HAMM ENGINEERS, INC.
CONSULTING ENGINEERS
CIVIL • STRUCTURAL

2804 LA GRAN VIA
RANCHO LA COSTA, CALIFORNIA 92008
(714) 436-9871

REPORT

OF

THE INVESTIGATION OF

KANSAS GAS & ELECTRIC COMPANY STUDY

OF THE LOW CONCRETE CYLINDER STRENGTHS

OF THE REACTOR CONTAINMENT BUILDING

BASE MAT

OF WOLF CREEK GENERATING STATION,

UNIT NO. 1 LOCATED NEAR

BURLINGTON, KANSAS

FEBRUARY 2, 1979

Prepared for: U.S. Nuclear Regulatory Commission
Region IV

NRC Contract 05-77-186
Task Order 4

Thru: Parameter, Inc.
Consulting Engineers
Elm Grove, Wisconsin

By: Rolland C. Hamm, P.E.
Hamm Engineers
San Diego, CAlifornia

Rolland C. Hamm P.E.

SUMMARY

The investigation of the KG&E Study could not verify the KG&E conclusion that "the in-situ strength of the reactor building base mat is considerably above the 5000 psi design strength and that the apparent low strength of a portion of the 90-day cylinders was due to testing conditions in measuring their actual strength."

While the KG&E Study is extensive in scope and depth, it is incomplete and inadequate in that it did not significantly involve strength testing of concrete which did not meet the strength level requirements of the specification as well as the aspects of adverse chemical reaction in concrete and inadequate hydration of cement.

The Study conducted by KG&E does not provide assurance of the structural adequacy of the in-situ base mat concrete.

INDEX

Scope of the Investigation

The purpose of the investigation was to verify the conclusion by Kansas Gas & Electric Company (KG&E) that the Reactor Containment Building base mat concrete of Wolf Creek Generating Station, Unit No. 1, located near Burlington, Kansas is above specifications (5000 psi) and that the cause of the apparent low strength of a portion of the 90 day cylinders was testing machine conditions.

The investigation was conducted by a task force composed of the following:

C.R. Oberg, Wolf Creek Project Inspector, NRC, Region IV

A.B. Rosenberg, Reactor Inspector, NRC, Region IV

E.J. Gallagher, Reactor Inspector, NRC, Region III

R.C. Hamm, Consulting Engineer

The task force made announced inspection visits to the site on the following dates:

Nov. 13-17, 1978 Oberg, Rosenberg, Gallagher, and Hamm

Dec. 5-8, 1978 Oberg, Rosenberg and Hamm

Background

The Wolf Creek Generating Station, Unit No. 1 is a nuclear power plant authorized by Construction Permit No. CPPR-147 issued by the Nuclear Regulatory Commission. The power plant is presently under construction and is jointly owned by Kansas Gas and Electric Company and Kansas City Power and Light Company. The Architect/ Engineer for the project is Bechtel Power Corporation, Gaithersburg, Maryland. (Bechtel) The general contractor is Daniel International Corporation (DIC) who also operate the on-site concrete batch plant and concrete testing laboratory.

The Reactor Containment Building base mat is a concrete foundation measuring 150' in diameter and 10 feet in thickness. Plans and sections showing the base mat can be found in Appendix A. The base mat concrete, involving approximately 6600 cubic yards of concrete was placed in a continuous placement from about 9:30 a.m. on December 12, 1977 to 11:30 p.m. on December 13, 1977.

The specified design strength of the base mat concrete was 5000 psi at 90 days. The specifications identify cause for rejection of base mat concrete as outlined in Paragraph 4.3.3 of ACI 318-71. ACI 318 required that the 90 day cylinders tests (average of 2 companion specimens) to meet the following strength levels:

1. The averages of all sets of three consecutive 90 day strength tests results must be equal to or greater than the 5000 psi specified design strength.
2. No individual 90 day strength test result could fall more than 500 psi below the specified 5000 psi design strength or 4500 psi. (The strength level values are based on statistical procedures to determine potential quality and 1 strength test value in a 100 falling below the 5000 psi and 4500 psi values is permitted by ACI 318)

A set of six test specimens consisting of 6 x 12-inch cylinders were required to be taken from every 100 cubic yards of base mat concrete which was placed. Two cylinders from each set were

required to be tested at 7, 28, and 90 days. The concrete cylinders were required to be made and cured in accordance with ASTM C31 and tested in accordance with ASTM C39. The cylinders also were required to be maintained at a temperature of 60°F to 80°F prior to stripping, stripped within 24 hours after casting, marked and stored in the curing room until the designated date for testing. Cylinders not made or cured in accordance with the required standards were to be discarded.

There were 66 cylinder sets taken from the base mat placement. The sets represent approximately 1900 cubic yards of concrete placement on December 12, 1977 and approximately 4700 cubic yards of concrete placement on December 13, 1977. The 90-day concrete cylinders were capped on March 10, 1978 and then stored in the curing room. On March 13, 1978 they were all tested, giving 91 and 90-day results for the December 12 and 13 cylinders respectively.

The 91/90 test results were lower than anticipated and KG&E conducted a study to investigate the 90-day cylinder breaks related to the base mat concrete. The elements of the study are identified in the index of Non Conformance Report (NCR) No. I-0229-C which is shown in Appendix B.

Kansas Gas & Electric Company (KG&E) Study of NCR #1-0229C

The KG&E study indicates an investigation was begun immediately after the March 13, 1978 test results were known and completed on October 26, 1978.

Analysis of 90-Day Concrete Strength Data. This analysis, dated March 20, 1978 determined that the average strength of the base mat concrete as represented by the 90 day cylinder strength test results was 5067 psi with a standard deviation of 487 psi. In determining

the average strength and standard deviation values the analysis references ACI 214 as justification for omitting two low strength cylinder specimen values of 3270 psi and 2870 psi along with their companion cylinder specimen values of 4830 psi and 5230 psi. The 3270 psi and 2870 psi values are more than 3 standard deviations from the 5067 psi average strength of all the cylinder test results. ACI 214 permits discarding a specimen value greater than 3 standard deviations if there are three or more specimens in a test (average of all specimens of a sample). There are only two cylinder specimens for each 90-day cylinder of the base mat. ACI 214 states that the practice of arbitrary rejection of test cylinders which appear "too far out of line" is not recommended since the normal pattern of probability establishes the possibility of such results.

The analysis compares the cylinder strength data of the base mat concrete to the specification requirements (Section 4.3.3 of ACI 318-71) and identifies 33 failures. The comparison used only the higher companion cylinder specimen values of 4830 psi and 5230 psi to identify 33 failures and did not include the lower 3270 psi and 2870 psi specimen values as required by ACI 214.

The analysis also states that if the values were only 350 psi greater there would be no failures.

There is no discussion in the analysis of 90-day test strength results which were lower than the 28-day test strength results.

Finding:

Discarding of the 3270/4830 psi and 2870/5230 psi specimen values is not a recommended practice and does not conform to the referenced ACI 214 Standard. The method used in the analysis distorts the conclusions, and did not result in identification

of all of the 36 failures. Following is a comparison of values:

Item	KG&E Analysis Values	Revised Values
Average Strength	5067 psi	5035 psi
Standard Deviation	487 psi	435 psi
Number of Failures	33	36
Strength of Increase Req'd for No Failures	350 psi	580 psi

[The 36 failures (i.e. cylinder tests which did not meet strength acceptance criteria) noted above are shown in Appendix C.]

Of the 66 cylinder tests there were thirty 90-day compression test results which were lower than 28-day results. The identification of the 30 cylinder tests and the strength values is shown in Appendix D.

Non Conformance Report (NCR) No. I-0229-C. This report, dated April 4, 1978, of the KG&E Study describes a total of thirty-two (32) cylinder test sets which had 90-day compression test results with strength values less than 5000 psi. The compression test report sheets which were attached to the NCR identifies 34 cylinder test sets which had 90-day test results that were less than 5000 psi. (Test sets 532 and 537 were included in the test report sheets but not described in the NCR). The NCR listing was compared to the list of cylinders identifying failures (i.e. those which did not meet strength acceptance criteria) found in Appendix C.

Finding:

Non Conformance Report (NCR) No. I-0229-C does not identify 8 tests of 90-day cylinders which failed to meet strength acceptance criteria. (See Appendix E.)

The NCR identifies 11 tests of 90-day cylinders which met strength acceptance criteria. (See Appendix F.)

KG&E Investigation. Discussions and meetings which involved KG&E, Bechtel Power Corporation, Daniel International Corporation and Portland Cement Association representatives resulted in the following areas of investigations being identified.

