ENGINEERING REPORTS AND STUDIES
COVER SHEET

Subject: INTERIM ENGINEERING REPORT
ASSESSMENT OF SPENT FUEL POOL LINER LEAKAGE

Control Number: ERPT-M0209

Initiated required follow-up documents [ ] YES [ ] NO [ ] NOT REQUIRED

10 CFR 50.59 Determination [ ] Required (and attached)
[X] Not Required (see DCP/PDQ No. _______)

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1.0 EXECUTIVE SUMMARY

1.1 CHRONOLOGY OF EVENTS

- Pool leaks identified during initial fill.
- Leak chase isolation has caused water to back-up and seep out of concrete on approximately two occasions.
- Leakage estimates varied from 1 gallon per day to 300 gallons per day.
- No accurate mass balance done until October of 1989.
- Current data indicates liner leakage to the leak chase system and then on to the Radwaste System of approximately 0.5 gallons per hour.
- No unquantified leakage to the environment exists.
- Leakage data before and after the recent Santa Cruz earthquake showed no affect due to the seismic event.

1.2 CURRENT STATUS AND BASIS FOR INTERIM NATURE OF THIS REPORT

Several portions of the Technical Services Spent Fuel Pool Action Plan, TSAP 89-007, are not complete. Specifically the following portions have been initiated but will not be completed prior to defueling the Reactor:

1.2.1 Leak location by vacuum box testing.

1.2.2 Leak repair by welding.

1.2.3 Instrumentation modifications to allow trending.

1.3 DISTRICT'S POSITION

It is prudent and proper to proceed with defueling the Reactor for the following reasons:

1.3.1 The Spent Fuel Pool Leakage does not pose a threat to the health and safety of station personnel or the public.

1.3.2 Experienced station personnel are necessary to properly defuel the Reactor and these people will not remain on staff indefinitely, given the status of the station. Our best trained people are available for core offload now, but they will leave as more desireable positions become available in the Industry. These trained crews are ready to support defueling now and should be utilized now.

1.3.3 The sooner the Reactor is defueled, the sooner the fuel is in an inherently safe configuration in the Spent Fuel Pool.

The following actions will be accomplished following defueling:

1.3.4 A comprehensive testing program to locate the leak(s).

1.3.5 Repair of the leaks as found.

1.3.6 Instrumentation to facilitate trending.

1.4 JUSTIFICATION

1.4.1 The Design Basis of the Spent Fuel Pool is uncompromised. The Spent Fuel Pool Liner, in combination with the liner leak chase system and the Spent Fuel Building is performing in accordance with the intent of the Design Basis (i.e., to preclude leakage of contaminated effluent to the environment).

1.4.2 All liner leakage has been accurately quantified and is routed to the Radioactive Waste System with no leakage to the environment.

1.4.3 There is no evidence of reinforcing steel corrosion in the outer wall mat of the building.

1.4.4 Visual inspections of interior wall areas show no spalling or rust bleed through normally associated with concrete structure degradation.

1.4.5 Similar experience at San Onofre Nuclear Generating Station Unit One showed no building degradation.

1.4.6 Long Term degradation of Spent Fuel Pool Building concrete by liner leakage is not a factor.

1.4.7 Long Term degradation of Spent Fuel Pool Building reinforcing steel by liner leakage will not occur.

2.0 HISTORY REVIEW

2.1 USAR DESIGN BASIS

1.6.13 SAFETY GUIDE 13 - FUEL STORAGE FACILITY DESIGN BASIS

The fuel storage and handling systems are designed to (1) assure adequate safety under normal and postulated accident conditions; (2) have appropriate containment, confinement, and filtering systems, and (3) prevent a significant reduction in the spent fuel coolant inventory under accident conditions. This design includes the following provisions:

A. The spent fuel storage facilities (including the fuel storage building, storage racks, and fuel transfer mechanism) are Seismic Category I.

B. The capability of the spent fuel pool to withstand high winds and high-wind generated missiles is presented in the discussion of the Criteria 4, Section 1.5.4.

C. The Turbine Building gantry crane is electrically interlocked to prevent movement of the trolley over the fuel storage rack area.

D. A ventilation and filtration system is used to limit the potential release of radioactive iodine and other radioactive materials (see Section 9.7.3). The design of the ventilation and filtration system is based on the assumption that the cladding of all the fuel rods in one fuel assembly might be breached.

E. The spent fuel storage facility design is such that the fuel cask of other heavy loads need not be moved directly over either the spent fuel or new fuel storage areas. The fuel pool is designed to withstand, without significant leakage, the impact of the fuel cask dropped from the maximum height to which it can be lifted by the gantry crane.

F. The fuel pool cannot be inadvertently drained by gravity since water must be pumped out.

G. Spent fuel pool high and low level, pool high temperature, and area high radiation indicators and alarms are provided. The high radiation level instrumentation does not actuate the ventilation system since this system is designed to run continuously.

H. Since no significant fuel storage pool leakage is expected to result from the dropping of loads, from earthquakes, or from missiles originating from high winds, the spent fuel pool makeup water system is Seismic Category II. Makeup water is either provided by the spent fuel coolant demineralizer pump taking suction on the borated water storage tank (BWST) or the decay heat removal pumps which can take suction from the BWST or the concentrated boric acid storage tank. Demineralized water can be added from a hose station in the pool area.

Further details are provided in [the USAR, specifically] Section 9.6 (spent fuel cooling system), 9.7.3 (fuel storage area ventilation system), 5.4 (fuel storage building(, and 9.8 (fuel handling system). Fuel handling accidents are discussed in Section 14.3.5.

5.4.2.2 Design Criteria

The main consideration in the structural design criteria for the Fuel Storage Building was to provide a leak tight pool to contain spent fuel under all conditions of loading, including earthquakes.

Except as noted in these criteria, ACI 318-63 and AISC, Sixth Edition, design methods and allowable stresses are for the design of reinforced concrete and steel, respectively.

The strength of the structure at working stress and overall yielding was compared to various loading combinations to ensure safety. The structure is designed to meet the performance and strength requirements under the following conditions:

A. At design loads

B. At factored loads

C. Loads from fuel

D. Loads from the fuel transfer cask

9.8.1.3 Spent Fuel Storage Pool

The spent fuel storage pool is a reinforced concrete pool, lined with stainless steel, in the Fuel Storage Building. The pool is sized to accommodate 1080 spent fuel assemblies in high density storage racks. Control rod assemblies that are permanently removed from the reactor are stored in the spent fuel pool prior to being chopped up and disposed of. Additional spaces are provided for the storage of four failed fuel containers in the fuel storage pool.

The high density spent fuel racks consist of individual cells with approximately 9" x 9" square cross section, each of which accommodates a single fuel assembly. The cells are arranged in modules of varying number of cells with a 10.50 inch center to center spacing. A total of 1080 cells are arranged in 11 distinct modules. These high density spent fuel storage racks employ a free-standing and self-supporting rack design. A borated flexible polymeric neutron absorber (Boraflex) is sandwiched between double stainless steel sections which comprise the rack walls.

The high density racks are engineered to achieve the dual objectives of maximum protection against structural loadings (arising from ground motion, thermal stresses, etc.) and the maximization of available storage locations. In general, the modules are made as wide as possible within the constraints of transportation and site handling capabilities to provide as great a margin as possible against rigid body tipping.

The module are not anchored to the pool floor, to each other, or to the pool walls. A minimum gap of 2.0" is provided between the modules to ensure that kinematic movements of the modules during the Plant Design Basis Earthquake will not cause inter-module impact, or violate the minimum distance to ensure adequate margins for nuclear subcriticality. Adequate clearance with other pool hardware, e.g. cask catchers, pool elevator, etc. is also provided.

In accordance with NRC acceptance criteria, the high density spent fuel storage racks for the Rancho Seco Plant are designed to assure that a K_{eff} equal to or less than 0.95 is maintained with the racks fully loaded with fuel of the highest anticipated reactivity and flooded with unborated water at a temperature corresponding to the highest reactivity. The maximum calculated reactivity includes a margin for uncertainty in reactivity calculations and in mechanical tolerances, statistically combined, such that the true K_{eff} will be equal to or less than 0.95 with a 95% probability at a 95% confidence level.

2.2 COMPARISON WITH APPLICABLE REGULATORY GUIDANCE

2.2.1 OBJECTIVE

The objective of this section is to provide a comparison of the existing spent fuel pool condition with the applicable requirements/recommendations of NUREG-0800, IE Notices and Bulletins, and NRC Generic Issue 82.

2.2.2 APPROACH

2.2.2.1 IE Notices and Bulletins
A search was made of IE Notices and Bulletins pertaining to leakage of spent fuel pools.

2.2.2.2 NUREG-0800
A review was made of the NUREG-0800 index to identify applicable Branch Technical Positions and/or Standard Review Plans.

2.2.2.3 GENERIC ISSUE 82
A review was made of Generic Issue 82 as addressed by Brookhaven National Laboratory in NUREG/CR-4980.

2.2.3 ACTION TAKEN

2.2.3.1 IE Bulletins and Notices
A computer search was made to extract available information on NRC Communications pertaining to spent fuel pool leakage.

2.2.3.2 NUREG-0800

NUREG-0800 was reviewed for applicability to spent fuel pool leakage.

2.2.3.3 GENERIC ISSUE 82

NUREG/CR-4982 was reviewed for applicability to Rancho Seco's Spent Fuel Pool leakage.

2.2.4 RESULTS

2.2.4.1 IE Notices and Bulletins

No IE Notices or Bulletins were found pertaining to spent fuel pool leakage due to liner failure. Others were found concerning system lineups and inadvertent drainage, but were not applicable for this review.

2.2.4.2 NUREG-0800

A review of NUREG-0800 revealed one SRP (9.1.2) relating specifically to spent fuel pools and their liners. SRP 9.1.2 specifies an acceptable pool as one which meets the appropriate requirements of ANS 57.2, and Regulatory Guides 1.13, 1.29, 1.115 and 1.117. ANS 57.2 and Reg. Guide 1.13 were found to be directly applicable to the objective of this report. Reg. Guides 1.29, 1.115 and 1.117 relate to the seismic design missile protection, and tornado considerations, respectively, and provide no guidance for this effort.

