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TITLE: DESIGN, CONSTRUCTION, AND INITIAL OPERATION OF THE
LOS ALAMOS NATIONAL LABORATORY SALT-GRADIENT SOLAR POND

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SUBMITTED TO To be presented at the ASME Solar Energy Division Meeting
held in Orlando, Florida, on April 19-21, 1983.

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SALT-GRADIENT SOLAR POND

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ABSTRACT

A 232 m² solar pond was constructed at Los Alamos National Laboratory for the purpose of studying pond hydrodynamics on a large scale and to complement the flow visualization and one-dimensional pond simulator experiments that are ongoing at the Laboratory. Design methods and construction techniques, some of which are unique to this pond, are described in detail. The pond was excavated from a soft volcanic rock known as tuff; such rock forms a large fraction of the Los Alamos area surface geology. Because tuff has a small thermal conductivity, little insulation was required to reduce perimeter energy losses. In addition, the strength of tuff permitted the pond to be built with vertical side walls; this design eliminated local side wall convection in the gradient zone that is possible with sloping side walls. Instrumentation in the pond consists of traversing and fixed rakes of thermometers and salinity probes, an underwater pyranometer, and a weather station. The traversing rake is a wheeler trolley driven vertically on a rectangular rail. Installed on the trolley are coplanar platinum RTDs, a point conductivity probe, and an induction salinometer. The stationary rake supports 28 thermocouples and 28 sample-fluid withdrawal taps located every 10 cm. About 127 T of sodium chloride has been introduced and is nearly dissolved. A 120-cm-thick salinity gradient was established and the pond is heating. Preliminary results indicate a lower-convective-zone heating rate of 1.2°C/day during the pond's first month of operation. Recommendations on pond design, construction, and instrumentation are presented.

I. INTRODUCTION

This paper discusses the design, construction, and initial operation of the solar pond at Los Alamos National Laboratory. This 232 m² pond is the third facet of a threefold approach to the study of hydrodynamic effects in double diffusive systems, such as solar ponds. The first two facets are flow visualization experiments and one-dimensional laboratory tank tests. Data from these experiments in addition to other data from the literature are used to validate the one-dimensional dynamic performance pond model developed by one of the authors (K. A. Meyer¹). Our particular interest is the boundary layer structure at the interfaces between the convecting and nonconvecting zones, interaction between the zones, and surface zone effects including diurnal heating effects and wind-induced turbulence. A large-scale pond, such as the one this paper describes, provides possible insight into several pond physical processes that may not occur in smaller scale laboratory experiments or may be impossible to simulate.

The paper addresses each phase of the solar pond project under separate headings: design, construction, and preliminary results. In addition, individual sections are provided for instrumentation; salt mixing and gradient establishment; and a final section on construction, design, and instrumentation recommendations.

II. DESIGN CONSIDERATIONS

The solar pond at Los Alamos National Laboratory is primarily a research facility. It was built to study pond hydrodynamics on a large scale and to complement the flow visualization and tank tests that are ongoing at the Laboratory. An acceptable design would accommodate our research experiments as well as include representative dimensions and layer thickness so that performance results could be applied to other ponds. Furthermore, the overall design was constrained by funding limitations. Using this approach, we decided on a square pond, 15.3 m on a side excavated to a depth of 3.6 m. We considered a 1.2-m thick lower convective zone (LCZ) and a 1.2 m nonconvecting zone (NCZ) as representative layer thicknesses. A 10-cm-thick upper convective zone (UCZ) was included to give an overall pond depth of 2.5 m. The LCZ was designed for a salinity of 22% by weight sodium chloride (NaCl).

