APPENDIX E

"Diablo Canyon Power Plant, Tests and Analysis of Structural Concrete at the Intake Structure - Visual Examination of the Reinforcing Steel, Chloride Content and Carbonation," Pacific Gas and Electric Company, Technical and Ecological Services Report No. 420DC-91.1105, November 12, 1991.

Report Issued: November 12, 1991 Report #420DC-91.1105

70 146 (7/88)
Technical and Ecological Services

Pacific Gas and Electric Company
Laboratory Test Report

3400 Crow Canyon Road
San Ramon, CA 94583

SUBJECT: DIABLO CANYON POWER PLANT
TESTS AND ANALYSIS OF STRUCTURAL CONCRETE
AT THE INTAKE STRUCTURE - VISUAL EXAMINATION OF THE
REINFORCING STEEL, CHLORIDE CONTENT AND CARBONATION

An inspection which includes locating the reinforcing steel and coring the concrete so that the reinforcing steel could be visually examined and tests to determine the chloride content and carbonation were performed to determine the engineering properties of the concrete at Diablo Canyon Power Plant Intake Structure.

This inspection was conducted to confirm the results of previous half cell potential testing of the reinforcing steel in concrete and to obtain additional information as to the cause of the reinforcing steel corrosion. In several areas of the intake, where previous testing indicated high half cell potentials, there appeared to be little or no corrosion of the steel. In most of these areas the concrete was saturated with sea water or had standing sea water on it. From previous half cell testing that has been conducted, when the concrete was saturated with sea water, high background potentials made it impossible to take accuracy half cell potential measurements.

Tests were conducted in areas where previous testing indicated high half cell potentials and delaminations. These areas were selected to provide an indication of corrosion activity in the most severe areas of the intake.

Distribution: LEMcMillan
JAFledderman
LLMahroom
DOvadia
TMTurner
DGWong

Date: November 12, 1991

Tested By: Louis E. Liensa

Approved By: Arte Reif

THE TEST PROGRAM

The test program for the concrete was comprised of the evaluation of the following inspection activities:

1. Reinforcement location and cover determination.
2. Core sampling of the Concrete.
3. Visual inspection.
4. Determination of the concrete chloride content.
5. Determination of the concrete carbonation.

REINFORCEMENT STEEL LOCATION AND COVER DETERMINATION

A reinforcing steel locator was used to determine reinforcing steel location and cover. The reinforcing steel locator has an accuracy of +/-0.3 inches for concrete cover measurements.

CORE SAMPLING OF THE CONCRETE

Concrete core samples were obtained in accordance with ASTM-C42. Once the reinforcing steel was located the first core was drilled directly over the bar. Drilling was stopped as soon as the bit came into contact with the steel by using a ground fault interrupter. The second and third cores were taken on either side of the first core perpendicular to the reinforcing steel. These cores were drilled to a depth of 4-3/4 inches.

VISUAL INSPECTION

The visual inspection consisted of inspecting the reinforcing steel for corrosion, determining the depth of the delaminated section and obtaining photographs of the cored locations.

DETERMINATION OF THE CONCRETE CHLORIDE CONTENT

The chloride content was determined at various depths of the concrete core samples in accordance with the Rapid Chloride Test Method. The chloride content was measured as a percentage of the concrete's mass.

Depending on the actual conditions, the critical content for corrosion of the reinforcing steel can be in the range of 0.02% to 0.05% of the concrete's mass or 0.14% to 0.35% by cement mass.

In reinforced concrete structures, chloride may attack the reinforcing by breaking down the steels passive film, leading to corrosion. In addition to weakening the reinforcement, the resultant corrosion products may exercise expansion forces on the surrounding concrete, thereby causing delamination and spalling of the cover layer.

Chlorides may be carried to a structure from the environment in various ways. Inland, chlorides in the air may appreciably contribute to the chloride charge of the concrete

surface. Concrete in a marine environment receives chlorides from sea sand and sea water. Outdoor concrete structures near coastlines constantly receive airborne chloride ions.

DETERMINATION OF THE CONCRETE CARBONATION

Concrete carbonation was determined at various depths of the core samples. A pH-sensitive liquid indicator (Rainbow Indicator) was applied to fractured and sawcut surfaces.

The Rainbow Indicator combines proprietary chemicals to produce a range of pH-correlative color when sprayed on a concrete surface. Colors and pH values are: red-5, yellow-7, green-9, purple-11 and violet to black-13. Using color chart pH can be determined to the nearest 0.5.

Carbonation occurs on all exposed portland cement concrete surfaces. Carbon dioxide in air or water reacts with compounds in the hardened cement paste to form carbonates, primarily calcium carbonate.

The rate of carbonation depends on paste permeability, temperature, relative humidity and the concentration of carbon dioxide in the air. Paste permeability is affected by water-cement ratio, amount of moist curing and density of the concrete surface.