Reg. Guide 1.13, dated December, 1985, requires that spent fuel pools be designed to withstand anticipated occurrences without significant loss of watertight integrity. Section B.1 further elaborates that even when preventative measures to prevent loss of leak-tight integrity are followed, small leaks may still occur as a result of structural failure or other unforeseen events. The predecessor to this Reg. Guide (Safety Guide 13, dated 3/10/72) has similar language on spent fuel pool design.

SRP 9.1.2, dated 1981, references the 1976 version of ANS 57.2, design requirements for spent fuel pools. ANS 57.2 (1976) paragraph 6.6.1 (4) requires that spent fuel storage pools be designed for the lowest practicable leakage. A review of the most recent publication of ANS 57.2 (1987)? revealed a tightening of spent fuel pool design requirements. Section 5.1.2 of ANS 57.2 (1983) specified fuel pools to be designed for zero leakage.

2.2.4.3 Another consideration factored into to Spent Fuel Pool leak was Generic Issue 82, "Beyond Design Basis Accidents in Spent Fuel Pools" assigned by the NRC in 1983. This issue was formally analyzed by the Brookhaven National Laboratory and the results documented in NUREG/CR-4982 (BNL-NUREG-52093).

The preface to NUREG-4982 specifically notes that fuel damage process during a slow pool drainage is excluded from the Brookhaven study. Review of the study will be performed for completeness of Rancho Seco's Spent Fuel Pool leak considerations.

Based upon a review of two older Spent Fuel Pools (Millstone and Ginne), NUREG/CR-4982 concluded that the risk assessment was uncertain but dominated by the uncertainty in the likelyhood of the loss of pool integrity due to beyond design basis seismic events. This uncertainty is driven by the uncertainty in the seismic hazard and the Spent Fuel Pool fragility. This report further concludes that if the fragility estimates for plant, which meet the new seismic design criteria, were used, a significant reduction in the predicted likelyhood of seismically initiated pool failure would result. Other significant factors considered by this report are:

- Probability of draining the Spent Fuel Pool
- Pool structural failure due to heavy load drop.
- Structural failures of pool due to missiles.

Drainage of Rancho Seco's Spent Fuel Pool from piping/personnel error is not credible due to the system design which does not allow drainage of the pool below the active level.

Heavy load risk is very limited due to procedural constraints and the attenuation of the crane mechanism.

Missile probability has been examined with essential equipment being shielded, protected or provided with redundant equipment which is protected.

Based on the above discussion, it can be concluded that Rancho Seco's Spent Fuel Pool design does not possess significant radiological risk.

2.2.5 CONCLUSION

A spent fuel pool liner plate with a minimal leakage meets the design criteria of the fuel storage pool at the time of construction. The leakage rate has been calculated to be minimal and can be trended for stability verification. The newer standards are considered useful for providing guidance in evaluating potential design changes but not for providing design requirements of existing equipment. NUREG/CR-4982 was not directly applicable as a requirement/recommendation.

The Rancho Seco Spent Fuel Pool currently exhibits zero leakage to the environment as evidenced by the Mass Balance (see section 3.0).

2.3 CATASTROPHIC FAILURES

2.3.1 In the event of a total failure of the Spent Fuel Pool Liner, the only water losses are:

2.3.1.1 Through the leak chase system to the radwaste system.

2.3.1.2 Through the Spent Fuel Building Concrete walls.

2.3.2 In both pathways described above, the leak rate is drastically limited by the nature of the pathway.

2.3.2.1 The leak chase system, due to its size, will pass 30 gpm maximum

2.3.2.2 The Spent Fuel Building Concrete, when subjected to an isolated leak chase condition in the past, has seeped approximately 5 gallons per hour.

2.3.3 Under no circumstances would failure of the Spent Fuel Pool Liner result in unrestricted flow of the Spent Fuel Pool water to the environment since the Spent Fuel Building Concrete has no penetrations below the Fuel Racks, other than the small leak chase lines.

3.0 MASS BALANCE RESULTS (STP-1242)

3.1 OBJECTIVE

3.1.1 The objective of the Spent Fuel Pool Mass Balance was to develop a method, collect data, and calculate the net Spent Fuel Pool leakage considering the effects of evaporation, measured liner leakage, spent fuel pool level change and temperature change.

3.2 APPROACH

3.2.1 The general approach used was to determine the parameters needed to calculate the Mass Balance, develop a special test procedure to set the plant conditions and data collection requirements, perform the special test procedure with the added requirement to obtain the general location of the spent fuel pool leak, calculate the uncertainty associated with the mass balance determination, and determine if any water is leaking from the spent fuel pool based on the analyzed data.

3.3 ACTIONS TAKEN

3.3.1 Ten factors affect mass balance determination. Nine of these factors were developed, derived, and documented by SMUD in calculation Z-SFC-M2535. The tenth factor is a correction made due to miscellaneous water additions or samples taken from the spent fuel pool during the Mass Balance data collection period.

Factors used in calculating Mass Balance are:

- Mass of water loss determined from the fuel pool level drop.
- Mass of water loss from evaporation.
- Apparent water mass gain due to volumetric expansion of the Spent Fuel Pool water.
- Apparent water mass loss due to thermal expansion of the Spent Fuel Pool structure.
- Apparent water mass loss due to evaporation monitor buoyancy changes.

- Apparent water mass gain due to volumetric expansion of structural steel.

- Apparent water mass gain due to volumetric expansion of Boraflex.

- Mass loss through leak chase drain header.

- Mass loss through fuel cask pit leak chase drain line.

3.3.2 A special test procedure was developed to perform the measurements required of the mass balance calculation. STP-1242, "Spent Fuel Pool Mass Balance", specified the spent fuel pool conditions required during the data collection process. The following details the method used to determine the ten factors of the mass balance:

- Mass of water loss determined from the fuel pool drop.

  - A precision "J" hook micrometer centered in a stillwell was attached to the side of the spent fuel pool to obtain spent fuel pool water level measurements. This instrument is graduated in thousandths of an inch.

- Mass of water loss from evaporation.

  - An evaporation monitor was constructed with an installed precision "J" hook micrometer centered in the monitor with a still well surrounding the "J" hook. The calculation of evaporation included the measurement of the water level in the evaporation monitor and temperature measurements of the spent fuel pool to determine the specific weight of water which evaporated.

- Apparent water mass gain due to volumetric expansion of the spent fuel pool water.

  - Water temperature was monitored using submersible thermistor thermometers. Eighteen locations in the pool were monitored to determine the specific weight change.

- Apparent water mass loss due to thermal expansion of the spent fuel structure.

  - Thermistor thermometers were used to monitor temperature of the water, liner and structure to determine the thermal expansion of the structure.

- Apparent water mass loss due to evaporation monitor buoyancy change.

  - This measurement used the evaporation monitor's "J" hook measurement system to determine the change in buoyancy.

- Apparent water mass gain due to thermal volumetric expansion of structural steel.

  - Thermistor thermometers submersed in the pool in eighteen locations provided the data for calculation of volumetric expansion.

- Apparent water mass gain due to volumetric expansion of Boraflex.

  - Thermistor thermometers submersed in the pool in eighteen locations provided the data for calculating the temperature change and specific weight of the pool water needed in the volumetric expansion factor.

- Mass loss through the leak chase drain header.

  - Poly bottles and tygon tubing was attached to the drain header to collect all the water passing into the drain lines.

- Mass loss through the fuel cask pit leak chase drain line.

  - Poly bottles and tygon tubing was attached to the drain line to collect all the water passing into the drain line.

3.3.3 Three different conditions were specified by STP-1242. The first phase placed the spent fuel pool at a low water level with the spent fuel cooling system out of service. A change was made to bring the spent fuel pool level to normal for the second phase. The pool water level was initially lowered to determine both the mass balance and total spent fuel pool liner leak chase collected leakage at what had been thought to be a level at which no leakage occurred. The final phase placed the spent fuel cooling system in service to maintain spent fuel pool temperature. By maintaining temperature, errors associated with water temperature changes in the mass balance calculation would be minimized.

3.3.4 During STP-1242, each leak chase line was individually monitored to associate the identified leakage with a particular area of the spent fuel pool.

3.3.5 The data collected by STP-1242 was input to a computer program generated to perform the mass balance calculations. This software was validated by SMUD calculation Z-SFC-M2538.

3.3.6 In an effort to understand the acceptability of the mass balance, SMUD prepared an uncertainty calculation (Z-SFC-M2539) based on a multi-day test and a calculation based on a constant temperature test. The goal of this calculation was to determine the 95% confidence level uncertainty.

3.4 RESULTS

3.4.1 The results of the mass balance test are presented as follows:

<u>LOW LEVEL</u> (Spent Fuel Cooling Isolated)
Test start date: September 26, 1989
Pool Level: 36 feet
Duration: 134.5 hours
Liner Leakage: 0.43 GPH
Average Temp.: 97°F
Mass Balance: -0.36 GPH
Uncertainty @ 95%: ± 0.92 GPH
NOTE: Temperature increased 15.3°F during test.

<u>HIGH LEVEL</u> (Spent Fuel Cooling Isolated)
Test start date: October 3, 1989
Pool Level: 39 feet
Duration: 87 hours
Liner Leakage: 0.78 GPH
Average Temp.: 105°F
Mass Balance: -1.06 GPH
Uncertainty @ 95%: ± 0.92 GPH
NOTE: Temperature increased 7.5°F during test with a large swing in evaporation monitor temperature. The poor coupling between the Spent Fuel Pool and the evaporation monitor is evidence that this test's accuracy is doubtful.

<u>HIGH LEVEL</u> (Spent Fuel Cooling In Service)
Test start date: October 14, 1989
Pool Level: 38' 10"
Duration: 71 hours
Liner Leakage: 0.18 GPH
Avg. Temp.: 78.6°F
Mass Balance: +0.047 GPH
Uncertainty @ 95%: ±0.24 GPH
NOTE: Temperature decreased 0.1°F during test. This test is obviously the most accurate.

3.4.2 Figures 1 through 7 are presented to show the results of accumulated leak chase water and trends of levels and temperature over the test periods. By viewing the trends of levels and temperature it can be seen that the pool/evaporation pan tracks very well on the High Level Test #2. Note that pool temperature was nearly constant for the entire test duration, designed specifically to reduce the tracking errors between evaporation monitor parameters and pool parameters. During the Low Level Test and High Level Test #1 there was at least a 45 hour difference between times at which the pool and evaporation monitor parameters were identical. During the High Level Test #2 the difference was reduced by more than one half.

