into a settling box that was inspected for residue five times a week. The residue was collected at the end of the test.

LABORATORY CERTIFICATION

The latest CCRL (Cement and Concrete Reference Laboratory) certification for the laboratory of TP is in Appendix C.

SUMMARY OF TEST RESULTS

AGGREGATE COMPACTION TEST

REVISED (Intentionally left blank)

TEST CYLINDERS

Eight test cylinders were made from concrete Mix A (Portland cement porous concrete) and six test cylinders were made from concrete Mix B (Lumnite porous concrete) at the time of pouring. In addition, four test cylinders were made from each grout layer. The cylinders made at the time of the pour remained at the site until the next pour, see Table 1 for time interval, and then were held in the laboratory fog room. Four cylinders from Mix A and three cylinders from Mix B were tested at 7 days and 28 days. The average strengths of the Mix A cylinders from the pour broken at 7 days and 28 days were 1,678 psi and 2,152 psi, respectively. The increase in strength from the 7 day strength to the 28 day strength was approximately 28% for Mix A. These cylinders weighed between 124 and 126 lbs/cuft. The average strengths of the Mix B cylinders from the pour broken at 7 days and 28 days were 1,706 psi and 1,787 psi, respectively. The increase in strength from the 7 day strength to the 28 day strength was approximately 5% for Mix B. The Mix B cylinders weighed between 123 and 126 lbs/cuft. Compression tests were also conducted on the motar layers used in the molds. The test reports for all compression tests are contained in Appendix E.

FLOW TESTING

The residue in the 6 inch drain lines of Mold A and Mold B was removed prior to hydraulic testing. The residue samples were weighed and the chemical content analyzed. Mold A pipes contained 32.7 grams of material while Mold B pipes contained 45.0 grams of material. This material consisted of dry concrete particles and small pieces of cement coated aggregate. The size of the aggregate was limited by the diameter of the holes in the drain pipe. The report on the chemical content of the residue is in Appendix F as samples 9 and 10.

At the conclusion of the 7 day curing period, flowing water was introduced into the three molds at a pressure of approximately 5 psi for a series of tests, each 8 hours in duration. The water which circulated through the slabs was filtered through a 5 micron filter upon leaving the slab. The residue collected was dried and weighed. During each test, the flow rate was measured. The weights and flow rates are shown in Tables 2, 3, and 4.

TABLE 2

MOLD A RESIDUE WEIGHT AND FLOW RATE

TEST	WEIGHT grams	FLOW gpm	DESCRIPTION
1	84.4	2.3	Light Brown Powder
2	92.1	2.7	Light Brown Powder
3	68.0	2.6	Light Brown Powder
4	50.3	2.4	Light Brown Powder
5	83.5	4.6	Light Brown Powder
6	38.1	4.6	Light Brown Powder
7	32.2	4.3	Light Brown Powder
8	41.3	4.1	Light Brown Powder

TABLE 3

MOLD B RESIDUE WEIGHT AND FLOW RATE

TEST	WEIGHT grams	FLOW gpm	DESCRIPTION
1	111.1	1.9	
White Residue			
2	136.1	2.3	White Residue
3	35.4	2.5	White Residue
4	25.4	2.3	White Residue
5	22.2	2.5	White Residue
6	3.2	2.4	White Residue
7	4.5	2.3	White Residue
8	20.9	2.3	White Residue

TABLE 4

MOLD C RESIDUE WEIGHT AND FLOW RATE

TEST	WEIGHT grams	FLOW gpm	DESCRIPTION
1	45.4	0.5	White Residue
2	173.7	2.4	White Residue
3	46.7	2.7	White Residue
4	49.4	2.4	White/Brown Residue
5	24.5	2.5	Light Brown Residue
6	12.7	2.5	Light Brown Residue
7	13.1	2.5	Light Brown Residue
8	27.7	2.2	Light Brown Residue

During the curing process, a white residue leached from all three of the molds. This material deposited on the wooden box and on the floor any where the curing water went, see Figure 8. When the flowing water was introduced into the slabs, the molds produced a similar appearing white residue which was filtered out and collected as the material tabulated above. The results of the chemical analysis to determine the type of cement contained in the residue is in Appendix F and indicate that the residue is from both cements with no conclusive results as to what fraction of the residue is from the two types of cement used in the molds.

At the conclusion of the 8 hour tests, all three molds were tested for 30 days introducing water through all holes shown in Figures 1, 2, and 3. The rate of flow through the slabs was measured during the test period. The average flow through Mold "A", Mold "B", and Mold "C" was 23.4 gpm, 27.8 gpm, and 15.7 gpm, respectively. Each collection box was cleaned and material shown in Table 5 was collected.

TABLE 5

RESIDUE COLLECTED AFTER 30 DAY TEST

MOLD	WEIGHT OF RESIDUE (grams)
A	73.0
B	87.0
C	145.0

CORE TESTING

After the 30 day test period, fourteen 6 inch diameter cores were taken from each slab at the locations shown in Figures 1, 2, and 3. Each core consisting of a core of Portland Cement porous concrete and a core of Lumnite Cement porous concrete was tested in compression. The coring operation was successful in all three molds. Appendix G contains the boring logs for each mold.

The cores from Mold "A" were recovered in two pieces with the break coming at the interface between the two pours. This was expected since there was little opportunity for the upper layer of the porous concrete to bond to the bottom layer of concrete. Four cores damaged in the lumnite concrete section as well as at the interface.

The cores from Mold "B" and Mold "C" generally broke into three sections. The upper layer of porous concrete separated from the layer of motar below it and this layer of motar was separated from the lower layer of porous concrete by the membrane. Only five cores from Mold "C" broke into more than three sections. All of the damaged cores were broken in the lumnite concrete section of the core. All Mold "B" cores were recovered.

After the cores were removed, the water was again applied to the molds to determine the water level in the mold at each core location. A column in each of the boring logs records the water

depth above the horizontal floor of the mold at each core location. The water depth measurements indicate that all core locations had a similar water elevation and that there was no measurable hydraulic gradeline in the molds. It was initially thought that there might be a measurably higher water level in the cores near the water inlet ports

Each core was trimmed and prepared for a compression test. Of the 84 cores removed from the molds, 69 were tested. The remaining 15 cores were broken or damaged during removal and could not be tested. The results of the compression tests are in Appendix G. The variation in strength was compared first with the weight of the concrete presuming that heavier concrete, i.e., more dense, more tightly compacted concrete, would have a higher compressive strength. The Lumnite Concrete core strengths are shown in Figure 9 and in general, there is a trend for greater strength with higher density. The Lumnite Cement Concrete in Mold "B" was the most compacted and had the highest strength. A similar result was found in the Portland Cement Concrete with strengths increasing with increased density, see Figure 10.

The core strength data was also analyzed based on location in the mold as it related to the flow of water. In Mold "A", if the flowing water had a tendency to remove cement then it would be expected that both Lumnite cement cores and Portland cement cores located between the water source and the drain lines, cores A, B, G, K, J, and M, would show a reduced strength when compared to cores E, F, I, and N located on the opposite side of the mold taking into consideration the density of the cores. In Mold "B", the Portland cement cores were all subject to the same flow and were not used in the analysis. The Lumnite cement cores in Mold "B" were used in the analysis because cores A, B, E, F, G, I, J, K, M, and N were subjected to flowing water where cores C, D, H, and L were not subject to flow. Cores from Mold "C" made from both Portland cement and Lumnite cement were considered in the flow when there were slits in the membrane at the cores. Cores exposed to flow were B, C, F, H, K, and M. Cores not exposed to flow were A, D, E, G, I, J, L, and N.

The core strength vs. weight plotted for Lumnite Cement Concrete, see Figure 11, indicated that the strength of the cores was not effected by the flowing water. Similarly, the Portland Cement Concrete did not show any change in concrete strength due to flowing water, see Figure 12.

CONFINED COMPRESSION TESTING OF CORES

Cores removed in the steel perforated cages from selected locations in each mold were tested in confined compression and the stress vs strain was recorded. The confined compression test was conducted by removing the perforated steel cylinders and sealing the specimen in a rigid steel cylinder using leadite and an impermeable paper barrier to keep the leadite out of the voids in the concrete.

Two specimens were tested from Mold "A" namely cages AH and AE. Each specimen was prepared by cutting the ends of the specimen square to the axis of the cylinder and by placing equal lengths of Lumnite porous concrete and Portland porous concrete in the steel pipe cylinder. The interface between the two layers of concrete was the interface created by pouring the Lumnite porous concrete on top of the Portland porous concrete in the mold. The displacement as a function of load for the two specimens is shown in Figure 13. Core AH had significantly more displacement after reaching a load of 500 psi than did core AE. Examination of the two specimens indicated that crushing of the aggregate had taken place only in specimen AH. Test logs are contained in Appendix H.

Specimens contained in the steel cages taken from Molds "B" and "C" were tested in two sections, i.e., the Lumnite porous concrete section of the specimens were tested individually as were the Portland porous concrete sections of the specimen. These sections were separated since there was no direct contact between the two concretes, i.e., they were separated by a membrane and a layer of motar.

The stress strain relationship for Lumnite porous concrete for specimens BE, BJ, BH, and CJ are shown on Figure 14. The curves for all four cylinders are very nearly parallel indicating that after an initial displacement which varied for each specimen the units of displacement for each unit of load was nearly the same for all specimens. At a load of 900 psi, the displacement ranged from 0.022 inches to 0.025 inches in specimens that were nine inches high. This is roughly a 0.02% change in height. There was no evidence of aggregate crushing.

The Portland porous concrete specimens taken from the same locations behaved very similar to the Lumnite concrete, see Figure 15. The displacement at a load of 900 psi was slightly more than the Lumnite concrete ranging from 0.023 inches to 0.028 inches in specimens that were ten inches high. The change in height expressed in percent ranged from 0.02 to 0.03%. There was no evidence of crushing aggregate.

CONCLUSIONS

These conclusions have been drawn on the experimental work conducted under this study. No attempt has been made to relate this data to existing field conditions.

1. The aggregate used to conduct these tests was obtained from the same source, the Wauregan Quarry operated by Tilcon Connecticut, as that used during construction of the porous concrete at Millstone.

2. The aggregate used in the tests lacked fines but generally met the required ASTM #57 specifications.

3. Both the Calcium aluminate cement (Lumnite) and the Portland Cement Type II met the requirements of specification SP-CE-363.

4. The water chemistry at the concrete plant and at ARL met ASTM requirements for batch water and curing water, respectively.

5. Contamination of either cement with the other cement during batching causes a loss in strength of the concrete.

6. All concrete handling equipment was cleaned before usage to avoid contamination of cements.

7. During the confined compression test of aggregate alone, the aggregate compacted approximately 40% at a 910 psi load.

8. Portland cement porous concrete cylinders made at the time of the pour weighed approximately 125 lbs/cuft and had a 28 day strength of 2,152 psi.

9. Lumnite cement porous concrete cylinders made at the time of the pour weighed approximately 125 lbs/cuft and had a 28 day strength of 1,787 psi.

10. The compressive strength of both the Portland cement porous concrete and the Lumnite cement porous concrete was not effected by the location of the core as it is related to the flowing water. In both concretes, the strength, however, was related to the density of the concrete.

11. The confined compression tests indicated that the stress strain relationship was similar for all cores made from the same cement, i.e., all Lumnite cores exhibited similar behavior.

12. At a loading of 900 psi, the specimens decreased in height, 0.02% and 0.03% for Portland cement porous concrete and Lumnite cement porous concrete, respectively. There was no crushing of aggregate.

REFERENCE

1. Northeast Utilities Service Company Specification SP-CE-354; Specification for Porous Concrete Mock-up Testing; January 8, 1992; Revision 1, March 9, 1992.