Carbonation increases the concrete drying shrinkage, but a more harmful effect is lowered alkalinity. The inherent high alkalinity (pH of greater than 12.5) protects embedded reinforcing steel from corrosion by causing a protective oxide film to form on the steel surface. By reducing the pH, carbonation can destroy the protective film and in the presence of moisture and oxygen, allow the steel to corrode. The protective film is maintained when the pH is in the range of 8 to 13.

Specifying a minimum concrete cover over reinforcing steel, assumes that the small depth of carbonated concrete will fall short of the steel. During the life of a structure, because the depth of carbonation is insignificant in good quality concrete, the depth of cover required by codes provides an adequate safety factor against corrosion.

INSPECTION RESULTS

Nine areas were tested, one at the 17.5 foot elevation, four at the -2.1 foot elevation and four at the -24.5 foot elevation. The test locations are shown on Figures 1, 2, 3A and 3B. Photos of the sample are shown in Appendix A.

The chloride content results are summarized in Table 1. The chloride content was measured as a percentage of the concrete's mass. The chloride content measurements have an accuracy of +/-0.02 percent. The average chloride content for all samples is 0.35 percent. The average chloride content for samples at a depth of 0-1/4 inches is 0.31 percent. The average chloride content for samples at a depth

of 1 inch is 0.37 percent. The average chloride content for samples at a depth of 2 inch is 0.46 percent. The average chloride content for samples at a depth of 3 inch is 0.21 percent.

The effect of carbonation as measured by the determination of the alkalinity are summarized in Table 2. The pH was measured with an accuracy of +/-0.5. Samples 1, 2, 3 and 4 had pH values of less than 12.5 for the surface to 1/4 inch in depth. Sample 7 had pH values of less than 12.5 from the surface to 1/2 inch in depth. All of the other pH values are 12.5. The average pH value for all samples is 12.3 percent. The average pH value for samples at a depth of 0-1/4 inches is 10.7 percent. The average pH value for samples at a depth of 1/4-1/2 inches is 12.3 percent. The average pH value for samples at a depth of 1, 2 and 3 inches is 12.5 percent.

SUMMARY

All the areas inspected showed signs of reinforcing steel corrosion, except sample area number 5 located at the -2.1 foot elevation. Corrosion was located at the top and top ribs of the reinforcing steel only.

The high half cell potentials in sample area number 5, which did not show signs of reinforcing steel corrosion must be due to stray voltages and not reinforcing steel corrosion. The reinforcing steel cross sectional area were reduced by an average of 4 percent or less from the remaining eight cores inspections. These results were anticipated since the core locations selected, with the exception of number 5, are in areas previously identified as having concrete delaminations.

Typically we would expect the chloride content to be highest at the surface and get lower as the depth of concrete increases. The chloride content at 0-1/4 inch was less than the chloride content at greater depths. This is probably due to the short duration between wetting and drying. The chloride ions did not have time to concentrate in the top layer of concrete.

All the chloride content measurements were greater than the critical content for corrosion of the reinforcing steel 0.05% of the concrete's mass. From the results of the chloride content and carbonation, the corrosion is due to chloride ion intrusion and not carbonation.

TABLE 1

CONCRETE CHLORIDE CONTENT

Sample Number	Depth in inches 0-1/4	1	2	3
	Chloride Content, percent			
1	0.25	0.47	0.51	
2	0.32	0.21	0.54	
3	0.21	0.42		
4	0.14	0.14		
5	0.34	0.51	0.51	0.34
6	0.33	0.44		
7	0.32	0.31		
8	0.50	0.52		
9	0.36	0.35	0.28	0.08
Average	0.31	0.37	0.46	0.21