3.5 FURTHER ACTIONS

None

3.6 CONCLUSIONS

3.6.1 All of the water (~0.5 gallons per hour) which leaks from the liner into the leak chase system is collected and routed to the radioactive waste system. The test case at high level with the Spent Fuel Cooling system in service, in particular, demonstrates this conclusion. The test at low level and high level with the Spent Fuel Cooling systems isolated also supports this conclusion.

3.6.2 Temperature changes have a large effect on the mass balance determination. This is as shown in the results discussion above and it is shown in the uncertainty calculation for the constant water temperature.

3.6.3 In summary, all water which is leaking from the spent fuel pool is currently collected by the leak chase system and routed to controlled radioactive waste systems. No water is released through the spent fuel pool structure into the ground.

4.0 LEAK DETECTION (STP 1307)

4.1 Results of the Spent Fuel Pool Leak Chase Drain Monitoring (Mass Balance) (STP 1242) indicated that the North wall of the pool, containing the stop-log, is the source of the leakage to the leak chase system. This narrowed the area of interest to the North wall.

4.2 Result of Spent Fuel Pool Liner Leak location, STP 1310 indicated that the leak(s) in the Spent Fuel Pool were lower than Elevation 25'. This further narrowed the area of interest.

4.3 Spent Fuel Pool Leak Detection (STP 1307) is in progress to locate the leak. This test uses vacuum boxes, positioned by divers, in conjunction with Helium injection behind the liner and a mass spectrometer to locate the leak.

4.4 Current efforts have tested all welds above the Fuel Racks above elevation 15' above the floor and have not found the leak.

4.5 Calculations indicate that a 0.01" diameter hole could cause the leak rate we are experiencing.

4.6 A Design Change Package, currently in process, will install an appropriate flow meter on the leak chase drain lines to allow future trending of the leak rate.

4.7 The following actions will be completed following defueling:

4.7.1 A comprehensive testing program to locate the leak(s).

4.7.2 Repair of the leaks as found.

4.7.3 Instrumentation to facilitate trending.

5.0 STRUCTURAL IMPACT

5.1 CONCRETE/REBAR CORROSION STUDY AND ANALYSIS

5.1.1 OBJECTIVE

5.1.1.1 To gather relevant documents in order to make a determination as to the condition of concrete and interior reinforcing steel mats of the spent fuel pool building.

5.1.2 APPROACH

5.1.2.1 Consult available Industry literature for applicable information.

5.1.2.2 Employ the services of Bechtel to analyze the potential degradation of concrete or reinforcing steel by Spent Fuel Pool water.

5.1.3 ACTIONS TAKEN

5.1.3.1 Reports collected include:

5.1.3.1.1 Effects of Substances on Concrete and Guide to Protective Treatment, Portland Cement Association, 1981 (Attachment B).

5.1.3.1.2 ACI Manual of Concrete Practice, Part 5-1986, American Concrete Institute (Attachment C).

5.1.3.1.3 Memorandum, Potential Degradation of the Fuel Pool Due to Leakage of Borated Water From Fuel Pool Liner, Bechtel, August 30, 1989 (Attachment D).

5.1.3.1.4 ERPI Report ND-5985 "Boric Acid Corrosion of Carbon and Low Alloy Steel Pressure Boundary Components in PRWs.

5.1.4 RESULTS

5.1.4.1 EPRI Report NP-5985/Project 2006-18 "Boric Acid Corrosion of Carbon and Low-Alloy Steel Pressure-Boundary Components in PWR's" was reviewed for applicability to the Spent Fuel Building Reinforcing study. This report was considered not applicable based on the fact that the reinforcing steel would be in a submerged Boric Acid Environment, instead of cycles of wetting and drying as described in the EPRI Report. In addition much of the corrosion problems in the EPRI Report was in an environment where evaporation of water increases Boric Acid concentration and an abundant supply of oxygen exists. The conditions under which reinforcing steel might be exposed to Boric Acid involve negligible amounts of oxygen and evaporation. Based on these factors the EPRI Report was not included as a source of information.

5.1.4.2 Both Attachments B and C address chemical effects on concrete caused by permeation of chemicals through concrete. Boric acid has negligible effects on concrete chemistry and strength.

5.1.4.3 Attachment D addresses spent fuel pool water effects on reinforcing steel. This analysis assumes worst case conditions of a direct leak path to the reinforcing steel through concrete cracks instead of "normal" permeation through solid concrete which tend to neutralize boric acid effects. This analysis conservatively assumes a steady state exposure of the reinforcing steel to the spent fuel pool water. With this condition assumed, the amount of corrosion after 40 years would be a reduction in diameter of 50.4 mils which represents a loss of 4.5% of the total diameter of the smallest building reinforcing steel. This small amount of cross-sectional area reduction is acceptable.

5.1.5 FUTURE ACTION

5.1.5.1 From the above results, there is no indication that future action is necessary.

5.1.6 CONCLUSIONS

5.1.6.1 Based on reviewed information and analysis, it can be concluded that the concrete and interior reinforcing steel mat will be negligibly affected by the Spent Fuel Pool Liner leakage and the Spent Fuel Building is and will remain capable of performing its design basis including design basis earthquake.

5.2 INSPECTION OF CONCRETE BEHIND THE UPENDER PIT LINER

5.2.1 OBJECTIVE

To evaluate the condition of the concrete surface and reverse liner surface in the upender pit liner bulge area.

5.2.2 APPROACH

As part of the investigation for the disposition of PDQ 89-0758 (Bulge in the Upender Pit), a hole was drilled into the bulge area in a wall which had shown seepage on the exterior to allow a boroscope to view the back surface of the liner and to view the surface of the concrete.

5.2.3 ACTIONS TAKEN

A hole was drilled in the liner bulge and a boroscope was used to view the concrete surface and the reverse liner surface. The results were recorded on video tape. The area covered by observation was approximately a three foot circle centered on the hole.

5.2.4 RESULTS

5.2.4.1 No standing water was observed when the hole was drilled.

5.2.4.2 There was no spalling of concrete observed.

5.2.4.3 No embedded backing plate was observed in the area of hole.

5.2.4.4 No evidence of rebar corrosion (bleed through) was observed.

5.2.5 FUTURE ACTIONS

There are no future actions contemplated concerning the liner plate bulge.

5.2.6 CONCLUSION

Based on the observations made of the area behind the liner plate bulge, it is concluded that there is no significant structural degradation of the spent fuel building structure due to the pool leakage.

5.3 EXPERIENCE AT SOUTHERN CALIFORNIA EDISON SAN ONOFRE UNIT 1

5.3.1 OBJECTIVE

To evaluate the experience with spent fuel pool liner leakage, repair methods and data collected at San Onofre (SONGS) Unit 1 for its applicability to Rancho Seco Unit 1.

5.3.2 APPROACH

The approach taken was to discuss the SONGS Unit 1 spent fuel pool liner leakage problem with appropriate Southern California Edison (SCE) personnel and to review with them any data that they collected in their evaluation of causes and effects.

5.3.3 ACTIONS TAKEN

5.3.3.1 Mr. Rick Zbavitel was contacted by telephone and he provided a copy of the SCE response to the Region V NRC questions regarding the SONGS Unit 1 spent fuel pool liner leakage and repair.

5.3.3.2 Rancho Seco Chemistry Department personnel were contacted to discuss historical spent fuel pool water chemistry analysis and control.

5.3.4 RESULTS

5.3.4.1 The liner at SONGS Unit 1 is only 1/16" thick and the failure was attributed to stress corrosion cracking induced by higher than normal sulphate concentrations over a long period of time. The stress was attributed to the hydrostatic head and thermal expansion on the thin liner. Sulphate limits were 0.5 ppm up to the time of failure and have since been reduced to 0.1 ppm. The source of the sulphate was determined to be lubricants used on fuel handling equipment and reactor vessel studs.

5.3.4.2 The leakage reached approximately 100 gallons per day prior to the repair. It was reduced to approximately 25 gallons per week by covering the leaking areas with an underwater curable epoxy.

5.3.4.3 There was no known leakage to the surrounding soil and a report by Bechtel determined that there was no reduction in structural capacity of the concrete or rebar. Core samples were taken from the fuel pool wall. There was no evidence of concrete deterioration or rebar corrosion.

5.3.4.4 The liner at Rancho Seco is 3/16" thick which significantly reduces the effect of hydrostatic and thermal expansion on the level of stress in the liner. Water chemistry limits for the RCS and DHS systems is 0.1 ppm for sulphate and while no specific limit is set for the Borated Water Storage Tank and the Spent Fuel Pool, there is no reason to believe that sulphate have exceeded 0.1 ppm since this water is transferred between the systems from time to time.

5.3.5 FUTURE ACTIONS

5.3.5.1 No future action is recommended with regard to changing plant conditions for the spent fuel pool.

5.3.6 CONCLUSIONS

5.3.6.1 The conditions that existed at San Onofre Unit 1 that caused the failure of the spent fuel pool liner were high limits on sulphate combined with a very thin liner. These conditions do not exist at Rancho Seco and therefore sulphate stress corrosion cracking is not a considered failure mode.

5.4 ELECTROCHEMICAL POTENTIAL MAPPING RESULTS (STP-1308)

5.4.1 OBJECTIVE

5.4.1.1 The purpose of this test was to determine corrosion activity in exterior reinforcing steel curtain in the spent fuel building concrete wall.

5.4.2 APPROACH

5.4.2.1 The methodology was in accordance with ASTM C876-87, Standard Test Method for Half-Cell Potential of Uncoated Reinforcing Steel in Concrete.

5.4.2.2 The procedure for the test (STP-1308, "Nondestructive Examination of Spent Fuel Building Reinforcing Steel") was prepared to encompass the suspected worst-case areas of the building based on previous appearance of boron crystals.

5.4.2.3 The acceptance criteria, based on ASTM-C876, requires potential readings more positive than -0.2v to assure that there is a greater than 90% probability that no corrosion is occurring in the exterior reinforcing steel.

5.4.3 ACTIONS TAKEN

5.4.3.1 In accordance with the procedures, probe points were located in a grid to cover the areas of study. Reinforcing steel was exposed to perform half-cell tests and visual inspections were made.