The material from which the pond was excavated was not soil or clay as with most other ponds, but a lightweight, friable volcanic rock known as tuff;

such rock forms a major fraction of the Los Alamos surface geology. It is because of tuff that the Los Alamos National Laboratory solar pond is unique among other ponds. First, tuff has a relatively small thermal conductivity (about $0.05 \text{ W/m}^\circ\text{C}$ or twice that of polyurethane foam) which implies that little, if any, insulation is required to minimize pond perimeter heat losses. Second, the strength of the tuff is sufficient to permit vertical pond walls. Vertical walls insure that the horizontal isosalinity planes in the NCZ remain horizontal and do not bend downward at the pond edges as would occur in a pond with sloping walls; thus, possible local convection at the walls caused by this phenomenon is eliminated. Because of these factors we expect salt and heat transport processes in the Los Alamos National Laboratory solar pond to be nearly one-dimensional. The disadvantages of vertical walls are that excavation is more difficult, liner stresses are usually greater, and more shadowing of the pond is possible when compared with a solar pond with sloping walls. The overall relative merit of vertical walls will be determined as pond operation continues.

The pond was designed with its sides aligned in the north, east, south, and west directions, respectively. The location of the pond facility was determined by a number of factors: close proximity to the existing solar energy laboratory, relatively inexpensive accessibility to electric power and water, and a level area on which the main pond and evaporation pond could be located. We decided on a wooded area on a rim of a nearby canyon, accessible from the existing solar energy laboratory by a 1-min car ride and equipped with water and power supplies within 150 m. However, the area sloped gently towards the canyon rim with a vertical drop of 4.3 m in a 60-m horizontal distance. The site had to be leveled before pond excavation could begin.

The evaporation pond was designed to be 28-m long by 9.2-m wide and 1.4-m deep at its shallowest location; the long dimension is in the east-west direction. All the walls are vertical (to conserve ground area) except for the west end, which was sloped at a 16° angle into the pond. This ramp provides access into the pond for salt removal and maintenance.

During the design phase of the project, computer simulations were performed to estimate rates of heat loss from the bottom and side walls of the pond for various combinations of insulation thickness. These assumed that foamed-in-place polyurethane insulation ($k = 0.029 \text{ W/m}^\circ\text{C}$) would be used. The results from the simulations indicated only a 13% decrease in the heat loss

rate when proceeding from the case of no insulation to the case of a 15.3-cm-thick layer on the side walls and on the floor for a distance of one meter from the walls. The apparent insensitivity of heat loss to insulation thickness is due to the small thermal conductivity of tuff, which is approximately twice that of the insulation. In comparison, the conductivity of moist, sandy soil can be more than 100 times as large. Thus, insulation to reduce perimeter heat losses was judged to be ineffective here. Nevertheless, to provide a smooth surface on which to install the main pond's back-up vapor barrier and primary liner we decided to install a 7.6-cm-thick layer of insulation on the pond side walls.

III. POND CONSTRUCTION

Construction began in October 1981; first, a bulldozer was used to grade the site, after which a large backhoe excavated the main and evaporation ponds (Fig. 1). The vertical side walls in both ponds were cut by the edge of the backhoe's bucket, for the most part without incident. In two areas, however, fractures in the tuff resulting from tree roots caused some of the tuff to break away. The voids caused by these breakouts were eventually filled with polyurethane insulation blocks held together with foamed-in-place polyurethane. After the ponds were excavated, a 30.5-cm-deep square trench was dug into the tuff around each pond's edge for burying the edges of the liners. The inner edge of each trench was 107 cm from the pond rim. Next, continuous rows of sandbags, each bag weighing 22.6 kg, were laid along the rims of the main pond and the evaporation pond. The bags overhung the pond rims slightly to provide smooth, large radii supports on which liners would rest. Six holes were then drilled in the main pond for the heat flux meters; one in each of the pond walls and two in the floor. Compressed nitrogen was blown into each hole as the drilling proceeded; this was necessary to prevent the powdered tuff from binding the masonry drill bit in the rock. The heat flux meters were installed after drilling was completed and the thermocouple wires from them were run in the perimeter trench to a common point close to the future location of the data acquisition shed.