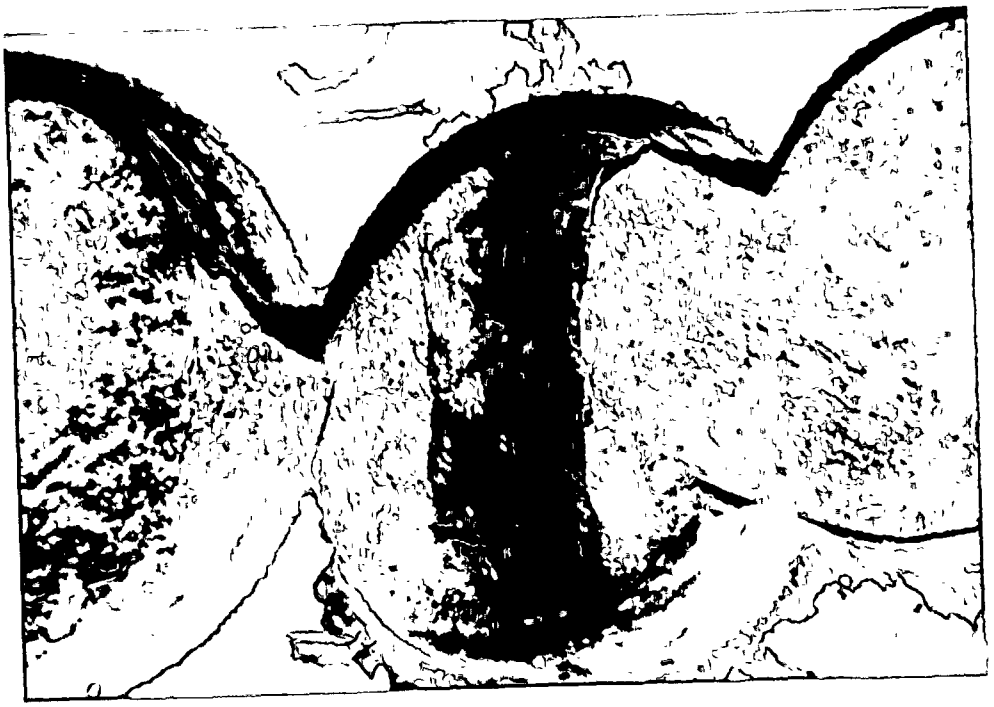
TABLE 2

CONCRETE CARBONATION

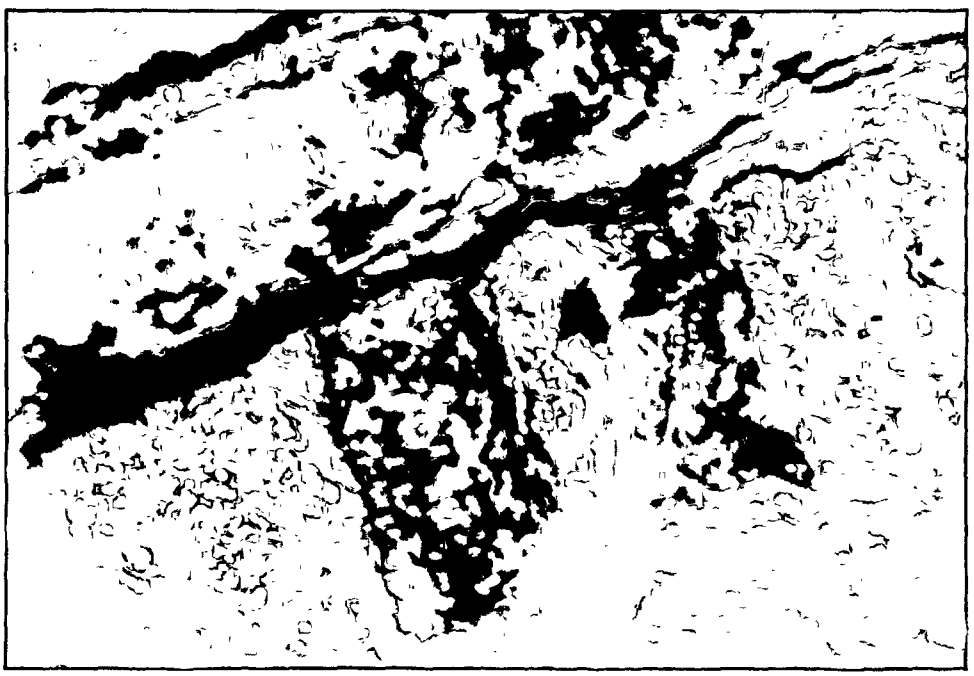
Sample Number	Depth in inches 0-1/4	1/4-1/2	1	2	3
	pH-Values				
1	9.5	12.5	12.5	12.5	
2	10.0	12.5	12.5	12.5	
3	6.0	12.5	12.5		
4	10.0	12.5	12.5		
5	12.5	12.5	12.5	12.5	12.5
6	12.5	12.5	12.5		
7	10.5	10.5	12.5		
8	12.5	12.5	12.5		
9	12.5	12.5	12.5	12.5	12.5
Average	10.7	12.3	12.5	12.5	12.5