5.4.4 RESULTS

5.4.4.1 The data collected from the electrochemical potential test is shown on Attachment A.

5.4.4.1.1 Test results in all cases were more positive than the acceptance level of -0.20v.

5.4.4.2 The result of the visual surveillance was that no signs of rebar corrosion was observed.

5.4.4.2.1 At probe points where rebar was exposed for attaching probes for the half-cell testing, no indication of corrosion on exposed reinforcing steel was found.

5.4.4.2.2 Area survey indicated no evidence of rust stains from concrete cracks or spalling of concrete.

5.4.5 FUTURE ACTION

5.4.5.1 No further action is contemplated nor required to determine that corrosion is not occurring in exterior reinforcing steel in the spent fuel building.

CONCLUSIONS

5.4.6.1 Based on the electrochemical half-cell potential test and observation of the outer reinforcing steel mat, the conclusion is that corrosion has not been or is not currently occurring in the exterior reinforcing steel.

6.0 ENVIRONMENTAL

6.1 RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM

6.1.1 OBJECTIVE

Assess Radiological Environmental Monitoring Program (REMP) groundwater monitoring activities with respect to the identification of above-background concentrations of fission and activation radionuclides.

6.1.2 APPROACH

Perform a Controls for Environmental Pollution (CEP) document search and related District documents summarizing REMP groundwater monitoring activities.

6.1.3 ACTIONS TAKEN

6.1.3.1 Reviewed all available REMP groundwater radiochemistry analysis data supplied to the District since the REMP was initiated in 1974.

6.1.3.2 Identified sample locations where above-background activity concentrations of fission/activation radionuclides.

6.1.3.3 If possible, provided justification for all radionuclide identifications.

6.1.4 RESULTS

6.1.4.1 The current REMP monitors seven (7) wells by grab sample analysis on a quarterly and weekly basis.

6.1.4.2 On four separate occasions, radioactivity was identified in well samples. Two of the four measurements were reported to the USNRC as being probably anomalous (RS89). The identification of Iodine in the third sample was a one-time occurrence (RS87).

6.1.4.3 The identification of tritium radioactivity in the fourth sample (January 31, 1989) is still under investigation (RS89a). Interim investigation results do not eliminate the possibility that sample processing error contributed to the reported tritium result. It is expected that this sample will not be considered representative of groundwater at the sampled location; as such, this sample measurement result will probably be reported as "anomalous."

6.1.5 FUTURE ACTIONS

Complete the investigation of the January 31, 1989 RWW2.1MO well water sample tritium analysis results (RS89a). Current forecast for completion of this investigation is mid-December, 1989.

6.1.6 CONCLUSIONS

Radiological environmental monitoring program results for the 1974 through second quarter, 1989, monitoring period do not indicate with certainty that fission/activation radionuclides of Station origin were present in sampled groundwater.

6.1.7 REFERENCES

CEP Controls for Environmental Pollution, Inc., 1974 - 1989, "Quarterly Report for Rancho Seco Unit 1", REMP sample analysis reports submitted to the Sacramento Municipal Utility District.

RS87 Rancho Seco Nuclear Generating Station, 1987, "Annual Radiological Environmental Monitoring Report, January - December 1986," Sacramento Municipal Utility District report.

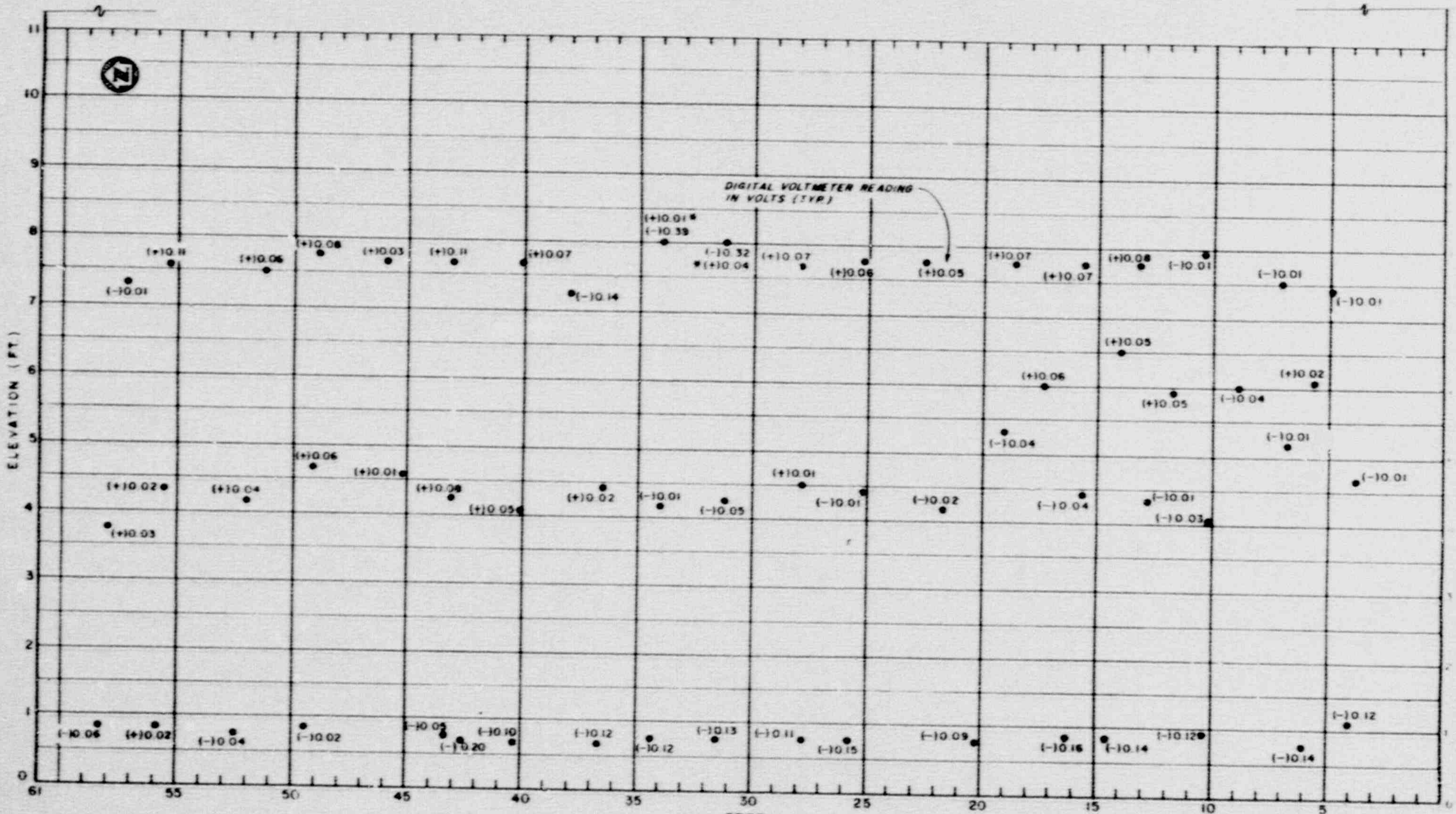
RS88 Rancho Seco Nuclear Generating Station, 1988, "Radiological Environmental Monitoring Program Manual," revision 2 procedure.

RS89 Rancho Seco Nuclear Generating Station, 1989, "Annual Radiological Environmental Monitoring Report, January - December 1988," Sacramento Municipal Utility District report.

RS89a Rancho Seco Nuclear Generating Station, 1989, "Tritium Identified in January 31, 1989 Well Water Sample RWW2.1MO," Potential Deviation from Quality report PDQ #89-0689.

