UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of:	)	Docket Nos. STN 50-528
Arizona Public Service Company, et al.	)	STN 50-529
(Palo Verde Nuclear Generating Station, Units 1, 2 and 3)	)	STN 50-530

REBUTTAL TESTIMONY OF WILLIAM G. BINGHAM

Q. Please state your name and business address.

A. My name is William G. Bingham. My business address is 11445 South Lakewood Blvd., Downey, California 90650.

Q. Are you the same William G. Bingham who testified on behalf of Joint Applicants in these proceedings on April 30, May 25 and May 26, 1982?

A. Yes, I am.

Q. What is the purpose of your rebuttal testimony?

A. The purpose of my rebuttal testimony is to respond to the testimony of William Paul Robinson, who testified on behalf of the Intervenor in these proceedings on May 28, 1982. In this connection my testimony will deal with the following matters:

1) the circulating water tests - objectives and their intent, structure, key parameters, and results and conclusions;

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2) the flexibility available in the design and operation of the Circulating Water System ("CWS") for the Palo Verde Nuclear Generating Station ("PVNGS"); and

3) the reliability of the Palo Verde Water Reclamation Plant ("WRP").

Q. What were the specific objectives of Joint Applicants' circulating water test studies?

A. As stated on page 5-1 of Part 5 of Joint Applicants' Exhibit BB, they were:

"[1] Verify the practicality of operating the plant circulating water systems at 15 cycles using the specified reclaimed wastewater,

[2] Identify potential plant operational problems associated with this level of operation,

[3] Determine the in-cycle treatment requirements for the plant circulating water system, and

[4] Determine relative corrosion rates for candidate condenser tube and tube sheet materials."

Q. Please explain each of the four objectives and their intent in greater detail.

A. Regarding Objective 1, I knew that several power plants utilized municipal wastewater for condenser cooling at 2.5 to 5 cycles of concentration. These plants are described in Table 4-1, page 1-30, Part 1, of Joint

Applicants' Exhibit BB. I also knew about experience at thermal power plants operating with surface water for condenser cooling at 8 to 15 cycles of concentration. This experience is described in Table 4-2, page 1-31, Part 1, of Exhibit BB. This convinced me that there was a sound basis upon which to proceed with design of the CWS for PVNGS. However, since there was a lack of experience with the use of municipal wastewater at cycles of concentration greater than five, I developed a program to prove that such usage was practical. I was particularly interested in identifying key design parameters and demonstrating that there would be no unexpected synergistic effects. This was the intent of Objective 1.

Because there was a lack of experience with the use of municipal wastewater at cycles of concentration greater than five, I established Objective 2 to identify potential plant operational problems, such as growth of algae or slime, microbiological fouling of the condenser, or foaming due to laundry detergents.

Objective 3 dealt with system in-cycle treatment design. I wanted to verify that standard circulating water system chemical treatment practices would be adequate for the treated wastewater in the Palo Verde CWS.

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Regarding Objective 4, at the time of the studies, corrosion due to seawater was becoming recognized as a problem at coastal power plants and desalting plants. I set up Objective 4 to determine whether the copper alloy materials currently in use for condenser tubing -- admiralty and copper-nickel -- would adequately withstand corrosion in the CWS or whether titanium would be required. The test program was designed to supplement data from operating plants and existing literature.

Q. How were Joint Applicants' tests structured to achieve these four intended objectives?

A. We actually ran two types of circulating water test programs. One utilized the circulating water test facility ("CWTF") located at the 91st Avenue Sewage Treatment Plant and was conducted as shown in Figure 5-4, page 5-19, Part 5, of Exhibit BB. The other was a Bench Scale test program conducted as shown in Figure 5-5, page 5-20, Part 5, of Exhibit BB.

The CWTF was set up to closely simulate the key parameters necessary to meet the intended objectives. It contained the essential components of a typical power plant circulating water system (heat source, heat exchanger, cooling tower, circulating water pump, piping, and controls for operation, makeup and blow-

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down). A line diagram of the CWTF is shown in Figure 5-1, page 5-14, Part 5, of Exhibit BB.

The circulating water in the CWTF was heated and evaporated to produce a concentrated solution similar to that of an operating system. The makeup water was effluent produced by the reclamation demonstration plant. The CWTF also included loops for sampling and material coupon testing as well as chemical injection lines in the cooling tower basin.