FIGURES

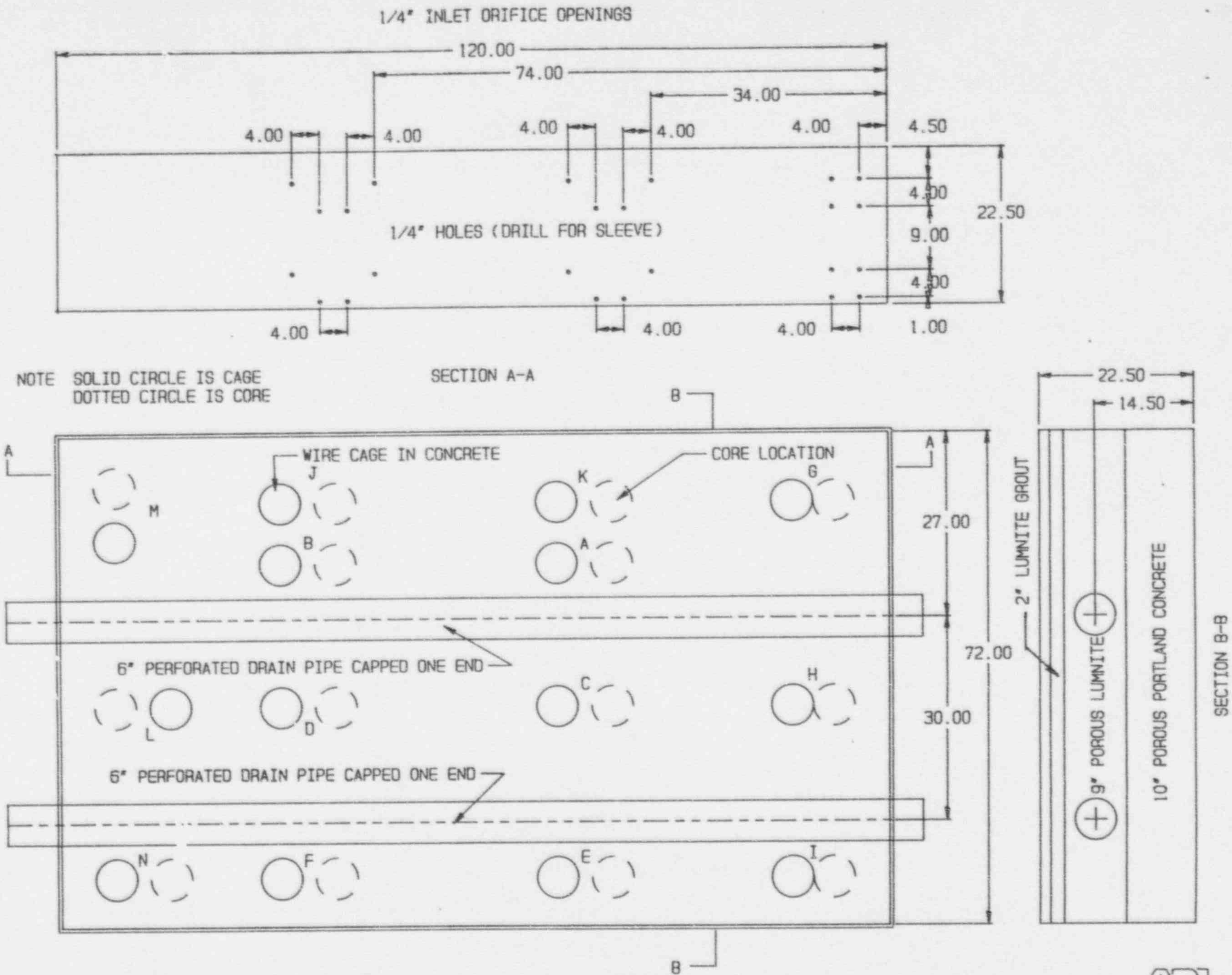


FIGURE 1 MOLD A SHOWING CAGE AND CORE LOCATIONS

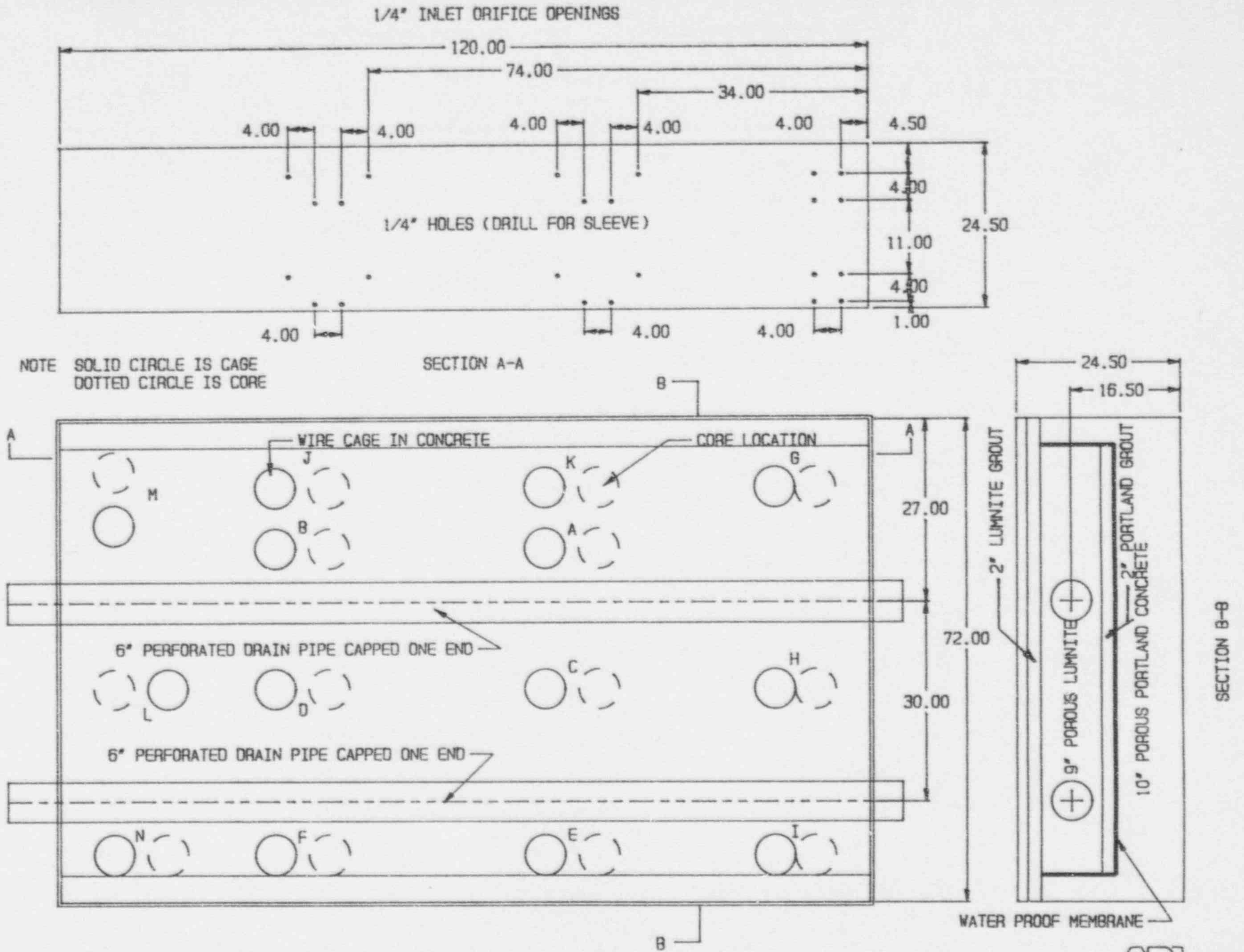


FIGURE 2 MOLD B SHOWING CAGE AND CORE LOCATIONS

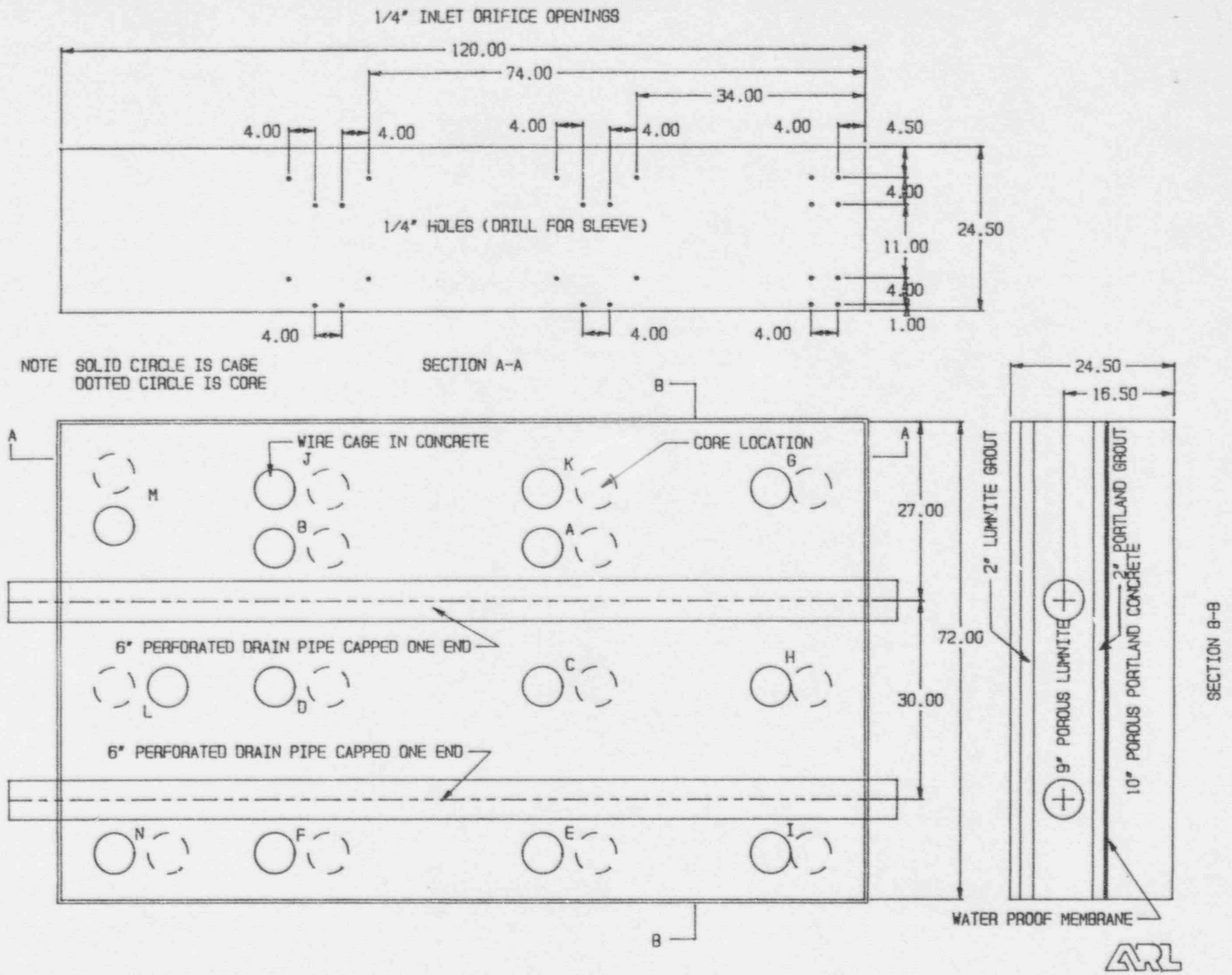


FIGURE 3 MOLD C SHOWING CAGE AND CORE LOCATIONS

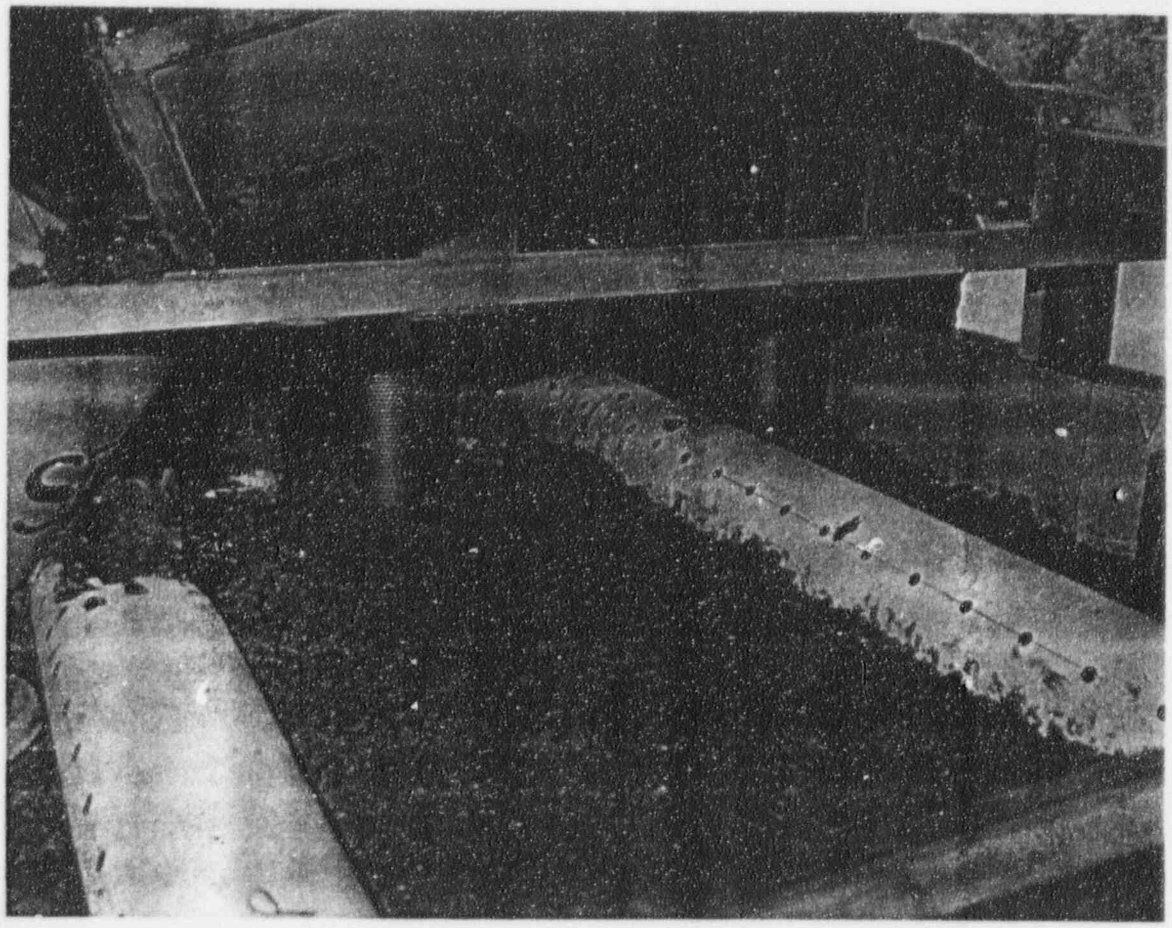


FIGURE 4 MOLD CONSTRUCTION

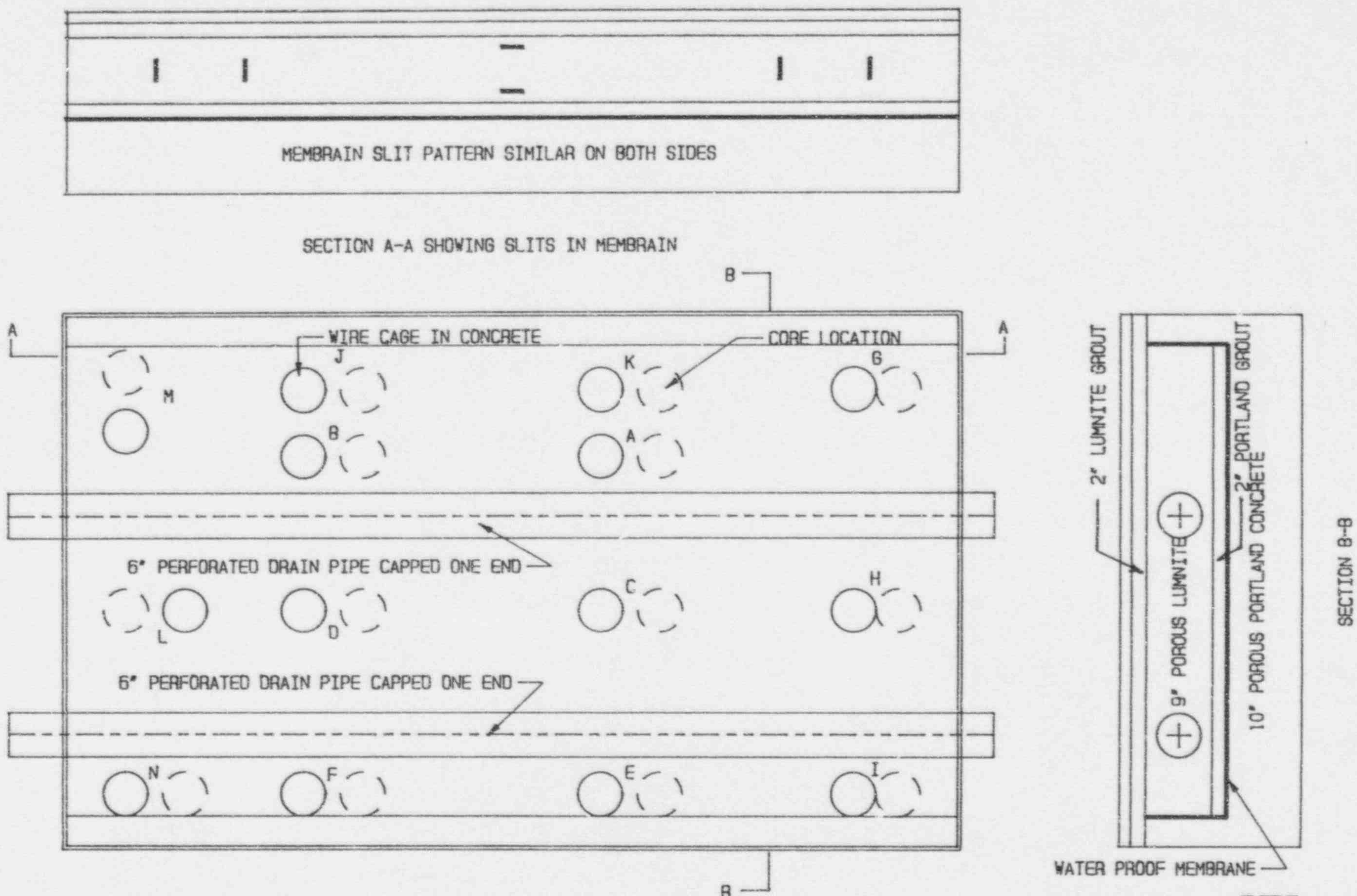


FIGURE 5 MOLD B SHOWING LOCATION OF SLITS IN MEMBRANE

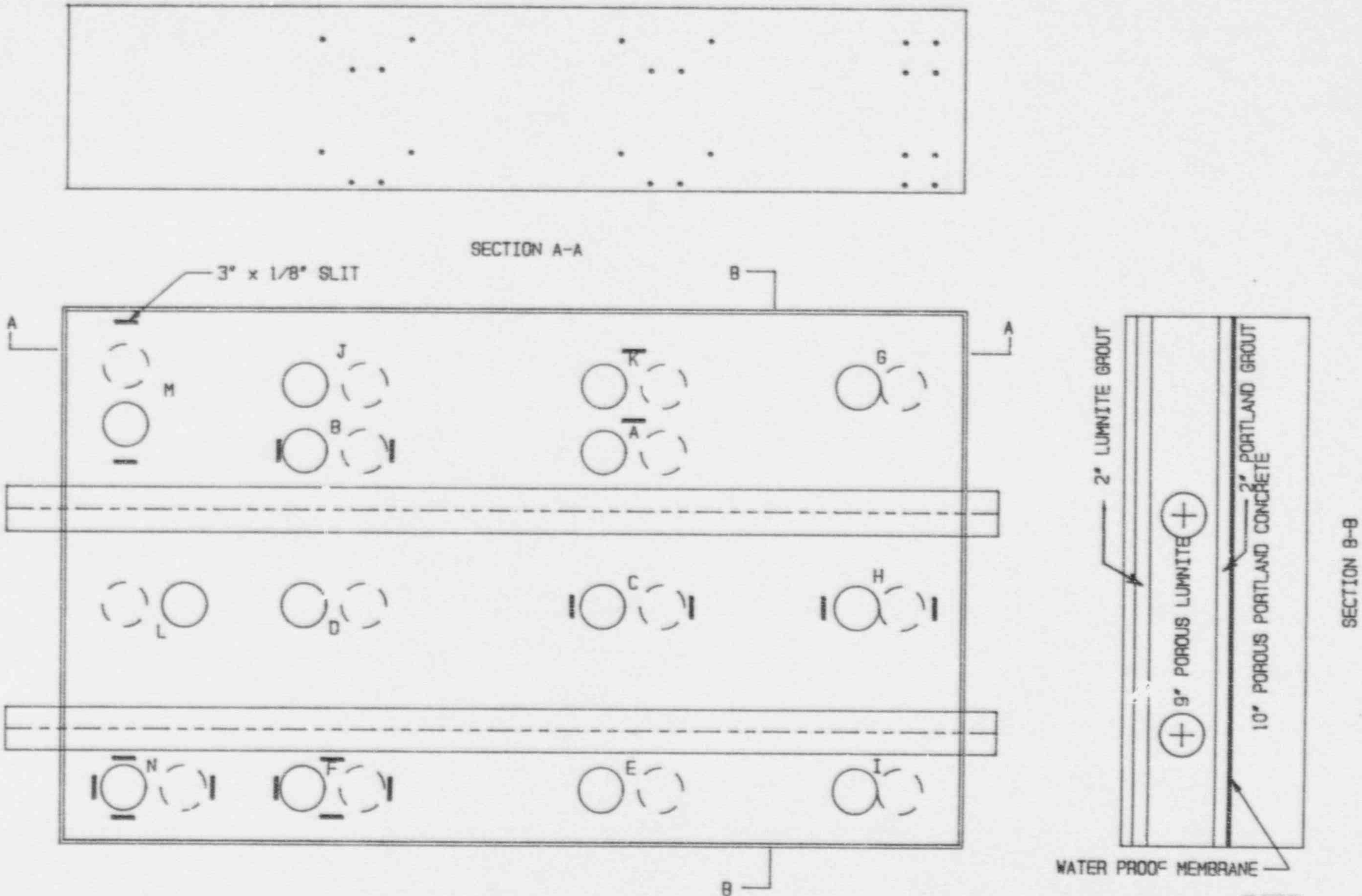


FIGURE 6 MOLD C SHOWING LOCATION OF SLITS IN MEMBRANE

REVISED (Intentionally left blank)