The insulation work began in early June 1982, after a winter of soliciting and evaluating bids and awarding the contract. When the tuff breakout areas were filled, the contractor applied a 7.6-cm-thick layer of polyurethane

foam (2.5 lb/ft^3 nominal density) to the pond walls (Fig. 2). The evaporation pond received a thin coating of insulation in the region of the sandbags to smooth the rocky edge. The insulation in the main pond was applied from the rock floor up to the sandbags, where the thickness was gradually reduced as it was applied over the bags. This provided a smooth, well-rounded surface on which the main liner would rest.

Next, a 0.5-mm thickness of Hypalon² (a chlorosulfonated polyethylene) was applied with rollers over the entire insulation surface area to serve as a vapor barrier for the walls (Fig. 3). After this was completed, about 15 cm of smooth, rock-free plaster sand was dumped onto the pond floor and spread out evenly. A sheet of 0.5-mm-thick polyvinyl chloride (PVC) was then laid over the sand and run up each wall for a distance of about 30 cm, overlapping the Hypalon coating this distance. Smooth-headed roofing nails were then pressed through the PVC and the Hypalon coating into the insulation to hold the edges of the PVC flush against the Hypalon. After a primer was applied to the PVC, the Hypalon coating was then extended down over the edges of the PVC a distance of about 8 cm. In many locations, the primer tended to warp the PVC edges so that they were no longer flush with the Hypalon; these areas were caulked to ensure that the PVC-Hypalon joint was leaktight. The back-up liner was now complete.

Before the main liner was installed, a second layer of plaster sand, 6.4-cm thick, was dumped onto the PVC liner and spread evenly. Four leak detectors were imbedded in this layer and their locations from the walls measured and recorded.

The Hypalon main liner of 1.2-mm thickness was shipped to us in three pieces; two pieces 6.3 m by 16.5 m were to be installed on the east and west vertical walls, and one piece 27.8 m by 16.5 m was to be run down the south wall, across the pond floor and up the north wall. The liner installation went smoothly with the help of only an outside contractor's foreman and six laborers (Fig. 4). The only heavy equipment required was used to help unfold the largest section of the liner. The liner was installed in about 3 h, with field seaming and leak testing taking another 4 h. We delayed burying the main pond liner until after some salt and water were in the pond to prevent over-straining the vertical sections of the liner. The main pond now neared completion, lacking only the installation of the diffuser and instrumentation.

The evaporation pond liner consisting of 0.9-mm-thick CPER (chlorinated polyethylene reinforced with polyester) was installed by the Laboratory's service contractor. It was supplied to us in one piece 30-m long by 15.5-m wide. The floor of the evaporation pond was first swept clean of large rocks that could puncture the liner. A dozen laborers worked together for about 1 h to drag the partially unfolded liner across the pond's width. The corner areas were then folded neatly to provide a good form fit. After ensuring that sufficient slack was provided for in the vertical sections of the liner, the liner edges were buried in the perimeter trench and the trench backfilled and compacted.

While pond insulation work was in progress, a passive solar shed was built to house the data acquisition and experiment control systems. The shed is square in plan view, measuring 2 m on a side; it is located on an elevated bank of tuff about 8 m west of the main pond's west bank. In addition to housing the data acquisition system, it also served as an on-site storage room for tools during the construction of the pond and afterward for pond instrumentation and maintenance. The above-water pyranometer was mounted on the shed's near-horizontal roof, this area being the least susceptible to shadowing.