The CWTF tests concentrated the treated wastewater and circulated that water through the heat exchangers and the tower. This permitted evaluation of performance relative to Objective 1. A series of tests were run with varying chemistries (cycles, scale inhibitors, corrosion inhibitors, and ammonia content) to see if problems developed. This allowed an evaluation with respect to Objectives 2 and 3. Two different types of heat exchanger materials -- admiralty and titanium -- were used in the tests. Coupon and galvanic series tests for a number of materials were included to provide corrosion data relative to Objective 4.

The Bench Scale testing was set up to corroborate the CWTF and to look at accelerated corrosion. A line diagram of the Bench Scale test facility is shown in Figure 5-3, page 5-16, Part 5, of Exhibit BB. A column

served as a small, forced draft cooling tower. The tower basin was a two-liter beaker containing a heating coil to preheat the circulating water. The coil was part of a separate water-filled loop with a pump and a temperature controlled water bath. A pump circulated the cooling water through a single tube heat exchanger to the top of the column. The heat exchanger tube could be changed to test different materials. Effluent from the demonstration reclamation plant was shipped to the laboratory for testing. This laboratory apparatus was suitable for testing a wide range of materials under a broad spectrum of chemistries and permitted setting up extreme conditions that would not be expected in a power plant.

Q. Was it your intention that the circulating water test facilities model the Palo Verde CWS? Please explain.

A. No. There was no need to construct complete scale models since the design and operating criteria for circulating water systems had been well established over many years based on the design, construction and operation of hundreds of thermal power plants of all sizes in the United States and elsewhere. Just as the size of operating power plants had increased from the 50 MW range to the 1100 MW range, there had been a commensurate increase in the size of circulating water systems. Thus, practical operating experience had given us the

confidence that we did not have to consider design scale in the objectives for the CWTF. The four objectives described previously were the only reasons for the circulating water tests. We conducted fundamental testing to assure that we could reliably use treated municipal wastewater in our standard circulating water system design at cycles of concentration greater than five.

Q. What key parameters did you consider and why did you select them?

A. The key parameters are tube flow velocity, the temperature rise of the circulating water in the condenser (heat exchanger), circulating water chemistry, and geometry in the context of scale formation, fouling and corrosion.

Tube flow velocity is relevant to surface effects associated with corrosion and deposition. It determines whether protective oxide films would be stripped away or whether the geometry of the surface-flow interface would be conducive to deposition of suspended or supersaturated material. The flow velocities agreed closely between the CWTF with titanium tubes (7.1 to 8.0 feet per second) and the Palo Verde CWS, which also has titanium tubes (7.8 feet per second). We were not concerned with the volumetric flow rate in gallons per

minute but the relevant parameters of flow. Volumetric flow rate is meaningless in this context.

We also considered circulating water temperature rise in the condenser. This relates to the tendency of scale to form at the contact between the circulating water and the hot condenser tubes. The CWTF and Bench Scale tests simulated summer conditions for the CWS (nominal 30° F rise in the condenser) since the circulating water temperature rise is highest in the summer months. Both tests had condenser (heat exchanger) outlet temperatures (119° F) that agree with the outlet temperature projected for the CWS (119° F).

We considered chemistry and set up the circulating water tests to ensure that the choice of design materials and treatment methods would handle high concentrations of potential problem constituents. Particular attention was paid to those constituents customarily encountered with municipal wastewater. We ran the tests at high factors of concentrations with extremes in pH and ammonia. We verified that our design had adequate margin to handle fluctuations in circulating water chemistry. Since testing used actual demonstration plant effluent and encompassed extremes in circulating water chemistry, the testing established that the Palo Verde CWS will function properly.

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We also considered geometry in the context of scale formation, fouling and corrosion. The CWTF heat exhanger was configured in a manner similar to the tube/tubesheet arrangement found in typical condensers. I am satisfied we adequately explored geometry in the tests.

Q. Mr. Robinson testified that galvanic corrosion testing reported in Exhibit BB did not include titanium. (Tr. at 1625, lines 1-5.) Did the galvanic corrosion testing include titanium?

A. Yes. As I testified earlier, galvanic testing included titanium. (Tr. at 1300, lines 13-15.)

Q. Is there a conclusion that can be drawn from the corrosion tests? Please explain.

A. On the basis of the tests, we found that corrosion for the concentrated treated wastewater conditions in the CWTF was similar to that for seawater conditions. Accordingly, we were not limited to the corrosion data base established in the tests. Instead, we made use of the wealth of data established by corrosion experience with seawater.