1. Review of the required testing and investigations by the specifications as follows:
   a. Cement strength tests by Ash Grove Cement Company and Daniel International Corporation
   b. Source qualification test for coarse aggregate by Soil Testing Services including chemical analysis and petrographic analysis by Erlin Hime Association
   c. Source qualification tests for fine aggregate by Law Engineering Testing Company including petrographic and chemical analysis
   d. Source qualification tests for water by Law Engineering Testing Company
2. Inspection of the testing machine and review of testing practices and procedures
3. Calibration check of machine accuracy
4. Investigation of the effect of testing machine factors on measured concrete cylinder strength by Construction Technology Laboratory (a Division of the Portland Cement Association)
5. Investigation and examination by Construction Technology Laboratory of 22 selected 90-day cylinder specimen fragment samples as follows:

a. Petrographic analysis and air content determination and chemical analysis including cement content, approximate water-cement ratio and $\%SO_3$ determination (4 samples)

b. Chemical analysis for presence of admixtures (4 samples)

c. Compression strength testing (14 samples)

(19 of the 22 selected samples met the strength level acceptance criteria 3 did not)

6. Compression strength testing on the PCA machine of 20 untested companion cylinders (from the same concrete mix from other than the base mat concrete) for comparison with 20 mating cylinders tested on the on-site testing machine

7. Analysis and examination by Construction Technology Laboratory as follows:

a. Analysis of chemical admixture materials

b. Chemical and physical analysis of two cement samples representative of cement used in base mat concrete

c. Analysis of capping compound and the planeness of cylinder ends

d. Evaluation of the fracture surfaces on broken cylinder specimens

8. Obtaining measurements of Windsor Probe values of the vertical peripheral surface of the in-situ base mat concrete and developing a correlation between Windsor Probe Concrete cylinders and concrete core values

9. Analysis of water samples of curing room and batch plant waters

10. Investigation by Daniel International Corporation of the following:

    a. Review of Central mix plant batch tickets to verify mix proportion requirements

    b. Review of placement of concrete to determine if there was a trend linking low strength cylinders to location or method of placement or to a particular lab technician making cylinders

    c. Review of time cast/break data to determine a particular time during placement low strength values were obtained

    d. Review of curing room temperature records and the curing room itself

    e. Review of compression test reports of cylinders related to the base mat for mathematical errors

    f. Review of user tests on cement, admixtures, aggregates, etc. for compliance with specification requirements

    g. Testing of capping compound and checking of capping compound temperatures

    h. Witnessing of numerous compression strength tests of cylinders for operator technique, including rate of loading, specimen centering, casting techniques and proper recording of dial values

11. Review of the KG&E Study by Bechtel Power Corporation

Significant Specification Requirements and Information from the KG&E Study

Significant specification requirements and information obtained during review of the KG&E Study data are the following:

1. Cement. The specification required the cement to be Type II Portland Cement conforming to ASTM C150-74 with a maximum percent of the sum of tricalcium silicate and tricalcium aluminate to be 58% and the maximum percent of alkalies ($Na_2O + 0.658K_2O$) to be 0.60%. Minimum 7-day and 28-day cement strengths were required to be 1700 psi and 2800 psi respectively. The cement supplier was required to furnish mill test reports showing the chemical composition and physical properties and certifying the cement complies with the above requirements. To confirm the mill tests and compliance certifications the testing laboratory (on site) was required to make the necessary tests for every shipment. The minimum 3-day strength requirement of ASTM C150 was 1500 psi. The strength at any age was required to be higher than the preceding age. No cement was to be used until notice was given by the owner that the mill tests are satisfactory. (KG&E delegated responsibility for determining that mill test results are satisfactory to DIC on March 1, 1976.) The certified mill test reports from Ash Grove Cement Company and the user test reports were reviewed by the task force. The user test reports did not show 3-day compressive strength values, and identified the specification requirements for 3, 7 and 28 days as 1500 psi, 2500 psi and 3500 or 4000 psi respectively. The user 7-day strength test values decreased

from 3950 psi to 2550 psi between 10/19/77 and 12/19/77 and the 28 day strength test values decreased from 5790 psi to 3680 psi between 10/19/77 and 12/12/77. The 7 and 28-day strength values of Ash Grove Cement Company tests did not show a similar decrease in strength. The cement samples which remained after the user tests were completed on 11/19/77(CU-T-16) and 12/12/77 (CU-T-17) were sent to the Construction Technology Laboratory in late March and tested (using cubes) at 7, 28 and 45 days. The resulting test strength values of the PCA cubes and the 7 and 28-day Ash Grove and user values are shown in Table 1.

Table 1. - Comparison of Ash Grove, PCA and User Tests

User Sample Date	Cement Sample	7 Day Strength psi			28 Day Strength psi			45 Day Strength psi
		Ash Grove	PCA	User	Ash Grove	PCA	User	PCA
11/21/77	C-UT-16	3531	3625	3260	5317	5525	5180	5900
12/12/77	C-UT-17	3531	3720	3570	5317	5600	3370	6020
				2860 (retest)			3680 (retest)	

PCA test strength values were higher than the user test strength values particularly in C-UT-17 which had a 28 day user test strength of 3680 psi compared to the 5600 psi value from the PCA test. A graph showing cement strength test values is shown in Appendix G.

Finding:

The cement mill test reports showed the cement furnished to the project met the specification requirements.

The user test reports did not properly or accurately identify what the required specification strength values were. The 3-day values were not identified and the 7 and 28-day values were not identified with the proper specification values.

The user test reports did not include any 3-day strength test values.

The user test reports did show 7 and 28-day strength values. These met the specification strength requirements.

The user test results of 12/12/77 are considerably lower than and inconsistent with the Ash Grove and PCA test results.

2. Aggregates. The specifications required the aggregate to conform to ASTM C33-71a. No aggregate was to be used until tested by the owner approved testing laboratory and written approval was received from the owner. The aggregate source selected was not permitted to be changed unless approved by the owner. (KG&E delegated owner responsibility to the general contractor in its letter to DIC, dated March 1, 1976). Aggregates were to be stored on concrete slabs (unless waived by owner) in such a manner as to avoid the inclusion of any foreign materials in the concrete. Muddy or oil leaking equipment was not permitted to operate on the storage pile. Suitable drainage was required to maintain the uniformity of moisture content.

Acceptability of aggregates and source was required to be based on the following tests:

Test	ASTM Designation
Organic Impurities in Sand	C40
Effect of Organic Impurities on Strength of Mortar	C87
Soundness of Aggregates	C88
Material Finer than No. 200 Sieve	C117
Lightweight Pieces in Aggregate	C123
Specific Gravity and Absorption of Coarse Aggregate	C127
Specific Gravity and Absorption of Fine Aggregate	C128
L. A. Abrasion (Coarse Aggregate)	C131
Sieve Analysis	C136
Friable Particles	C142
Scratch Hardness of Coarse Aggregates	C235
Potential Reactivity of Aggregates	C289
Petrographic Examination of Aggregates	C295
	Corps. of Engr. Designation
Flat and Elongated Particles	CRD C-119

Aggregate tests required to be performed during the course of production and the required frequency of testing are as follows:

Test	ASTM Designation	Frequency Required
Sieve or Screen Analysis	C136	At beginning and midpoint of placement
Organic Impurities in Sand	C40	At beginning and midpoint of placement
Material Finer Than No. 200	C117	Daily
Friable Particles	C142	Monthly
Lightweight Pieces	C123	Monthly
Scratch Hardness of Coarse Aggregate	C235	Monthly
L. A. Abrasion (Coarse Aggregate)	C131	Every 6 months
Potential Reactivity of Aggregates	C289	Every 6 months
Soundness of Aggregates	C88	Every 6 months
	Corps of Engrs. Designation	
Flat and Elongated Particles	CRD C-119	At beginning and midpoint of placement

When aggregates contained montmorillonite clays, top soil and claystone, fine aggregate was required to have a minimum sand equivalent of 75 when tested in accordance with Test Method No. Calif. 217 and coarse aggregate was required to have a minimum cleanness value of 75 when tested, in accordance with Test Method No. Calif. 227, as specified in the California Division of Highways Test Methods.

a. Coarse aggregate. Coarse aggregate was required to be washed gravel or washed crushed rock having hard, strong durable pieces and rejected if the loss when subjected to the Los Angeles Abrasion Test, ASTM C131-69 using grading A, exceeds 40 percent by weight at 500 revolutions. The particle shape was required to generally be rounded or cubical and not contain thin, flat and elongated particles. Soft particles, when tested in accordance with ASTM C235, were not to exceed 5 percent by weight of the total sample. The source selected for the coarse aggregate used in the base mat concrete was Christie Quarry in Lamont, Kansas, located 30 miles southeast of the site.

b. Fine Aggregate. Fine aggregate was required to consist of clean, sharp, washed natural or washed crushed sand of uniform gradation when delivered to batch plant storage. The required range of fineness nodulus was 2.5 to 3.1. The fine aggregate source selected for the concrete used in the base mat concrete was a natural sand from the KAW River located 80 miles northeast of the site.