IV. INSTRUMENTATION

Instrumentation for the solar pond consists of an Eppley Model 8-48 underwater pyranometer³, traversing and fixed salinity and temperature measuring rakes, and a weather station. The traversing rake is a 316 stainless steel wheeled trolley (see Fig. 5) driven vertically at a rate of 0.9 cm per min on a 316 stainless steel rail measuring 2.5 cm by 1.3 cm. Installed on the trolley are two 100-ohm platinum resistance thermometers (RTD)⁴, a platinum point conductivity probe⁵, and a Beckman induction salinometer.⁶ All instruments were installed in such a way that measurements were taken in the same horizontal plane. Typically, one or two traverses per day are run. Each traverse provides salinities and temperatures at vertical increments of 0.9 cm. The fixed rake is constructed from 3.8 cm by 3.8 cm, 316 stainless steel angle; it supports 28 copper-constantan thermocouples and 28 sample-fluid withdrawal taps located every 10 cm. This rake provides us with instantaneous temperature profiles; fluid withdrawal provides periodic *in situ* recalibration of the point probe and very accurate salinity profiles. Both rakes rest on 3.2-mm-thick square base plates of 316 stainless steel, each having a side dimension of 61 cm. A 6.4-mm-thick layer of neoprene rubber was installed on the bottoms

and sides of each plate to prevent damage to the main liner; top supports were provided to prevent swaying. The weather station consists of a horizontally mounted Eppley Model 8-48 pyranometer³, a MET-ONE wind anemometer and planer wind direction indicator⁷, and a MET-ONE thermally shielded ambient temperature sensor.⁷

Six heat flux meters were installed in the tuff walls of the pond: one in each wall and two in the floor to gauge perimeter heat losses from the pond and to provide us with perimeter temperature distributions in the tuff. Each meter consists of three copper-constantan thermocouples installed equidistant from each other along a vinyl rod 91.0-cm long. The meters were installed normal to the perimeter area by drilling into the tuff as described in Sec. III.

Four electric-resistance leak detectors were designed for installation in the sand layer between the primary and back-up liners: one detector per pond quadrant. Resistances from the detectors are scanned along with the other pond data. Independent experiments were performed to determine the resistance of the detectors when immersed in fresh water; a leak is indicated if the resistance of any detector falls below this threshold value.

The data acquisition system consists of a Hewlett-Packard Model 87 desk-top computer⁸ and the following Hewlett Packard interface equipment: one 3490A digital voltmeter, two 3495A scanners, two 59303A digital-to-analog converters, one 82901M flexible disc drive, and one 82905B line printer. Data from approximately 80 channels is sampled every 50 s and suitably integrated or averaged before storage on a disc every hour.

Both instrument racks, the underwater pyranometer, and the diffuser were designed to be supported from a catwalk which extends about 3.4 m over the pond from its west bank. The catwalk is 61-cm wide by 4.3-m long with a frame constructed of galvanized structural "H" sections 7.6-cm deep by 3.8-cm wide. The catwalk frame was covered on top by marine-grade plywood 1.9-cm thick with a nonskid surface applied after its top, sides, and bottom were painted. Two 304 stainless steel tubes, 3.5-m long by 8.9-cm outside diam, support the catwalk on the pond floor. The legs are attached to a neoprene-rubber-covered baseplate of 304 stainless steel, 61-cm wide by .2-m long, at their lower end and to a mild-steel baseplate, 61-cm long by 23-cm wide, at their top. The latter was bolted directly to the catwalk. Two knee braces were welded between the two vertical tubes above the water line to prevent

catwalk sideways. The back end of the catwalk is securely anchored to the ground by a poured concrete block; steel handrails and a wooden kickplate complete the safety features.

The instrument rakes were installed about 1.6 m from the front end of the catwalk with their top supporting arms bolted directly to it. The underwater pyranometer was suspended from the end of a 3.4-m-long pivoting boom by a 2.4-m-long rod of 316 stainless steel. The boom was mounted at the far end of the catwalk. A marine-type manual winch is used to change the boom's angle which, in turn, alters the elevation of the pyranometer in the pond. Markers were installed on the rod every 7.6 cm to gauge the pyranometer's depth.