Q. Please summarize the provisions to minimize corrosion you have included in the design of the CWS.

A. The condenser tubing is titanium, which has not experienced corrosion in circulating water systems; the tubesheet and pump impellers are aluminum bronze. Selec-

tion of this combination is supported by experience at operating plants. The condenser water boxes are rubber lined in accordance with standard practice. The cooling towers and the CWS canal are concrete. The piping is either concrete or lined carbon steel to protect against corrosion. Material specifications also include allowances for corrosion.

Q. Please summarize the circulating water system test results and conclusions.

A. The results and conclusions of the CWTF and Bench Scale tests are reported in Part 5 of Joint Applicant's Exhibit BB.

In summary, operation of the CWTF showed no pitting, corrosion or hard scaling of the admiralty tube heat exchangers during initial CWTF testing. There was, however, a persistent condition of sludging in the water which included oxides and salts of copper and iron with moderate to heavy organics.

Sludge formation was at first thought to be due to ammonia leaching of copper in the system. Accordingly, the decision was made to extend testing with a reduction in system copper-bearing components and with makeup water of ammonia content less than 1 ppm (as N).

The inspection following the fourth test at increased flow velocities revealed the continued formation and deposition of sludge on tube and tube sheet

surfaces, though in lesser quantity than in previous tests. The tubes were in good condition except for the soft sludge deposition. With the low ammonia content of makeup and circulating water, it became apparent that occasional low pH conditions and inadequate chlorination control were responsible for the sludge problem. Copper was being leached from nails in the tower fill and possibly from other components. Iron was being leached from the unprotected tower structure and from cast iron components.

Accordingly, the original tower fill was replaced with new fill, the tower structure was coated, and bronze and cast iron components were replaced. A hypochlorite metering pump was added to enhance chlorine control, and steps were taken to reduce or eliminate acid leakage which had caused excursions to low pH.

The fifth and sixth field tests with improved process control of the circulating water pH and the shock chlorination treatment led to minimal fouling and sludging problems, even with an increase to 20 cycles of concentration. It was concluded that higher ammonia content was probably permissible in the presence of copper alloys if biological activity and pH were controlled. This was verified later by the laboratory Bench Scale tests.

Prior to the start of the seventh field test, the admiralty tubed heat exhangers were removed and replaced with titanium tubed heat exhangers. The seventh and subsequent field tests were all operated at 20 cycles of concentration and at a further increase in flow velocity. The ammonia level of the makeup water was increased to 5 to 10 ppm (as N) in the seventh and eighth tests. The circulating water ammonia content ranged from 13 to 97 ppm (as N) without any sludge formation. Post-test inspection of the titanium tubes showed a very light, chalk-like, soft deposit on the last two inches of the discharge end of the tubes with the bulk of the surface in a clean and bright condition. No pitting or corrosion was observed.

The ninth and tenth field tests were performed using 25 to 35 ppm ammonia (as N) in the makeup water. The circulating water ammonia content ranged from 34 to 158 ppm (as N) with no sludge formation. Post-test inspection of tubes revealed clean and bright surfaces as in the previous tests. Again, no pitting or corrosion was observed.

The final four tests had provided eight weeks of continuous, successful operation with an array of corrosion test coupons exposed to the circulating water. Analysis of all corrosion data acquired during the test

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program indicated a similarity of corrosion tendencies between seawater and concentrated makeup water.

Coupon corrosion tests of candidate tube and tube sheet materials resulted in the following relative ranking of materials:

1. Titanium
2. Stainless steel (SS) 304
3. Monel alloy 400/405
4. Nickel aluminum bronze
5. 70-30 cupro-nickel
6. Aluminum bronze
7. 90-10 cupro-nickel
8. Admiralty
9. Copper, EC grade
10. Muntz
11. Steel alloy 1020.

In summary, field tests with the CWTF conclusively demonstrated that the Palo Verde CWS can be operated at 20 cycles of concentration without scale formation or excessive condenser tube fouling or corrosion. The tests did not foreclose operation at cycles of concentration greater than 20. The water chemistry for this type of operation using reclaimed municipal wastewater has been adequately defined. Standard circulating water system treatment will control the water chemistry.

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Titanium tubes were specifically tested during the Bench Scale tests under conditions simulating an acid pH excursion in Tests No. 7 through No. 9. No sludging or scaling resulted, and no corrosion or pitting was detected, with the circulating water at 20 cycles and at a pH range of 2.5 to 5.0. Makeup water ammonia was at 30 ppm (as N).

Ammonia concentration had a moderate effect on corrosion rates of admiralty and 90-10 cupro-nickel. It had no effect upon titanium and 300 series stainless steel.