Review of information on the aggregate testing for the acceptability of aggregates and source and the required testing of aggregates during production was not completed because all requested information was not received at the time of the preparation of this report. Complete information was received on the ASTM C289 and C295 tests. These tests are performed to indicate the possibility of adverse chemical reactivity in concrete using the aggregates tested.

Finding:

The required ASTM C289 and ASTM C295 source qualification tests and the required ASTM C289 tests performed during production indicate that use of the aggregates would not result in adverse chemical reactivity in the concrete. The requested additional information is needed to make additional findings.

3. Admixtures. The specifications required an air entraining admixture capable of entraining 3 to 6 percent air and conforming to ASTM C260-69 and a water reducing admixture conforming to ASTM C494-71, Types A and D. Type A was to be used whem ambient temperatures were below 70F and Type D when ambient temperatures were above 70F. Admixtures were required to be stored in their original containers in such a manner to prevent damage. Liquid admixtures delivered in tank trailers were to be stored in tanks approved for storage. The manufacturer of the admixture was required to furnish certification, based on chemical analysis test results obtained from testing a composite sample by the infared spectrophotometry method, for every delivery stating the materials originally approved have not changed.

The certification was required to state that the WRA contains no added chlorides. The contractor was to review the manufacturer's certification and verify compliance with specification requirements.

The manufacturer's certifications were reviewed by the task force for MBVR air entraining admixture and MB-300N water reducing admixture manufactured by Master Builders.

Finding:

Manufacturers certificates show conformance to specifications for both the air entraining and water reducing admixtures.

4. Water. The specifications required the water used in the mixing of concrete to be free of injurious amounts of oil, acid, alkalai, organic matter or other deleterious substances and conform to AASHTO T26. The 7 and 28 ASTM C109 day cubes required to be tested by AASHTO T26 could not have a reduction in strength greater than 10% when compared to cubes made with distilled water. The water was required to be tested and contain not more than 250 ppm of chlorides as cl, nor more than 1000 ppm of sulfates as SO_4. The pH range was to be 4.5 to 8.5 unless otherwise approved.

The physical and chemical water test results were reviewed by the task force. The 7 and 28 day cube strength values were as follows:

ASTM C109 Cube Strengths

Date of Sample	7-Day		28-Day	
	Site Water	Distilled Water	Site Water	Distilled Water
10/4/77	3346	3133	5224	5196
12/29/77	3173	2973	3973	4307

Finding:

Based on the information reviewed the water used in the base mat concrete met specification requirements.

5. Concrete Mix. The base mat concrete was required to be a 5000 psi mix at 90 days. The specification required the Owner to furnish the contractor with mix designs prior to the manufacture of concrete. Furnishing of the mix designs by the owner was not to relieve the contractor of his responsibility for compliance with the specification. (KG&E delegated owner responsibility to DIC in its letter dated March 1, 1976).

The concrete mix proportions were required to be established according to Paragraph 3.8 of ACI, 301, Method 1. The use of Method 1 requires making trial mix batches using at least three different water-cement ratios which produce a range of 90-day strengths. At least three compression test cylinders for each water-cement ratio is required to be made, cured and tested at 90 days. Also a curve is required to be plotted showing the relationship between water-cement ratio and compressive strength. From this curve the water cement ratio was to be selected to produce the average strength required. The average strength required is determined from a control record of at least 30 consecutive strength tests of a similar mix or mixes obtained within the past year representing similar materials and conditions to those expected. The average strength is required to exceed the 5000 psi design strength from 400 psi to 1200 psi depending on the standard

deviation value established from the record of strength test performance. If there is less than 30 consecutive strength tests available the average strength must be exceeded by 1200 psi.

While not part of the project specification, and specifically eliminated from it, the referenced ACI 301 also identifies Methods 2 and 3. Method 2 requires use of appropriate field test data with mixture proportions subject to approval by the architect/engineer based on the demonstrated ability to produce concrete meeting all requirements of the specification. A strength test record of 30 or more tests made during the past year is required to determine the ability of the mix proportions to produce the required strength. Method 3 of ACI 301 establishes a maximum water-cement ratio and is not permitted to be used for concrete with specified design strengths in excess of 4000 psi or concrete containing admixtures other than those used exclusively for the purpose of entraining air.

Finding:

The provision of Paragraph 3.8 of ACI 301, Method 1, as required by the specification, was not followed for the 5000 psi 90-day concrete mix placed in the base mat.

Information for the following specification requirements was requested but was not able to be furnished:

The 90 day compression strength tests of three cylinder specimens for each of the three water-cement ratio used in trial mix batches.

The data showing that the water-cement ratio was selected from the curve showing the relationship between water-cement ratio and compressive strength and could produce the required average 90-day strength.

Control record of at least 30 consecutive 90-day strength tests.

Information for the following requirements for Method 2 of ACI 301 was also requested but was not able to be furnished.

Approval of mixture proportions by the architect/engineer.

A strength test record of 30 or more 90-day tests to determine the ability of the mix proportions to produce the required average strength.

6. Compressive Strength Cylinders. Compressive strength test cylinders were required to be cast from representative concrete samples taken from either the discharge of the batch plant stationary mixer or the discharge of the transport system in accordance with Paragraph 3, ASTM C172.

If water was added after mixing cycle in accordance with the provisions of ASTM C94, compressive strength cylinders were to be taken at the discharge of the transport system. Slump, air content, unit weight and temperature of the concrete were to be recorded when cylinders are being cast.

Sets of six 6 x 12 cylinder specimens were taken at the discharge of truck chutes or the last pump line during base mat concrete placement. The cylinders were made by the on-site laboratory quality control technicians. The cylinders were stored and covered with a plastic sheet in a nearby heated shed which was required to be kept at a temperature of 60°F to 80°F. According to lab personnel no temperature records were kept, and the cylinders were moved to the laboratory using a styrofoam padded box in a truck between 16 and 24 hours after casting. The cylinders were stripped immediately after arrival at the laboratory and placed in the curing room according to lab personnel. Except for the following instances the curing room records showed the room was kept at the required temperature of 73.4 $\pm$3°F and at a relative humidity of not less than 95%

Length of Time	Lowest Temperature Level	Curing Period
2.5 days	69.8°F	12/7 to 12/14/77
3.0 days	68.0°F	1/5 to 1/12/78
4.0 days	62.0°F	1/12 to 2/2/78

Finding:

The cylinders appeared to be made according to specification requirements.

There is no temperature record of the heated shed used for the temporary storage. Personnel involved indicated temperatures appeared above 60°F and at or near 80°F.

The curing room temperature was below the specification requirement for a maximum of 8.0 days and to as low a temperature as 62.0°F. The slightly lower curing temperatures for eight days would not significantly affect the cylinder strength values.

7. Measuring, Batching, Mixing and Delivery. Measuring materials, batching, mixing and delivery of all concrete was required to be in accordance with ASTM C94, Sections 7, 8, 9, and 10; ACI 30, Chapters 2, 3, 7 and 14; and ACI 304, Chapters 1, 2, 3, 4 and 6, unless otherwise noted.

The concrete batch plant, including the truck fleet, was required to be certified in accordance with standards established by the National Ready Mix Concrete Association, (NRMCA), with the scales tested and sealed by the Bureau of Weights and Measures or a qualified independent testing agency or laboratory.

Tests of scales and metering devices were required to be performed at least once every 6 months. Renewal of the batch plant certification was to be in accordance with the requirements of NRMCA. Test certificates and the test reports showing errors as found were required to be submitted to the owner at the completion of each test. Such tests, equipment, and operations at all times were subject to owner's approval. Plant and equipment was required to be

capable of a continuous production of 150 cubic yards per hour and at a rated production of 200 cubic yards per hour delivered at point of placement. Mixer uniformity tests were required to be performed on the stationary mixer at the batch plant initially and every 6 months thereafter, in accordance with ASTM C94, Appendix XI. The batch plant, including the delivery truck fleet, scales and metering devices, received the required NRMCA certification on June 3, 1977. Mixer uniformity tests for the batch plant were made on June 21, 1977, December 19, 1977 and June 6, 1978.

The mix time in the mixer uniformity tests was 45 seconds. The mixer uniformity test on December 19, 1977 showed a 6.2% difference in the 7 day compressive strength comparison of front to back batches in the mixer. The mix used in the test was the same mix design as used in the base mat concrete.

Finding:

The information reviewed shows that the batch plant met the specification requirements at the time of base mat concrete placement.