V. SALT MIXING AND GRADIENT ESTABLISHMENT

We took delivery of 127 T of 98% pure coarse, granular NaCl in five truck loads beginning July 8, 1982. An actual salt delivery using a long wooden chute we built is shown in Fig. 6. After each salt load was delivered, the dissolving process began using water from a local fire hydrant; 6.4-cm-diam fire hose was used to transfer the water from the hydrant to the pond site. During the salt-mixing procedure we found that the combination fog-spray hose nozzle we were using caused too large a flow restriction in the water line. By removing the nozzle and by slightly bending the hose near the water outlet instead, a water jet with a much larger velocity was directed onto the salt pile. We found this mixing technique to be most effective.

After the final salt load was delivered, salt mixing continued by means of two large gasoline-powered centrifugal pumps, each capable of pumping about 400 ℓ /min. They were floated on the pond's surface on styrofoam sheets 7.6-cm thick, 91-cm wide and 1.9-m long and were designed to take suction from the floor region of the pond and thus improve the salt-mixing rate. When the pumping described above began, there was approximately 1 m of salt water in the pond. The pumps were run for about 6 h per day for a 7-day period during mid-July. Simultaneously, the brine was filtered with a Swimquip Model HRP-30 sand filter⁹ charged with 159 kg of silica sand. The brine was circulated with a Purex Series A, Model AH-8 bronze centrifugal pump¹⁰ with a built-in basket strainer. The filter was backwashed with fresh water daily, the backwash effluent being discharged into the evaporation pond.

On July 27 the brine was shocked with algicide as a precautionary measure before the gradient was established. An additional 80 cm of fresh

water was added and mixed with the existing salt solution. The following day all salt mixing and filtering was stopped to let the remaining suspended dirt settle to the bottom. The salinity of the brine was then about 18.5%.

The diffuser used to establish the salt gradient was constructed from two polymethylmethacrylate (PMM) circular disks 6.4-mm thick and about 1 m in diam. The disks are separated by six evenly spaced radial vanes of 6.4-mm-thick PMM. The vanes maintain a constant gap width between the two disks and add to the structural integrity of the diffuser. Water was supplied to the diffuser through a 5.4-cm-diam PVC pipe attached to the upper disk by a PMM flange.

The diffuser was installed on the south side of the catwalk by inserting the water supply pipe into two shimmed ring-type supports; the shims keep the diffuser horizontal. A manual winch, like the one used for the underwater pyranometer, was used to change the elevation of the diffuser in the pond. The completed diffuser is shown in operation in Fig. 7.

The salt gradient was established beginning August 4 by using a fresh water diffusion method. Starting with 180 cm of 18.5% saline water at 25°C, the following procedure was followed. The diffuser was lowered to a depth of 120 cm from the pond floor, this depth being the chosen LCZ thickness. With a flowrate from the diffuser of about $0.17 \text{ m}^3/\text{min}$ (this produces an exit velocity of 0.2 m/s from the diffuser gap), 5.1 cm of fresh water were added. Because the fresh water was less dense than the brine into which it was added, only upward mixing occurred. The incoming fresh water temperature, which was lower than the brine temperature, had no adverse effect on the stability of the layer(s) below the diffuser because the small incoming flow of fresh water was rapidly warmed by the large mass of brine. After the first increment of fresh water was added, the diffuser was moved up a distance twice the fill increment (10.2 cm). Another 5.1-cm layer of fresh water was diffused into the pond at this point and the procedure was repeated a total of 12 times until the pond's depth was about 2.4 m. A 10-cm layer of fresh water added to the surface completed the gradient establishment.

We encountered, during this procedure, the problem of entrained air bubbles in the fresh water supply and associated problems that could occur from disturbances that propagated downward as the bubbles left the diffuser outlet. The problem was not with air in the water supply system, as we had originally thought, but with air in the diffuser itself. The hose connection

to the diffuser supply pipe included a series of fittings that were located 1.8 m above the catwalk surface; thus, the water supply hose ran from the ground, a minimum of 1 m above the pond's surface, to the 1.8 m height. At the low rate of flow, the diffuser pressure drop was insufficient to prevent siphoning between the pond surface level and the supply hose on the ground. Because of this, a negative gauge pressure existed at the upper part of the water supply system. The fittings installed in this part of our system were permitting air to enter the diffuser. The problem was corrected by adding a stainless steel ball valve in the diffuser supply pipe and adjusting it so that siphoning was suppressed. No air entrainment occurred after this corrective procedure was performed.