The Bench Scale tests confirmed the field test results in terms of water chemistry, control of sludge formation, tube scaling and corrosion. The Bench Scale tests also did not foreclose operation at cycles of concentration greater than 20.

The tests demonstrated that titanium is the proper tube material and that the circulating water system can be operated at 20 cycles of concentration. Specific test results are provided in appendices C-6 and C-7 of Exhibit BB.

Q. Mr. Bingham, were you satisfied that the circulating water tests achieved the four intended objectives?

A. Yes, I was. However, I was also interested in having an independent evaluation of the tests. For this reason Bechtel contracted with the Nalco Chemical

Company to independently review the testing methodology and results. I am providing their report as Exhibit DD as marked for identification and attached hereto.

Q. Did the Nalco report confirm your conclusions that the tests achieved the four intended objectives?

A. Yes, the Nalco report confirmed that the Bench Scale and CWTF test program to evaluate scaling was adequate to represent the circulating water at 15 and 20 cycles of concentration as compared to the specified feed, and that the CWTF testing was adequate to evaluate corrosion and the use of chlorination to control slime and microbiological fouling organisms.

Q. Mr. Robinson has testified that the constituents in the treated wastewater concentrated at varying rates in the CWTF and that, as a result, the chemistry of the treated wastewater should be evaluated further to determine how such varying rates of concentration will affect the operation of the Palo Verde CWS. (Tr. at 1652, lines 10-14; Tr. at 1655, lines 3-8, lines 15-22; Tr. at 1658, lines 6-16; Tr. at 1659, lines 5-14.) Mr. Bingham, do you have an opinion as to whether the chemistry of the treated wastewater should be evaluated further? Please explain.

A. I do not believe further investigations are warranted. I consider the discrepancies between the test data and

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the theoretical projections for a closed, steady-state system to be not significant.

We were testing a simulation of an actual circulating water system and not a hypothetical, closed, steady-state system. The testing was dynamic. We added chemicals and varied feed concentrations. Therefore, our testing just cannot be compared to the type of controlled experiment that a research chemist would use to test a scientific hypothesis. That was not our purpose.

In our tests we were trying to confirm our ability to deal with actual concentrations of potential problem constituents by chemical control, selection of materials, or otherwise. We were not trying to prove that precise multiples of concentration of the potential problem constituents would occur. In fact the cycles of concentration do not determine a limit for the operation of the CWS.

Q. Do you know of any concrete evidence that supports your conclusions that the Palo Verde CWS can be operated at at least 20 cycles of concentration without scale formation, or excessive fouling or corrosion?

A. Yes. I have reviewed operating plant experience at several power plants in the Southwest. Each of the plants, with one exception, was designed by Bechtel. I have had a table prepared which compares the estimated

chemical concentrations for Palo Verde to those of the other plants. This table has been identified as Joint Applicants' Exhibit EE and is attached hereto. The experience reflected on Exhibit EE represents more than one hundred plant years of operation. The water source, condenser tube material and measured values of concentrations of the potential problem constituents for these operating plants are shown. Exhibit EE indicates values for PVNGS which are identical to WRFS Table 4-2. Inspection of the operational data shows that Palo Verde's chemistry is well within the envelope of the concentrations of the potential problem constituents for these operating plants except for phosphate. Phosphate is not expected to present any operational concerns based on operating experience at Southwestern Public Service Company and Burbank as shown in Tables C-8-2 and C-8-3, pages C-8-4 and C-8-7, respectively, Appendix C of Exhibit BB. The projected concentration of phosphate for Palo Verde is below the phosphate concentrations for these two plants. In my opinion this comparison shows that Palo Verde could operate at cycles of concentration above 20 without excessive scaling, corrosion, or fouling.

Q. Intervenor's Exhibit XXVII, Table WPR-3, identifies "limitations" for the product of the concentrations of calcium and sulfate and the product of calcium and

alkalinity. Mr. Bingham, what is your opinion as to the validity of the stated limits?

A. Page WPR-3 of Intervenor's Exhibit XXVII identifies a limit of 500,000 for the product of the concentrations of calcium and sulphate. This value is only a small fraction of the values for the operating plants shown in Exhibit EE. Page 25 of Intervenor's Exhibit XXVIII and Mr. Robinson's testimony at page 1696 in the transcript both characterize the value as a "rule of thumb." I conclude that the value of 500,000 does not constitute a limit at all and that the Palo Verde CWS will operate properly at the level of 2×10^6 shown in Exhibit EE since this level is substantially below values encountered in operating plants.