8. Testing Machine. The testing machine was required to be a 300,000 pound automatic portable compression machine and was subject to owners approval for use. The contractor was required to keep a current list of his testing equipment and dates each was calibrated. A sticker was required to be affixed to the testing equipment to identify the latest calibration and date of

certification. The on-site testing machine used in the testing of 90-day cylinders related to the base mat concrete was a Forney Model QC-150 DR, S/N 76011. The calibration records show that the machine was checked for accuracy as follows:

Date	Accuracy Found Within 1%	Independent Calibrating Laboratory
3/29/77	yes	Mobile Calibration
6/28/77	yes	Mobile Calibration
12/20/77	yes	Mobile Calibration
2/28/78	yes	Mobile Calibration
3/28/78	yes	Southern Calibration & Service

Manufacturers Inspection, Calibration Check and Investigation of the Testing Machine

On March 27, 1978 representatives of Forney's Incorporated, the manufacturer, performed an inspection of the jobsite testing machine and the operational procedure by the testing laboratory quality control technicians. The results of the inspection was as follows:

1. The testing practices and procedures used by the laboratory quality control technicians was monitored carefully and verified all testing practices conformed to Forney and ASTM specifications.
2. The accuracy of the load readout gages were found within the 1% specification limit of ASTM E4.
3. All load platens were checked for planeness in accordance with ASTM C39 and found in excellent condition.
4. The 6½" diameter spherically seated top platen was completely disassembled and checked for undue wear. No evidence was found.
5. The testing machine was found out of level front to back by 1/16" in 8" backwards, well within Forney requirements.
6. Excessive material (crushed fine powder) was found between the wear plate and the lower platen. The load readout accuracy was checked with and without the material beneath the wear plate with no affect between accuracy results.

PCA Investigation on the Effect of Testing Machine Factors.

The onsite testing machine was investigated by Construction Technology Laboratories (a Division of the Portland Cement Association) for the effect of testing machine factors on measured concrete cylinder strengths. The investigation resulted in the following findings:

1. Strain data obtained from instrumented cylinders during compressive strength tests indicated non-uniform loading for cylinders centered in the machine.
2. Compressive strengths obtained with cylinders centered under the top swivel head were 7.5% less than those calculated for cylinders loaded uniformly.
3. Compressive strengths obtained for misalignments of 1/8 and 1/4 in. due to cylinder positioning were 10.5 and 14.8%, respectively, less than the calculated strength for a cylinder load uniformly.
   (The values were obtained by adding 3.0% and 7.3% test data values to the 7.5% value of finding 2)
4. Probability of improper cylinder positioning during routine testing was high. Cylinder capping molds had a tolerance of 1/8 in. Also, the upper machine swivel head used to position cylinders was 1/2" larger in diameter than the cylinder.
5. Fixed or locked upper loading head swivel reduced recorded compressive strength by up to 27%.

6. Oil and grease swivel head lubricants were evaluated; they performed well.
7. Neither fixed tilts of 1/8 and 1/4 in or rocking action (simulation of excessive material between wear plate and the lower platen) had any appreciable effect on recorded compressive strengths.
8. Loose threads between the lower base plate and hydraulic piston did not affect recorded compressive strengths significantly.
9. A literature review verified findings regarding the machine factor influences obtained in this investigation. Previous studies indicated 12 to 14.8% reduction in recorded compressive strengths for concrete cubes misaligned by 1/4 in.

Additional Testing Machine Information. Discussion with the testing laboratory quality control personnel indicated that when the 90-day compression strength cylinder test results from the base mat concrete placement were lower than anticipated the lead quality control technician proceeded to perform the testing operations and experienced the same lower than anticipated compressive strength test results. The lab personnel indicated the cylinder itself and not the capping was used to align the cylinder with the swivel head. According to lab personnel, the top swivel head did not stick and performed satisfactorily during the testing. Other than the maintenance involving removal of excessive material between the wear plate and the lower platen, the lab personnel indicated no repairs or modification were made to the testing machine

after the completion of the testing of the 90-day cylinders related to the base mat concrete placement and prior to the investigation/ inspection and maintenance of the testing machine on March 27/28, 1978. Between March 15 and 27, 1978, the 90-day cylinder strength test results of other than base mat concrete placements involving the same concrete mix showed test results with a significant increase in strength test values when compared to the strength test value of the base mat concrete cylinders. A comparison of 7, 28 and 90-day cylinder test strength values of concrete placements made before and after the base mat placement is shown in Table 2.

Table 2

Date of Placement	91/90 Day Test Date	Average of 90 Days	Max. Test Value	Min. Test Value	Average of 28 Days Tests	Average of 7 Days Test
		psi	psi	psi	psi	psi
12/1/77	3/1/78	5560	5560	5560	5215	3785
12/12/77	3/13/78	5230	6110	4690	4660	3510
12/13/77	3/13/78	4957	5910	4050	5045	3510
12/15/77	3/15/78	6360	6395	6325	5110	3920
12/20/77	3/30/78	6450	6585	6280	6245	4340
12/21/77	3/21/78	5410	5696	5190	4590	3570
12/22/77	3/22/78	5640	5640	5640	4550	3450
12/27/77	3/27/78	6090	6240	5955	5280	4310
12/28/77	3/28/78	6685	6995	6375	4750	4240

As part of the investigation by Construction Technology Laboratory (PCA), a comparison of 90-day cylinder specimens was made involving the testing of companion cylinders on the PCA and on-site Daniel International Corporation (DIC) machine. The comparison testing was done between April 19, 1978 and May 24, 1978. The results of the averag maximum and minimum strengths and standard deviation were as follows:

	Compressive Strength	
	DIC	PCA
Average Strength	6467 psi	6219 psi
Maximum Strength	6920 psi	6690 psi
Minimum Strength	6000 psi	5830 psi
Standard Deviation	261 psi	302 psi

Finding:

The information reviewed shows that the testing machine met specification requirements and there is no data which shows the load readout during the 91/90 day testing of base mat concrete cylinders was not within 1% accuracy.

The higher test results of the on-site machine for the comparison testing of Power Block companion cylinders conflict with the PCA finding that the on-site machine test result values should be 7.5% lower than actual.

The PCA finding that the 27% reduction in compressive strength for fixed or locked upper loading head swivel is not applicable to test results for the base mat concrete cylinders.

The relationship of cylinder positioning of base mat concrete cylinders to the 90-day test result values obtained was not established in the PCA report.

9. Investigation and Examination of 90 Day Cylinder Fragments.

The PCA investigation, involving petrographic examination, chemical analysis and compressive strength testing, was made on samples from twenty-two 90-day cylinder specimen fragments. The 22 samples were selected from 42 identifiable fragments which had been picked out of the bone-pile (i.e. place where broken cylinders were dumped after testing).

The cylinder specimen fragments picked from the bone pile and selected for testing was almost exclusively related to the base mat concrete which met the acceptance criteria. Thirty-five of the 42 fragments picked from the bone pile and 19 of the 22 fragments examined, analyzed or tested were from concrete which met the acceptance criteria. Only 3 of the 19 fragments examined, analyzed or strength-tested were related to concrete which did not meet the acceptance criteria. One of the 3 was subjected to petrographic examination and chemical analysis; one was combined with a fragment from concrete which met the acceptance criteria and was analyzed for chemical admixture; one was cut into a 2" cube and strength tested. A summary of samples involved in the PCA investigation is shown in Table 3.

The PCA report does not identify whether cube samples were soaked before testing and tested wet or dry. (Dry tested values are considerably higher than wet tested values.) A discussion with PCA personnel indicated that the 2" cubes were soaked for 40 hours prior to testing and tested wet. The information reviewed indicate cylinder fragments, from which cubes were cut, were sent to the PCA on April 12, 1978 via a Daniel International Corporation truck. The PCA report indicates atesting date of April 17, 1978. The cylinder test values were obtained from cylinders tested wet.

The PCA report does not indicate whether cubes were cut from fragments which were the top or bottom of the cylinders. (Cubes cut from the bottom of cylinders would have higher test values than cubes cut from the top.)

Table 3. - Summary of Samples in PCA Investigation

Item	Cylinder Numbers	Number of Samples Picked From Bone Pile	Number of Samples Examined, Analyzed or Strength Tested by PCA				Number of Samples Not Tested
			Petrographic Chemical	Admixture Analysis	Strength Test	Total	
1	6407-6510	28	2	2	13	17	11
2	6521-6534 6581-6594 6629-6678 6689/90 6778/79 6844-45	4	0	0	0	0	4
3	6850-6857	3	1	1	0	2	1
Total		35	3	3	13	19	16
4	6515-6803 (except as shown in item 2)	7	1	1[1]	1	3	4
Total		42	4	3	14	22	20

[1]Sample 6623 combined with Sample 6414 of Item 1

Description of Items

1. Base mat concrete placed 12/12/77 which met acceptance criteria
2. Base mat concrete placed 12/13/77 which met acceptance criteria
3. Concrete placed 12/20/77 which met acceptance criteria
4. Base mat concrete placed 12/12-13/77 which did not meet acceptance criteria

The PCA examination, analysis and testing resulted in the conclusion that

1) microscopic analysis reveals no evidence which could conceivably cause significant strength reduction at 90 days.
2) cylinder strength may have been affected slightly by minor differences in air content and water-cement ratio.
3) The concrete appears to be of high quality with strengths apparently well above the 5000 psi specification at 90 days. The PCA determined the average compressive strength of the 2" test cubes to be 5970 psi with a minimum value of 5060 psi and a standard deviation of 752 psi. The values are 80 percent of the actual test values to correct for difference between cylinder and cube strengths. The average compressive strength of the cylinder from which the 2" cubes were cut was 5370 psi with a minimum value of 4360 psi and a standard deviation of 477 psi.