APPENDICES

0014L

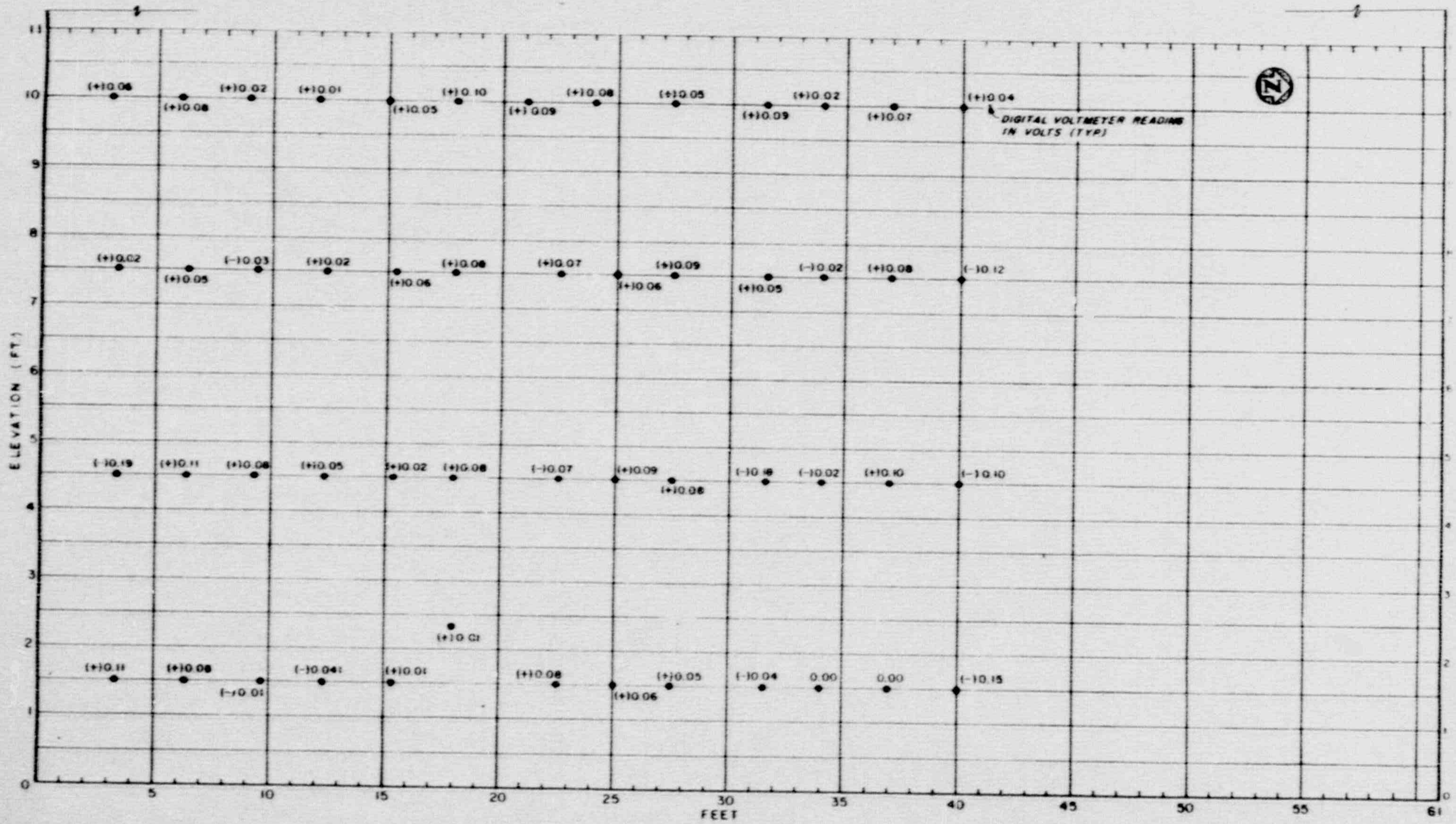


*RETESTED VALUE

ELEVATION

WEST WALL

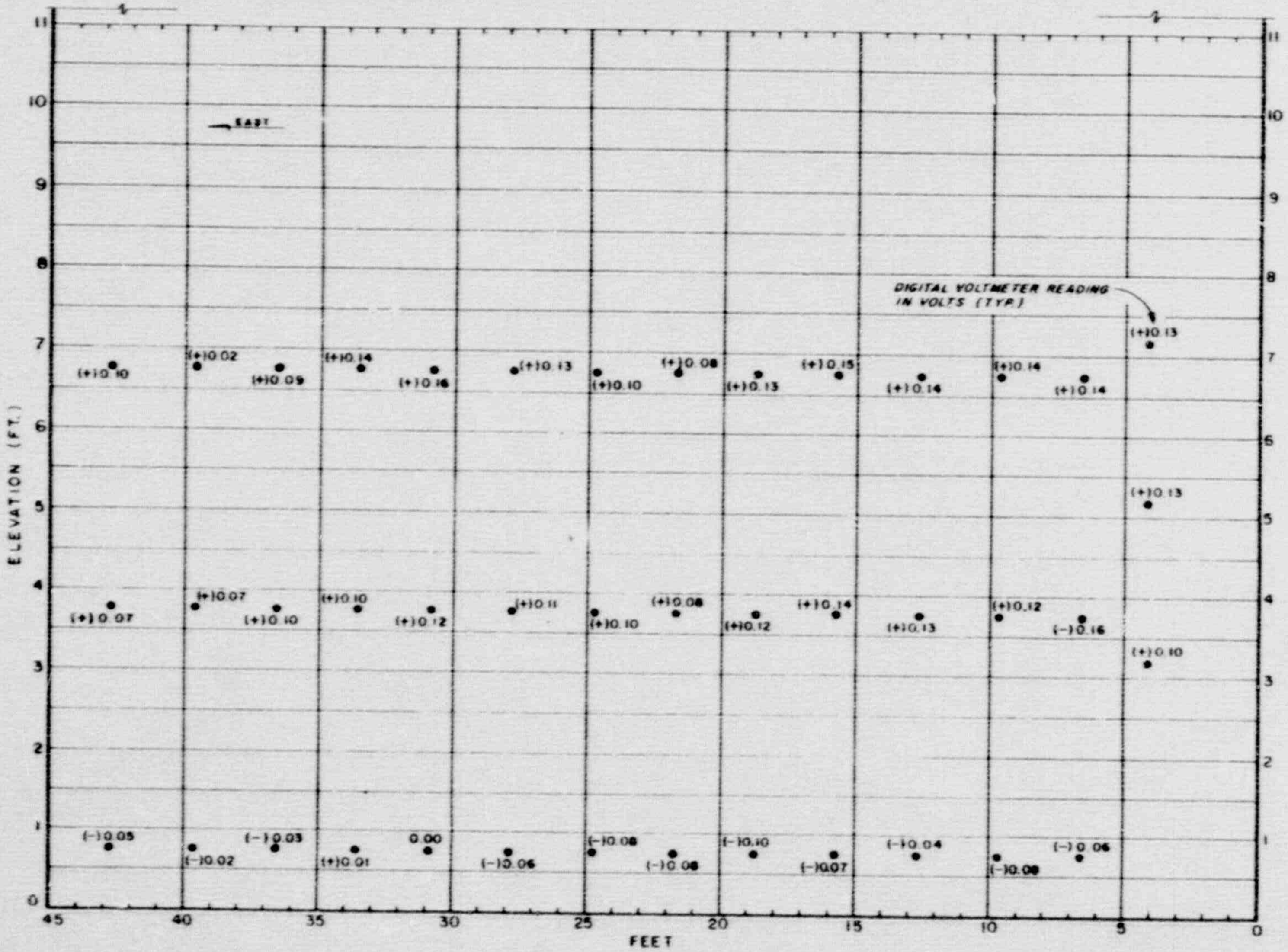
FUEL STORAGE BUILDING
HALF CELL POTENTIAL DATA



ELEVATION

EAST WALL

FUEL STORAGE BUILDING
HALF CELL POTENTIAL DATA



ELEVATION

NORTH WALL

FUEL STORAGE BUILDING
HALF CELL POTENTIAL DATA

concrete INFORMATION

PCA

Effects of Substances on Concrete and Guide to Protective Treatments

Quality concrete must be assumed in any discussion on how various substances affect concrete. In general, achievement of adequate strength and sufficiently low permeability to withstand many exposures requires proper proportioning, placing, and curing. Certain fundamental principles by which the quality of concrete can be controlled are well established:

- *Low water-cement ratio*—not to exceed 0.49 by weight.
- *Minimum cement content*—564 lb per cubic yard (335 kg/m³).
- *Suitable cement type*— such as portland cement low in tricalcium aluminate, C_3A, to reduce or prevent attack by some chemicals that react with C_3A, notably sulfates.
- *Adequate air entrainment*—the amount dependent on maximum aggregate size.
- *Suitable workability*—avoiding mixes so harsh and stiff that honeycomb occurs, and those so fluid that water rises to the surface. Slump should be 2-4 in. (50-100 mm).
- *Thorough mixing*—until all concrete is uniform in appearance, with all materials evenly distributed.
- *Proper placing and consolidation*—filling all corners and angles of forms without segregation of materials. Where possible, construction joints should be avoided.
- *Adequate curing*—supplying additional moisture to the concrete during the early hardening period or covering concrete with water-retaining materials. (Rapid evaporation of moisture from the concrete surface soon after it is placed may cause plastic shrinkage cracking.) *Curing compounds must not be used on surfaces that are to receive protective treatment.* Concrete should be kept moist and above 50°F (10°C) for at least the first week, but longer curing periods usually increase resistance to corrosive substances. Concrete should not be subjected to hydrostatic pressure during this period.

Design Considerations

Whenever concrete is to be coated for corrosion protection, the forms should be coated with materials that will not impregnate or bond to the concrete after they have been stripped. Hence, forms coated with form oils or waxes should not be used against surfaces to be coated. Curing membranes that are weakly bonded to the concrete may develop little or no bond to coatings applied over them. If form oils, waxes, or curing membranes are present, they should be removed by acid washing, sandblasting, scarifying, or other such processes.

Where spillage of corrosive substances is likely to occur, a floor should have a slope to drains of at least 2% to facilitate washing.

Many solutions that have no chemical effect on concrete, such as brines and salts, may crystallize upon drying. It is especially important that concrete subject to alternate wetting and drying of such solutions be impervious to them. When free water in concrete is saturated with salts, the salts crystallize in the concrete near the surface during the drying process, sometimes exerting sufficient pressure to cause scaling. Structures exposed to brine solutions and having a free surface of evaporation should therefore be provided with a protective treatment on the side exposed to the solution.

In addition, movement of salts into the concrete may result in corrosion of reinforcing steel. The corrosion reactions form compounds that cause expansion and disruption of the concrete. Significant corrosion of steel in reinforced concrete will occur if (1) sufficient oxygen is available, and (2) the normally passive state of steel in concrete is impaired. Porous concrete or surface cracks permit the penetration of oxygen to the reinforcement. The steel is normally passive because a protective oxide film is formed and maintained on it by the high concentration of hydroxide ions (high pH) in the water solution in concrete. This protective film may be impaired by (1) sufficient lowering of the pH value, as by reaction of carbon dioxide from the air or other sources, or (2) a sufficient concentration of chloride ions in solution. High cement content in high-quality impermeable concrete provides protection against corrosion of reinforcement by producing a high pH value and limiting exposure to the air.

It is important that sufficient concrete coverage be provided for reinforcement where the surface is to be exposed to corrosive substances. Carbon steel bar and hot-applied ⅜-in.-thick (10-mm) asphaltic materials, both plain and glass cloth reinforced, are preferred for the membrane lining, depending on the corrosive substance. The primer should conform to Standard Specifications for Primer for Use with Asphalt in Dampproofing and Waterproofing (ASTM D41), except that the asphalt content should not be less than 35% by weight. Floor slabs that are to receive a masonry lining should have a smooth wood-float finish. A slab having a steel-trowel finish may be too smooth for adhesion of the asphaltic membrane.

17. Sheet rubber. Soft natural and synthetic rubber sheets ⅛ to ½ in. (3 to 12 mm) thick may be cemented to concrete with special adhesives. Sometimes two layers of soft rubber are used as a base, with a single layer of hard rubber over them.

Chemical-resistant synthetics available as sheeting are neoprene, polyvinylidene chloride-acrylonitrile, plasticized polyvinyl chloride, polyisobutylene, butyl, nitrile, polysulfide, and chlorosulfonated polyethylene rubbers.

18. Resin sheets. Synthetic resins, particularly polyester, epoxy, and polyvinyl chloride, are available as sheet materials. *These sheets are not referred to in the tables but may be used wherever comparable resin coatings are recommended.* They are often glass fiber reinforced and may be cemented to concrete with special adhesives.