Page WPR-3 also described a limit from Intervenor's Exhibit XXIX of 41,600 for the product of calcium times alkalinity. Exhibit EE shows that even though the Palo Verde CWS is below this value, there are plants operating substantially above this value. I conclude this value also does not constitute a limit.

Q. Mr. Bingham, is the plant designed with sufficient flexibility to deal with variations in concentrations of the constituents in the influent to the WRP? Please explain.

A. Yes. The WRP is designed for variable process flow rates, variable chemical addition rates, and variable

recycle processing. Thus, a broad range (a factor of two) of inlet constituent concentrations can be accommodated while still achieving the quality specifications for the treated effluent being supplied as makeup to the CWS.

Normally, the WRP will send water to the reservoir at a better quality level than required by the quality specifications. In addition, the reservoir provides dilution volume that will tend to mask any short-term fluctuations in the WRP effluent.

The CWS provides additional flexibility. We have incorporated the capability for the addition of such items as acid, scale inhibitors, antifoam agents, and chlorine. This will permit operation without scaling at concentrations above the specified water quality.

Q. There has been considerable discussion of the reliability of the WRP as described in Exhibit BB. Is the reliability of the WRP as constructed the same as stated in Exhibit BB?

A. No.

Q. Why not?

A. We modified the design of the WRP. As shown in the attached Exhibit FF as marked for identification, we no longer have a three module design. We now have a parallel arrangement of active components sized to permit design capacity to be realized with any one of

the parallel paths out of service. Further, reservoir capacity was not included in the WRP reliability studies. Any estimate of the overall reliability of the supply of treated makeup would need to consider the reservoir.

Q. Mr. Robinson testified as follows regarding TDS:

> "The Nestor article [Intervenor's Exhibit XXVI] notes that in high velocity flows, the total dissolved solids can be a significant contributor to corrosion and pitting and it may be just the total dissolved solids irrespective of the specific may be significant according to that document." (Tr. at 1644, lines 21-25; Tr. at 1645, line 1.)

Do you agree with Mr. Robinson's interpretation of the Nestor article?

A. No. In my opinion the testimony incorrectly characterizes the article for at least two reasons. The second page of Intervenor's Exhibit XXVI states:

> "On the other hand, high velocity water streams, especially those high in dissolved <u>and suspended</u> solids or dissolved and entrained gases, often damage passive oxide films, causing extreme localized corrosion. An example or a metal that is prone to impingement attack caused by high velocity is <u>copper</u>." [Emphasis added.]

First, the article does not state that TDS, alone, can be a significant contributor to corrosion.

Second, Mr. Robinson has incorrectly applied this article to Palo Verde since the Palo Verde condenser tubes are titanium, not copper. The oxide film of

titanium is tightly adhering and quickly repairs itself upon damage.

Q. Does this conclude your rebuttal testimony?

A. Yes, it does.

NALCO

Joint Applicants'
Exhibit DD

CONSULTING REPORT

For

BECHTEL POWER COMPANY

Norwalk, CA.

Job No. 10407

SUBMITTED BY:

B. A. Kronmiller, P.E.
Manager, West Coast
Engineering Services

June 26, 1974

INDUSTRIAL DIVISION

NALCO CHEMICAL COMPANY

180 N. MICHIGAN AVENUE ▫ CHICAGO, ILLINOIS 60601 ▫ AREA 312-822-1200

June 26, 1974

Mr. W. G. Bingham, Project Engineer
Bechtel Power Corporation
A.N.P.P. - Job No. 10407
P.O. Box 60860 Terminal Annex
Los Angeles, CA 90060

Dear Mr. Bingham:

Pursuant to the agreement for Consulting Services between Bechtel and Nalco Chemical Company dated May 1, 1974, I have completed my study of data and preliminary partial rough draft presentation being prepared by Mr. D. R. Colman and his group.

The preliminary rough draft concluded that the A.N.P.P. cooling tower could be operated on 91st Avenue Phoenix Sewage Plant treated effluent cycles of concentration without unusually strict cont -- costly pretreatment.

In working closely with Mr. Harry Heinlein, I was asked to give special consideration to the following questions:

1. Do we have enough data to formulate a cooling water treatment program?

2. What is the quality of the data collected on the pilot plant?

In addition, I was asked to give guidance to the personnel involved in the preparation of their report from a water treatment technology standpoint.