FIGURE 7 AGGREGATE COMPACTION STRESS VS STRAIN

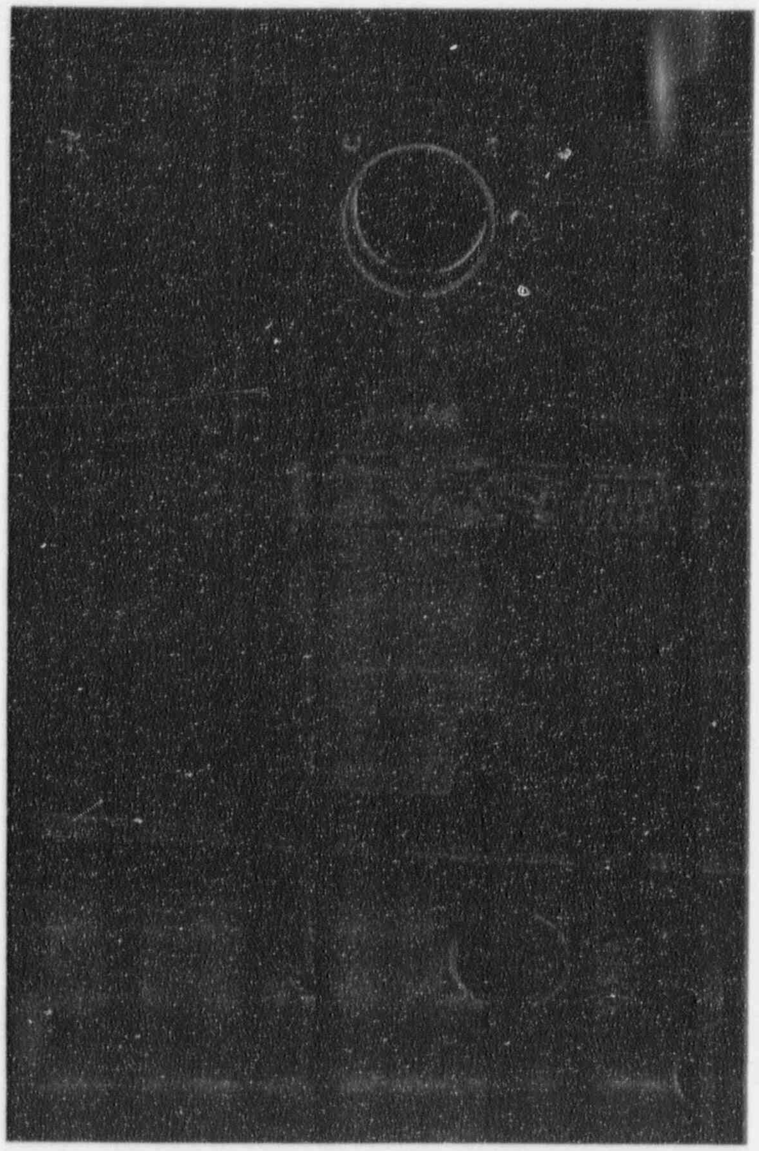


FIGURE 8 WHITE RESIDUE FROM MOLD

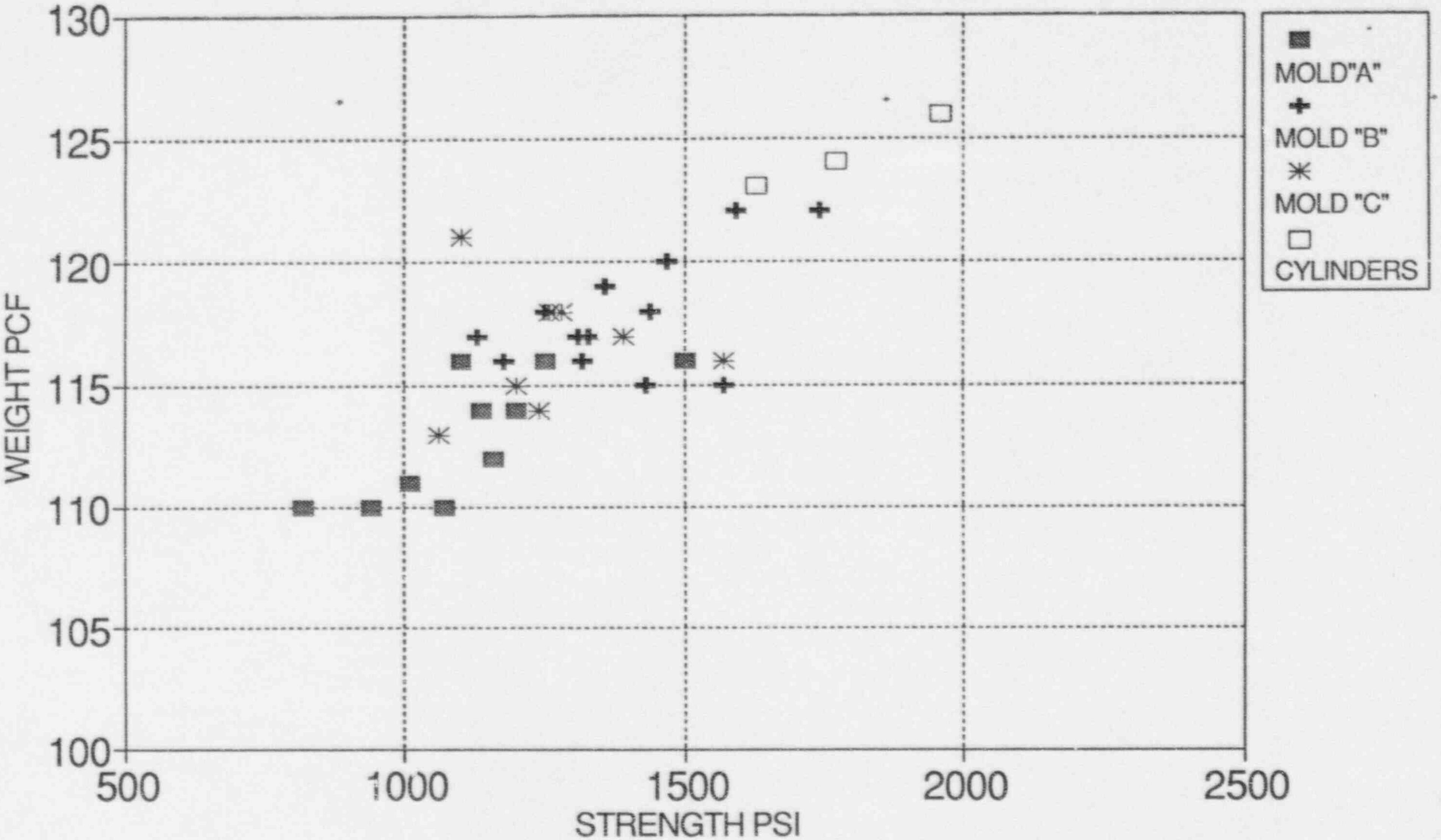


FIGURE 9 CORE STRENGTH VS WEIGHT LUMNITE CONCRETE

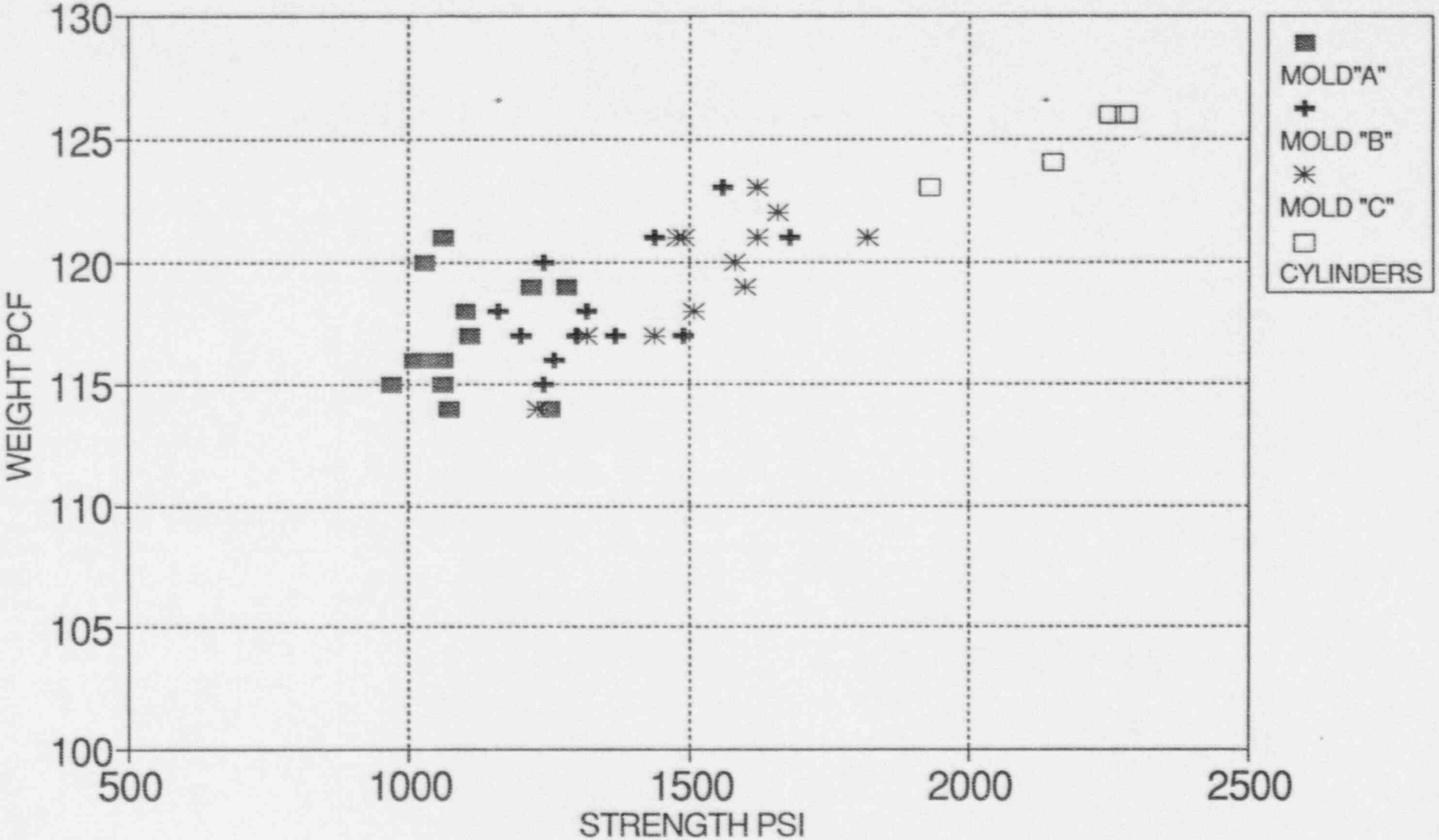


FIGURE 10 CORE STRENGTH VS WEIGHT PORTLAND CONCRETE

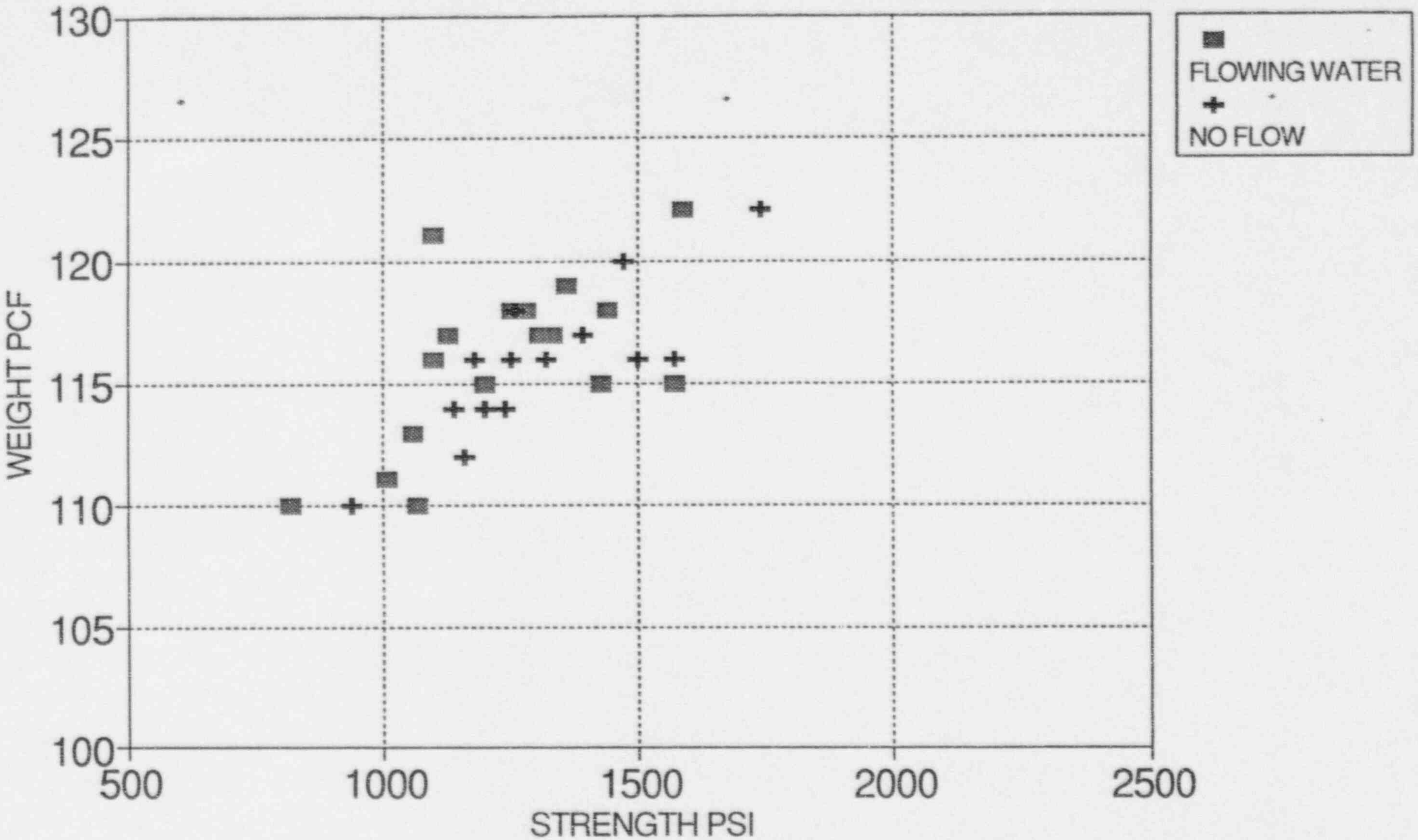


FIGURE 11 CORE STRENGTH VS WEIGHT LUMNITE CONCRETE

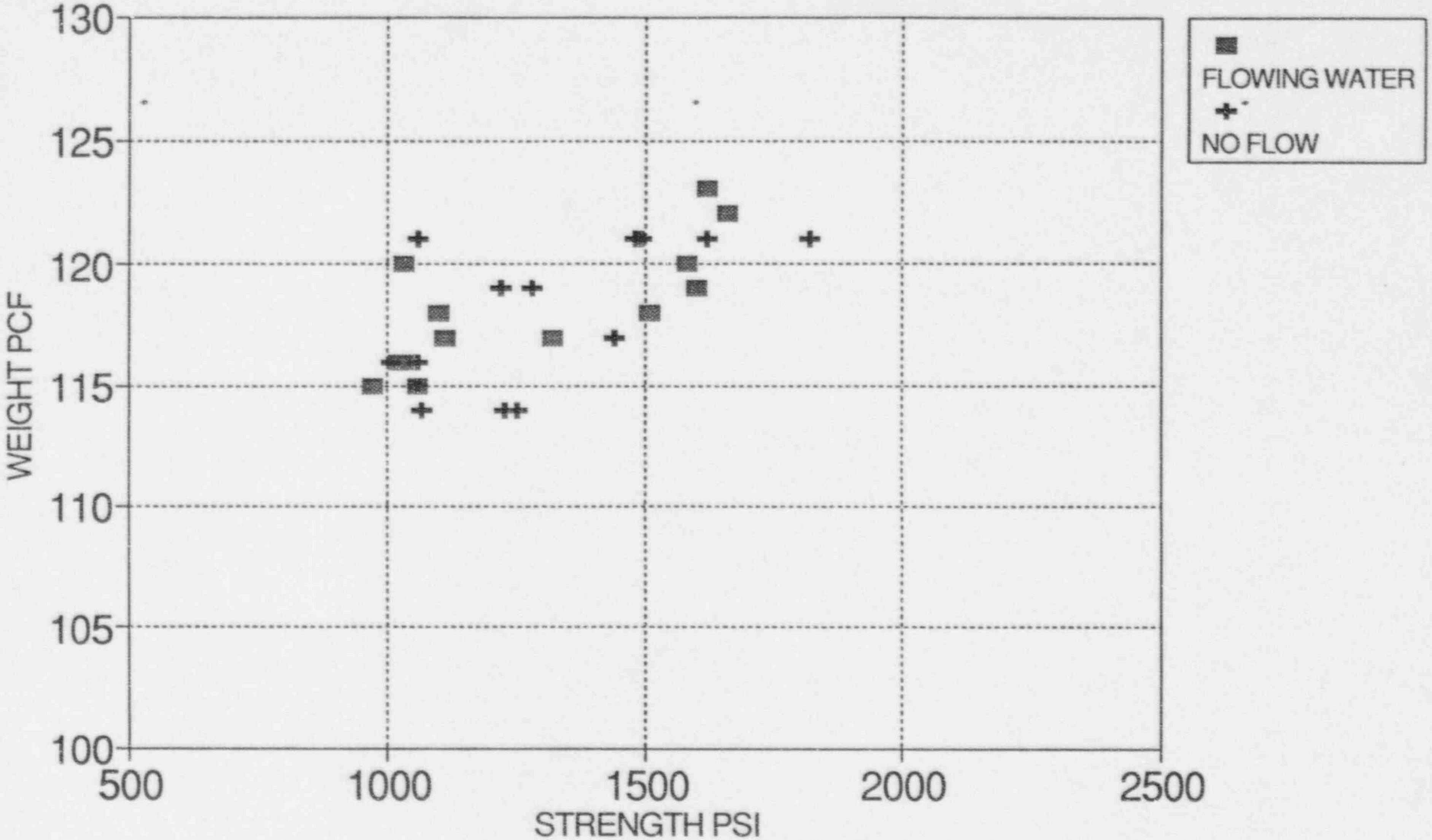


FIGURE 12 CORE STRENGTH VS WEIGHT PORTLAND CONCRETE

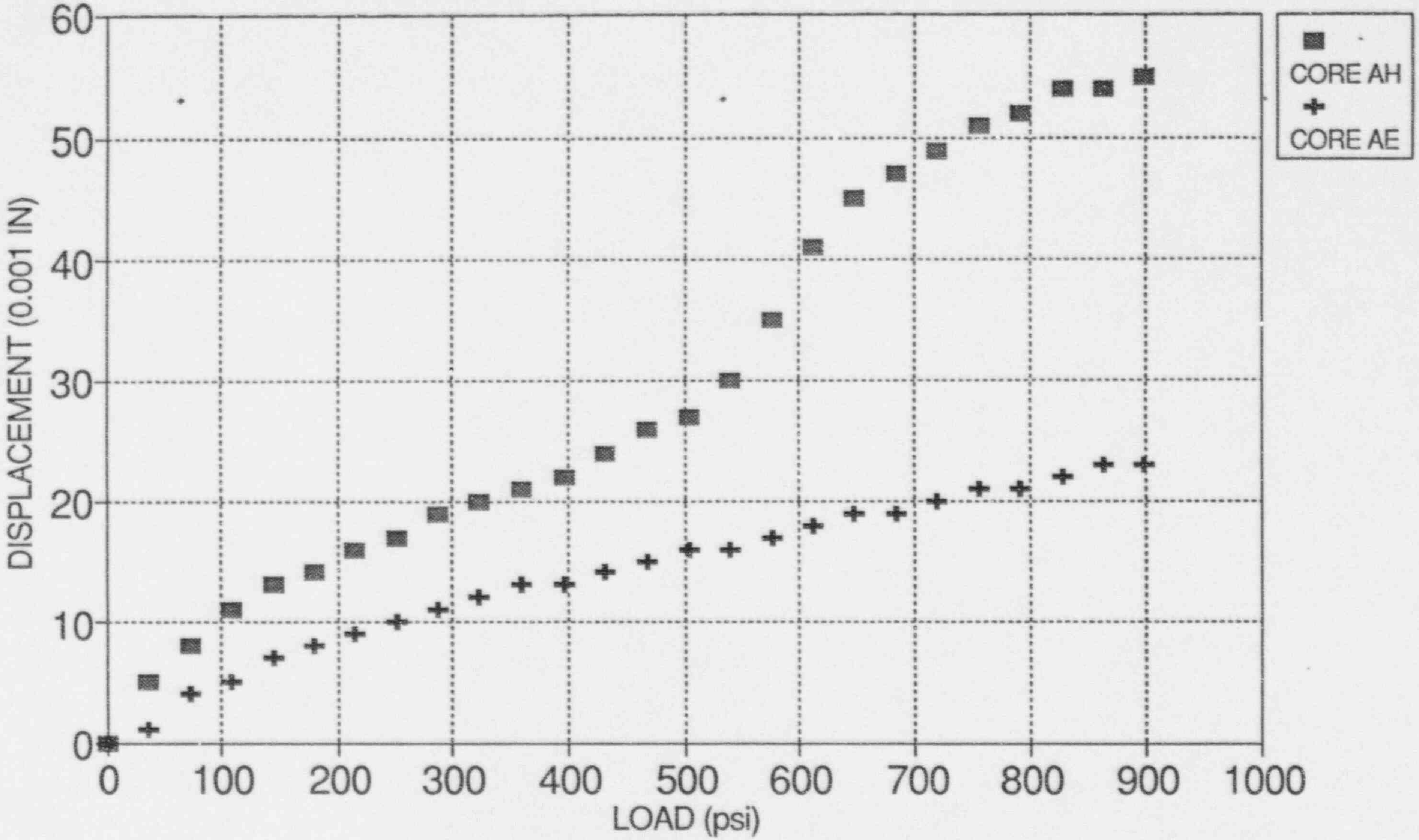


FIGURE 13 CONFINED COMPRESSION TEST MOLD "A" INTERFACE

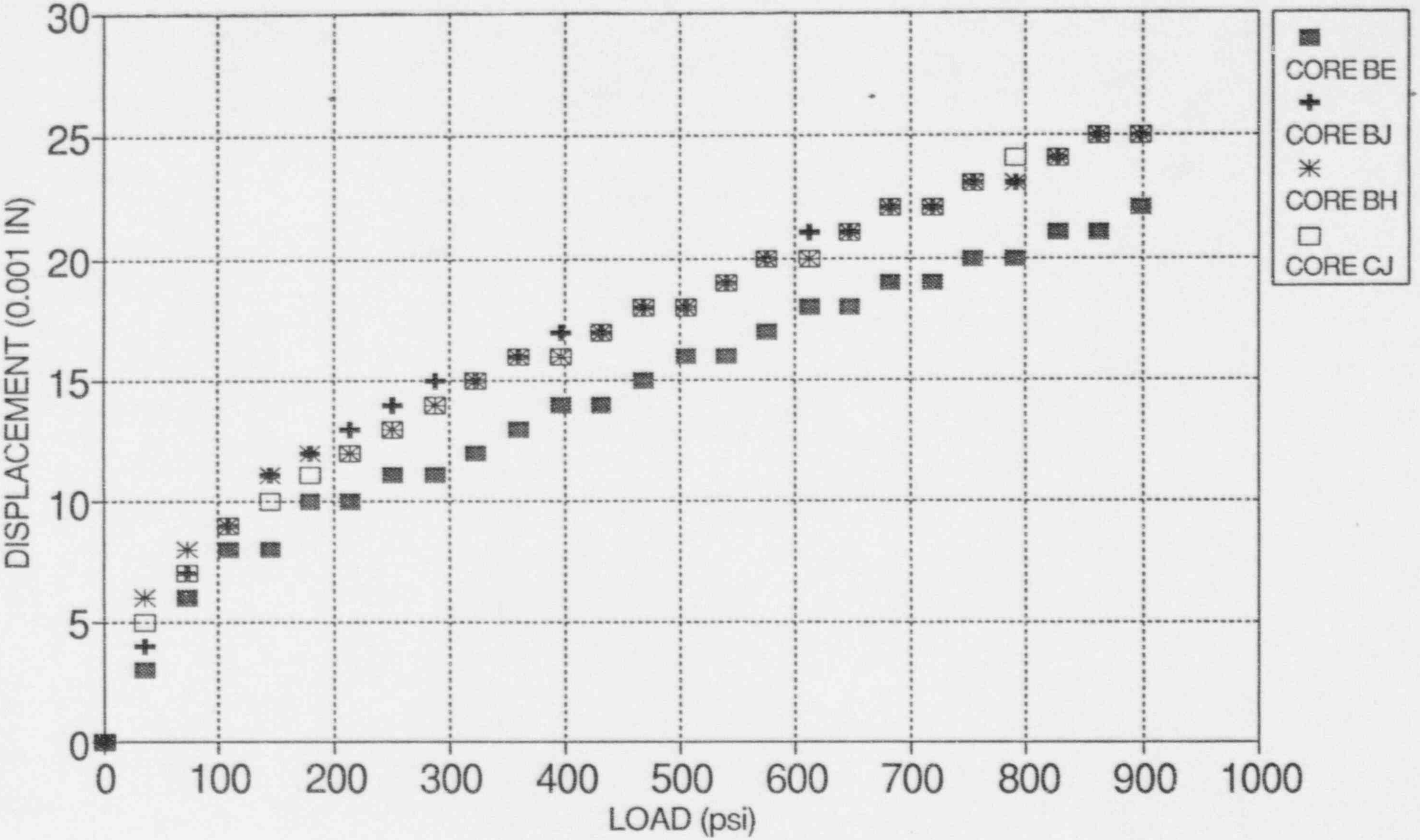


FIGURE 14 CONFINED COMPRESSION TEST MOLD "B" & "C" LUMNITE CONCRETE

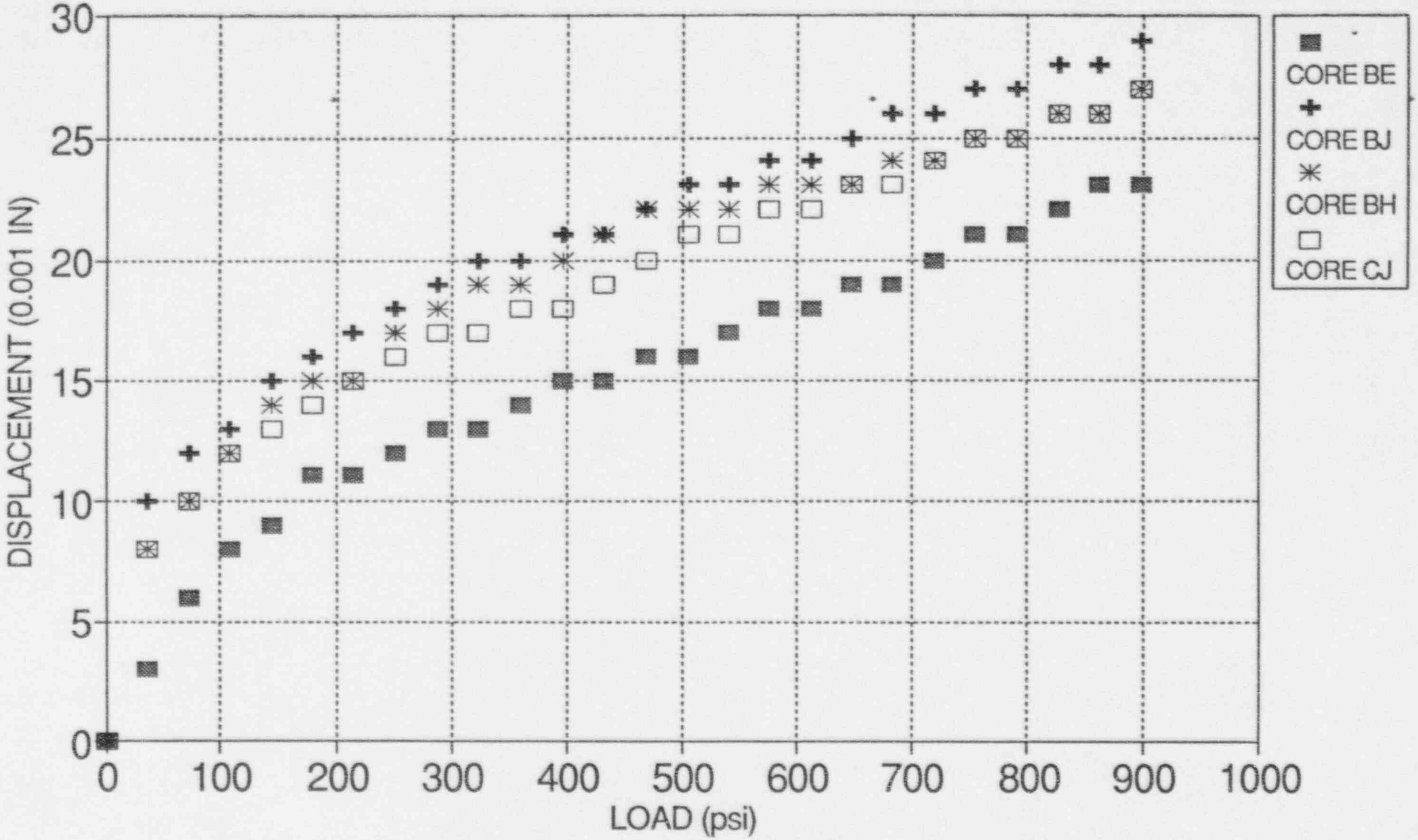


FIGURE 15 CONFINED COMPRESSION TEST MOLD "B" & "C" PORTLAND CONCRETE

APPENDIX A

MATERIAL SPECIFICATIONS AND DOCUMENTATION

Trow Protze Consulting Engineers

67 Fourth Avenue
Needham Heights, MA 02194

Telephone (617) 444-4910
Facsimile (617) 444-5135

Project No. TP-4518-B2

ALDEN RESERARCH LABORATORY, INC.
HOLDEN, MASSACHUSETTS

TEST OF CONCRETE COARSE AGGREGATE
POROUS CONCRETE MOCK-UP TESTING
MILLSTONE, UNIT 3, WATERFORD, CT.
ARL; NU/CONCRTE II-295/93/1

REFERENCE NUMBER 93S-93

DATE RECEIVED 4-16-93

SOURCE Submitted from the Waregan quarry by Tilton Connecticut, Inc.

SAMPLE Three 55-gallon drums of Tilton 3/4" trap rock for use in preliminary test samples for concrete for subject project.

TEST PROCEDURE ASTM C33

RESULTS

SIEVE	RETAINED
1"	0%
3/4	3
1/2	49
3/8	76
#4	97
F.M	6.76

Organic Plate	Zero
Specific Gravity	2.75 (Bulk)
Absorption	0.3%
Acid	None
Alkali	None
Organic	None

REMARKS The coarse aggregate is clean, well graded and suitable for the given use.

Project No. TP-04518-B2

Alden Research Laboratory, Inc.
Shrewsbury, Massachusetts

Preliminary Analyses of Tilcon 3/4" Aggregate

Sieve Size	Original Sample 4/16/93	Morning Truck 6/22/93	PM Truck 6/22/93	ASTM Requirements 3/4"	ASTM Requirements 1"
1"	0%	0%	0%	0%	0-5%
3/4	3	6	5	0-10	
1/2	49	70	65		40-75
3/8	76	90	85	45-80	
#4	97	96	95	90-100	90-100
F.M.	6.76	6.92	6.85	6.70	6.95
Remarks:	OK	Lacks Fines	Lacks Fines		

Material was approved based upon past experience and the preliminary sample submitted on 4/16/93 which was a well graded 3/4" stone. The material delivered on 6/22/93 lacked fines and barely met ASTM grading requirements for the 1" grading. It did not meet the 3/4" requirements. The two typical samples carefully selected from the materials used (as shown on the Concrete Control Sheets herewith) lacked even more fines than the above gradations.

The original sample received on 4/16/93 was analyzed for additional physical properties as follows:

Bulk Specific Gravity	2.75
Total Absorption	0.3%
Weight dry loose	96 lb/cu.ft.
Weight dry rodded	106 lb/cu.ft.
Voids, dry loose	44%
Voids, dry rodded	38%

A blend of the poorly graded material delivered on 6-22-93 and used in the three forms at Alden Laboratory gave the following properties:

Weight dry loose (ASTM Standard)	83 lb./cu.ft.
Weight tamped lightly, 4 layers	93 "
Weight heavily tamped, 4 layers	97 "
Voids heavily tamped	43%
Desired density, dry rodded	126-131 lb./cu.ft.

A3

RECEIVED

JUN 1 1 1993

AHL, INC.

MILL TEST REPORT

LEHIGH PORTLAND CEMENT CO.

BUFFINGTON PLANT — GARY, INDIANA

CONSIGNEE: ______ ADDRESS: ______

DATE SHIPPED: ______ ______

CEMENT TYPE: LUMNITE TRUCK/CAR NUMBER ______

PHYSICAL TEST DATA:

FINENESS,

BLAINE, (m^2/kg) 336

INITIAL SET

VICAT (hr:min) 05:10

COMPRESSIVE STRENGTH

ASTM C-109, 24 HOURS

(psi) 6080

CHEMICAL ANALYSIS:

SILICA, % SiO_2 6.25

ALUMINA, % Al_2O_3 50.93

IRON OXIDE, % Fe_2O_3 7.28

CALCIUM OXIDE, % CaO 34.16

MAGNESIA, % MgO 0.65

SULPHUR TRIOXIDE, % SO_3 0.38

LOSS ON IGNITION, % 0.36

WE WARRANT THAT TEST RESULTS SHOWN WERE OBTAINED USING GENERALLY ACCEPTED LABORATORY PRACTICES, INCLUDING ASTM METHODS AND PROCEDURES WHERE APPLICABLE.

DATE: 6/8/93

QUALITY CONTROL SUPERVISOR: [signature]

Laboratory Test Report

LEHIGH PORTLAND CEMENT COMPANY

CEMENTON, NY

030
KESSELI & MORSE
242 CANTERBURY ST
FOB CEMENTON PLANT
WORCESTER MA

Consignee: Address:

CUSTOM

Date: 2/18-24/93 Plant : Cementon

32-34051

Type: I-II Car/Truck: Bin No.: 56 TONS:

Results of Tests

Chemical	
Si02:	21.5
Al203:	4.5
Fe203:	2.9
Ca0:	63.8
Mg0:	2.2
S03:	2.5
K20:	0.48
Na20:	0.09
Na20 Equiv.	0.42
LOI:	1.3
Insol.:	0.30
Potential Compounds:	
C3S:	54
C2S:	21
C3A:	7
C4AF:	9

Physical	
Fineness, Specific Surface-m2/kg	
Blaine:	397
Autoclave:	0.01
Air Content %	9
Gilmore, Time of Set	
Initial (Min)	150
Final (Min)	270
Compressive Strength, psi:	
1-day	1790
3-day	3360
7-day	4360
28-day	

We certify that the above-desribed cement, at the time of shipment, meets the chemical and physical requirements of the current applicable specification ASTM C-150, AASHTO M-85. We are not responsible for improper use or workmanship.

OK Herman G. Protzo

Date: 15-Mar-93

Quality Control Supervisor: [signature]

67 Fourth Avenue
Needham Heights, MA 02194

Trow Protze Consulting Engineers

Telephone (617) 444-4910
Facsimile (617) 444-5135

TP-04518-B2

ALDEN RESEARCH LABORATORY, INC.
HOLDEN, MASSACHUSETTS

CHEMICAL ANALYSES OF WATERS
POROUS CONCRETE MOCK-UP TESTING
MILLSTONE, UNIT 3, WATERFORD, CT
ARL; NU/CONCRETE II - 295/93/1

REFERENCE NUMBER 93S-93A,B

DATE RECEIVED 4-16-93

SOURCE Submitted by you as taken at (A.) your facility for proposed curing water and at (B.) Concrete Services, Inc., North Grafton concrete plant (the source of concrete and batch water for the proposed concrete for the subject project).

SAMPLE Two 1 quart samples of water identified as:

- A, Curing Water
- B, Batch Water

TEST PROCEDURE APHA methods of analysis

RESULTS The following data have been obtained:

		A	B
Chloride ions,	parts per million	Trace	20
Salt as NaC1,	parts per million	Trace	35
Salt as Na_2SO_4,	parts per million	None	< 5
Oil		None	None
Organic (3.0% NaOH)		None	None

REMARKS It is indicated that both sources of water are totally suitable for the given proposed uses.

Project No. TP-04518-B2