19. Lead sheet. In the United States, lead sheet used for chemical resistance is called chemical lead. The sheets should be as large as possible (to minimize the number of joints) but not too heavy to handle—the thinnest sheet may be as large as 8×20 ft (2.5 × 6.0 m). Thicknesses range from 1/64 to ½ in. (0.4 to 12 mm). Lead may be cemented to concrete with an asphaltic paint. Each sheet should be overlapped and the seam welded by conventional lead-burning techniques. If the lead is to be subjected to high temperatures, it may be covered with chemical-resistant masonry to reduce thermal stresses.

20. Glass. Two types have been used for corrosion resistance: high-silica glass and borosilicate glass. Borosilicate glass, the more alkali-resistant material, is recommended because alkalies in concrete may cause glass etching. Glass may be cemented to the concrete. Thermal shock is often a cause of failure in glass-lined structures.

References

1. "A Guide to the Use of Waterproofing, Dampproofing, Protective, and Decorative Barrier Systems for Concrete," Report No. ACI 515.1R-79, *Concrete International*, November 1979.
2. Kleinlogel, A., *Influences on Concrete*, Frederick Ungar Publishing Co., New York, 1950.
3. Biczok, Imre, *Concrete Corrosion and Concrete Protection*, Akademai Kiado, Budapest, 1964.
4. ACI Committee 201, *Guide to Durable Concrete*, American Concrete Institute, Detroit, 1977.

Guide for the Selection of Protective Treatments

Adapted (with a few modifications) from Reference 1. Footnotes appear at the end of each table.

ACIDS

Material	Effect on concrete	Protective treatments
Acetic		
<10%	Slow disintegration	1, 2, 9, 10, 12, 14, 16 (b, c, e, f, g, h)
30%	Slow disintegration	9, 10, 14, 16 (c, e, f, g)
100% (glacial)	Slow disintegration	9, 16 (e, g)
Acid waters (pH of 6.5 or less)	Slow disintegration.* Natural acid waters may erode surface mortar but then action usually stops	1, 2, 3, 6, 8, 9, 10, 11, 12, 13, 16 (h, c, e, f, g, h), 17
Arsenious	None	
Boric	Negligible effect	3, 6, 7, 8, 9, 10, 12, 13, 15, 16 (b, c, e, f, g, h), 17, 19
Butyric	Slow disintegration	3, 4, 8, 9, 10, 12, 16 (b, c, e, f)
Carbolic	Slow disintegration	1, 2, 16 (c, e, g), 17
Carbonic (soda water)	0.9 to 3 ppm of carbon dioxide dissolved in natural waters disintegrates concrete slowly	2, 3, 4, 8, 9, 10, 12, 13, 15, 16 (b, c, e, f, h), 17
Chromic:		
5%	None*	3, 6, 7, 8, 9, 10, 16 (f, g, h), 19
50%	None*	16 (g), 19
Formic:		
10%	Slow disintegration	2, 5, 6, 7, 10, 12, 13, 16 (b, c, e, g), 17
90%	Slow disintegration	2, 7, 10, 12, 16 (c, e, g), 17
Humic	Slow disintegration possible, depending on humus material	1, 2, 3, 9, 10, 12, 15, 16 (b, c, e)
Hydrochloric:		
10%	Rapid disintegration, including steel	2, 5, 6, 7, 8, 9, 10, 12, 14, 16 (b, c, e, f, g, h), 17, 19, 20
37%	Rapid disintegration, including steel	5, 6, 8, 9, 10, 16 (c, e, f, g, h)
Hydrofluoric:		
10%	Rapid disintegration, including steel	5, 6, 7, 8, 9, 12, 16 (carbon and graphite brick; b, c, e, h), 17
75%	Rapid disintegration, including steel	16 (carbon and graphite brick; c, h), 17
Hypochlorous, 10%	Slow disintegration	5, 6, 9, 10, 16 (f, g)
Lactic, 5%	Slow disintegration	3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 15, 16 (b, c, e, f, g, h), 17
Nitric:		
2%	Rapid disintegration	6, 8, 9, 10, 13, 16 (f, g, h), 20
40%	Rapid disintegration	8, 16 (g)
Oleic, 100%	None	
Oxalic	No disintegration. It protects concrete against acetic acid, carbon dioxide, and salt water. POISONOUS, it must not be used on concrete in contact with food or drinking water.	
Perchloric, 10%	Disintegration	8, 10, 16 (e, f, g, h)
Phosphoric:		
10%	Slow disintegration	1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 (b, c, e, f, g, h), 17, 19

ACI MANUAL OF CONCRETE PRACTICE

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BOX 19150, REDFORD STATION
DETROIT, MICHIGAN 48219

A Guide to the Use of Waterproofing, Dampproofing, Protective, and Decorative Barrier Systems for Concrete

Reported by ACI Committee 515

This Guide updates and expands the scope of the committee report "Guide for the Protection of Concrete Against Chemical Attack by Means of Coatings and Other Corrosion Resistant Materials," which appeared in the December 1966 ACI JOURNAL. The previous Guide has been revised and is found in Chapter 6 of this Guide entitled "Protective Barrier Systems." In addition, there are new chapters on "Waterproofing Barrier Systems," "Dampproofing Barrier Systems," and "Decorative Barrier Systems." A separate chapter on conditioning and surface preparation of concrete is included because it is relevant to all the other chapters.

This Guide is not to be referenced as a complete unit.

Keywords: abrasive blasting; acid treatment; abrasion; acid resistance; adhesion; asphalts; chemical attack; chemical cleaning; clay brick; concrete bricks; concretes; detergents; emulsifying agents; epoxy resins; finishes; furan resins; glass fibers; inspection; joint sealers; latex (rubber); mortars (material); paints; phenolic resins; plastics, polymers, and resins; polyester resins; polyurethane resins; protective coatings; repairs; sealers; silicones; sulfur; surface temperature; tests; vapor barriers; waterproofing.

Foreword

ACI Committee 515 was organized in 1936 and published a report "Guide for the Protection of Concrete Against Chemical Attack by Means of Coatings and Other Corrosion Resistant Materials," in the December 1966 ACI JOURNAL. William H. Kuenning was chairman when this Guide was published. Albert M. Levy was chairman from 1974 to 1977 when some of the information, found in the chapters on "Waterproofing Barrier Systems" and "Dampproofing Barrier Systems," was developed.

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1.3 — Barrier performance difficult to define
1.4 — Economic factors for barrier selection
1.5 — Inspection during application
1.6 — Safety requirements

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3.1 — General requirements
3.1.1 — Release agents on forms
3.1.2 — Curing compounds
3.1.3 — Admixtures in concrete

TABLE 2.5.2 — Effect of chemicals on concrete

Material	Effect
*Acetic acid, <10 percent	Disintegrates slowly
*Acetic acid, 10 percent	Disintegrates slowly
*Acetic acid, 30 percent	Disintegrates slowly
*Glacial	Disintegrates slowly
Acetone	Liquid loss by penetration. May contain acetic acid as impurity (which see)
Acid waters (pH of 6.5 or less)	Disintegrates slowly. In porous or cracked concrete, attacks steel
*Alcohol	See ethyl alcohol, methyl alcohol
Alizarin	Not harmful
*Almond oil	Disintegrates slowly
*Alum	See potassium aluminum sulfate
Aluminum chloride	Disintegrates rapidly. In porous or cracked concrete, attacks steel
*Aluminum sulfate	Disintegrates. In porous or cracked concrete, attacks steel
*Ammonia, liquid	Harmful only if it contains harmful ammonium salts (see below)
Ammonia vapors	May disintegrate moist concrete slowly or attack steel in porous or cracked moist concrete
Ammonium bisulfate	Disintegrates. In porous or cracked concrete, attacks steel
Ammonium carbonate	Not harmful

Material	Effect
*Ammonium chloride	Disintegrates slowly. In porous or cracked concrete, attacks steel
Ammonium cyanide	Disintegrates slowly
Ammonium fluoride	Disintegrates slowly
Ammonium hydroxide	Not harmful
Ammonium nitrate	Disintegrates. In porous or cracked concrete, attacks steel
Ammonium oxalate	Not harmful
*Ammonium sulfate	Disintegrates. In porous or cracked concrete, attacks steel
Ammonium sulfide	Disintegrates
Ammonium sulfite	Disintegrates
Ammonium superphosphate	Disintegrates. In porous or cracked concrete, attacks steel
Ammonium thiosulfate	Disintegrates
Animal wastes	See slaughter house wastes
Anthracene	Not harmful
Arsenious acid	Not harmful
Ashes	Harmful if wet, when sulfides and sulfates leach out (see sodium sulfate)
Ashes, hot	Cause thermal expansion

Material	Effect
Automobile and diesel exhaust gases[a]	May disintegrate moist concrete by action of carbonic, nitric, or sulfurous acid
*Baking soda	See sodium bicarbonate
Barium hydroxide	Not harmful
Bark	See tanning bark
*Beef fat	Solid fat disintegrates slowly, melted fat more rapidly
*Beer	May contain, as fermentation products, acetic, carbonic, lactic, or tannic acids (which see)
Benzol (benzene)	Liquid loss by penetration
Bleaching solution	See specific chemical, such as hypochlorous acid, sodium hypochlorite, sulfurous acid, etc.
Boracic acid	See boric acid
*Borax	Not harmful
*Boric acid	Negligible effect
*Brine	See sodium chloride or other salt
Bromine	Gaseous bromine disintegrates. Liquid bromine disintegrates if it contains hydrobromic acid and moisture
*Buttermilk	Disintegrates slowly
Butyl stearate	Disintegrates slowly

Material	Effect
Calcium bisulfite	Disintegrates rapidly
*Calcium Chloride	In porous or cracked concrete, attacks steel.(b) Steel corrosion may cause concrete to spall
*Calcium hydroxide	Not harmful
Calcium nitrate	Not harmful
*Calcium sulfate	Disintegrates concrete of inadequate sulfate resistance
Carbazole	Not harmful
Carbolic acid	See phenol
*Carbon dioxide	Gas may cause permanent shrinkage (see also carbonic acid)
*Carbon disulfide	May disintegrate slowly
*Carbon tetrachloride	Liquid loss by penetration of concrete
*Carbonic acid	Disintegrates slowly(c)
Castor oil	Disintegrates, especially in presence of air
Chile saltpeter	See sodium nitrate
China wood oil	Liquid disintegrates slowly. Dried or drying film harmless
Chlorine gas	Slowly disintegrates moist concrete
Chrome plating solutions[d]	Disintegrates slowly

Bechtel

Interoffice Memorandum

To	R. A. Goldenburg	File No.	
Subject	Potential Degradation of the Fuel Pool Due to Leakage of Borated Water from Fuel Pool Liner - SMUD Job No. 12334-705, Activity 010	Date	August 30, 1989
		From	R. A. White
		Of	SFRO/M&QS
Copies to	R. A. Manley/F. C. Breismeister S. S. Sharma DCC 0530171	At	50/15/B20 Ext. 2862

We were asked to update our December 22, 1986 letter on the same subject. Specifically, we were asked to address two concerns expressed by the NRR:

1. The water chemistry in the fuel pool is different than stated in the December 22, 1986 letter.

2. Permeation calculations indicate very low penetration of water into the concrete yet moisture was detected on the outside of the walls.