VI. PRELIMINARY RESULTS

The pond began warming from a temperature of 25°C and a salinity of about 18.5‰ when gradient establishment began on August 4. At that time, although most of the salt had dissolved, a thin layer remained visible on some sections of the pond floor. However, dirt that settled on top of the bottom salt layer darkened the floor considerably. As Figs. 8 and 9 show, on September 3 the LCZ salinity and temperature were 21‰ and 50°C, respectively. Inspection of the LCZ temperature profile in Fig. 9 shows the existence of a second gradient zone extending from the pond floor to about 20 cm above it. This gradient was caused by the presence of undissolved salt and was eliminated by using the diffuser and pumping salt water from the floor region to a region just below the LCZ interface at a low velocity. Because convective motion in the LCZ was not sufficient to suppress the regrowth of the secondary gradient under the then existing pond conditions, periodic pumping was necessary. The last temperature point plotted in Fig. 9 is that measured by a thermocouple exposed to air above the pond.

The rates of increase in the LCZ temperature and salinity are shown in Figs. 10 and 11, respectively, for the period of August 8 through October 17. Figure 10 indicates a large rate of LCZ heating in the beginning of the period of about 1.2°C/day. At the end of the period, the increased rate of losses through interface and pond perimeter decreased this value to about 0.25°C/day. Figure 11 shows a large rate of increase in the LCZ salinity until Julian day 243, after which a smaller rate of increase occurred. Before day 243, pumping

was performed to eliminate the secondary gradient and the resulting mechanical agitation caused the rapid rate of dissolution during this period.

VII. RECOMMENDATIONS

From our experience to date, we make the following recommendations on solar pond design, construction, and instrumentation:

1. If a pond with vertical or near vertical walls is considered, it is necessary to take precautions to minimize liner tensile stress. We recommend the placement of sandbags or a similar material around the bottom perimeter of the pond before liner installation to increase the bending radius of the liner at this location. This is especially important if field or factory seams are located at this point and if a soft sand or soil base is used under the liner. Shifting of the sand or base away from the wall or vertical settling may place large strains on the liner. In addition, the pond may be filled to its operating level before burying or securing the liner in the pond banks. This permits both adequate settling of the base without straining the liner and the release of air trapped between the liner and the pond walls.
2. A method for detecting the location of leaks in the pond liner, in addition to overall leak detection, should be considered during the design phase of the pond. An inexpensive method would involve partial burial of a length of perforated tube (rubber or plastic hose would be ideal) in a serpentine arrangement in the layer underneath the liner. The tube is plugged at the buried end and run above ground at the other end. Upon suspecting a leak (because of a drop in leak-detector resistance or a falling of the pond water level over time as indicated by plotting isosalinity lines), compressed air or nitrogen is carefully introduced into the tube with sufficient pressure to equal the hydrostatic pressure at the bottom of the pond. The leak locations are then found by locating gas bubble streams from the liner. Small holes made in the liner at several places above the water line will permit the gas to escape and can be easily patched later.

3. A stationary rake of thermometers spaced incrementally in the vertical direction should be considered as a fundamental component of pond instrumentation. Data from such rakes provide instantaneous temperature distributions from which problems such as local convection in the gradient zone (possibly caused by improper gradient maintenance) and other pond phenomena may be detected.
4. Severe problems continue to exist with electric conductivity point probes (see Ref. 5). These center on two aspects of the method as follows:
 - (a) the sensitivity of the measured specific conductivity to the easily-perturbed electrical condition of the platinized point probe tip requiring continual probe recalibration; and
 - (b) the saturation effect of the specific conductivity as a function of salinity at large ($\gtrsim 20\%$) values of salinity for all temperatures. Constant probe recalibration and the probes' inaccuracy in large salinity environments dictate that other methods of measuring salinity be pursued. Further work is required on inexpensive, simple instruments to accurately measure in situ point density with in a contained electrolyte solution.