Alden Research Laboratory, Inc.
Shrewsbury, Massachusetts

Mixtures Used in Preliminary Compression Tests

Each mixture includes 3 cores drilled from the Sonotube forms 18" diameter by 12" high and 4 cylinders cast in standard 6"x12" plastic molds from same batches.

Series 1, Ref. No. 336

Portland Cement	447 lb.	22.35 lb.
Tilcon Stone	2638 "	131.9 "
Water	17.5 gal.	7.28 "
Amount	1.0 cu.yd.	1.35 cu. ft.

Series 2, Ref. No. 337

Lumnite Cement	447 lb.	22.35 lb.
Tilcon Stone	2835 "	141.75 "
Water	17.5 gal.	7.28 "
Amount	1.0 cu.yd.	1.35 cu. ft.

Series 3, Ref. No. 338

Portland Cement, 10%	44.7 lb.	2.24 lb.
Lumnite Cement, 90%	402.3 "	20.11 "
Tilcon Stone	2815.3 "	140.76 "
Water	17.5 gal.	7.28 "
Amount	1.0 cu.yd.	1.35 cu.ft.

Series 4, Ref. No. 339

Portland Cement, 90%	402.3 lb.	20.11 lb.
Lumnite Cement, 10%	44.7 "	2.24 "
Tilcon Stone	2657.7 "	132.89 "
Water	17.5 gal.	7.28 "
Amount	1.0 cu.yd.	1.35 cu.ft.

67 Fourth Avenue
Needham Heights, MA 02194

Trow Protze Consulting Engineers

Telephone (617) 444-4910
Facsimile (617) 444-5135

Project No. TP-04518-B2

Alden Research Laboratory, Inc.
Shrewsbury, Massachusetts

Preliminary Compression Tests of Crushed Stone Concrete Cylinders & Cores

Date Cast: May 14, 1993
Dates Tested: See Below
Core Size: 5.68" x 11.35"
Cylinder Size: 6.0" x 12.0"

Cores drilled from 18" diameter x 12" high Sonotube forms at 28 days.

Ref No.	Series	Cement	Specimens	Voids	Density pcf	Days Age	Compress. Strength
336-1	1	100% Portland	Core		117	31	1380
336-2	1	"	"		116	31	1280
336-3	1	"	"		117	45	1420
336-A	1	"	Cylinder	26.7%	116	39	1500
336-B	1	"	"	25.6	117	39	1490
336-C	1	"	"	26.9	116	39	1340
336-D	1	"	"	24.6	117	45	1850
				25.95%			
337-1	2	100% Luminite	Core		121	31	1940
337-2	2	"	"		121	31	1930
337-3	2	"	"		121	45	2150
337-A	2	"	Cylinder	26.7%	116	39	1980
337-B	2	"	"	26.2	116	39	2010
337-C	2	"	"	25.9	116	39	2140
337-D	2	"	"	25.2	118	45	2420
				26.00%			
338-1	3	10% Ptld.,90% Lum.	Core		118	31	1550
338-2	3	"	"		118	31	1530
338-3	3	"	"		118	45	1580
338-A	3	"	Cylinder	27.6%	115	39	1610
338-B	3		"	26.0	117	39	1650
338-C	3	"	"	25.4	117	39	1770
338-D	3	"	"	26.1	117	45	1720
				26.28%			
339-1	4	90%Ptld.,10%Lum.	Core		119	31	1200
339-2	4	"	"		119	31	1210
339-3	4	"	"		119	45	1440
339-A	4	"	Cylinder	25.7%	118	39	1230
339-B	4	"	"	25.7	120	39	1350
339-C	4	"	"	23.9	120	39	1490
339-D	4	"	"	24.7	118	45	1730
				25.00%			

Trow Protze Consulting Engineers

67 Fourth Avenue
Needham Heights, MA 02194

Telephone (617) 444-4910
Facsimile (617) 444-5135

Project No. TP-04518-B2

Alden Research Laboratory, Inc.
Shrewsbury, Massachusetts

Compression Test of Cement Blends & Mortars (Laboratory Tests Only)

Date Cast: 5-19-93
Date Tested: 6-16-93
Age at Test: 28 days

Cylinder Size:
Diameter: 3.0"
Height: 3.0"

Mix Compositon

Ref. No.	CaA1	Ptld.	Sand	W/C	Density lb./c.f.	Compress Strength	Remarks
354-A	90%	10%	0	0.19	131	4670	
354-B	"	"	"	"	131	4850	
355-A	10%	90%	0	0.21	121	7360	
355-B	"	"	"	"	121	*	Cracked
356-A	50%	50%	0	0.27	117	1300	Stiffens fast
356-B	"	"	"	"	118	1720	
357-A	0%	100%	0	0.20	121	9060	
357-B	"	"	"	"	122	9200	
358-A	100%	0%	0	0.18	126	8620	
358-B	"	"	"	0.18	126	7740	
359-A	90%	10%	215%	0.50	138	9320	
359-B	"	"	"	"	139	9490	
360-A	10%	90%	"	0.47	138	7670	
360-B	"	"	"	"	138	7550	
361-A	50%	50%	"	0.48	136	2570	Flash Set
361-B	"	"	"	"	135	2550	"
362-A	0%	100%	"	0.50	137	8740	
362-B	"	"	"	"	137	8480	
363-A	100%	0%	"	0.49	140	10090	
363-B	"	"	"	"	139	9930	

*Excessive reaction; specimen disintegrated in 3 hours after casting.

APPENDIX B

CONCRETE BATCH WEIGHTS AND MIX CONTROL

CONCRETE CONTROL For Alden Research Laboratory, Inc.
Shrewsbury, Massachusetts

Log No. 1
Date 6-23-93
TP-04518-B2

LOCATION OF PLACEMENT Research Models IIA, B, C
Bottom 10" layer (Mix A)

TYPICAL BATCH QUANTITIES

Vendor	Concrete Service Inc.			
Plant	North Grafton (Plant 2)			
Mix No. & Form	A (IIC)	A(IIB)	A(IIA)	
Class Concrete	---	---	---	
Time at Site	8:50	9:40	10:35	(Batched at 8:05 AM)
Size Load, Cu.Yd.	6.5			
Cement, lbs.	2925		+94	
Fine Agg, lbs.	---			
Coarse Agg, lbs.	17400			
Water Added, gal	50+45+3	+3	+2+6	
Moisture in FA, %	---			
Moisture in CA, %	1.0			
W/C Ratio, gal/sack	3.5	3.6	3.7	
Admix	None			

ANALYSIS OF AGGREGATES

Sieve	None Used	Sieve	Tilcon 3/4" Crushed Stone
#4		1	0%
16		3/4	5
30		1/2	70 - high
50		3/8	90 - high
100		#4	97
F.M.		F.M.	6.92

Organic

MISCELLANEOUS INFORMATION

Weather	Fair, 62-70°F
Cement Brand	Lehigh Type II
Test Cylinders	1ABCD, 2ABCD
No. Loads Inspected	1
Inspection Ticket Nos.	None issued
C.Y. Inspect. this Date	6.5 (Extra 1/2 cu.yd. added to compensate for wet load)
C.Y. Inspect. to Date	6.5
Plant Inspection Time	2 1/4 hours (7:00AM - 8:15AM + Travel) + Site
Plant Inspector	E. Van Buren

REMARKS

Equipment: Truck checked for cleanliness.
Scales checked during batching.
Aggregate poorly graded. Lacks fines.
Special Items: Aggregate bin & truck washed out prior to batching.

CONCRETE CONTROL For — Alden Research Laboratory, Inc.
Shrewsbury, Massachusetts

Log No. 2
Date 6-28-93
TP-04518-B2

LOCATION OF PLACEMENT — Research Models IIB, C
Second lift, 2" layer (Mix D)

TYPICAL BATCH QUANTITIES

Vendor	Concrete Service Inc.
Plant	North Grafton (Plant 2)
Mix No. & Form	D (IIB and IIA)
Class Concrete	---
Time at Site	8:30 (Batched at 7:50 AM)
Size Load, Cu.Yd.	3
Cement, lbs.	2940
Fine Agg, lbs.	6680 at 5.0% Moisture
Coarse Agg, lbs.	---
Water Added, gal	150+35
Moisture in FA, %	5.0
Moisture in CA, %	---
W/C Ratio, gal/sack	6.0
Admix	None

ANALYSIS OF AGGREGATES

Sieve	Millbury Sand	Sieve	None Used
#4	1%	1 1/2"	
8	13	1	
16	33	3/4	
30	53	1/2	
50	76	3/8	
100	93	#4	
F.M.	2.69	F.M.	

Organic 0+

MISCELLANEOUS INFORMATION

Weather	Fair, 71-75°F
Cement Brand	Lehigh Type II
Test Cylinders	3ABCD
No. Loads Inspected	1
Inspection Ticket Nos.	None issued
C.Y. Inspect. this Date	3
C.Y. Inspect. to Date	9.5
Plant Inspection Time	2 1/4 hours (7:00AM - 8:15AM + Travel) + Site
Plant Inspector	E. Van Buren

REMARKS

Equipment satisfactory.
Scales checked during batching.
Aggregate well graded.
Special Items: Mixer washed before batching. No water in drum.