In the course of this review upon which my conclusions are drawn, I have taken the following steps:

A. Personal inspection of the Belmont laboratory bench scale recirculating system

B. Personal inspection of the 91st Ave. pilot plant

C. Personal inspection of a complete set of corrosion coupons after Run No. 9 from the hot loop

D. Complete review and careful study of all available data obtained from the Belmont lab and the pilot plant including the following:

1. Scaling tendencies
2. Corrosion coupon rates
3. Corrosometer rates
4. Alpha meter rates
5. Microbiological counts
6. Chlorination practices
7. Flow rates
8. Inhibitor levels
9. Concentration ratios
10. Ammonia levels

The above data listed in Section D were accumulated from the various runs made either in the Belmont lab or in the 91st Ave. pilot plant or both.

E. Complete review and careful study of the writings in the preliminary rough draft to date of June 20, 1974

Based upon the above listed efforts, I am attaching my report of conclusions. These conclusions are a result of the analysis of data and writings with reference to the state of the art in treatment of recirculating cooling water systems as it exists today.

I believe this report covers the initial scope of responsibility; however, should you need further comment or desire to expand the scope, please don't hesitate to contact me.

Very truly yours,

B. A. Kronmiller

B. A. Kronmiller, P.E.
Manager, West Coast
Engineering Services

NALCO

June 26, 1974

ARIZONA NUCLEAR POWER PLANT

Palon Verdes Nuclear Generating Station

BECHTEL JOB. NO. 10407

SCOPE OF PROJECT:

We were asked to make comments regarding the following two questions:

1. In the operation of the Belmont bench scale test facility and the 91st Ave. pilot plant in Phoenix, do we have enough data to formulate a recirculating cooling water treatment program?

2. What is the quality of the data collected from the pilot plant operation?

In addition to the above specific questions, we were also asked to make whatever comments we felt would be pertinent to the overall water usage in this facility using the reclaimed water from the 91st Ave. sewage treatment plant treated effluent.

DISCUSSION:

Based upon the activities listed in our letter of June 26, 1974, we offer the following:

1. Test Facility

   A. Bench Scale Facility

      Satisfactory for deposition study - probably not adequate for microbio study and was not used for this.

   B. Pilot Plant Facility

      Facility hardware is adequate for purpose of test, i.e. to examine methods of use of reclaimed sewage for tower make-up, cycles of concentration and microbial control. Also, equipment is adequate for test coupon exposure for corrosion rate comparison.

NALCO

June 26, 1974

A.N.P.P.
Job No. 10407

CONCLUSIONS

1. Scale Control

I believe you have accumulated sufficient data from the Belmont lab and the Phoenix pilot plant to indicate maintaining 20-40 ppm of scale inhibitor, pH in the range of 6.8-7.2 and applying chlorine on a regular basis provides a viable program to prevent scale deposition on the treated sewage as supplied during the several tests.

This opinion is based on the data and reports presented and visual inspection coupled with field experience obtained from plants using similar makeup and treatment programs for cooling towers.

It is made in spite of the fact the Belmont lab reports some loss of silica and the pilot plant data shows lower calcium, silica, nitrate and sulfate than would be indicated using the chlorides as the means of measuring concentrations. I believe this discrepancy is analytical in nature and, in no way, reflects on the actual stability of the cooling water.

Based on the above, I do not feel that further test data are needed.

2. Microbiological Growth Control

The pilot plant test work done on the chlorination practices, indicates that chlorine is an acceptable method of controlling slime forming or micro-bio fouling organisms. You may find the A.N.P.P. tower will require a modification of the optimum program established in the test facility due to larger holding capacity vs. circulating rate which may require a longer chlorination schedule to maintain control.

The test data appears to be excellent and further work should not be required.

NALCO

June 26, 1974

A.N.P.P.
Job No. 10407

2. Operation of Facilities

A. Bench Scale Facility

Flow rate held between 6 - 8 fps.

Inhibitor levels held within recommended range

Cycles of concentration held at 15 and 20
Ammonia varied from less than 1 to 75 mg/l

Temperature held at 119°F with 30° drop
Tests ran 80 hours

B. Pilot Plant Facility

Flow rate through coupon holders at 5 gpm is equivalent to 3.7 fps while flow through heat exchanger bundle is estimated at 0.5 - 2.5 fps for Runs No. 1, 2. Flow through heat exchanger increased to 5.0 fps for Runs No. 3,4,5,6 at which time the titanium bundle was installed with flow rate of 6 - 8 fps.

Except for part of Run No. 1, the inhibitor levels were maintained within recommended range.