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REFERENCES

1. K. A. Meyer, "A One-Dimensional Model of the Dynamic Layer Behavior in a Salt Gradient Solar Pond," AS/ISES, Proc. of the Annual Meeting, Solar Energy Society Meeting, Philadelphia, Pennsylvania, May 26-30, 1981 (American Section of the International Solar Energy Society, Newark, Delaware, 1981), pp. 763-767.
2. Information on Hypalon is available from Stevens Elastomeric and Plastic Products, Inc., subsidiary of J. P. Stevens and Company, Easthampton, MA 01027. Fabrication of our liner was by Watersaver Company, Inc., Denver, CO 80216.
3. Information on pyranometers is available from the Eppley Laboratory, Inc., 12 Sheffield Avenue, Newport, Rhode RI 02840
4. Resistance thermometer and other temperature measuring instrumentation information is available from Omega Engineering, Inc., 1 Omega Drive, Stamford, CT 06907.
5. D. P. Grimmer, G. F. Jones, J. Tafuya, K. A. Meyer, and T. J. Fitzgerald, "Development of a Point-Electrode Conductivity Salinometer with High Spatial Resolution for Use in Very Saline Solutions," in preparation.
6. Information on the induction salinometer is available from Beckman Instruments, Inc., 89 Commerce Road, Cedar Grove, NJ 07009.
7. Information on weather station instrumentation is available from MCI ONE, 154 San Lazaro, Sunnyvale, CA 94086.
8. Data acquisition system information is available from Hewlett-Packard Company, 1101 Embarcadero Road, Palo Alto, CA 94303.
9. Information on the HRP-30 sand filter is available from Swimquip Company, 3301 Gilman Road, El Monte, CA 91732.
10. Information on the Series A Model AH-8 pump is available from Purex Pool Products, 18400 E. Mohr Avenue, City of Industry, CA 91749.

Fig. 1. Backhoe excavation of the main pond showing the vertical rock ("tuff") walls and broken rock on the pond floor. View is looking towards south.

Fig. 2. Insulation of the main pond vertical sidewalls with 7.6 cm of polyurethane foam. Sandbags line the pond rim. The trench into which the liner edges are to be buried is visible on the far right. The data acquisition shed is in the background. View is looking towards WSW.

Fig. 3. Hypalon vapor barrier coating being applied to polyurethane insulation.

Fig. 4. Hypalon main liner installation. Workers pull unfolded liner from east to west sides of pond. The 6.4 cm-thick layer of plaster sand they walk on covers the PVC backup liner. The far edge of this liner is visible as it protrudes from the sand at the floor's north end where it is bonded to the Hypalon vapor barrier. Vapor barrier and insulation covered sandbags are visible in the foreground.

Fig. 5. Traversing rake trolley, rail, and part-view of rubber-covered baseplate before installation in the pond. The induction salinity probe is mounted on the trolley's front while brackets for two resistance temperature detectors and a platinum point probe are in the back. The trolley wheels are white teflon and all else is 316 stainless steel.

Fig. 6. Salt dumping operation showing the wooden chute that was made to channel the salt to the pond's floor. The finished main liner is also shown here. View is looking toward the SW.

Fig. 7. Overhead view of diffuser from the catwalk while the final fresh water increment was being added. Water supply pipe extends vertically through its lower support. The pressure reducing valve is visible just above the diffuser plates.

Fig. 8. Salinity profile for September 3, 1982. Depth is measured from the pond's bottom.

Fig. 9. Temperature profile for September 3, 1982. Depth is measured from the pond's bottom.

Fig. 10. Temperature of lower convective zone for August 4 through October 17, 1982.

Fig. 11. Salinity of lower convective zone for August 8 through October 17, 1982.