CONCRETE CONTROL For Alden Research Laboratory, Inc.
Shrewsbury, Massachusetts

Log No. 3
Date 6-30-93
TP-04518-B2

LOCATION OF PLACEMENT Research Models IIA,B,C
Third Lift (9" layer), Mix B

TYPICAL BATCH QUANTITIES

Vendor	Concrete Service Inc.			
Plant	North Grafton (Plant 2)			
Mix No. & Form	B (IIC)	B(IIB)	B(IIA)	
Class Concrete	---	---	---	
Time at Site	8:35	11:25	2:10	(Batched at 8:05, 10:45, 1:35)
Size Load, Cu.Yd.	3	3	3	
Cement, sacks @ site	15	15	15	
Fine Agg, lbs.	---	---	---	
Coarse Agg, lbs.	8975	8975	8960	
Water Added, gal	55	5	55	
Moisture in FA, %	---	---	---	
Moisture in CA, %	0.5	0.5	0.4	
W/C Ratio, gal/sack	3.7	3.7	3.7	
Admix	None	None	None	

ANALYSIS OF AGGREGATES

Sieve	None Used	Sieve	Tilcon 3/4" Crushed Stone
#4		1 1/2"	
8		1	0%
16		3/4	6
30		1/2	73 - high
50		3/8	92 - high
100		#4	99 - high
F.M.		F.M.	6.97

Organic

MISCELLANEOUS INFORMATION

Weather	Cloudy, 72-80°F
Cement Brand	Lumnite, Calcium Aluminate
Test Cylinders	4AB, 5AB, 6AB
No. Loads Inspected	3
Inspection Ticket Nos.	None issued
C.Y. Inspect. this Date	9
C.Y. Inspect. to Date	18 1/2
Plant Inspection Time	8 1/2 hours (7:00AM - 1:30PM + Travel) + Site
Plant Inspector	E. Van Buren

REMARKS

Equipment: Bins and truck mixer washed before initial batching.
Scales checked during batching.
Aggregate very poorly graded. Lacks fines.
Special Items: Truck washed & scrubbed before and after each use.

CONCRETE CONTROL For Alden Research Laboratory, Inc.
Shrewsbury, Massachusetts

Log No. 4
Date 7-7-93
TP-04518-B2

LOCATION OF PLACEMENT Research Models IIA,B,C
Final 2" layer (Mix C)

TYPICAL BATCH QUANTITIES

Vendor	Concrete Service Inc.			
Plant	North Grafton (Plant 2)			
Mix No. & Form	C (IIC)	(IIB)	(IIA)	
Class Concrete	---	---	---	
Time at Site	8:50	9:10	9:20	(Batched at 8:00AM)
Size Load, Cu.Yd.	2			
Cement, sacks @ site	23			
Fine Agg, lbs.	4680 @ 5.0% moisture			
Coarse Agg, lbs.	---			
Water Added, gal	120+25			
Moisture in FA, %	5.0			
Moisture in CA, %	---			
W/C Ratio, gal/sack	6.3	6.3	6.3	
Admix	None	None	None	

ANALYSIS OF AGGREGATES

Sieve	Millbury Sand	Sieve	None Used
#4	4%	1 1/2"	
8	12	1	
16	19-low	3/4	
30	38-low	1/2	
50	62-low	3/8	
100	82-low	#4	
F.M.	2.17-unsatisfactory	F.M.	

Organic 0+

MISCELLANEOUS INFORMATION

Weather	Fair, 76-80°F
Cement Brand	Lumnite, Calcium Aluminate
Test Cylinders	7AB, 8AB
No. Loads Inspected	1
Inspection Ticket Nos.	None issued
C.Y. Inspect. this Date	2
C.Y. Inspect. to Date	20 1/2
Plant Inspection Time	5 hours (6:45AM - 8:15AM + Travel) + Site
Plant Inspector	E. Van Buren

REMARKS

Equipment: Truck mixer washed and without water in drum.
Scales checked during batching.
Aggregate very poorly graded (too fine).
Special Items: Mixer drum inspected and certified clean and suitable before and after use.

APPENDIX C

CONCRETE TESTING LABORATORY INSPECTION REPORT

C1

NIST
UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

RECEIVED
AUG 29 1991
TROW-PROTZE
THANK YOU

August 27, 1991

Mr. Herman G. Protze, P.E., Executive Engineer
Trow-Protze, Consulting Engineers
70 Jaconnet Street
Newton Highlands, Massachusetts 02161

Subject: Inspection of Concrete Testing Laboratory

Dear Mr. Protze:

Enclosed is a confirmatory report on Inspection No. S-970, which was completed in your testing laboratory at Newton Highlands, Massachusetts, on July 3, 1991, by a representative of the Cement and Concrete Reference Laboratory.

This letter, and the accompanying report, provide written evidence that your laboratory has been inspected during the 27th Inspection Tour.

It is requested that these evidences of the inspection not be used for advertising, publication, or promotional purposes.

Very truly yours,

James H. Pielert

James H. Pielert, Manager
Cement and Concrete Reference Laboratory
Building Materials Division
Building and Fire Research Laboratory

Enclosure

cc: C. J. Dinezio

CEMENT and CONCRETE REFERENCE LABORATORY

INSPECTION REPORT

U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, MD 20899

CEMENT AND CONCRETE REFERENCE LABORATORY
AT THE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
GAITHERSBURG, MARYLAND 20899
(301) 975-6704

SPONSORED BY
COMMITTEE C-1 ON CEMENT
COMMITTEE C-9 ON CONCRETE
CONCRETE AGGREGATES
AMERICAN SOCIETY FOR TESTING AND MATERIALS

August 27, 1991

INTRODUCTION
TO
REPORT ON INSPECTION
OF
CONCRETE TESTING LABORATORY

This report covers an inspection, designated Inspection No. S-970, which was performed by a representative of the Cement and Concrete Reference Laboratory in the concrete testing laboratory of Trow-Protze, Consulting Engineers, at Newton Highlands, Massachusetts, on July 3, 1991.

The report has one, two or three parts, depending on the scope of the inspection. Part I covers the inspection of concrete testing facilities; Part II, when included, covers the inspection of aggregate testing facilities; and Part III, when included, covers the inspection of the testing facilities for concrete reinforcing bars.

Each part has three sections. The first section describes the scope of the inspection. The second section contains a summary of the findings. The third section contains a series of footnotes in which departures from specification requirements, mechanical deficiencies in apparatus, and other important matters are covered in detail. In addition, there is a closure.

Several pieces of apparatus in the laboratory have been assigned CCRL identification numbers. Some of these numbers are listed in the summary and footnote sections.

In the interest of brevity, any minor adjustments of apparatus which may have been made while the inspection was in progress have not been mentioned. When necessary, additional explanatory information about the inspection will be furnished in separate correspondence.

Information concerning the qualifications of supervisory personnel is included where appropriate.

Unless otherwise indicated, the specifications and methods of test to which references are made are standards of the American Society for Testing and Materials.

Copies of this report, or parts thereof, are not to be used for promotional purposes.

PART I: INSPECTION OF CONCRETE TESTING FACILITIES

DESCRIPTION OF INSPECTION

The inspection of concrete testing facilities was designed to include an examination of the apparatus prescribed for use in the methods of test for concrete indicated in Section 7.2 of ASTM C1077; a review of the laboratory's quality assurance system; an examination of the apparatus or procedures prescribed in any optional test methods presented for inspection; and an observation of several of the procedures used in the testing of concrete.

The ASTM Standards on which the work was based are as follows: C31-90, C39-86, C138-81, C143-90, C172-90, C173-78, C231-89, C470-87, C511-85, C617-87, C1077-90, E4-89, and E171-82.

Apparatus

Tamping Rods (C143)

The 5/8-inch diameter tamping rods which were immediately available for use in various rodding operations were checked for conformance to the design and dimensional requirements of C143.

Slump Cones (C143)

Each slump cone presented for inspection was checked for conformance to the design and dimensional requirements of C143, and the physical condition was observed.

Unit Weight Apparatus (C138)

The capacity of each scale or balance used in determining the unit weight of plastic concrete was recorded, and the accuracy checked for conformance to the requirements of Section 4.1 of C138. The design, dimensions, and physical condition of each unit weight measure presented for inspection was checked for conformance to the requirements of Section 4.4; a check was made to determine if the required flat strike-off plate was available; and inquiry was made as to whether the measure had been calibrated in accordance with Section 5.

Apparatus for Air Content of Plastic Concrete (Volumetric Method) (C173)

The design of each air meter used in determining the air content of concrete by the volumetric method was checked for conformance to the design requirements of C173, and observations were made to determine that the necessary funnel, strike-off bar, metal measuring cup, syringe, pouring vessel, tamping rod, trowel, and scoop were on hand.

Apparatus for Air Content of Plastic Concrete (Pressure Method) (C231)

The design of at least one of the air meters used in determining the air content of freshly mixed concrete by the pressure method was checked for conformance to the design requirements of C231, and observations were made to determine that the necessary trowel, syringe, tamping rod, mallet, strike-off bar, and pouring vessel were on hand.

Compression Test Apparatus (C39, C470 and C617)

Apparatus used in making compressive strength tests of concrete not covered elsewhere in this report includes the cylinder molds and vibrators used in fabricating specimens, the capping equipment and materials used to obtain smooth load bearing surfaces on specimens, and the compression machine in which specimens are tested.

Cylinder Molds. - Cylinder molds are classified according to intended use as reusable molds and single-use molds. Where reusable molds were employed, the design, dimensions, and watertightness of several molds considered to be typical of those used by the laboratory were checked for conformance to the requirements of C470. Where single-use molds were employed, the design, dimensions, and water absorption characteristics of several molds considered to be typical of those used by the laboratory were checked for conformance to the specification.

Vibrators. - Each vibrator used in consolidating test specimens made from low-slump concrete was checked for conformance to the requirements for such devices set forth in Section 4.5 of C31.

Capping Equipment and Materials. - The apparatus and material used in capping concrete cylinders were checked for conformance to the requirements of C617, with particular attention being given to the dimensions, planeness, surface condition, and thickness of capping plates; and to the preparation and use of the capping material. In addition, the planeness of the caps on several specimens was checked.

Compression Machine. - Unless otherwise noted, only one testing machine was inspected. During this inspection, several of the more important mechanical and design features were noted; the design, dimensions, and surface planeness of bearing blocks used in testing concrete cylinders were checked for conformance to the requirements of C39; and the accuracy of load indication was verified.

The verification tests were made using force measuring instruments calibrated at the National Institute of Standards and Technology. In these tests, each load indicator was set at the zero position customarily employed by the laboratory. Test loads were approached by increasing the load from a lower load as specified in Method E4; the force-measuring instrument and the machine were individually operated as is considered to be good practice; and all load readings were corrected for differences between the test temperature and the temperature at which the instrument was calibrated.

Facilities for Curing Test Specimens (C31 and C511)

An investigation was made to determine if storage facilities for curing of concrete test specimens were available. Each tank or moist room used for curing compression specimens were then checked for conformance to the requirements of C511.

During the examination, temperature and relative humidity readings were taken as appropriate to determine if the curing environment conformed to the requirements of applicable standards; an observation was made to determine if all specimens in storage had free water on the entire surface area; and a check was made to determine if each unit was equipped with thermostatic temperature control and with a recording thermometer as required by C511. In addition, it was asked if the water in each tank was saturated with lime, and the state of cleanliness of the water and the condition of the interior surfaces of the tank were noted.

Miscellaneous

The temperature of the air in the laboratory was checked for conformance with the range (20° to 30°C) set forth in E171.

The containers and packing materials which the laboratory prescribes for use in transporting cylinders were inspected for obvious deficiencies.

A check was made to determine if the laboratory had been supplied with a copy of the latest edition of the ASTM Book of Standards pertaining to the testing of concrete.

Optional Methods

At the discretion of the laboratory, selected optional test methods as set forth in Section 7.3.1 of C1077 may be presented for inspection. If presented, the inspection of these test methods for concrete may consist of an examination of prescribed equipment, specified procedures, or both, as the individual test method should warrant.

The apparatus examined and the procedures observed for any optional test method presented by the laboratory were checked for compliance with the referenced specification.

Quality Assurance System

Written records maintained by the laboratory and reviewed for compliance with C1077 included the following: an inventory of equipment and its required calibrations; personnel training and performance evaluations, including relevant certifications; general laboratory practice for fabrication, transfer and testing of concrete specimens; and test reports conforming to the requirements of Section 9.4. It was also ascertained whether the laboratory was under the technical direction of a registered engineer.

Procedures

The concrete testing procedures which were observed and discussed during the inspection were as follows: Sampling Freshly Mixed Concrete, Slump of Concrete, Unit Weight Test, Air Content Test (Volumetric Method), Air Content Test (Pressure Method), and Determination of the Compressive Strength of Molded Concrete Cylinders. The review of the strength test covered fabrication of cylinders, capping, storage after capping, measurement before testing, and testing. The laboratory's conformance to specified procedures was as indicated in the summary of findings.

All departures noted were reviewed in detail with laboratory personnel with particular attention being given to those matters described in the footnote section.

Inspection No. S-970
Concrete - 5

SUMMARY OF FINDINGS

Inspection Item	Apparatus	*Status
1. Tamping Rod(s)		See footnote (a)
2. Slump Cone(s)		Satisfactory
3. Unit Weight Apparatus		
a. Scale or Balance		Satisfactory
b. Unit Weight Measure(s)		See footnote (b)
c. Accessory Apparatus		Satisfactory
4. Air Content Apparatus (Volumetric)		
a. Air Meter(s)		Satisfactory
b. Accessory Apparatus		Satisfactory
5. Air Content Apparatus (Pressure)		
a. Air Meter(s)		Satisfactory
b. Accessory Apparatus		See footnote (c)
6. Compression Test Apparatus		
a. Cylinder Molds:		
(1) Reusable Molds		- - - - - - - - -
(2) Single-use Molds		Satisfactory
b. Vibrator(s)		Satisfactory
c. Capping Equipment and Materials:		
(1) Capping Equipment		See footnote (d)
(2) Capping Material		Satisfactory
(3) Planeness of Caps		Satisfactory
d. Compression Testing Machine:		
(1) Maker: Baldwin		
(2) Serial No.: 482195 (3) Capacity: 300,000 lbf		
(4) Accuracy of Indication:		
(a) Range: 300,000 lbf From: 50,000 to 200,000 lbf		Satisfactory
(b) Range: 50,000 lbf From: 6,000 to 45,000 lbf		Satisfactory
(c) Range: ____ From: ____ to ____		- - - - - - - - -
(d) Range: ____ From: ____ to ____		- - - - - - - - -
(e) Range: ____ From: ____ to ____		- - - - - - - - -
(f) Range: ____ From: ____ to ____		- - - - - - - - -
(5) Mechanical Condition		See footnote (e)
(6) Design		Satisfactory
(7) Bearing Blocks for Cylinders		Satisfactory
e. Additional Compression Machines		None

*Entry covers availability, physical condition, and/or conformance to specification requirements. Where reference is made to a footnote in which one or more deficiencies are described, it may be concluded that the item or items in question were judged to be satisfactory in all respects other than as described in the footnote.

1/91

Inspection Item	*Status
7. Curing Facilities	
a. Moist Air Storage Facilities........................	See footnote (f)
b. Water Storage Facilities............................	- - - - - - - - -
8. Miscellaneous	
a. Temperature of Air in Laboratory....................	Satisfactory
b. Specimen Shipping Containers........................	Satisfactory
c. Additional Observations of Interest to Laboratory.....	None
d. Qualifications of Supervisory Personnel..............	See attachment
9. Optional Methods..	None
10. Quality System	
a. Organization..	See footnote (g)
b. Human Resources.....................................	See footnote (g)
c. Operations..	See footnote (g)
d. Quality Assurance...................................	See footnote (g)
e. Equipment...	See footnote (g)

Procedures

Test	Method Reference	Technique in Exact Agreement With Standard Practice
Sampling Freshly Mixed Concrete.......	C172-90	See footnote (h)
Slump of Concrete.....................	C143-90	Yes
Unit Weight of Concrete...............	C138-81	Yes
Air Content (Volumetric Method).......	C173-78	Yes
Air Content (Pressure Method).........	C231-89	See footnote (i)
Compression Test:		
a. Fabrication of Cylinders..........	C31-90	Yes
b. Capping of Cylinders..............	C617-87	Yes
c. Storage After Capping.............	C617-87	Yes
d. Measurement Before Testing........	C39-86, C617-87.....	See footnote (j)
e. Testing of Cylinders..............	C39-86	Yes

FOOTNOTE SECTION

Tamping Rods:

(a) The small tamping rods examined were not 3/8 inch in diameter as required. These rods were subsequently replaced during the inspection.

Unit Weight Apparatus (C138-81):

(b) The top rim of the one-third cubic foot unit weight measure was not plane to 0.01 inch as required. This measure was replaced with an apparatus that conformed to the requirements of C138.

Air Content Apparatus (Pressure Method) (C231-89):

(c) The calibration vessel used with the Type A apparatus, which was designed to be placed in the meter during calibration, was found not to comply with the requirement that its inside depth be 1/2 inch less than that of the bowl.

Capping Equipment and Materials (C617-87):

(d) Four capping plates, designed for use in capping 4 x 8 inch cylinders, were checked and all were found not to conform to the requirement of C617 that the alignment device be located so that no cap will be off-centered on a test specimen by more than 1/16 inch.

Compression Testing Machine (C39-86 and E4-89):

(e) The maximum hands with which the 300,000-lbf and 50,000-lbf dials were equipped were checked and found not to be in satisfactory operating condition. It was recommended that the necessary repairs be made.

Facilities for Curing Test Specimens (C511-85):

(f) It was noted that several of the specimens in storage were not in a surface moist condition as required by C511, and it was recommended that several of the spray nozzles be redirected in an effort to correct this deficiency.

Quality System (C1077-90):

(g) No documentation or records pertaining to the quality system of the laboratory, as set forth in ASTM Standard Practice C1077, were presented for inspection.

Procedures:

(h) Sampling Freshly Mixed Concrete (C172-90): The concrete was sampled at only one interval, rather than at two or more intervals from the middle portion of the discharge batch as specified.

(i) Air Content Test (Pressure Method) (C231-89): It was understood that an aggregate correction factor had not been determined for the aggregates and that no aggregate correction factor was used in determining the air content of the concrete.

(j) Measurement before Testing (C39-86 and C617-87): It was understood that the laboratory did not check the planeness of caps at intervals that would include the minimum prescribed in C617.

PART II INSPECTION OF AGGREGATE TESTING FACILITIES

DESCRIPTION OF INSPECTION

The inspection was designed to include an examination of the apparatus prescribed for use in the methods of test for concrete aggregates listed in ASTM C1077; a review of the apparatus or procedures prescribed in any optional test methods presented for inspection; and an observation of several of the procedures used in the testing of concrete aggregates.

The ASTM Standards on which the work was based are as follows: C33-90, C40-84, C117-87, C127-88, C128-88, C136-84, C566-89, C702-87, C1077-90, D75-87, E11-87 and E171-87.

Apparatus

Drying Apparatus

The physical condition of the apparatus used in drying samples of aggregates for testing purposes was observed, and a check made to determine if the operating temperature was being maintained at less than 115°C.

Sample Splitters (C702)

The apparatus available for use in reducing field samples of aggregates to testing size was checked for conformance to the design requirements of C702, and its physical condition was observed. Note was taken as to whether the laboratory had at least one riffle sampler with no less than twelve chutes 1/2 inch in width for use with fine aggregate, and one riffle sampler with no less than 8 chutes of the appropriate chute width for use with coarse aggregate.

Sieves (E11)

The physical condition of each sieve presented for inspection was noted, and a check made to determine if the size of opening was marked on the side as required by E11.