The PCA chemical analysis for cement content, approximate water-cement ratio and admixture content of hardened concrete showed that

1) the cement contents of the [illegible] samples selected were comparable to the 564#/y[illegible] specified in the concrete mix design.
2) the approximate water-cement ratios for the same samples were below the level indicated in the mix design and

3) The chemical admixtures specified in the mix design appeared to be present in the three concrete samples at the appropriate dosage levels with no indication of improper admixture formulation (Pozzolith 300-N and MBVR) observed.

The PCA analysis of concrete samples for the presence of air entraining admixture concluded that it appears there was not an excess of air-entraining agent present in the concrete

The PCA analysis of two samples of Portland cement, reported to be Ash Grove Type II (Chanute, Kansas Plant) and identified as C-UT-16 (Bin #36, 11/21/77 and C-UT-17 (Bin #36, 12/12/77) showed no significant difference in SO_3 content, loss on ignition, specific surface (Blaine, air permeability) and particle size distribution (Sedigraph 5000).

Finding:

The selection of the 42 fragments from the bone-pile and the PCA investigation of the 22 selected samples was not adequate. The selection and investigation was deficient as follows:

Fragments from cylinders which had test results less than the required 4500 psi strength level were not strength tested for strength and only one fragment from the 30 cylinder tests, which did not meet the required 5000 psi strength level for the average of 3 consecutive tests, was strength tested. Fragments from cylinders which had 90-day test results less than 28-day results were not give a petrographic examination or chemical analysis.

The PCA conclusions in regard to its investigation of cylinder fragments is not applicable to the potentially deficient base mat concrete identified by low test results of the 90-day cylinders

The PCA report did not include the following areas of investigation of base mat concrete cylinders:

1) Investigation of as many failed specimen remnants as possible for mode of failure.
2) Investigation of capping compound on failed cylinders for possible defects in strength, application, etc.
3) Evaluation of the planeness of ends.

The first two items above were indicated to have been agreed upon at the meeting held at the site on April 7, 1978 involving representatives from KG&E, Bechtel, Daniel and the PCA. The second and third items were performed according to DIC letter (Hitt), dated May 24, 1978, to KG&E (Arterburn).

The only specific mention of rounded ends of cylinders in the PCA report is related to the Power Block cylinders. (Power Block cylinders were not from the base mat concrete.)

The Power Block cylinders with rounded ends had high 90-day cylinder strength values and experienced diagonal or diagonal/cone, or diagonal transverse type breaks.

10. Windsor Probe Testing Program. A Windsor Probe testing program was conducted by Daniel International Corporation. The program involved the placement of two separate concrete test slabs on March 30 and April 11, 1978. The same concrete mix design was used in the test slabs as in the base mat. From concrete placement in three locations in each of test slabs standard 6 x 12 cylinders were taken and tested at 28 and 90-days. The test values obtained were compared to Windsor Probe reading and four (4) inch core specimens taken for the same time periods and the same area. A correlation was then made using MOH's numbers 3 and 4, with MOH's number 4 more closely representing the concrete cylinder strength. Windsor Probe readings were taken on the circumference of the base mat at 10 degree intervals (except for 3 readings not taken because of accessibility). Approximately 4300 square feet of vertical circumference area was involved in the Windsor Probe readings. The average strength for the 33 Windsor Probe readings which were taken around the circumference was 6495 psi. The corresponding cylinder strength value was determined by Bechtel to be 5896 psi.

Finding:

The Windsor Probe investigation was related to the circumferential surface of the base mat and is not applicable to interior concrete located further than somewhere around 12 inches away from the exterior

circumferential surface. Over 95% of the base mat concrete is located 12 inches or more from the vertical circumferential surface.

Since the Windsor Probe readings are considered of value primarily for comparisons within the same job rather than as quantitative measures the strength value determinations from Windsor Probe readings do not provide assurance of structural adequacy.

Conclusion and Pertinent Comments:

The KG&E study, while extensive in scope, was not adequate in investigation of the base mat concrete cylinders which did not meet the required strength level of the specification and its conclusion that the base mat met the required 5000 psi concrete strength level is not valid for the total base mat.

The information in the study indicates that the testing machine was probably not the most likely cause of low concrete cylinder strengths.

The KG&E study did not indicate in its investigation of base mat cylinder fragment samples that there was any evidence which showed a direct relationship between evidence of improper molding and/or testing procedure to low concrete cylinder test values.

The study did not establish a cause of the low concrete cylinder strength and since adverse chemical reactivity is a possible cause, proper attention should be given to future investigation of cylinder fragments which had 90-day strengths less than 28-day strengths.

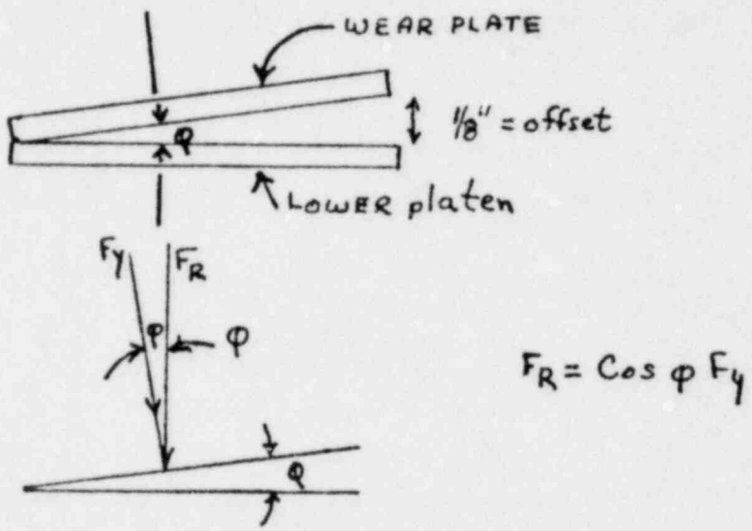
APPENDIX A

Analysis of Wear Plate Tilting

APPENDIX A

Analysis of Wear Plate Tilting

During the investigation effort at Wolf Creek, an accumulation of concrete dust was found under the wear plate and the lower platen. The wear plate was 1/8" higher off the lower platen in the back as in the front.[1/] In order to evaluate the magnitude of this condition, calculations were made using the example indicated below. Note that the dimension of the wear plate and the force is assumed only.



Example:

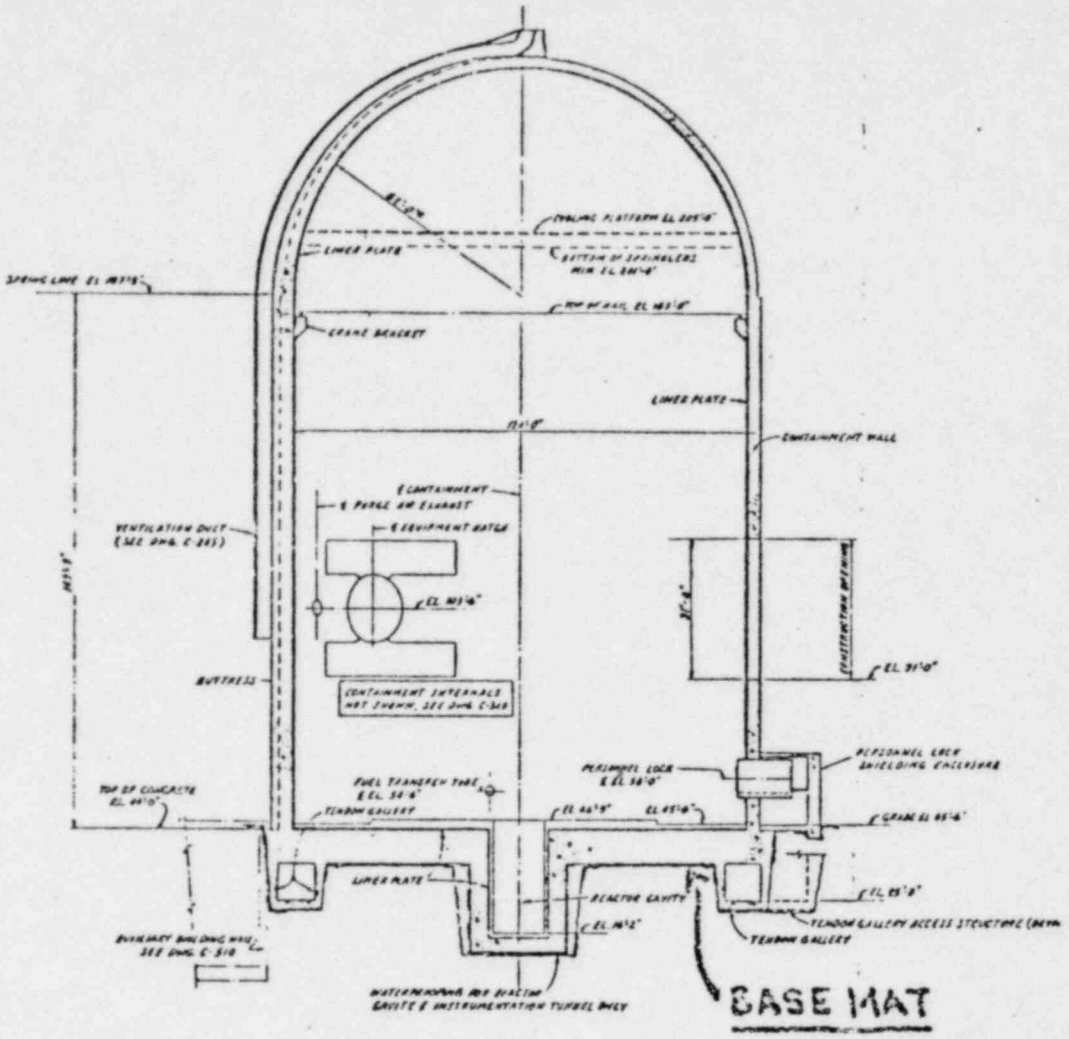
If the wear plate is assumed to be 9" long, and an offset of 0.125 in the Q = 0.795 degrees. If Fy = 150,000 pounds,