SAMPLE LOCATION NUMBER 1

SAMPLE LOCATION NUMBER 2

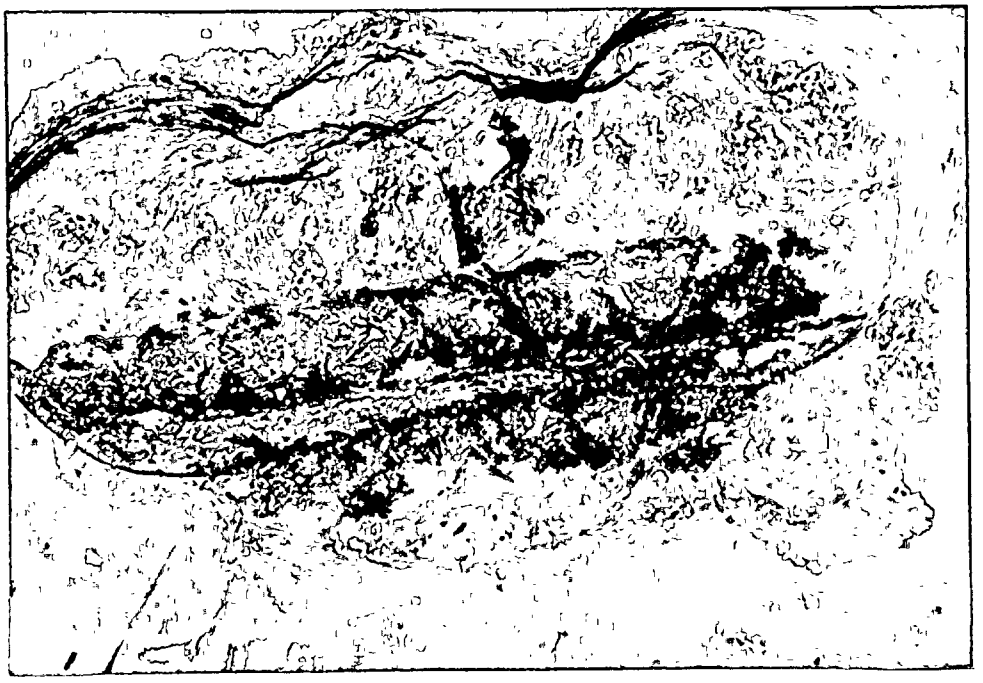


SAMPLE LOCATION NUMBER 3

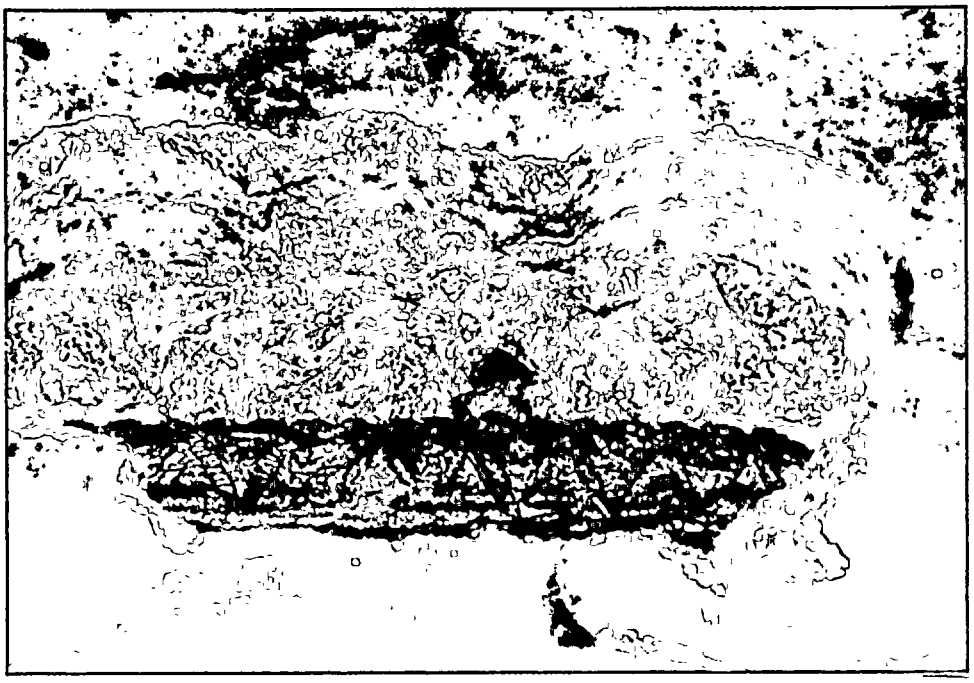


SAMPLE LOCATION NUMBER 4

SAMPLE LOCATION NUMBER 5



SAMPLE LOCATION NUMBER 6



SAMPLE LOCATION NUMBER 6
Shows typical delamination

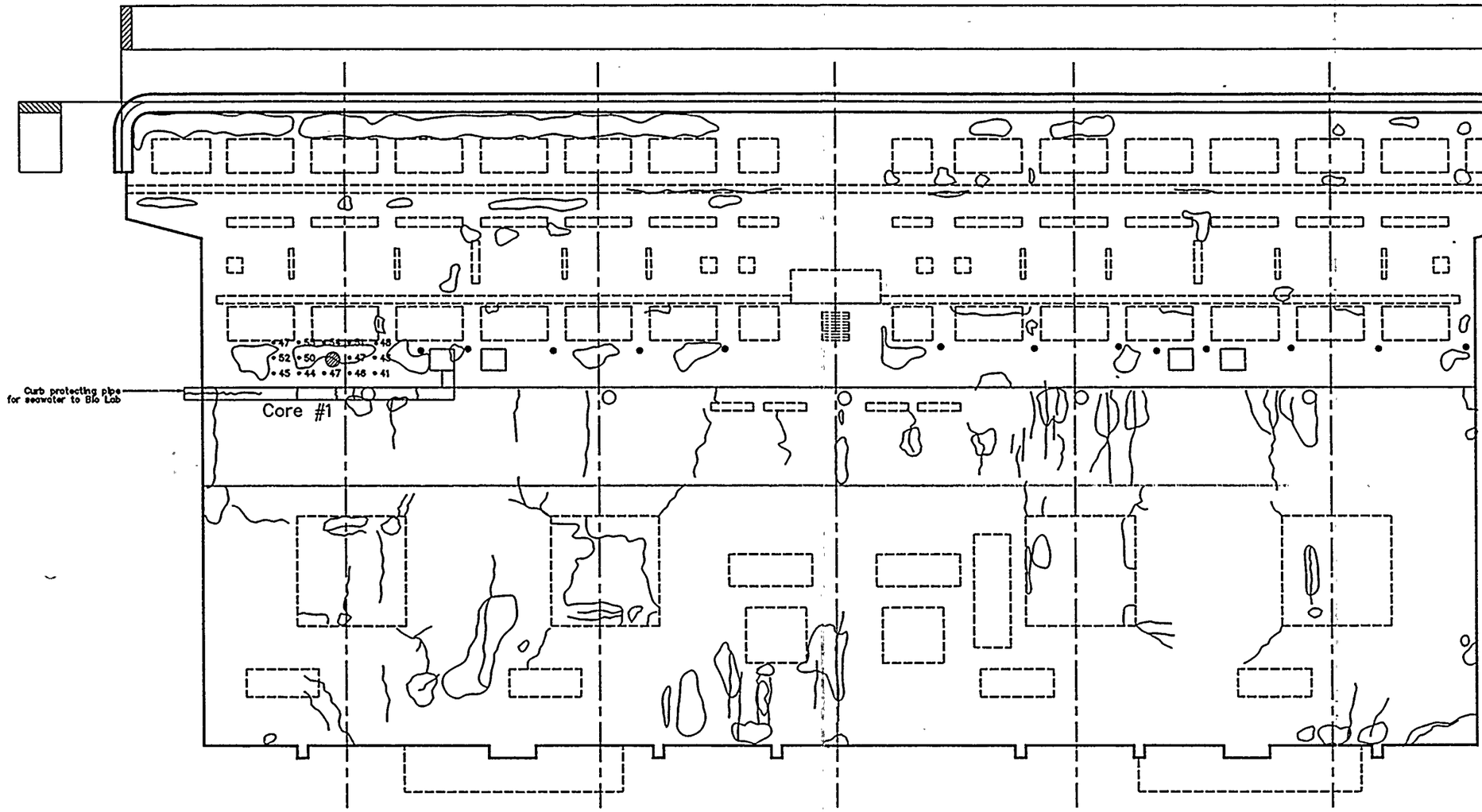
SAMPLE LOCATION NUMBER 7

SAMPLE LOCATION NUMBER 8

SAMPLE LOCATION NUMBER 9

APPENDIX F

"Diablo Canyon Power Plant, Test and Analysis of Structural Concrete of Intake Conduits 2-1 and 2-2, CWP Bays 2-1 and 2-2, ASW Bays 2-1 and 2-2," Pacific Gas and Electric Company, Technical and Ecological Services Report No. 420DC-91.1023, November 12, 1991.