With the exception of such omissions as may be set forth in the footnote section, the group of sieves presented for inspection contained one or more of each of the sieves with nominal openings ranging from 52 to .150 mm listed by size or number in C33, and one or more of each of the sieves listed by size or number in the various methods of test to which reference is made in this report. The particular sizes and numbers are: 2 in., 1 1/2 in., 1 in., 3/4 in., 1/2 in., 3/8 in., No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, and No. 200.

Mechanical Sieving Apparatus

The physical condition of each mechanical sieving device presented for inspection was noted.

Balances

The requirements for balances to which reference is made during the inspection were derived from a number o. sources.

A sensitivity requirement of 0.01 g is believed to be applicable to balances with capacities of less than 1000 g (Reference: Method D854). A basic maintenance tolerance (0.1 percent of the test load) considered to be appropriate for equal-arm balances used in the testing of aggregates (Reference: Method C136) is given in Paragraph T.3.2 of the Scales Section of the 1986 Edition of NIST Handbook 44. Tolerances believed to be applicable to the accuracy of indication of the direct-reading dials with which some small balances are equipped are given in Paragraph T.3 of the Weights Section of Handbook 44.

Sensitivity requirements for balances with capacities of 1000 g or more are found in Methods C127 and C128. The basic maintenance tolerance to which reference is made above is applicable. A tolerance of ± 0.2% for the accuracy of indication of beams or dials on balances which are so equipped is suggested by information given in Paragraph T.3.1. of the Scales Section of Handbook 44.

Each balance with a rated capacity of less than 1000 g presented for inspection was tested for conformance to the selected sensitivity requirement at zero load. When of the two-pan, equal-arm type, it was subsequently tested for conformance to the selected accuracy requirement at its maximum capacity. When of the single-pan type, the accuracy of indication of the direct-reading indicating system was subsequently tested for conformance to the selected tolerances at 50, 100, 200, 500 and 700 g as appropriate for the capacity of the system.

Each balance with a capacity of 1000 g or more presented for inspection was tested for conformance to the selected sensitivity requirements at 500, 1000, and 2000 g, as appropriate for the capacity. When of the two-pan, equal-arm type, it was subsequently tested for conformance to the selected accuracy requirement at the said three test points, and the dial or beams, if any, were tested separately for accuracy of indication at five points over their respective capacities. When of the single-pan type, the accuracy of indication of the direct-reading indicating system was subsequently tested for conformance to the selected tolerance at five points over the capacity of the system, or to 10,000 g, whichever was the lesser.

Testing Weights

All metric weights presented for inspection were checked for conformance to the maintenance tolerances for metric weights specified in Paragraph T.3 of the Weights Section of the 1986 Edition of NIST Handbook 44. When the weights in a set were within the specified limits and were suitably stored, each storage container was assigned a CCRL identification number.

Organic Impurities Apparatus (C40)

The glass bottles, the reagent, and the color standards used in testing for organic impurities in sands were checked for conformance to the requirements of C40.

Apparatus for Specific Gravity and Absorption of Fine Aggregate (C128)

Observations were made to determine if one or more pieces of each item of equipment (pycnometer, conical mold, and tamping rod) needed to determine the specific gravity and absorption of fine aggregates in accordance with the requirements of C128 were available for use and in good physical condition.

Apparatus for Specific Gravity and Absorption of Coarse Aggregate (C127)

Each basket used for holding samples of coarse aggregate during the specific gravity determination was checked for conformance to the requirements of C127, each suspending apparatus was examined, the capacity of each balance being used in conjunction with the foregoing items was noted, and a check was made on the temperature of the immersion water.

Sample Containers for C117 and C566

The size, physical condition, and shape of the pans used in the test for determining fine materials in aggregate (C117), and in the test for determining the total moisture content by drying (C566) were observed.

Miscellaneous

The temperature of the air in the laboratory was measured at random for comparison with the range for room temperatures (20° to $30^{\circ}C$) set forth in E171.

The containers used for transporting samples of aggregate to the laboratory were checked for cleanliness and to determine if they were so made that there would be no loss of fines during shipment.

A check was made to determine if the laboratory had been supplied with a copy of the latest edition of the ASTM Book of Standards pertaining to the testing of concrete aggregates.

Optional Methods

At the discretion of the laboratory, selected optional test methods as set forth in Section 7.3.1.2 of C1077 may be presented for inspection. If presented, the inspection of these test methods for concrete aggregates may consist of an examination of prescribed equipment, specified procedures, or both, as the individual test method should warrant.

The apparatus examined and the procedures observed for any optional test method presented by the laboratory were checked for compliance with the referenced specification.

Procedures

The concrete aggregate procedures which were observed and discussed during the inspection were as follows: Minus No. 200 Wet Sieving, Organic Impurities Test, Sieve Analysis of Aggregates, Specific Gravity and Absorption of Fine and Coarse Aggregate, Moisture Content by Drying, and Reducing Field Samples to Testing Size.

The laboratory's conformance to specified procedures was as indicated in the summary of findings. All departures noted were reviewed in detail with laboratory personnel with particular attention being given to those matters described in the footnote section.

Inspection No. S-970
Concrete Aggregates - 5

SUMMARY OF FINDINGS

Inspection Item	*Status
1. Drying Apparatus	
a. Oven(s):	
(1) Maker: Quincy ID No. 15744B	Satisfactory
(2) Maker: Laboratory design ID No. - - - -	Satisfactory
(3) Maker: ______ ID No. ______	- - - - - - - -
b. Hot Plate(s): Number Inspected: 0	- - - - - - - -
2. Sample Splitter(s)	
a. For Coarse Aggregates:...............................	See footnote (a)
b. For Fine Aggregates:................................	See footnote (a)
3. Sieves	
a. Number Inspected: 27	Satisfactory
b. Missing Sizes or Numbers:.............................	None
4. Mechanical Sieving Apparatus	
(1) Maker: Gilson ID No. 11306	Satisfactory
(2) Maker: Tyler ID No. 3227	Satisfactory
(3) Maker: ______ ID No. ______	- - - - - - - -
5. Balances	
(1) Maker: Mettler Capacity: 2400 g CCRL No.: S-4811	Satisfactory
(2) Maker: Mettler Capacity: 12 kg CCRL No.: S-4812	Satisfactory
(3) Maker: Mettler Capacity: 12 kg CCRL No.: S-4813	Satisfactory
(4) Maker: ______ Capacity: ______ CCRL No.: ______	- - - - - - - -
6. Testing Weights	
(1) CCRL No.: S-4810 No. Weights Checked 13	Satisfactory
(2) CCRL No.: ______ No. Weights Checked ______	- - - - - - - -
(3) CCRL No.: ______ No. Weights Checked ______	- - - - - - - -

*Entry covers availability, physical condition, and/or conformance to specification requirements. Where reference is made to a footnote in which one or more deficiencies are described, it may be concluded that the item or items in question were judged to be satisfactory in all respects other than as described in the footnote.

Inspection Item	*Status
7. Organic Impurities Apparatus	Satisfactory
8. Specific Gravity and Absorption Apparatus (F.A.) ...	Satisfactory
9. Specific Gravity and Absorption Apparatus (C.A.) ...	Satisfactory
10. Sample Containers	
a. For Minus No. 200 Sieve Test - C117	Satisfactory
b. For Test for Total Moisture Content by Drying - C566	Satisfactory
11. Miscellaneous	
a. Temperature of Air in Laboratory	Satisfactory
b. Sample Shipping Containers	Satisfactory
c. ASTM Standards	Satisfactory
d. Additional Observations of Interest to Laboratory ..	See footnote (b)
12. Optional Methods..................................	None

Procedures

Test	Method Reference	Technique Agrees with Standard Practice
Minus No. 200 Wet Sieving	C117-87...........	Yes
Organic Impurities Test..............	C40-84............	Yes
Sieve Analysis of Aggregates.........	C136-84...........	Yes
Specific Gravity and Absorption:		
a. Fine Aggregate..................	C128-88...........	Yes
b. Coarse Aggregate................	C127-88...........	Yes
Moisture Content by Drying...........	C566-89...........	Yes
Reducing Field Samples...............	C702-87...........	Yes

FOOTNOTE SECTION

Sample Splitters (C702-87):

(a) It was understood that the laboratory used the quartering method for reducing field samples of aggregate to testing size.

Miscellaneous:

(b) No equipment for the testing of steel reinforcing bars was presented for inspection; therefore, with reference to paragraph two of the Introduction, this report has only two parts.

ADDENDUM

The Cement and Concrete Reference Laboratory has been in existence since 1929. In April of that year, a Research Associate Program, known as the Cement Reference Laboratory, was established at the National Institute of Standards and Technology (formerly the National Bureau of Standards) under the sponsorship of Committee C-1 on Cement of the American Society for Testing Materials. The principal responsibility of the CRL was to promote uniformity in the testing of hydraulic cements through the inspection of laboratories.

In 1948, the first steps were taken in a gradual expansion of the field work to include some of the more important procedures used in the testing of concrete. On March 1, 1958, the resulting new inspection service was made available to any interested concrete testing laboratory within the prescribed areas of operation, and shortly thereafter Committee C-1 invited Committee C-9 to become a joint sponsor. The invitation was accepted and on July 1, 1960, the name "Cement and Concrete Reference Laboratory" was adopted in recognition of the new arrangement.

At the time of the redesignation, a joint C-1, C-9 Subcommittee on the Cement and Concrete Reference Laboratory, consisting of seven representatives of each of the parent committees, was created to work with the National Institute of Standards and Technology in administering the CCRL program. The new administrative plan perpetuated the earlier arrangements whereby selected representatives of the Federal Agencies, materials producers, construction and design firms, and national associations, who furnish either financial or technical assistance, participate in the direction of the activity through membership on the supervising ASTM Subcommittee.

As of January 1, 1991, organizations who were furnishing financial or technical support were as follows:

Federal:
Federal Highway Administration
National Institute of Standards and Technology
U.S. Army Corps of Engineers

Non-Federal:
American Concrete Institute
ASTM
National Ready Mixed Concrete Assn.
National Aggregates Association
Portland Cement Association
W. R. Grace and Company

Inspection No. S-970
Final Page (Concrete)

CLOSURE

This inspection was performed by the writer. While the work was in progress, many of the details covered by this report were discussed with laboratory personnel. At the conclusion of the inspection the special work sheets, on which all observations were recorded, were made available for review by members of the laboratory staff, and all of the entries thereon were discussed in detail.

Testing equipment that was used during the inspection to make temperature determinations, to determine compliance of selected apparatus to specified weights, and to verify the accuracy of indication of compression testing machines is identified as follows:

Thermometers	:	CCRL Nos. S33, S32, C164, C189 and C169
Test Weights	:	NIST Nos. 172810 and 163683
Proving Rings	:	Serial Nos. 585, 4893 and 3374B

It is recommended that this report be compared with the report of the preceding inspection which was made in March 1989.

This report is not to be used for advertising, publication, or promotional purposes.

CEMENT AND CONCRETE REFERENCE LABORATORY

Paul C. Burns

Paul C. Burns
Inspector

Report Approved By:
Raymond M. Kolb

SUMMATION OF QUALIFICATIONS OF MANAGERIAL AND SUPERVISORY PERSONNEL
(Reference: Section 6, ASTM Specification C1077)

Name of laboratory: Trow-Protze, Consulting Engineers

Location : 70 Jaconnet Street, Newton Highlands, MA 02161

Director of Inspection and Testing Services

Name and title : Herman G. Protze, P.E.
Mailing address: 24 Greystone Road
Dover, MA 02030

Full time employee of laboratory?.................................. yes
Registered engineer?... yes
Number of years experience in inspection and testing of
construction materials... 53

Supervising Laboratory Technician

Name and title : Edgar S. Van Buren
Mailing address: 23 Hadley Road
Framingham, MA 01701

Number of years of experience performing tests
on construction materials?... 34

Supervising Field Technician

Name and title : Edgar S. Van Buren
Mailing address: 23 Hadley Road
Framingham, MA 01701

Number of years of inspection experience in kind of work
involved on construction projects?................................. 45

Foregoing entries certified to be correct.

Signature: Herman G. Protze
Title : Executive Engineer

Date July 3, 1991

ADDENDUM

The Cement and Concrete Reference Laboratory has been in existence since 1929. In April of that year, a Research Associate Program, known as the Cement Reference Laboratory, was established at the National Institute of Standards and Technology (formerly the National Bureau of Standards) under the sponsorship of Committee C-1 on Cement of the American Society for Testing Materials. The principal responsibility of the CRL was to promote uniformity in the testing of hydraulic cements through the inspection of laboratories.

In 1948, the first steps were taken in a gradual expansion of the field work to include some of the more important procedures used in the testing of concrete. On March 1, 1958, the resulting new inspection service was made available to any interested concrete testing laboratory within the prescribed areas of operation, and shortly thereafter Committee C-1 invited Committee C-9 to become a joint sponsor. The invitation was accepted and on July 1, 1960, the name "Cement and Concrete Reference Laboratory" was adopted in recognition of the new arrangement.

At the time of the redesignation, a joint C-1, C-9 Subcommittee on the Cement and Concrete Reference Laboratory, consisting of seven representatives of each of the parent committees, was created to work with the National Institute of Standards and Technology in administering the CCRL program. The new administrative plan perpetuated the earlier arrangements whereby selected representatives of the Federal Agencies, materials producers, construction and design firms, and national associations, who furnish either financial or technical assistance, participate in the direction of the activity through membership on the supervising ASTM Subcommittee.

As of January 1, 1991, organizations who were furnishing financial or technical support were as follows:

<u>Federal</u>:
Federal Highway Administration
National Institute of Standards and Technology
U.S. Army Corps of Engineers

<u>Non-Federal</u>:
American Concrete Institute
ASTM
National Ready Mixed Concrete Assn.
National Aggregates Association
Portland Cement Association
W. R. Grace and Company

APPENDIX D

AGGREGATE CONSOLIDATION TEST

REVISED (Intentionally left blank)

APPENDIX E

CYLINDER TESTS

Project No. TP-04518-B2

July 15, 1993
August 27, 1993

TEST OF CONCRETE SPECIMENS

CLIENT	Alden Research Laboratory, Inc., Shrewsbury, Massachusetts
PROJECT	Final Porous Concrete Mock-Up Tests

Reference Number	93L-419ABCD
Date Received	6-28-93
Date Sampled	6-23-93 by us
Location Used	Alden Research Mold IIC, bottom 10" layer
Truck Number	Concrete Service 133
Load Number	1
Ticket Number	Concrete Service 204696
Class Concrete	Batch A
Cubic Yards	6 1/2
Cement	3014 lbs. Lehigh, type II (added one sack cement)
Fine Aggregate	None
Coarse Aggregate	17400 lbs. Tilcon 3/4" crushed stone
Water	3.7 gals/sack
Admixture	None
Time Sampled	10:45AM
Weather	Fair 65°F
Concrete Temperature	79°F
Slump	Zero
Entrained Air	Not determined
Appearance	Satisfactory
Storage	Site, then Laboratory Fog Room

Date of Test	6-30-93		7-21-93	
Age at Test	7 days		28 days	
Specimen Number	2A	2B	2C	2D
Dimensions	6x12"	6x12"	6x12"	6x12"
Density lbs/cu.ft.	125	126	126	126
Compressive Strength	1500	1540	2250	2280
Remarks	Strength normal each age.			

Respectfully Submitted,
TROW PROTZE

Herman G. Protze

1-ARL

Project No. TP-04518-B2

July 15, 1993
August 27, 1993

TEST OF CONCRETE SPECIMENS

CLIENT	Alden Research Laboratory, Inc., Shrewsbury, Massachusetts
PROJECT	Final Porous Concrete Mock-Up Tests

Reference Number	93L-418ABCD
Date Received	6-28-93
Date Sampled	6-23-93 by us
Location Used	Alden Research Molds IIA and IIB, bottom 10" layer
Truck Number	Concrete Service 133
Load Number	1
Ticket Number	Concrete Service 204696
Class Concrete	Batch A
Cubic Yards	6 1/2
Cement	2920 lbs. Lehigh, type II
Fine Aggregate	None
Coarse Aggregate	17400 lbs. Tilcon 3/4" crushed stone
Water	3.7 gals/sack
Admixture	None
Time Sampled	9:05AM
Weather	Fair 64°F
Concrete Temperature	70°F
Slump	Zero
Entrained Air	Not determined
Appearance	Satisfactory
Storage	Site, then Laboratory Fog Room

Date of Test	6-30-93		7-21-93	
Age at Test	7 days		28 days	
Specimen Number	1A	1B	1C	1D
Dimensions	6x12"	6x12"	6x12"	6x12"
Density lbs/cu.ft.	124	124	123	124
Compressive Strength	1850	1820	1930	2150
Remarks	Strength normal each age.			

Respectfully Submitted,
TROW PROTZE

Herman F. Protze

1-ARL

Project No. TP-04518-B

July 15, 1993
August 27, 1993

TEST OF CONCRETE SPECIMENS

CLIENT	Alden Research Laboratory, Inc., Shrewsbury, Massachusetts
PROJECT	Final Porous Concrete Mock-Up Tests

Reference Number	93L-434AB	
Date Received	7-1-93	
Date Sampled	6-30-93 by us	
Location Used	Alden Research Model IIA, top 9" layer	
Truck Number	Concrete Service 133	
Load Number	3	
Ticket Number	Concrete Service 204844	
Class Concrete	Batch B	
Cubic Yards	3	
Cement	15 bags Lumnite Calcium Aluminate	
Fine Aggregate	None	
Coarse Aggregate	8960 lbs. Tilcon 3/4" Crushed Stone	
Water	3.7 gals/sack	
Admixture	None	
Time Sampled	2:45PM	
Weather	Fair 80°F	
Concrete Temperature	80°F	
Slump	Zero	
Entrained Air	Not determined	
Appearance	Satisfactory	
Storage	Site, then Laboratory Fog Room	
Date of Test	7-7-93	7-28-93
Age at Test	7 days	28 days
Specimen Number	6A	6B
Dimensions	6x12"	6x12"
Density lbs/cu.ft.	126	124
Compressive Strength	1660	1770
Remarks	Strength normal each age.	

Respectfully Submitted,
TROW PROTZE

Herman G. Protze

1-ARL

Project No. TP-04518-B

July 15, 1993
August 27, 1993

TEST OF CONCRETE SPECIMENS

CLIENT	Alden Research Laboratory, Inc., Shrewsbury, Massachusetts
PROJECT	Final Porous Concrete Mock-Up Tests

Reference Number	93L-433AB	
Date Received	7-1-93	
Date Sampled	6-30-93 by us	
Location Used	Alden Research Model IIB, top 9" layer	
Truck Number	Concrete Service 133	
Load Number	2	
Ticket Number	Concrete Service 204842	
Class Concrete	Batch B	
Cubic Yards	3	
Cement	15 bags Lumnite Calcium Aluminate	
Fine Aggregate	None	
Coarse Aggregate	8975 lbs. Tilcon 3/4" Crushed Stone	
Water	3.7 gals/sack	
Admixture	None	
Time Sampled	12:00Noon	
Weather	Fair 76°F	
Concrete Temperature	79°F	
Slump	Zero	
Entrained Air	Not determined	
Appearance	Satisfactory	
Storage	Site, then Laboratory Fog Room	
Date of Test	7-7-93	7-28-93
Age at Test	7 days	28 days
Specimen Number	5A	5B
Dimensions	6x12"	6x12"
Density lbs/cu.ft.	126	126
Compressive Strength	1860	1960
Remarks	Strength normal each age.	

Respectfully Submitted,
TROW PROTZE

Herman F. Protze

1-ARL

Trow Protze Consulting Engineers
a division of Trow Engineering Consultants, Inc.