Cycles of consentration were held at 15 and 20 with variations both above and below the desired control levels typical of normal cooling tower operation. Run No. 7 reached a maximum Calcium Sulfate Factor ($CaCO_3 \times Na_2SO_4$) of 10 million due to high cycles of concentration for a short period. The average Factor at 15 cycles was 3.3 million and at 20 was 6.7 million. for Run No. 5 and 8.

Ammonia concentrations in the in the recirculating cooling water were varied from 4.5 to 127 mg/l with applied chlorine varying from 3.1 to 10.4 ppm during the 18-20 minute chlorination period.

Temperatures generally were held at $119^{\circ}F \pm 3^{\circ}$ with a 30° drop.

With the exception of one run of 13 days, the corrosion coupons were exposed for 24 to 36 days.

NALCO

June 26, 1974

A.N.P.P.
Job No. 10407

CONCLUSIONS, cont'd.

3. Corrosion Control

I believe you have accumulated sufficient data on corrosion rates of the several metals and alloys upon which to base a selection of the proper materials of construction for the recirculating cooling water system using the treated sewage as makeup.

As is indicated in the preliminary rough draft report, we concur that the various rates obtained should be interpreted only as comparative rates rather than as actual rates to be expected in service.

The very short exposure in the Belmont facility would normally result in high corrosion rates. This is demonstrated by the decline of corrosion rate in Run No. 6, which was extended to 150 hours. Corrator rates were much higher than those calculated by the analytical data using the material balance method of calculation. This is not unusual since it normally takes several days for the Corrator probes to "season" after initial exposure.

The coupons exposed in the pilot plant facility saw the typical conditions of high TDS, microbio in actual operation. Thus, these data should be useful, on a comparative basis, for material selection.

Only two mild steel coupons were exposed in the pilot plant facility in Runs No. 1, 2, 3, 4. The corrosion rates were excessively high and would be expected under the conditions of exposure. While this is limited data, it is readily accepted based on field experience. It points up that bare mild steel should be eliminated from the recirculating cooling water system. Mild steel is particularly susceptible to corrosion induced by corrosive bacteria, which are not completely controlled by chlorine, and by high dissolved solids.

NALCO

June 26, 1974

A.N.P.P.
Job No. 10407

COMMENTS

1. Based on the several microbiological analyses, continuous chlorination to a positive residual of the cooling tower make-up is indicated.

2. Use of the treated sewage as station service water in a mild steel system should be avoided.

3. Scale and corrosion monitoring equipment should be provided in the recirculating system.

4. While a modification of the scale inhibitor used in these tests is available which is designed to provide corrosion protection on mild steel and copper bearing alloys at a premium of about 50%, we do not have operating experience at the levels dissolved solids and ammonia present in this recirculating water. Since the degree of protection available is currently unknown, we concur with the concept of selecting the most corrosion resistant materials coupled with scale protection treatment.

5. On the subject of demineralizer operation with specific regard to minimizing regenerant usage and waste disposal problems, there are many routes available. These could include return of anion rinse to the plant service water system, and cation rinse to the cooling tower at the appropriate points in each cycle, precipitation of insoluble sulfates and re-causticizing spent liquor for caustic recovery.

This type of system analysis is regularly done by our Staff Specialist in our main office and can readily be carried out at your request.

B. A. Kronmiller, P.E.
Manager, West Coast
Engineering Services

Joint Applicants'
Exhibit EE

OPERATING PLANT COOLING WATER ANALYSES (mg/l)

	San Onofre 1	Etiwanda 3&4	Coronado 1&2	Mohave 1&2	Navajo 1,2,3	Coolwater 1&2	Coolwater 3&4	PVNGS[a]
Water Source	Ocean	Wells	Wells	Colorado River	Colorado River	Wells	Wells	Sewage Effluent
Condenser Material	Ti/Cu-Ni	Cu-Ni	Cu-Ni	Cu-Ni	Cu-Ni	Cu-Ni	Cu-Ni	Ti
Ca as $CaCO_3$	1045	1460	680	3000	650	1200	370	800
Mg as $CaCO_3$	5480	950	810	3000	2200	-	230	100
Alkalinity	120	100	150	100	150	200	-	40
Silica as SiO_2	0.04	70	80	150	135	150	115	80
Sulphate	2770	2800	5800	16,000	11,000	-	9,800	2,500
Phosphate	-	0.6	-	-	-	-	1.1	5.4
pH	-	6.8-7	7.4-7.8	7.5	7.5	7.7-8.2	7.1	6.8-7.2
Ca x SO_4[b]	2.9×10^6	4.1×10^6	3.9×10^6	48×10^6	7.2×10^6	-	3.6×10^6	2×10^6
Ca x Alk[c]	125,000	146,000	102,000	300,000	97,500	240,000	-	32,000