The following are our comments.

1. Fuel Pool Chemistry

   The fuel pool chemistry reported on the December 22, 1986 letter and the 1989 fuel pool chemistry are as follows:

	December 1986 Report	January 1 to August 7, 1989
pH	5.1 - 5.2	4.6 - 5.5
B (ppm)	less than 17.5	2140 - 2285
Cr (ppm)	less than 0.02	less than 0.026
F (ppm)	less than 0.02	less than 0.042
SO_4 (ppm)	less than 0.05	Not reported

The complete 1989 data are attached to this report.

As can be seen by comparing these two sets of analyses, the only significant difference in chemistry is the boron content. Though the boron content in the order of 2200 ppm rather than 10 ppm, this has no significant effect on the permeation rate of water in to concrete. More significantly, boron content in the order of 2200 ppm rather than 10 ppm has no significant effect on the pH (because boric acid is a buffer) as can be seen from the data.

2. Water Permeation

As was indicated in the December 22, 1986 letter, leakage through cracks in the concrete has occured in four to five places. The permeation rates calculated were based on crack free concrete, which represents all but the few areas where cracks exists.

It is reasonable to assume that the fuel pool water that leaked through cracks also permeated the walls of the crack by the same amount as it would permeate into the concrete from the inside of the concrete wall. Therefore, some short distance (in the order of inches) of some of the rebar, but only in the lower 3-feet of the fuel pool wall, probably has been exposed to fuel pool water. As was stated in the December 22, 1986 letter, even if the fuel pool water reached the rebar and the concrete were completely broken away from the rebar (otherwise the alkalinity of the concrete would tend to neutralize the boric acid) the corrosion rate of the carbon steel rebar would be 4 mils per year maximum. Under steady state conditions the corrosion rate decreases with time according to the equation:

$$v = kt^{-1/3}$$

where: v = corrosion rate in mils per year
t = time in hours
k = constant

If 4 mils per year represents the average corrosion rate for the first year, then the average corrosion rate for 40 years will be 0.63 mils per year from the above equation. This would mean a loss of 25.2 mils in 40 years or 50.4 mils on the diameter of the rebar. The smallest diameter rebar in that area is 1-1/8 inch or 1125 mils. Therefore, 50.4 mils represents a loss of 4.5 percent of the diameter.

We again conclude that we do not envision a significant effect on the rebar due to leakage from the fuel pool.

R. A. White

RAW/jjc

IOM/354-JF

CM-RP-[redacted]

MEASUREMENT REPORT
SACRAMENTO MUNICIPAL UTILITY DISTRICT
All Data

REPORT DATE: Monday August 7, 1989
TIME : 2103 PM
PLANT : RANCHO SECO UNIT 1

GROUP I.D. : RC
SYSTEM I.D. : SF
SAMPLE POINT I.D. : SF

DATE FROM : 01-JAN-1989
DATE TO : now

TYPE	DATE/TIME	OPER. MODE	POWER LEVEL	ANALYZED BY	VALUE
B	3-Jan-89 09:30	1	0.0	PJK	2207 PPM
	10-Jan-89 08:40	1	0.0	JD	2225 PPM
	17-Jan-89 10:[illegible]	1	60.0	NH	2222 PPM
	31-Jan-89 09:30	1	[illegible]2.0	DW	2234 PPM
	4-Feb-89 22:50	[illegible]	0.0	PJK	2217 PPM
	7-Feb-89 14:10	[illegible]	0.0	RSR	2250 PPM
	14-Feb-89 08:15	1	0.0	RLM	2222 PPM
	21-Feb-89 08:00	1	0.0	W	2212 PPM
	2[illegible]-Feb-89 14:40	1	0.0	LZ	2238 PPM
	7-Mar-89 10:40	1	0.0	PJK	2203 PPM
	12-Mar-89 03:15	1	0.0	SNG	2[illegible] PPM
	14-Mar-89 09:00	1	10.0	[illegible]	2179 PPM
	21-Mar-89 10:50	1	92.0	[illegible]	2220 PPM
	28-Mar-89 08:35	[illegible]	92.0	MJ	[illegible]7 PPM
	1-Apr-89 17:15	1	[illegible].0	RLM	22[illegible] PPM
	4-Apr-[illegible] 09:30	1	[illegible]	[illegible]	[illegible] PPM
	11-Apr-89 09:45	1	[illegible].0	SNB	220[illegible] PPM
	18-Apr-89 [illegible]:15	1	77.0	RLM	2225 PPM
	25-Apr-89 08:30	1	75.0	CAB	2215 PPM
	26-Apr-89 07:50	1	92.0	CAB	2105 PPM
	[illegible]-May-89 11:00	1	[illegible].0	RKH	[illegible] PPM
	9-May-89 09:35	1	92.[illegible]	LZ	2195 PPM
	13-May-89 01:00	1	[illegible]	CAB	[illegible] PPM
	16-May-[illegible] 09:30	1	65.[illegible]	PJK	[illegible] PPM
	23-May-89 09:25	1	[illegible].0	[illegible]	[illegible] PPM
	30-May-[illegible] 08:30	1	[illegible].0	[illegible]	[illegible] PPM
	6-Jun-89 08:00	1	35.0	[illegible]	[illegible] PPM
	13-Jun-89 10:15	1	[illegible]	[illegible]LK	[illegible] PPM
	20-Jun-89 08:50	[illegible]	0.0	[illegible]	2170 PPM
	27-Jun-89 08:50	[illegible]	0.0	RLM	2176 PPM
	30-Jun-89 [illegible]:10	1	0.0	[illegible]	[illegible] PPM
	[illegible]-Jul-[illegible] 09:30	1	0.0	[illegible]	2140 [illegible]
	18-Jul-[illegible] 06:05	1	0.0	MJ	[illegible] PPM
	25-Jul-89 09:1[illegible]	[illegible]	0.0	MJ	2198 PPM
	[illegible]-Aug-89 [illegible]:10	[illegible]	0.0	[illegible]	[illegible] PPM
	[illegible]				2159 PPM
	3-Jan-89 09:30	1	0.0	PJK	0.010 PPM
	10-Jan-89 08:40	[illegible]	0.0	JD	0.022 PPM
	17-Jan-89 10:00	1	60.0	[illegible]	0.014 PPM
	31-Jan-89 09:30	1	[illegible]2.0	DW	0.013 PPM
	7-Feb-8[illegible] 14:10	1	0.0	RSR	.0075 PPM

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MEASUREMENT REPORT
SACRAMENTO MUNICIPAL UTILITY DISTRICT
All Data

Page

REPORT DATE: Monday August 7, 1989
TIME : 2:09 PM
PLANT : RANCHO SECO UNIT 1

GROUP I.D. : RC
SYSTEM I.D. : SF
SAMPLE POINT I.D. : SF

DATE FROM : 01-Jan-1989
DATE TO : now

TYPE	DATE/TIME	OPER. MODE	POWER LEVEL	ANALYZED BY		VALUE
	14-Feb-89 08:15	1	0.0			
	21-Feb-89 08:00	1	0.0			.018 PPM
	28-Feb-89 14:40	1	0.0	W	<	0.020 PPM
	7-Mar-89 10:40	1	0.0	LZ	<	0.020 PPM
	14-Mar-89 09:00	1	0.0	PJK		0.011 PPM
	21-Mar-89 10:30	1	10.0	KJ		.010 PPM
	28-Mar-89 09:35	1	92.0	jd		0.012 PPM
	4-Apr-89 09:30	1	92.0	MJ	<	.005 PPM
	11-Apr-89 09:45	1	0.0	SG		.012 PPM
	18-Apr-89 08:17	1	0.0	SNG		0.020 PPM
	25-Apr-89 08:30	1	77.0	RLM		.026 PPM
	2-May-89 11:00	1	75.0	CAB	<	0.005 PPM
	9-May-89 09:35	1	92.0	RKH	<	.005 PPM
	16-May-89 09:30	1	92.0	LZ	<	0.005 PPM
	23-May-89 09:25	1	65.0	PJK	<	0.005 PPM
	30-May-89 08:30	1	65.0	PJK	<	0.005 PPM
	6-Jun-89 09:00	1	60.0	RSR	<	.005 PPM
	13-Jun-89 10:15	1	65.0	MJ	<	.005 PPM
	20-Jun-89 08:50	1	0.0		<	.005 PPM
	27-Jun-89 08:50	1	0.0	MJ	<	.005 PPM
	4-Jul-89 09:30	1	0.0	RLM	<	.005 PPM
	11-Jul-89 08:05	1	0.0	MJ	<	.005 PPM
	25-Jul-89 08:15	1	0.0	MJ	<	.005 PPM
	1-Aug-89 09:10	1	0.0	RKH	<	.005 PPM
			0.0	RLM	<	.005 PPM
	10-Jan-89 08:40	1				
	17-Jan-89 10:00	1	0.0	JD		0.019 PPM
	24-Jan-89 16:45	1	60.0	NH		0.032 PPM
	31-Jan-89 09:30	1	92.0	SNG		0.006 PPM
	7-Feb-89 14:10	1	92.0	[illegible]		0.005 PPM
	14-Feb-89 08:15	1	0.0	RSR	<	.005 PPM
	21-Feb-89 08:00	1	0.0			.04 PPM
	28-Feb-89 14:40	1	0.0	W		0.042 PPM
	7-Mar-89 10:40	1	0.0	LZ		0.031 PPM
	14-Mar-89 09:00	1	0.0	PJK		0.036 PPM
	21-Mar-89 10:30	1	10.0	KJ		.02 PPM
	28-Mar-89 09:35	1	92.0	jd		0.018 PPM
	4-Apr-89 09:30	1	92.0	MJ	<	.005 PPM
	11-Apr-89 09:45	1	0.0	SG	<	.005 PPM
	18-Apr-89 08:17	1	0.0	SNG		0.040 PPM
	25-Apr-89 08:30	1	77.0	RLM		.006 PPM
	2-May-89 11:00	1	75.0	CAB	<	0.005 PPM
		1	92.0	RKH	<	.005 PPM