Project No. TP-04518-B

July 15, 1993
August 27, 1993

TEST OF CONC' ETE SPECIMENS

CLIENT	Alden Research Laboratory, Inc., Shrewsbury, Massachusetts
PROJECT	Final Porous Concrete Mock-Up Tests

Reference Number	93L-432AB	
Date Received	7-1-93	
Date Sampled	6-30-93 by us	
Location Used	Alden Research Model IIC, top 9" layer	
Truck Number	Concrete Service 133	
Load Number	1	
Ticket Number	Concrete Service 204833	
Class Concrete	Batch B	
Cubic Yards	3	
Cement	15 bags Lumnite Calcium Aluminate	
Fine Aggregate	None	
Coarse Aggregate	8975 lbs. Tilcon 3/4" Crushed Stone	
Water	3.7 gals/sack	
Admixture	None	
Time Sampled	9:15AM	
Weather	Fair 75°F	
Concrete Temperature	80°F	
Slump	Zero	
Entrained Air	Not determined	
Appearance	Satisfactory	
Storage	Site, then Laboratory Fog Room	
Date of Test	7-7-93	7-28-93
Age at Test	7 days	28 days
Specimen Number	4A	4B
Dimensions	6x12"	6x12"
Density lbs/cu.ft.	123	123
Compressive Strength	1600	1630
Remarks	Strength normal each age.	

Respectfully Submitted,
TROW PROTZE

Herman G. Protze

1-ARL

Project No. TP-04518-B

July 15, 1993
August 27, 1993

TEST OF CONCRETE SPECIMENS

CLIENT	Alden Research Laboratory, Inc., Shrewsbury, Massachusetts
PROJECT	Final Porous Concrete Mock-Up Tests

Reference Number	93L-440AB	
Date Received	7-8-93	
Date Sampled	7-7-93 by us	
Location Used	Alden Research Model IIA, top layer of grout	
Truck Number	Concrete Service 133	
Load Number	1	
Ticket Number	Concrete Service 204954	
Class Concrete	Batch C	
Cubic Yards	2	
Cement	23 bags Lumnite Calcium Aluminate	
Fine Aggregate	4680 lbs. Millbury fine sand	
Coarse Aggregate	None	
Water	6.3 gals/sack	
Admixture	None	
Time Sampled	9:15AM	
Weather	Fair 80°F	
Concrete Temperature	80°F	
Slump	3 1/2"	
Entrained Air	Not determined	
Appearance	Satisfactory	
Storage	Site, then Laboratory Fog Room	
Date of Test	7-14-93	8-4-93
Age at Test	7 days	28 days
Specimen Number	8A	8B
Dimensions	4x8"	4x8"
Density lbs/cu.ft.	140	139
Compressive Strength	6360	5960
Remarks	Strength normal at 7 days. No gain to 28 days. Normal gain usually approximately 200 psi.	

Respectfully Submitted,
TROW PROTZE

Herman G. Protze

1-ARL

Trow Protze Consulting Engineers

a division of Trow Engineering Consultants, Inc.

Project No. TP-04518-B

July 15, 1993
August 27, 1993

TEST OF CONCRETE SPECIMENS

CLIENT	Alden Research Laboratory, Inc., Shrewsbury, Massachusetts	
PROJECT	Final Porous Concrete Mock-Up Tests	
Reference Number	93L-439AB	
Date Received	7-8-93	
Date Sampled	7-7-93 by us	
Location Used	Alden Research Model IIC, top layer of grout	
Truck Number	Concrete Service 133	
Load Number	1	
Ticket Number	Concrete Service 204954	
Class Concrete	Batch C	
Cubic Yards	2	
Cement	23 bags Lumnite Calcium Aluminate	
Fine Aggregate	4680 lbs. Millbury fine sand	
Coarse Aggregate	None	
Water	6.3 gals/sack	
Admixture	None	
Time Sampled	9:00AM	
Weather	Fair 80°F	
Concrete Temperature	80°F	
Slump	5"	
Entrained Air	Not determined	
Appearance	Flowable	
Storage	Site, then Laboratory Fog Room	
Date of Test	7-14-93	8-4-93
Age at Test	7 days	28 days
Specimen Number	7A	7B
Dimensions	4x8"	4x8"
Density lbs/cu.ft.	140	139
Compressive Strength	6280	6460
Remarks	Strength normal each age.	

Respectfully Submitted,
TROW PROTZE

Herman F. Protze

1-ARL

Project No. TP-04518-B

July 15, 1993
August 27, 1993

TEST OF CONCRETE SPECIMENS

CLIENT	Alden Research Laboratory, Inc., Shrewsbury, Massachusetts
PROJECT	Final Porous Concrete Mock-Up Tests

Reference Number	93L-431ABCD
Date Received	7-1-93
Date Sampled	6-28-93 by us
Location Used	Alden Research Models IIB and IIA grout layer
Truck Number	Concrete Service 133
Load Number	1
Ticket Number	Concrete Service 204782
Class Concrete	Batch D
Cubic Yards	3
Cement	2940 lbs. Lehigh, type II
Fine Aggregate	6680 lbs. Millbury Sand
Coarse Aggregate	None
Water	6.0 gals/sack
Admixture	None
Time Sampled	9:05AM
Weather	Fair 74°F
Concrete Temperature	82°F
Slump	2 1/4"
Entrained Air	Not determined
Appearance	Satisfactory
Storage	Site, then Laboratory Fog Room

Date of Test	7-5-93		7-26-93	
Age at Test	7 days		28 days	
Specimen Number	3A	3B	3C	3D
Dimensions	4x8"	4x8"	4x8"	4x8"
Density lbs/cu.ft.	141	141	142	142
Compressive Strength	5720	5740	6850	7500
Remarks	Strength good each age.			

Respectfully Submitted,
TROW PROTZE

Herman F. Protze

1-ARL

APPENDIX F

RESIDUE ANALYSIS

Project No. TP-04518-B2

Alden Research Laboratory, Inc.
Holden, Massachusetts

Analysis of Samples Taken
During and After Testing

REFERENCE NUMBER 93S-223

DATE RECEIVED 8-3-93

SAMPLES The following samples were delivered by you as obtained during and after the tests.

Sample	lbs	Date	Item	Mold	Test No.	Remarks
1	0.023	7/14	Sediment from	A	1	
2	0.135	7/14	" "	B	1	
3	0.015	7/14	" "	C	1	
4	0.047	7/19	" "	A	4	
5	0.082	7/20	" "	A	5	
6	0.020	7/23	" "	A	8	
7	0.004	7/23	" "	B	8	
8	0.018	7/23	" "	C	8	
9	0.072	7/14	Initial Pipe Cleanout	A	--	Sand & lumps
10	0.099	7/14	Initial Pipe Cleanout	B	--	" "

ANALYSIS The following is the standard inorganic analysis of the samples for the compounds indicated.

	% Of Sample				
Sample	Sand	SiO_2	Al_2O_3	CaO	Fe_2O_3
1	2.3	1.61	8.3	32.7	1.30
2	1.2	0.37	7.5	28.7	1.14
3	3.0	0.30	0.64	28.7	0.60
4	0.76	2.46	6.0	28.6	1.00
5	1.12	2.00	5.1	28.8	1.20
6	1.2	1.87	2.3	20.4	1.60
7	5.5	*	*	21.8	1.10
8	2.2	0.29	0.53	45.0	0.51
9	66.8	0.63	7.8	8.4	2.60
10	71.3	0.40	8.3	6.8	2.40

*Sample too scant for precise test.

RESULTS On the basis of these data, we have tried to compute the basic source of cement (Lumnite or type II) from which the sediments derived. This does not seem possible due to the limited solubility in the case of each oxide which causes extreme conflict in the case of each sediment.

Actually, the silica (SiO_2) solubility is very low anyway so this oxide is not a good guide. In each case with samples 1-8, the low alumina (Al_2O_3) is in step with Type II cement but in general, the soluble lime (CaO) could come from either cement except for sample #8 which must come mostly from type II.

We believe the sediments generally derive from both cements. Samples 9 and 10 are mostly fine sand.

The basis analyses of both cements are as follows:

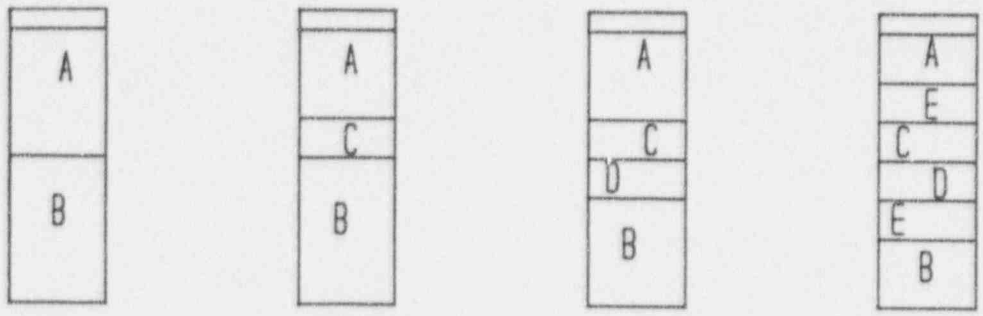
Oxide	SiO_2	Al_2O_3	CaO	Fe_2O_3
Lumnite	6%	52%	34%	7%
Type II	22	5	64	3

APPENDIX G

CORE BORING LOGS AND CORE COMPRESSIVE STRENGTH

CORE BORING LOG

MOLD A



I TWO PIECE — II THREE PIECE — III FOUR PIECE — IV FIVE OR MORE

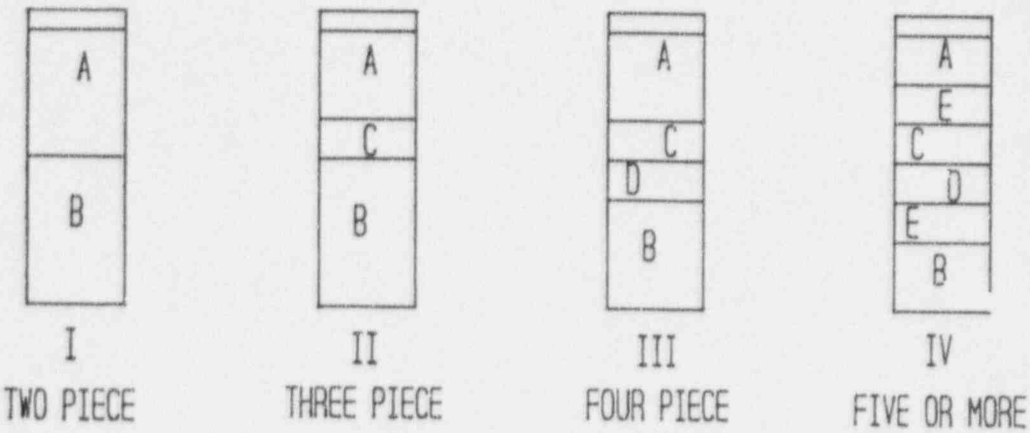
CORE SAMPLE TYPE

(1) WATER DEPTH WITH WATER RUNNING

CORE SAMPLE #	SAMPLE TYPE	MEASURMENT INCHES					WATER DEPTH FT (1)	COMMENT
		A	B	C	D	E		
A-A	I	8.25	7.5				1.09	crumble mid section
A B	I	10.5	8.5				1.12	solid midsection
A C	I	10.0	7.5				1.10	crumbled mid sec
A D	II	8.0	8.5	1.75			1.10	crumbled lower sec
A F	II	8.5	9.0	2.0			1.09	solid midsection
A G	I	10.25	9.5				1.23	crumbled mid section
A H	I	11.0	9.5				1.10	solid midsection
A I	I	9.0	9.0				1.07	crumbled mid section
A J	I	9.5	8.5				1.17	crumbled mid section
AK	II	6.25	8.25	2.75			1.18	solid midsection
AL	I	8.5	9.75				1.11	crumbled mid section
AM	I	9.5	9.0				1.11	crumbled mid section
AN	I	8.5	9.0				1.09	crumbled mid section
AE	II	7.5	8.25	2.0			1.09	solid mid section

CORE BORING LOG

MOLD B



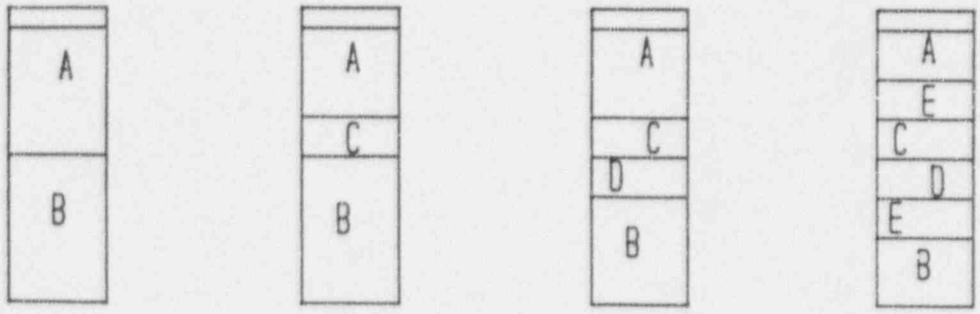
CORE SAMPLE TYPE

(1) WATER DEPTH WITH WATER RUNNING

CORE SAMPLE #	SAMPLE TYPE	MEASURMENT INCHES					WATER DEPTH FT (1)	COMMENT
		A	B	C	D	E		
BA	I	10.5	7.5	2.0			1.30	crumbling between Sec
BB	II	9.5	7.5	1.8			1.29	" " "
BC	II	10.5	9.0	2.0			1.28	No crumbling
BD	II	11.0	7.5	2.5			1.28	crumbling between Sec
BE	II	9.5	8.5	1.5			1.27	" " "
BF	II	10.5	8.0	1.5			1.27	No crumbling
BG	II	10.5	8.1	1.5			1.30	" "
BH	II	10.0	7.5	2.0			1.28	" "
BI	II	9.75	7.0	1.5			1.28	crumbling between Sec
BJ	II	10.75	8.25	1.4			1.30	" " "
BK	II	10.0	8.0	1.75			1.29	" " "
BL	II	9.5	7.5	2.25			1.28	" " "
BM	III	10.75	3.0	1.5	4.5		1.30	BAD Core location
BN	II	10.0	7.5	1.25			1.28	crumbling between Sec

CORE BORING LOG

MOLD C



I TWO PIECE | II THREE PIECE | III FOUR PIECE | IV FIVE OR MORE

CORE SAMPLE TYPE

(1) WATER DEPTH WITH WATER RUNNING

CORE SAMPLE #	SAMPLE TYPE	MEASURMENT INCHES					WATER DEPTH FT (1)	COMMENT
		A	B	C	D	E		
CA	C	9.0	9.25	2.0			1.24	Crumbling between Sec
CB	C	9.5	7.5	2.5			1.24	" " "
CC	C	8.75	7.75	2.0			1.23	" " "
CD	D	7.0	9.0	2.5	2.25		1.23	" " "
CE	C	8.5	7.5	2.5			1.23	" " "
CF	E	6.75	4.0	2	2.25	2.25	1.23	BADLY Crumbled
CG	C	8.0	8.0	2.5			1.23	Crumbling between Sec
CH	D	8.0	8.0	1.5	2.0		1.23	" " "
CI	C	8.0	7.5	2.25			1.20	" " "
CJ	C	9.0	7.5	2.0			1.24	" " "
CK	C	9.5	7.25	2.0			1.24	" " "
CL	D	4.0	9.0	4.5	2.0		1.24	" " "
CM	D	9.75	7.5	2.25	1.50		1.24	" " "
CN	C	8.0	9.5	2.0			1.23	" " "

G4
RECEIVED
OCT 21 1993
ARL, INC.
GEN-SKW

Trow Protze Consulting Engineers

67 Fourth Avenue
Needham Heights, MA 02194

Telephone (617) 444-4910
Facsimile (617) 444-5135

Project No. TP-04518-B2

October 19, 1993

ALDEN RESEARCH LABORATORY, INC.
HOLDEN, MASSACHUSETTS

Porous Concrete Mock-Up Testing
Millstone Unit 3, Waterford, CT
ARL; NU/Concrete II-295/93/1

REFERENCE NUMBER 93S-249

DATE RECEIVED 8-26-93 through 9-1-93

SAMPLES Sixty-nine Portland cement and calcium-aluminate cement porous concrete cores drilled from the two typical concretes (designated as Type "p" and Type "c" respectively) used in the bottom 10" and upper 9" layers respectively of the three Research Model forms IIA, IIB, IIC as cast on 6-23-93 (Log No. 1 herein) and 6-30-93 (Log No. 3 herein).

Actual samples retrieved by coring after 28 days by Superior Drilling Company. Core diameters all 5.73" and of somewhat varying average length due to some crumbling of lower ends during coring and after retrieval.

All cores sawed to square ends, of typical strong concrete. Cores stored in laboratory air at 70° - 80°F, at average R.H. of approximately 75% until capped and tested at ages of 12 weeks (Portland) and 11 weeks (calcium aluminate) respectively.

Specimens ends sawed and capped in conformity with ASTM Methods. Compression tests in conformity with ASTM including correction of strength for standard height-to-diameter ratio.

The data are presented on the following pages.

Respectfully submitted,
TROW PROTZE

Herman G. Protze

Herman G. Protze, P.E.

Reference No. 93C-1065

NOTED 2 1993 G.E.H.

Compression Test of Cores in Form A

Marking: note the first letter in the design nomenclature such as AAc stands for the large wooden form (A, B or C); the second letter stands for the location of the core in the form as shown on plans of Figure 1 or Figure 2 sketches in the Alden instructions of the Subcontract between Alden Research and Trow Protze, dated April 22, 1993. The final letter (c or p) advises whether the involved cement is Calcium Aluminate or standard Portland. All dimensions are in inches; density is in lbs. per cu. ft. and compressive strength is in psi. Those marked NG were not tested due to crumbles or damage.

MARK	AAc	AAp	ABc	ABp	ACc	ACp	ADc	ADp	AEc	AEp
Diameter	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
Height	5.95	8.55	8.45	10.60	7.95	10.00	6.10	9.27	NG	8.22
Density	111	118	110	115	116	121	112	119		114
Comp.Str.		1100	1070	1060	1250	1060	1160	1220		1250

MARK	AFc	AFp	AGc	AGp	AHc	AHp	AIc	AIp
Diameter	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
Height	NG	9.65	7.87	9.78	9.08	9.67	7.40	9.60
Density		114	110	115	110	116	114	116
Comp. Str.		1070	820	970	940	1060	1200	1010

MARK	AJc	AJp	AKc	AKp	ALc	ALp	AMc	AMp	ANc	ANp
Diameter	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
Height	7.22	10.20	NG	8.62	6.40	9.65	7.20	10.08	6.70	8.72
Density	116	120		117	116	119	111	116	114	115
Comp. Str.	1100	1030		1110	1500	1280	1010	1030	1140	1060

Compressive Test of Cores in Form B

MARK	BAc	BAp	BBc	BBp	BCc	BCp	BDc	BDp	BEc	BEp
Diameter	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
Height	8.24	NG	7.52	6.96	8.62	9.92	8.93	8.75	8.57	8.95
Density	118		117	117	116	120	120	121	115	116
Comp. Str.	1250		1330	1490	1180	1240	1470	1680	1570	1260

MARK	BFc	BFp	BGc	BGp	BHc	BHp	BIc	BIp
Diameter	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
Height	8.39	8.78	8.00	7.95	8.07	8.32	6.43	8.02
Density	117	117	117	117	116	118	119	117
Comp. Str.	1310	1200	1130	1370	1320	1160	1360	1300

MARK	BJc	BJp	BKc	BKp	BLc	BLp	BNc	BNp
Diameter	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
Height	8.92	9.25	8.05	8.82	8.82	8.10	8.72	8.21
Density	115	115	118	123	122	121	122	118
Comp. Str.	1430	1240	1440	1560	1740	1440	1590	1320

Compressive Test of Cores in Form C

MARK	CAc	CAp	CBc	CBp	CCc	CCp	CDc	CDp	CEc	CEp
Diameter	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
Height	7.48		7.58	8.29	7.35	8.18	NG	7.82	6.69	7.60
Density	114		118	122	121	120		121	118	121
Comp. Str.	1240		1280	1660	1100	1580		1490	1260	1820

MARK	CFc	CFp	CGc	CGp	CHc	CHp	CIc	CIp
Diameter	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
Height	NG	9.02	6.09	8.80	NG	8.29	NG	8.17
Density		119	116	114		118		117
Comp. Str.		1600	1570	1230		1510		1440

MARK	CJc	CJp	CKc	CKp	CLc	CLp	CMc	CMp
Diameter	5.73	5.73	5.73	5.73	5.73	5.73	5.73	5.73
Height	7.65	8.40	7.33	7.50	NG	8.88	6.48	7.38
Density	117	121	113	123		121	115	117
Comp. Str.	1390	1620	1060	1620		1480	1200	1320

APPENDIX H

CONFINED COMPRESSION TESTS

RECEIVED
OCT 27 1993
ARL, INC.