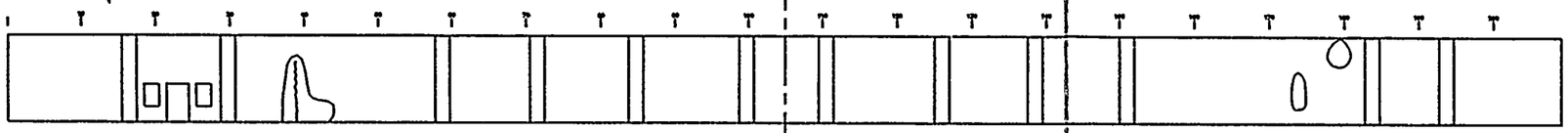


9112300043-01

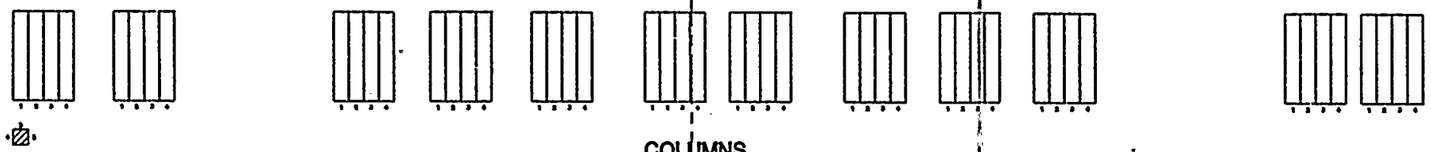
PG&E	REVISION 1	INTAKE STRUCTURE DELAMINATED AREAS	MICROFILM
	DES :		BILL OF MATL
	DRN : LPH	ELEVATION 17.5 FEET	DWG LIST
	CHKD: CSM		SUPSDS
	SUPV:	DIABLO CANYON POWER PLANT	SUPSD BY
	APVD:	Pacific Gas and Electric Company	SHEET 1 of 1 SHEETS
	APVD:	Technical and Ecological Services — Civil Unit	FIGURE 1 REV. 1
	DATE: 11-1-91		