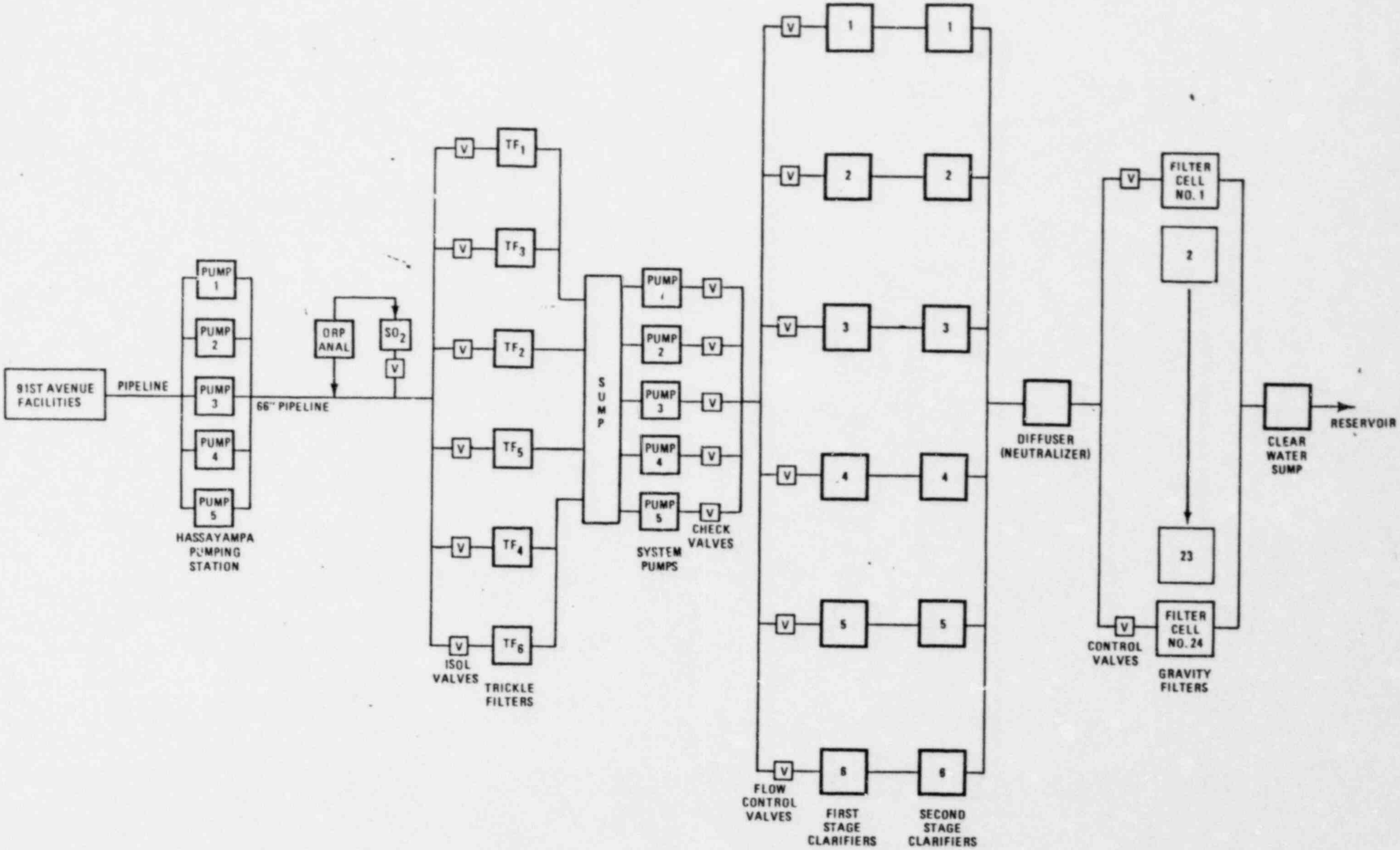
a. Estimated at 15 cycles.

b. Intervenor Exhibit XXVIII identifies limit as 500,000.

c. Intervenor Exhibit XXIX identifies limit as 41,600.

Joint Applicants'
Exhibit FF

PVNGS WATER RECLAMATION SYSTEM



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