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MEASUREMENT REPORT
SACRAMENTO MUNICIPAL UTILITY DISTRICT
All Data

REPORT DATE: Monday August 7, 1989
TIME : 2103 PM
PLANT : RANCHO SECO UNIT 1

GROUP I.D. : RC
SYSTEM I.D. : SF
SAMPLE POINT I.D. : SF

DATE FROM : 01-JAN-1989
DATE TO : now

TYPE	DATE/TIME	OPER. MODE	POWER LEVEL	ANALYZED BY		VALUE
	9-May-89 09:35	1	92.0	LZ	<	0.005 PPM
	16-May-89 09:30	1	65.0	pjk	<	0.005 PPM
	23-May-89 09:25	1	65.0	PJK	<	0.005 PPM
	30-May-89 08:30	1	60.0	RSR	<	.005 PPM
	6-Jun-89 08:00	1	65.0	MJ	<	.005 PPM
	13-Jun-89 10:15	1	0.0		<	.005 PPM
	20-Jun-89 08:50	1	0.0	MJ	<	.005 PPM
	27-Jun-89 08:50	1	0.0	RLM	<	.005 PPM
	4-Jul-89 09:30	1	0.0	MJ	<	.005 PPM
	18-Jul-89 09:05	1	0.0	MJ	<	.005 PPM
	25-Jul-89 08:15	1	0.0	RKM	<	.005 PPM
	1-Aug-89 09:10	1	0.0	RLM	<	.005 PPM
BETA	3-Jan-89 09:30	1	0.0	PJK		5.73E-4 uC/ml
	10-Jan-89 09:40	1	0.0	JD		5.61E-4 uC/ml
	31-Jan-89 09:30	1	92.0	JW		6.27E-4 uC/ml
	7-Feb-89 14:10	1	0.0	RSR		4.77E-4 uC/ml
	14-Feb-89 08:15	1	0.0			5.24E-4 uC/ml
	21-Feb-89 08:00	1	0.0	W		6.52E-4 uC/ml
	28-Feb-89 14:40	1	0.0	LZ		6.33E-4 uC/ml
	7-Mar-89 10:40	1	0.0	PJK		6.37E-4 uC/ml
	21-Mar-89 10:50	1	92.0	JD		6.33e-4 uC/ml
	28-Mar-89 08:35	1	92.0	MJ		4.95E-4 uC/ml
	4-Apr-89 09:30	1	0.0	CG		5.34E-4 uC/ml
	11-Apr-89 09:45	1	0.0	SNG		4.61E-4 uC/ml
	15-Apr-89 10:30	1	66.0	RKH		5.57E-4 uC/ml
	18-Apr-89 10:04	1	77.0	RLM		4.24E-4 uC/ml
	25-Apr-89 08:30	1	75.0	CAB		1.61E-4 uC/ml
	2-May-89 11:00	1	92.0	RKH		4.02E-4 uC/ml
	9-May-89 09:35	1	92.0	LZ		6.72E-5 uC/ml
	16-May-89 09:30	1	65.0	PJK		3.99e-4 uC/ml
	23-May-89 09:25	1	65.0	PJK		2.71E-4 uC/ml
	30-May-89 08:30	1	60.0	RSR		1.32E-4 uC/ml
	6-Jun-89 08:00	1	65.0	MJ		3.11E-5 uC/ml
	13-Jun-89 10:15	1	0.0			6.61E-5 uC/ml
	20-Jun-89 08:50	1	0.0	MJ		2.14E-5 uC/ml
	27-Jun-89 08:50	1	0.0	RLM		1.72E-5 uC/ml
	4-Jul-89 09:00	1	0.0	MJ		3.34E-5 uC/ml
	18-Jul-89 09:05	1	0.0	MJ		4.02E-5 uC/ml
	25-Jul-89 08:15	1	0.0	RKH		1.65E-5 uC/ml
	1-Aug-89 09:10	1	0.0	RLM		4.35E-4 uC/ml

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MEASUREMENT REPORT
SACRAMENTO MUNICIPAL UTILITY DISTRICT
All Data

REPORT DATE: Monday August 7, 1989
TIME : 2103 PM
PLANT : RANCHO SECO UNIT 1

GROUP I.D. : RC
SYSTEM I.D. : SF
SAMPLE POINT I.D. : SF

DATE FROM : 01-JAN-198[illegible]
DATE TO : now

TYPE	DATE/TIME	OPER. MODE	POWER LEVEL	ANALYZED BY	VALUE	
H3	3-Jan-89 09:30	1	0.0	TJK	5.00E-2	uC/ml
	10-Jan-89 08:40	1	0.0	JD	5.13E-2	uC/ml
	17-Jan-89 10:00	1	60.0		4.64E-2	uC/ml
	24-Jan-89 16:45	1	92.0	SNG	4.72E-2	uC/ml
	31-Jan-89 09:30	1	92.0	DW	5.92E-2	uC/ml
	7-Feb-89 14:10	1	0.0	RSR	4.74E-2	uC/ml
	14-Feb-89 08:15	1	0.0		5.34E-2	uC/ml
	21-Feb-89 08:00	1	0.0	W	5.55E-2	uC/ml
	28-Feb-89 14:40	1	0.0	LZ	4.94E-2	uC/ml
	7-Mar-89 10:40	1	0.0	PJK	5.80E-2	uC/ml
	21-Mar-89 10:50	1	92.0	JJ	5.44e-2	uC/ml
	28-Mar-89 08:35	1	92.0	MJ	5.13E-2	uC/ml
	4-Apr-89 09:30	1	0.0	SG	5.07E-2	uC/ml
	11-Apr-89 09:45	1	0.0	SNG	5.13E-2	uC/ml
	18-Apr-89 08:15	1	77.0	RLM	5.31E-2	uC/ml
	25-Apr-89 08:30	1	75.0	TAB	5.09E-2	uC/ml
	2-May-89 11:00	1	92.0	RKH	5.06E-2	uC/ml
	9-May-89 09:35	1	72.0	LZ	5.64E-2	uC/ml
	16-May-89 09:30	1	55.0	pjk	5.51e-2	uC/ml
	23-May-89 09:25	1	65.0	PJK	5.54E-2	uC/ml
	30-May-89 08:30	1	60.0	RSR	5.21E-2	uC/ml
	6-Jun-89 08:00	1	55.0	mJ	5.13E-2	uC/ml
	13-Jun-89 10:15	1	0.0		5.67E-2	uC/ml
	20-Jun-89 08:50	1	0.0	MJ	5.34E-2	uC/ml
	27-Jun-89 08:50	1	0.0	RLM	5.70E-2	uC/ml
	4-Jul-89 09:30	1	0.0	MJ	4.87E-2	uC/ml
	18-Jul-89 08:05	1	0.0	MJ	5.34E-2	uC/ml
	25-Jul-89 08:15	1	0.0	RKH	5.60E-2	uC/ml
	1-Aug-89 09:10	1	0.0	RLM	5.75E-2	uC/ml
PH	3-Jan-89 09:30	1	0.0	PJK	4.33	N/A
	10-Jan-89 08:40	1	0.0	JD	4.96	N/A
	17-Jan-89 10:00	1	60.0	NH	4.83	N/A
	24-Jan-89 16:45	1	92.0	SNG	4.92	N/A
	31-Jan-89 09:30	1	92.0	DW	4.85	N/A
	7-Feb-89 14:10	1	0.0	RSR	5.5	N/A
	14-Feb-89 08:15	1	0.0		4.82	N/A
	21-Feb-89 08:00	1	0.0	W	4.84	N/A
	28-Feb-89 14:40	1	0.0	LZ	4.65	N/A
	7-Mar-89 10:10	1	0.0	PJK	4.96	N/A
	14-Mar-89 09:00	1	10.0	JJ	5.[illegible]	N/A
	21-Mar-89 10:50	1	92.0	JJ	[illegible]	N/A

SEP 05 '89 10:02 415 7675790

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MEASUREMENT REPORT
SACRAMENTO MUNICIPAL UTILITY DISTRICT
All Data

REPORT DATE: Monday August 7, 1989
TIME : 3:09 PM
PLANT : RANCHO SECO UNIT 1

GROUP I.D. : RC
SYSTEM I.D. : SF
SAMPLE POINT I.D. : SF

DATE FROM : 01-JAN-1989
DATE TO : now

TYPE	DATE/TIME	OPER. MODE	POWER LEVEL	ANALYZED BY	VALUE
	28-Mar-89 09:35	1	92.0	MJ	5.06 N/A
	18-Apr-89 08:15	1	77.0	RLM	4.81 N/A
	25-Apr-89 08:30	1	75.0	CAB	4.70 N/A
	1-May-89 11:00	1	92.0	RKH	4.90 N/A
	9-May-89 09:35	1	92.0	LZ	4.75 N/A
	16-May-89 09:30	1	65.0	PJK	4.84 N/A
	23-May-89 09:25	1	65.0	PJK	4.78 N/A
	6-Jun-89 03:00	1	65.0	MJ	4.84 N/A
	13-Jun-89 10:15	1	0.0		4.6 N/A
	20-Jun-89 08:50	1	0.0	MJ	4.71 N/A
	27-Jun-89 08:50	1	0.0	RLM	4.67 N/A
	4-Jul-89 09:30	1	0.0	MJ	4.81 N/A
	18-Jul-89 08:05	1	0.0	MJ	4.80 N/A
	25-Jul-89 08:15	1	0.0	RKH	5.30 N/A
	1-Aug-89 09:10	1	0.0	RLM	4.72 N/A

\- Indicates a limit has been exceeded.

D OF THE MEASUREMENT REPORT