HATCHES

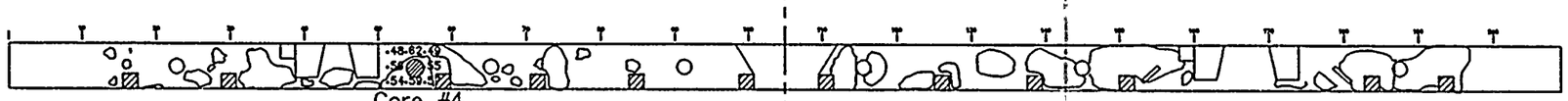
Hatch 1 Hatch 2 Hatch 3 Hatch 4



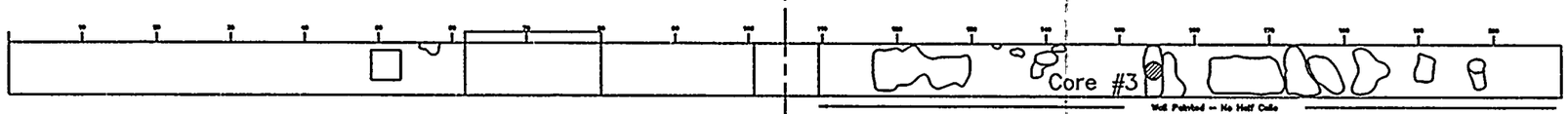
UPPER WEST WALL



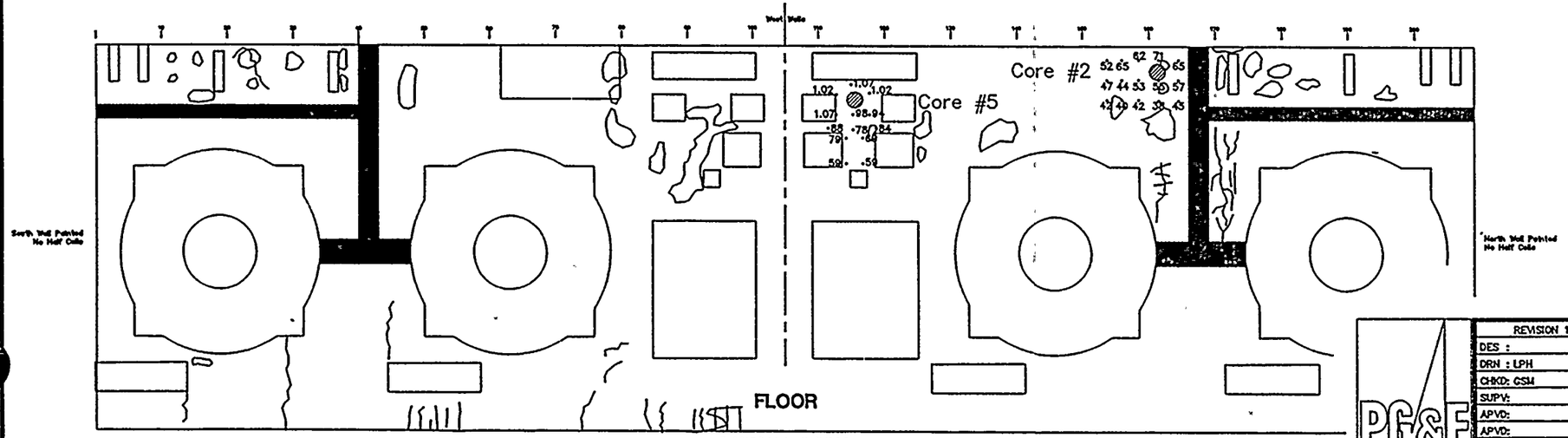
COLUMNS



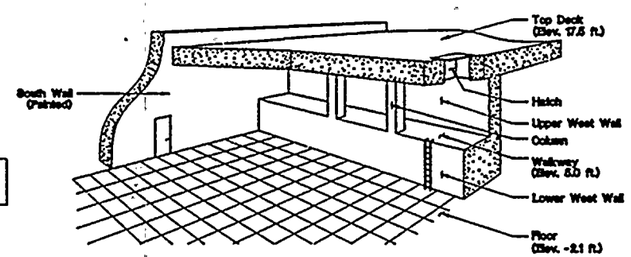
WALKWAY



LOWER WEST WALL



FLOOR



KEY

SI APERTURE CARD

Also Available On Aperture Card

9112300043-02

REVISION 1	
DES :	
DRN : LPH	
CHKD: GSM	
SUPV:	
APVD:	
APVD:	
DATE: 11-1-91	

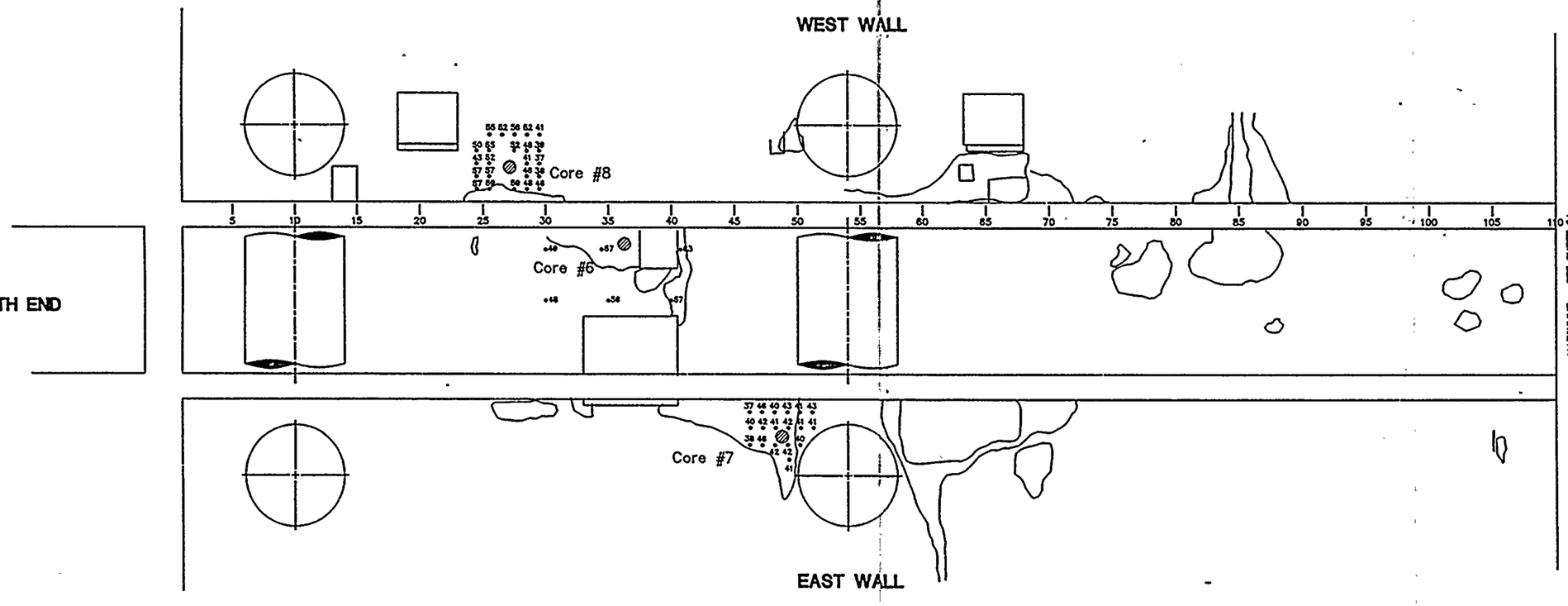
PG&E

INTAKE STRUCTURE DELAMINATED AREAS

ELEVATION -2.1 FEET
WEST WALLS AND WALKWAY
AT ELEVATION 5.0 FEET

DIABLO CANYON POWER PLANT
Pacific Gas and Electric Company
Technical and Ecological Services – Civil Unit