then F_R = Cos (0.795) X 150,000
F_R = .9999 (150,000) = 149,985.5 lbs.

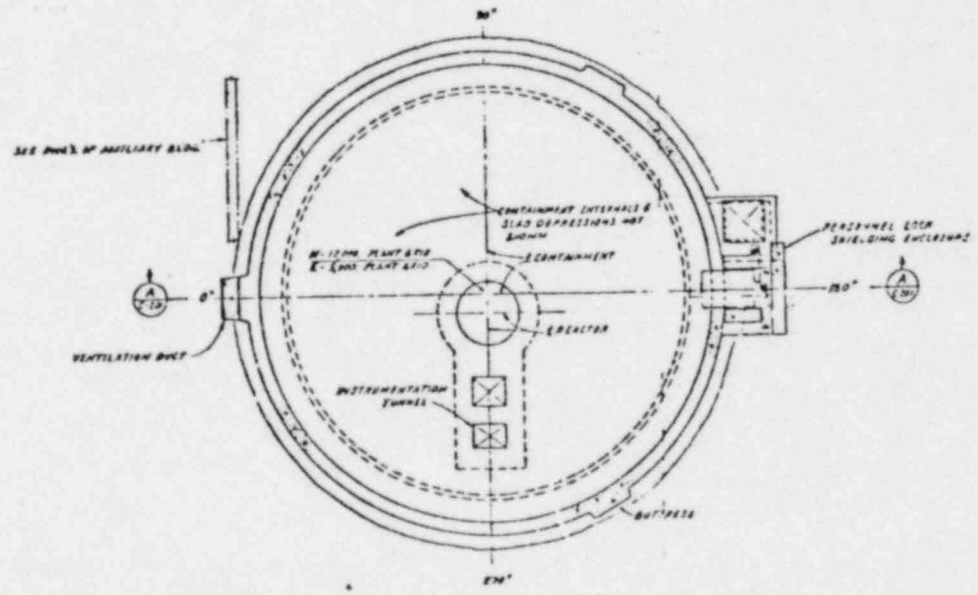
Comparing PSI results: Psi normal = 5305.16 Psi tilted = 5304.65

The conclusion is that any difference in compression test results, based on the amount of wear plate tilt, can be neglected.

1/ Forney Inc. (Kajundic) letter to Daniel International (Jones) April 4, 1978



SECTION A / C-201



PLAN AT EL 58'-0"

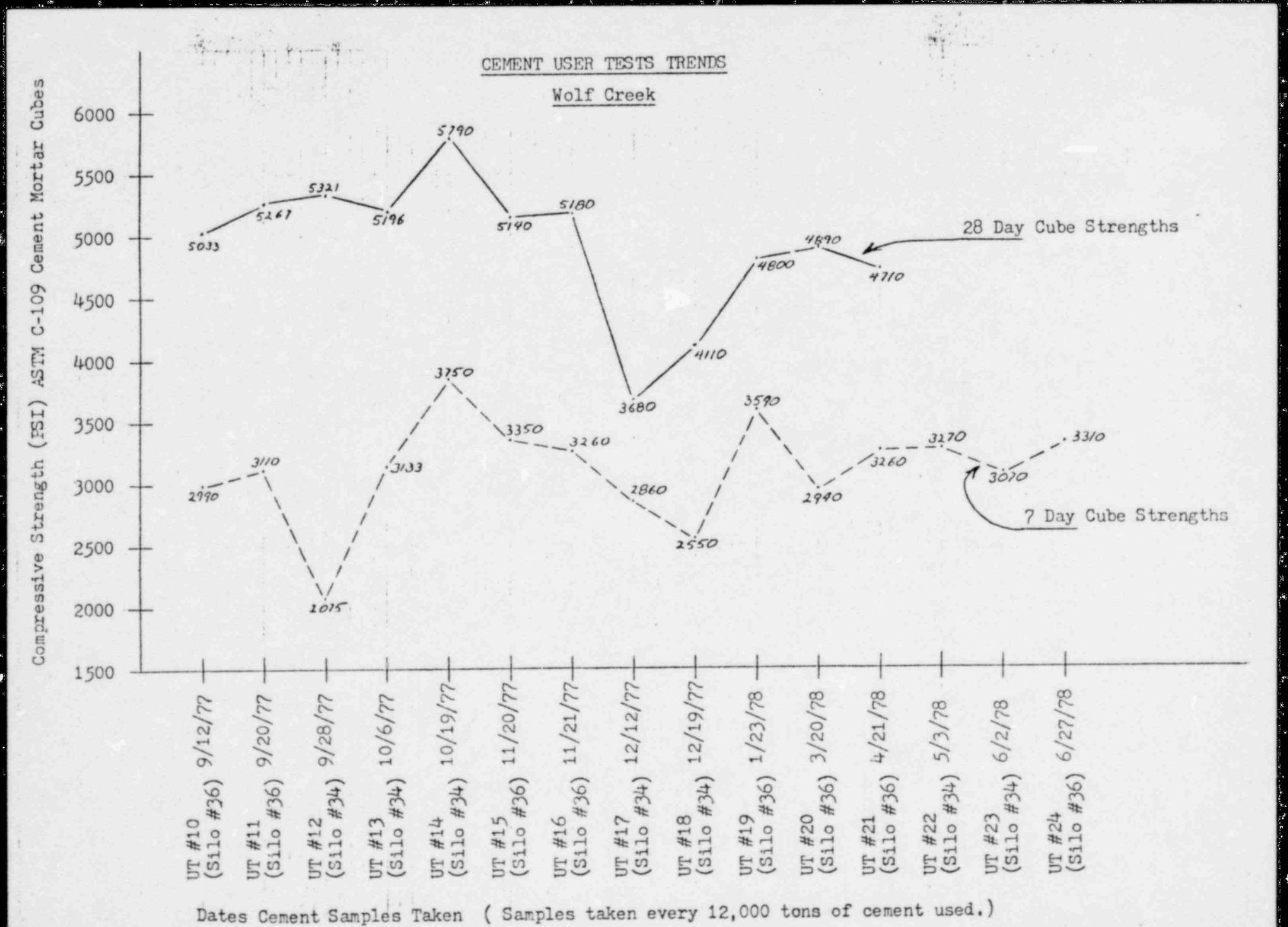

CEMENT USER TESTS TRENDS
Wolf Creek
Compressive Strength (PSI) ASTM C-109 Cement Mortar Cubes
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
28 Day Cube Strengths
7 Day Cube Strengths
5033
5261
5321
5196
5790
5140
5180
3680
4110
4800
4890
4710
2990
3110
2015
3133
3750
3350
3260
2860
2550
3590
2940
3260
3270
3070
3310
UT #10 (Silo #36) 9/12/77
UT #11 (Silo #36) 9/20/77
UT #12 (Silo #34) 9/28/77
UT #13 (Silo #34) 10/6/77
UT #14 (Silo #34) 10/19/77
UT #15 (Silo #36) 11/20/77
UT #16 (Silo #36) 11/21/77
UT #17 (Silo #34) 12/12/77
UT #18 (Silo #34) 12/19/77
UT #19 (Silo #36) 1/23/78
UT #20 (Silo #36) 3/20/78
UT #21 (Silo #36) 4/21/78
UT #22 (Silo #34) 5/3/78
UT #23 (Silo #34) 6/2/78
UT #24 (Silo #36) 6/27/78
Dates Cement Samples Taken (Samples taken every 12,000 tons of cement used.)