H1

Trow Protze Consulting Engineers

67 Fourth Avenue
Needham Heights, MA 02194

Telephone (617) 444-4910
Facsimile (617) 444-5135

Project No. TP-04518-B2

October 25, 1993

Alden Research Laboratory, Inc.
30 Shrewsbury Street
Holden, MA 01520

Attention: Mr. Dean White, Project Engineer

Concrete Core Strain Tests
Northeast Utilities Service Company
Millstone Unit #3
Waterford, Connecticut

Gentlemen:

On October 22 to 25, 1993, (at an average age of 13 weeks after casting), we tested samples removed from three test panels shown in Figures 1 and 2 of your test instruction sheets. These samples including the perforated steel forms were removed by Superior Drilling and you from the in-place concrete castings and delivered to us on 8-26-93 through 9-1-93.

The samples were free of cement mortar etc., on the outside of the perforated steel jackets. The samples were sawed by us to provide flat ends perpendicular to the axis at a total length of 13 5/8 inches, with equal lengths of the type II cement concrete (Mix A) and calcium aluminate cement concrete (Mix B) in the sample. The sample diameters were 5.95 inches. A layer of thin rice paper was fastened around the cylinders by us to prevent intrusion of the capping compound described below.

Three 7" I.D. steel pipes, 13 5/8" long with 3/8" walls (provided by you with ends machined square to their axis) were placed over the test samples centered lengthwise and diametrically. The circular gap was slowly filled will leadite capping compound to avoid "piping" and assure a completely filled area. Both ends of the test sample were then capped with leadite, flat and perpendicular to the sample. The total length of the sample + capping was 13 3/4". The outside edges of the top and bottom capping compound did not touch the steel pipe. The peripheral capping was to prevent expansion of the sides of the cylinders so that the only deformation was axial.

The sample was tested in our 300,000 lb. hydraulic Baldwin-Southwark testing machine recently verified for test accuracy by the National Institute of Standards and Technology. Two Ames dials (reading directly in 0.001" and accurate to 0.0001") were arranged on diametrically opposite locations to read changes in length of the interior concrete at each load application.

To prevent a hysteresis loop at the start of the test, each sample was slowly massaged twice to a 10,000 lbs. total load prior to the formal start of the test. Then the indicated successive loads of 1000 pounds were slowly applied, deformation readings taken to 0.001" accuracy and the tests stopped at 25,000 lbs. load (899 psi). Then after load removal, the final set was promptly recorded which is the permanent deformation of the entire sample.

The deformation were small and there was no measurable breakage of the aggregate during the tests.

Respectfully submitted,
TROW PROTZE

Herman G. Protze

Herman G. Protze, P.E.

LOAD TESTS OF RELATED CORES*

Applied Center Load		SAMPLE AH'cp			SAMPLE AE'cp			SAMPLE CE'cp		
lbs.	psi	L	R	Av.	L	R	Av.	L	R	Av.
Zero	0	0	0	0	0	0	0	0	0	0
		--	--	--	--	--	--	--	--	--
1000	36	3	6	5	1	1	1	3	6	5
2000	72	7	9	8	4	3	4	5	8	7
3000	108	10	12	11	6	4	5	7	10	9
4000	144	12	14	13	8	6	7	8	11	10
5000	180	13	15	14	9	7	8	10	12	11
6000	216	15	17	16	10	8	9	11	13	12
7000	252	16	18	17	11	9	10	12	14	13
8000	288	18	20	19	12	10	11	13	15	14
9000	323	19	21	20	12	11	12	14	15	15
10000	360	20	22	21	13	12	13	15	16	16
11000	396	21	23	22	14	12	13	15	17	16
12000	432	23	25	24	15	13	14	16	18	17
13000	468	26	25	26	15	14	15	17	19	18
14000	504	26	28	27	16	15	16	18	19	19
15000	540	29	31	30	17	15	16	19	20	20
16000	576	35	35	35	18	16	17	20	21	21
17000	612	41	41	41	18	17	18	20	22	21
18000	647	45	44	45	19	18	19	21	23	22
19000	683	48	46	47	20	18	19	22	23	23
20000	719	50	48	49	21	19	20	23	24	24
21000	755	52	49	51	21	20	21	23	24	24
22000	791	53	51	52	22	20	21	24	25	25
23000	827	55	53	54	23	21	22	25	26	26
24000	863	54	54	54	23	22	23	25	27	26
25000	899	54	55	55	24	22	23	26	28	27
Zero	0	24	30	27	20	0	10	0	3	2

All strains in 0.001".

All samples comprise two 6-13/16" long companion cores. Samples sealed in steel pipes with Basalt capping compound and cooled. Portland sample on the bottom; companion CaAl cement sample on top.

All samples first massaged twice to 10000 lbs. load prior to test to avoid hysteresis loop.

LOAD TESTS OF SINGLE CORES

Applied Center Load		SAMPLE BH'p			SAMPLE BH'c			SAMPLE CJ'p			SAMPLE CJ'c		
lbs.	psi	L	R	Av.	L	R	Av.	L	R	Av.	L	R	Av.
Zero	0	0	0	0	0	0	0	0	0	0	0	0	0
	--	--	--	--	--	--	--	--	--	--	--	--	--
1000	36	8	8	8	6	5	6	8	7	8	5	4	5
2000	72	10	10	10	8	7	8	11	9	10	8	6	7
3000	108	13	11	12	10	8	9	13	11	12	10	7	9
4000	144	14	13	14	12	10	11	14	12	13	12	8	10
5000	180	15	14	15	13	11	12	15	13	14	13	9	11
6000	216	15	15	15	13	11	12	16	14	15	14	10	12
7000	252	18	15	17	14	12	13	17	14	16	15	11	13
8000	288	19	16	18	15	13	14	18	15	17	16	12	14
9000	323	20	17	19	16	14	15	18	16	17	17	12	15
10000	360	20	18	19	17	14	16	19	17	18	18	13	16
11000	396	21	18	20	17	15	16	19	17	18	19	13	16
12000	432	22	19	21	18	16	17	20	18	19	19	14	17
13000	468	23	20	22	19	17	18	21	19	20	20	15	18
14000	504	23	20	22	19	17	18	21	20	21	21	15	18
15000	540	24	20	22	20	18	19	22	20	21	22	16	19
16000	576	25	20	23	21	19	20	22	21	22	22	17	20
17000	612	26	20	23	21	19	20	23	21	22	23	17	20
18000	647	26	20	23	22	20	21	23	22	23	24	18	21
19000	683	26	21	24	22	21	22	23	23	23	24	19	22
20000	719	27	21	24	23	21	22	24	23	24	25	19	22
21000	755	28	22	25	23	22	23	25	24	25	25	20	23
22000	791	28	22	25	24	22	23	25	24	25	26	21	24
23000	827	29	23	26	24	23	24	26	25	26	27	21	24
24000	863	29	23	26	25	24	25	26	26	26	27	22	25
25000	899	30	24	27	26	24	25	27	26	27	28	22	25
Zero	0	-2	-4	-3	2	4	3	5	4	5	2	2	2

All strains in 0.001". All samples 6-13/16" high.

p = Portland Cement; c= Calcium Aluminate Cement

Same method as previous samples.

Massage twice to 10,000 lbs. load prior to test.

LOAD TESTS OF SINGLE CORES

Applied Center Load		SAMPLE BE'p			SAMPLE BE'c			SAMPLE BJ'p			SAMPLE BJ'c		
lbs.	psi	L	R	Av.	L	R	Av.	L	R	Av.	L	R	Av.
Zero	0	0	0	0	0	0	0	0	0	0	0	0	0
		--	--	--	--	--	--	--	--	--	--	--	--
1000	36	1	5	3	2	4	3	11	8	10	3	5	4
2000	72	4	7	6	6	6	6	13	10	12	6	8	7
3000	108	7	8	8	8	8	8	15	11	13	8	9	9
4000	144	8	10	9	7	9	8	17	12	15	10	11	11
5000	180	10	11	11	8	11	10	18	13	16	11	12	12
6000	216	10	11	11	8	11	10	20	14	17	12	13	13
7000	252	11	12	12	9	12	11	20	15	18	14	13	14
8000	288	12	13	13	10	12	11	22	16	19	15	14	15
9000	323	13	13	13	10	13	12	22	17	20	15	15	15
10000	360	13	14	14	11	14	13	23	17	20	16	15	16
11000	396	14	15	15	12	15	14	24	17	21	17	16	17
12000	432	14	15	15	13	15	14	24	18	21	17	17	17
13000	468	15	16	16	13	16	15	25	18	22	18	17	18
14000	504	15	17	16	14	17	16	26	19	23	18	18	18
15000	540	16	17	17	15	17	16	26	20	23	19	19	19
16000	576	17	18	18	15	18	17	27	20	24	20	20	20
17000	612	17	19	18	16	19	18	27	21	24	21	20	21
18000	647	18	19	19	16	20	18	28	22	25	21	21	21
19000	683	18	20	19	17	21	19	29	22	26	21	22	22
20000	719	19	21	20	17	21	19	29	23	26	22	22	22
21000	755	20	21	21	18	21	20	30	23	27	23	23	23
22000	791	20	21	21	18	22	20	30	24	27	23	23	23
23000	827	21	22	22	19	22	21	31	25	28	24	24	24
24000	863	22	23	23	19	23	21	31	25	28	24	25	25
25000	899	22	23	23	20	24	22	32	26	29	25	25	25
Zero	0	7	4	6	-2	+2	0	2	0	1	2	4	3

All strains in 0.001". All samples 6-13/16" high.

p=Portland cement; c=Calcium Aluminate cement

Same method as previous samples.

Massage twice to 10,000 lbs. load prior to test to avoid hysteresis loop start.

Docket No. 50-423
B15985

Attachment 4

Millstone Nuclear Station Unit 3

Particle Size Distribution Analysis of Cements by Sedigraph

November 1996

CTL Structural/Architectural Engineering, Testing and Materials Technology
5420 Old Orchard Road, Skokie, Illinois 60077-1030
847/ 965-7500 800/ 522-2CTL Fax: 847/ 965-6541

Client: Northeast Utilities System
Project: Millstone

Contact: K. Lakshmipathiah
Submitter: Mr. W. Klemm, CTL
Date Received: 20-Nov-96

CTL Project No.: 060943
CTL Proj. Mgr.: Borje Ost
Analyst: Linda Hills
Approved: E. [signature]
Date Analyzed: 21-Nov-96
Date Reported: 21-Nov-96

PARTICLE SIZE DISTRIBUTION ANALYSIS BY SEDIGRAPH®

Percentage at Stated Size

Sample Identification	Size @ 50%	Size @ 95%	+100µm	<45 µm	<30 µm	3-30 µm	<7 µm	<1 µm
HAC cement	15.4	52.0	0.7	91.5	78.1	67.6	28.8	2.0
SRM 114n TII portland cement	15.3	59.0	0.2	89.2	76.5	61.9	29.3	4.5

Notes:
1. The HAC sample is a Lumnite cement from the Phase III mock-up study; it was submitted by ARL.
2. The SRM 114n is a NIST (formerly NBS) fineness standard. The values provided for this sample are from a previous analysis.
3. This report may not be reproduced except in its entirety.

PARTI... SIZE DISTRIBUTION

SAMPLE IDENTIFICATION #050943 HAC Cement Northeast Utilities

DATE 21 Nov 94

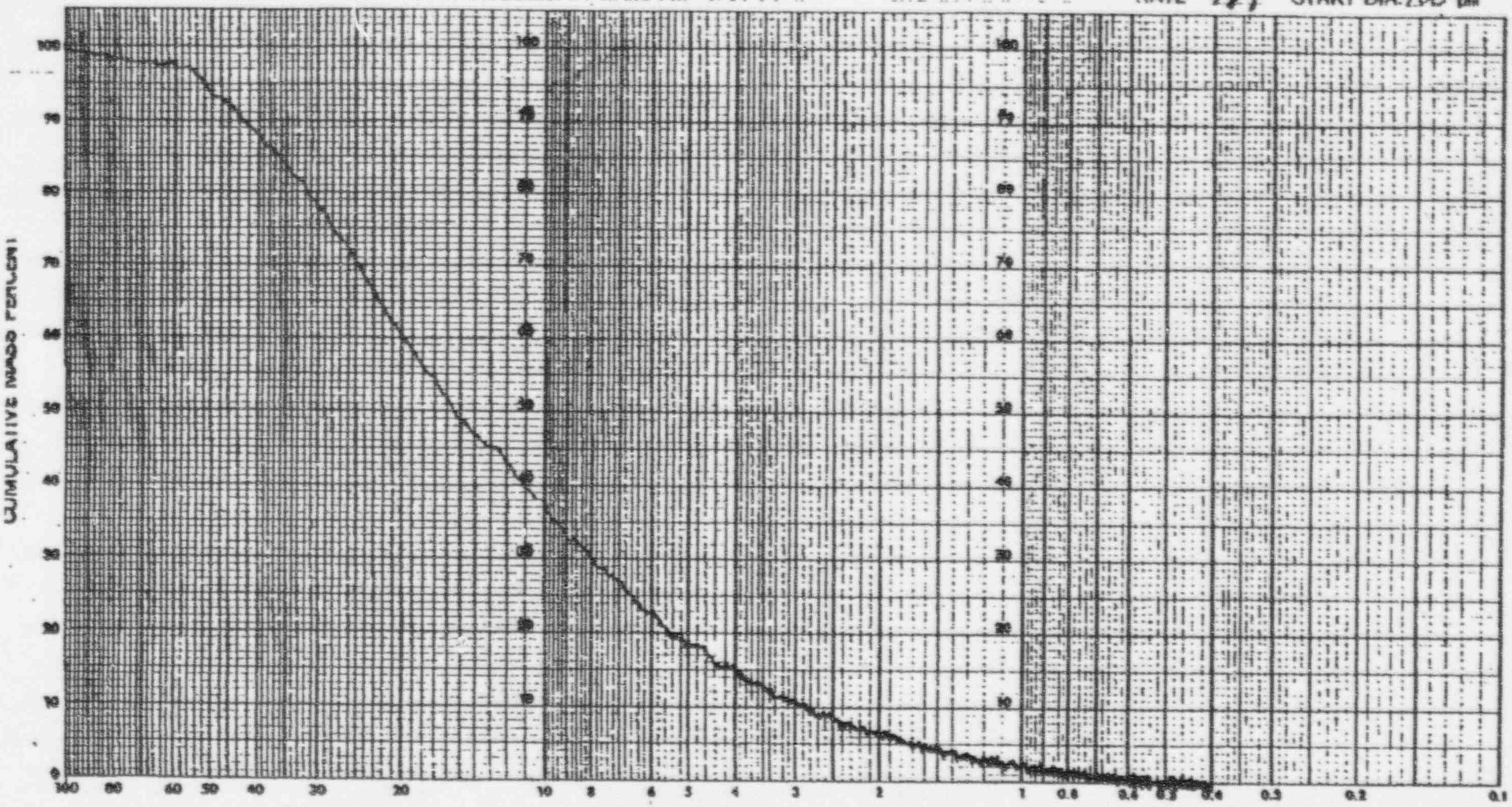
Density 3.02 g/cc LIQUID A12 Density 0.809 g/cc Viscosity 3.91 cp

BY LMHolt

Preparation Standard

TEMPERATURE 35 °C

RATE 479 START DIA. 100 µm



EQUIVALENT SPHERICAL DIAMETER, µm

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Form 600/42701

NOV 21 '96 02:03PM CTL 847 9655416

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SAMPLE IDENTIFICATION 114 N

DATE 1-30-95

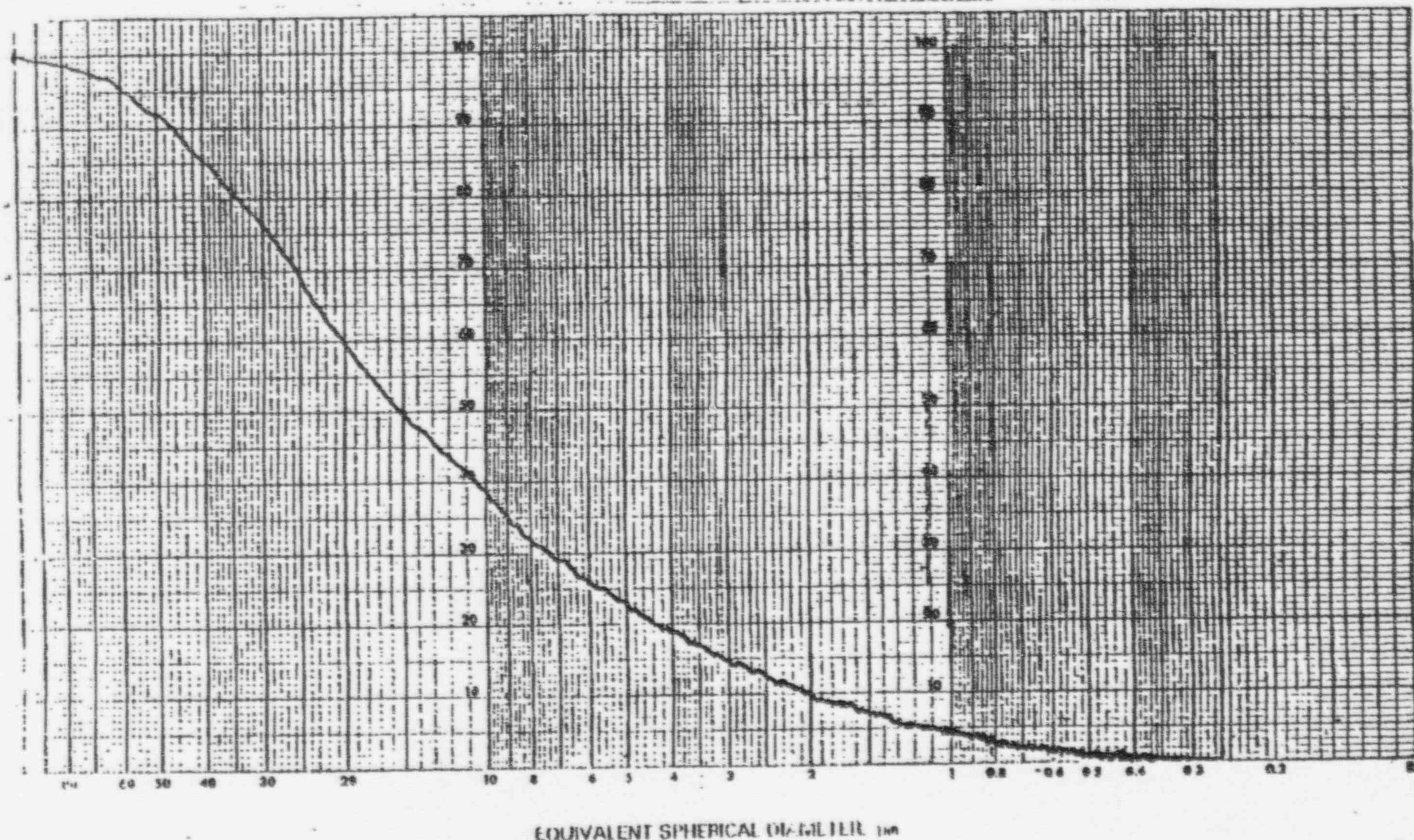
Density 3.20 g/cc LIQUID a12 Density 0.808 g/cc Viscosity 3.80 cp

BY ES

Preparation Standard

TEMPERATURE 33 °C

RATE 536 START DIA. 100 µm



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Docket No. 50-423
B15985

Attachment 5

Millstone Nuclear Station Unit 3

NNECO's Commitments in Response to the Nine Requests Regarding Issues Related to Millstone Unit 3 Containment Basemat Concrete

November 1996

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
B15985-1:	A final report detailing the results of the Phase III Mock-up Testing will be provided to the NRC by December 31, 1996.	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
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