MICROFILM	
BILL OF MATL	
DWG LIST	
SUPSDS	
SUPSD BY	
SHEET 1 of 1	SHEETS
FIGURE 2	REV. 1



SI APERTURE CARD

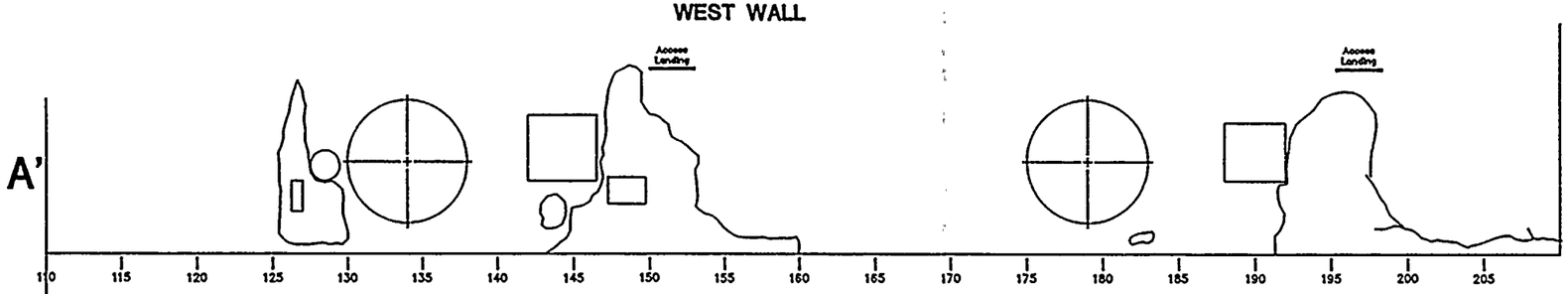
Also Available On Aperture Card

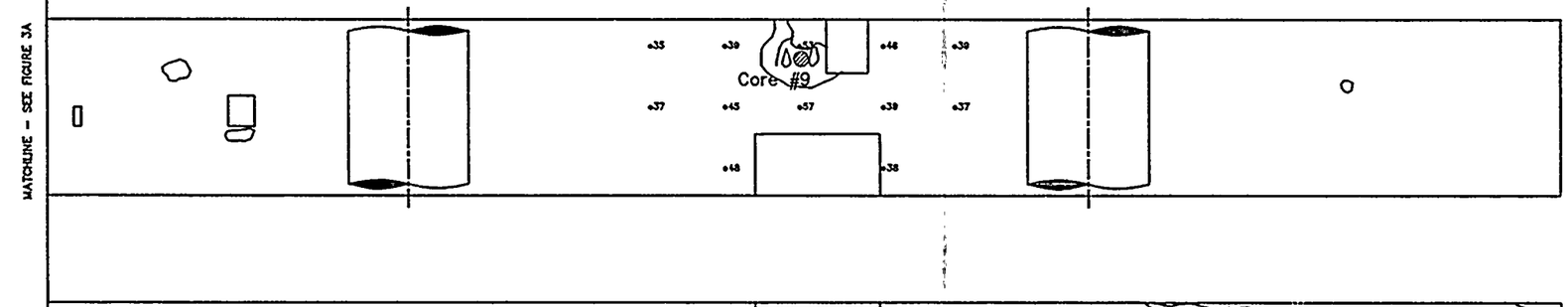
9112300043-03

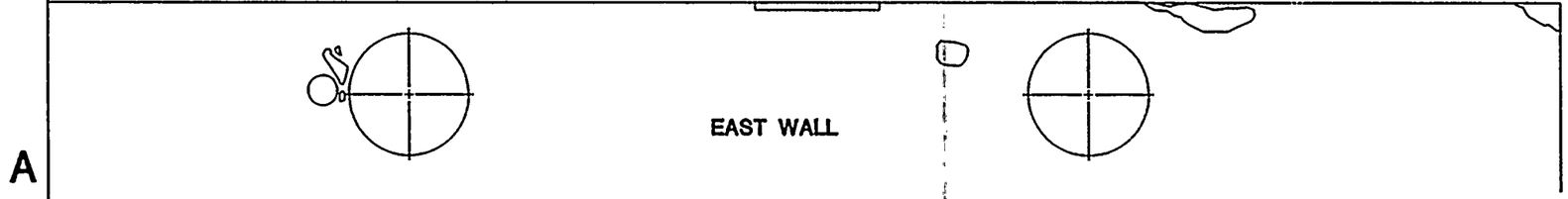
REVISION 1	INTAKE STRUCTURE	MICROFILM	
DES :	ELEVATION -24.5 FEET	BILL OF MATL.	
DRN : LPH		DWG LIST	
CHKD: GSM		SUPSDS	
SUPV:		SUPSD BY	
APVD:	DIABLO CANYON POWER PLANT	SHEET 1 of 1 SHEETS	
APVD:	Pacific Gas and Electric Company	REV.	
DATE: 11-1-91	Technical and Ecological Services – Civil Unit	FIGURE 3A	1

WEST WALL

A'







EAST WALL

A

9112300043-04

REVISION 1	INTAKE STRUCTURE	MICROFILM	
DES :	ELEVATION -24.5 FEET	BILL OF MATL	
DRN : LPH		DWG LIST	
CHKD: GSM		SUPSDS	
SUPV:		SUPSD BY	
APVD:	DIABLO CANYON POWER PLANT	SHEET 1 of 1 SHEETS	
APVD:	Pacific Gas and Electric Company	FIGURE 3B	REV. 1
DATE: 11-1-91	Technical and Ecological Services — Civil Unit		