Figure 1

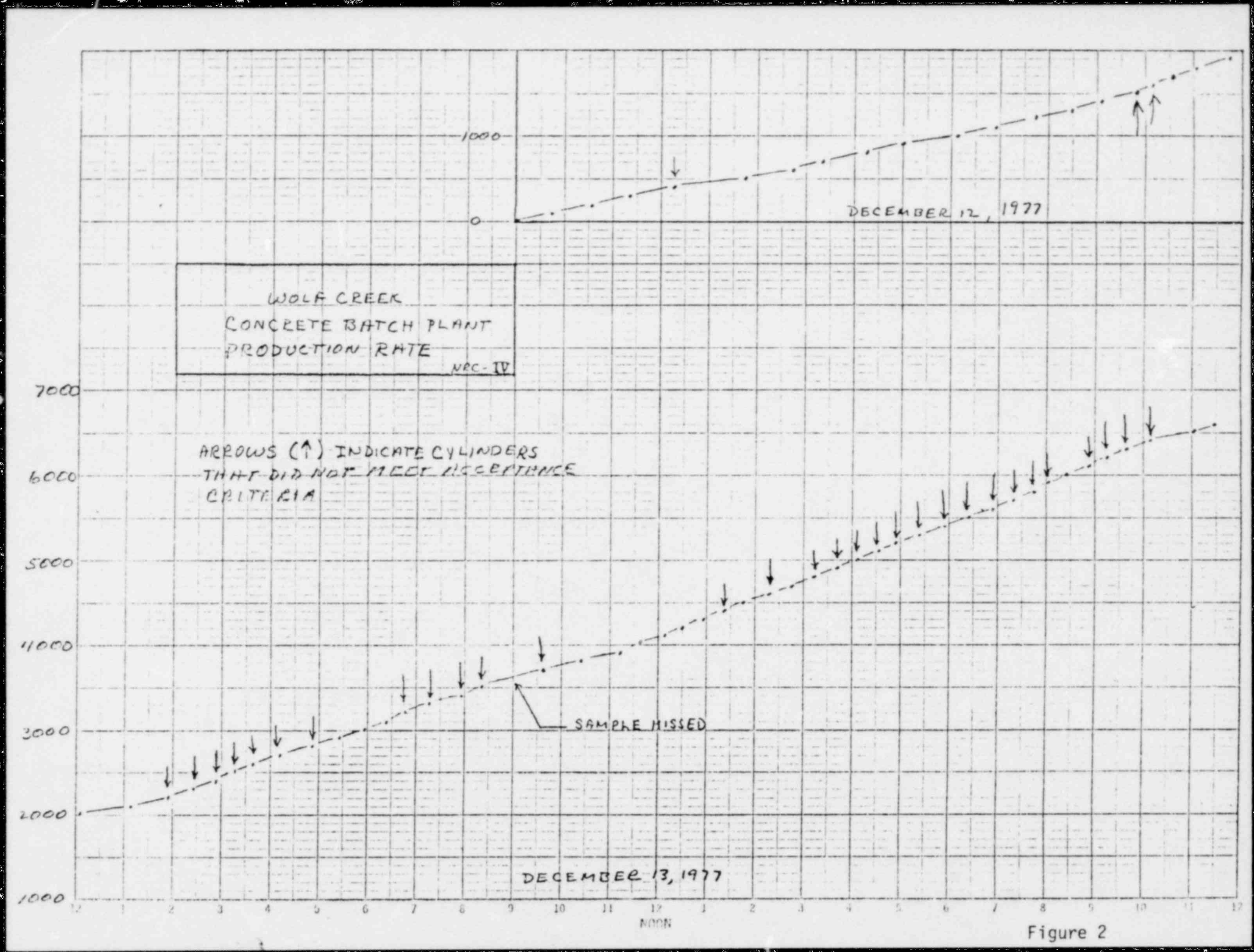

WOLF CREEK
CONCRETE BATCH PLANT
PRODUCTION RATE
NRC-IV
ARROWS (↑) INDICATE CYLINDERS
THAT DID NOT MEET ACCEPTANCE
CRITERIA
DECEMBER 12, 1977
1000
0
7000
6000
5000
11000
3000
2000
1000
SAMPLE MISSED
DECEMBER 13, 1977
12
1
2
3
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
9
10
11
12
NOON

Figure 2

APPENDIX B

ACI 211.1 Mix Design Computation Base
(OIE Calculations)

APPENDIX B

ACI 211.1 Mix Design Computations Base

ACI 211.1 computations for Mix Design were based on the following:

Type II cement

Severe exposure in air ACI 211.1 (Table 5.3.4(b))

Max w/c ratio = .48

Aggregate size = 3/4"

Entrained air = 3-6%

Specified strength = 5000 psi at 90-day

Specific gravity fine aggregate - 2.61

Specific gravity coarse aggregate - 2.62

Fineness modules - 2.8

Moisture content of fine aggregate 2.0%

Moisture content of coarse aggregate - 1.5%

Absorption of fine aggregate - 1.5%

Absorption of coarse aggregate - 2.0%

TABLE A

CEMENT DELIVERIES

This table indicates the amount of cement delivered to the Wolf Creek Site

TABLE A

Cement Deliveries

INFORMATION FROM USER TEST BREAK SHEETS (1)

UT TEST NO.	DELIVERY DATE	DELIVERY TRUCK NO.	TOTAL TONS RECEIVED (2)
10	9/12/77	50247	10,746.18
11	9/20/77	50267	11,856.78
12	9/28/77	50265	13,048.45
13	10/06/77	54021 and 57021	14,148.34
14	10/19/77	50247	15,326.67
15	11/10/77	50277	16,425.43
16	11/21/77	50257	17,664.54
17	12/12/77	50263	18,805.39
18	12/19/77	50249	20,019.92

NOTE:

(1) User tests (UT) are required in Bechtel Specification C-191, paragraph 6.2.1

(2) Cumulative totals indicated.

TABLE B

Comparison of Cement Strength Tests

This table assembles information from

- User Test Reports
- Cement Manufactures Test Reports
- PCA Test Reports

This table is incomplete in that PCA testing has not been completed on additional cement samples.

TABLE B

COMPARISON OF CEMENT TESTS

UT NO.	DATE SAMPLED	DATE TESTED	MILL TEST NO.	SILO NO.	DATE SILO FILLED	USER TESTS 3/7/28-DAY	MANUF. TESTS 3/7/28-DAY	PCA TESTS 3/7/28-DAY
UT-10	9/12/77	9/26/77	8	36	8/23-25/77	NA/2990/5033	2492/3563/5379	
UT-11	9/20/77	9/26/77	8			NA/3110/5267		
UT-12	9/28/77	10/04/77	7	34	7/06-10/77	NA/2075/5321	2516/3878/5072	
UT-13	10/06/77	10/11/77	7			NA/3133/5196		
UT-14	10/19/77		10	34	10/10-14/77 (XFR from SILO #9)	NA/3950/5790	2438/3652/5044	
UT-15	11/10/77	11/16/77				NA/3350/5140		
UT-16	11/21/77	11/21/77	9	36	9/23-10/5/77	NA/3260/5180	2403/3531/5317	/3625/5525
UT-17	12/12/77	12/20/77				NA/3570/3370 NA/2860/3680*		/3720/5600
UT-18	12/19/77	12/27/77	11	34	11/22-27/77	NA/2550/4110	2076/2950/4841	
UT-19	1/23/78	2/06/78	12	36	1/10-18/78	NA/3590/4800	2114/2995/4847	
UT-20	3/20/78	3/28/78	11	34		2150/2940/4890		
UT-21	4/21/78	4/26/78	13	36		2280/3260/4710		
UT-22	5/03/78	5/04/78	11	34		2130/3270/5430		
UT-23	6/02/78	6/09/78	11	34		2000/3070/4580		
UT-24	6/27/78	6/29/78	13	36		2150/3310/5340		

*Retest - NCR 1-0146-C

TABLE C

90-DAY CONCRETE CYLINDERS

This table is a list of 90-day cylinders in order of their casting (concrete placement order). The cylinder set numbers, the corresponding cylinder numbers, and their 90-day break values are indicated. The cylinder strength test results per ACI 318 are shown. The cylinders which were submitted to PCA for the original testing (April) are also marked. Footnotes and a legend for the PCA test codes are at the end of the table.

TABLE C

90-DAY CONCRETE CYLINDERS[1][7]

CY.SET NO.	CY NO.	90-DAY PSI	TEST AV./[8] RUN. AV.	ACI-318-71 ACCEPTABLE	ACI-318-71 NOT ACCEPTABLE	PCA TEST
508	6407 6408	5710 5620	5665	X		S,C[6]
509	6413 6414	5550 5110	5330	X		S,C S,CAA,C[6][3]
514	6425 6426	4420 5180	4800/5265	X		S,A
515	6431 6432	5300 5020	5160/5097	X		S,C S,CAA
516	6437 6438	5260 6110	5690/5217	X		S,C
517	6443 6444	5360 4640	5000/5283	X		S,C[6] S,P,CA
518	6449 6450	5270 5110	5190/5293	X		S,C S,C
519	6455 6456	5310 5290	5300/5163	X		S,C
520	6461 6462	4640 5180	4910/5133	X		S S
521	6467 6468	6130 5850	5990/5400	X		S S
522	6473 6474	4780 4970	4875/5258	X		S,C[6]
523	6479 6480	5730 4710	5220/5362	X		S,C S
524	6485 6486	4800 5310	5055/5050	X		S S

CY.SET NO.	CY NO.	90-DAY PSI	TEST AV./RUN. AV.(8)	ACI-318-71 ACCEPTABLE	ACI-318-71 NOT ACCEPTABLE	PCA TEST
525	6491	5390				S
	6492	4600	4995/5090	X		S
531	6497	6260				S
	6498	5940	6100/5383	X		S,C
526	6503	4190				S,P,CA
	6504	5830	5010/5368	X		
*532	6509	4370				S,C(6)
	6510	5010	4690/5267	X		S,C
527	6515	4880				
	6516	4660	4770/4823		X	S
(2)533	6521	5920				
	6522	5410	5665/5042	X		
*528	6527	4700				
	6528	4920	4810/5082	X		
*534	6533	4810				
	6534	4660	4735/5070	X		
*529	6539	4940				
	6540	4320	4630/4725		X	
*530	6545	4830				
	6546	3270	4050/4472		X	
*541	6551	4290				
	6552	5110	4700/4460		X	
*542	6557	4180				
	6558	5380	4780/4510		X	
*543	6563	4620				
	6564	4440	4530/4670		X	
*535	6569	4160				
	6570	5020	4590/4633		X	
536	6575	5600				
	6576	5090	5345/4822		X	

CY.SET NO.	CY NO.	90-DAY PSI	TEST AV./RUN. AV.(8)	ACI-318-71 ACCEPTABLE	ACI-318-71 NOT ACCEPTABLE	PCA TEST
*544	6581	5170				
	6582	5130	5150/5028	X		
*545	6587	4670				
	6588	4970	4820/5105	X		
*546	6593	5060				
	6594	5310	5185/5052	X		
*537	6599	4010				
	6600	4970	4490/4832		X	
*547	6605	4350				
	6606	4340	4345/4673		X	
548	6611	5180				
	6612	4690	4935/4590		X	
549	6617	5570				
	6618	5500	5535/4938		X	
*550	6623(3)	2870				S,CAA
	6624	5230	4050/4840		X	
551	6629	6270				
	6630	5410	5840/5142	X		S
552	6635	5180				
	6636	5620	5400/5097	X		
553	6641	5530				
	6642	5460	5495/5578	X		
554	6647	5480				S
	6648	5150	5315/5403	X		
*555	6653	5200				
	6654	4990	5095/5302	X		
556	6659	5390				
	6660	5530	5460/5290	X		

CY.SET NO.	CY NO.	90-DAY PSI	TEST AV./RUN. AV.[8]	ACI-318-71 ACCEPTABLE	ACI-318-71 NOT ACCEPTABLE	PCA TEST
557	6665	5410				S
	6666	5410	5410/5322	X		
*558	6671	4370				
	6672	5230	4800/5233	X		
*559	6677	5130				
	6678	4620	4875/5028	X		S
*560	6683	4490				
	6684	5320	5155/4943		X	
*561	6689	4830				
	6690	5940	5385/5138	X		
*562	6695	4650				
	6696	4280	4465/5002		X	
563	6701	5040				S
	6702	4620	4830/4893		X	
565	6707	5620				
	6708	5530	5575/4957		X	S,C[6]
564	6713	4630				
	6714	4370	4500/4968		X	
566	6719	4650				
	6720	4950	4800/4958		X	
*568	6725	4800				
	6726	4950	4875/4725		X	
*567	6731	5620				
	6732	4970	5295/4990		X	S
569	6737	4520				
	6738	4300	4410/4860		X	
570	6743	5240				
	6744	5080	5160/4955		X	

CY.SET NO.	CY NO.	90-DAY PSI	TEST AV./[8] RUN. AV.	ACI-318-71 ACCEPTABLE	ACI-318-71 NOT ACCEPTABLE	PCA TEST
[5] 598	6844	5810				
	6845	6010	5910/5263	X[5]		
572	6754	4810				
	6755	4860	4835/4802		X	
*573	6760	4790				
	6761	4710	4750/4915		X	
*581	6766	4620				
	6767	5850	5235/4940		X	
*574	6772	4990				
	6773	4780	4885/4957		X	
*575	6778	4900				
	6779	4970	4935/5018	X		
576	6784	4780				S,P,CA
	6785	4830	4805/4875		X	
577	6790	4700				
	6791	5110	4905/4882		X	
*578	6796	4630				
	6797	4480	4555/4755		X	
579	6802	5340				S
	6803	5310	5325/4928		X	

See Note (4)

Legend:
- CAA - Chemical Analysis
- S - Submitted to PCA
- P,CA - Petrographic and Chemical Analysis
- C - PCA Cube
- * - 90-day strengths less than 28-day strengths

(1) Listed in order of concrete placement in base mat.

(2) Start of placement on December 13, 1977.

(3) Sample Combined (6623 & 6614) for chemical analysis.

(4)

6850	S,P,CA
6851	S
6857	S,CAA

The above cylinders were sent to PCA. However, they were not part of the base mat placement for Wolf Creek.

(5) Cylinder set No. 571 with cylinder Nos. 6745-6749 were cancelled. Set No. 598 was assigned to cylinders of this set (No. 6840 thru 6845 assigned and used). Batch plant ticket 4398 refers.

(6) Two cubes made from one cylinder fragment.

(7) One sample sent to PCA was not identified in the correspondence. (6503)

(8) This column indicates the cylinder tests (average of two cylinders) and running average of three consecutive cylinder tests.

TABLE D

PCA TEST DATA

This table contains specific information on the PCA testing done on the original cylinder fragments submitted to PCA.

TABLE D

PCA TEST DATA

Ref: J. Shideler (PCA) to C. Phillips (DIC) of April 19, 1978

PETROGRAPHIC ANALYSIS

CLYINDER NO.	SET NO.	PLACEMENT NO.	CYLINDER PSI	DATE POUR
6503	526	OC-221S1212	4190	12/12
6444	517	OC-221S1212	4640	12/12
6784	576	OC-221S0007	4780	12/13
6850	not base mat	Column 11	5920(data) 6640(ltr) (1)	12/20

COMPRESSION TEST DATA

CYLINDER NO.	SET NO.	PLACEMENT NO.(2)	CYLINDER PSI	CUBE PSI	DATE POUR
6408	508	OC221S1212	5620	6680/6700	12/12
6413	509	OC221S1212	5550	6400/7950	12/12
6438	516	OC221S1212	6110	6350	12/12
6443	517	OC221S1212	5360	5700/6440	12/12
6449	518	OC221S1212	5270	5640	12/12
6450	518	OC221S1212	5110	5280	12/12
6456	519	OC221S1212	5300	6500	12/12
6473	522	OC221S0007	4780	5060/5210	12/12
6479	523	OC221S0007	5730	6380	12/12
6498	531	OC221S0007	5940	6200	12/12

6509	532	0C221S0007	4360	5540	12/12
6510	532	0C221S0007	5010	5160/5180	12/12
6707	565	0C221S0C07	5620	5166/5920	12/13

NOTE:

(1) Cylinder fragment 6850 was not part of the base mat, but was of the same design mix. The PCA letter indicates a value of 6640 psi, however, a check of the data indicates the value was 5920. Fragment 6850 was submitted for comparison purposes.

(2) Placement No. 0C221S1212 and 0C221S0007 are the two numbers assigned to the base mat placement. Two numbers were required to accomodate the computer programming used for analysis.

TABLE E

PORTLAND CEMENT TESTING TIMES (ASTMC-150-74)

UT NO.	DATE SAMPLED	DATE STARTED	DATE ENDED
8	8/11/77	8/15/77	9/13/77
9*	8/30/77	9/07/77	10/25/77
10*	9/12/77	9/26/77	10/25/77
11*	9/20/77	9/26/77	10/25/77
12*	9/28/77	10/04/77	11/01/77
13*	10/06/77	10/11/77	11/16/77
14	10/19/77	10/20/77	11/21/77
15*	11/10/77	11/16/77	12/14/77
16	11/21/77	11/21/77	12/21/77
17*	12/12/77	12/20/77	02/14/77
18*	12/19/77	12/28/77	01/24/78
19*	01/23/78	02/06/78	03/06/78
20*	03/20/78	03/28/78	04/25/78

*Total time for user test limitations exceeded.

TABLE E

Portland Cement Testing Time

This table contains summary information on the total time (days) used from sampling to completion of testing. This data was taken from the Cement User Test Reports.