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ABSTRACT

The Center for Energy and Environment Research (CEER) of the University of Puerto Rico plans to install a 39 m^2 (415 ft^2) research salt-gradient solar pond. The design, construction and instrumentation of this pond is presented. Drawings illustrate the pond's design and instrumentation methodology. This pond will operate in conjunction with a much shallower evaporative pond of the same diameter. The research pond installation will be used to study automatic and semiautomatic pond operation with the maintenance of the salinity gradient being a main concern. The basic materials of the pond construction and the sensors and equipment used in the instrumentation system are listed in tabular form. The measurements of principal pond parameters such as brine temperature, ground temperature and moisture, brine flow through the heat exchanger, brine transmissivity and solar radiation are described. The scanning system, the data acquisition system, and the pond operation and maintenance are also discussed.

1. INTRODUCTION

Salt-gradient solar ponds are large pools of water open to the environment. They are filled with salty water in such a way so that the liquid top layer (upper convective zone) has a salt content of 1-4 percent while the bottom layer (lower convective zone) has a salt content as high as 23-27 percent (see Fig. 1). When exposed to solar radiation, the denser bottom layer heats up to a much higher temperature than the surface layer. The heat accumulated in the lower convective zone is "trapped" by the low salinity nonconvective zone that separates the high density brine at the pond bottom from the upper convective zone. Because heat is stored at the pond bottom, the separate thermal storage normally required in solar installations is not needed.

Since the discovery of natural solar ponds [1], interest in the practical use of pond phenomena has led to the construction

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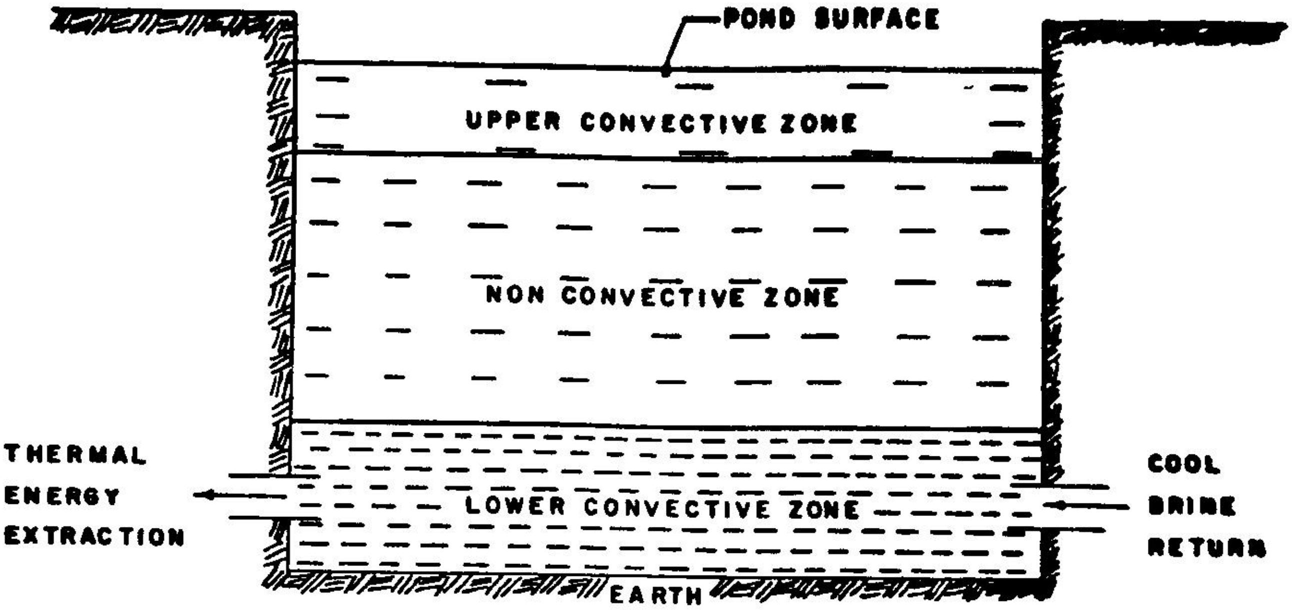


Fig. 1. Cross-Sectional View of Salt-Gradient Pond.

of salt-gradient solar ponds throughout the world. These activities stimulated work on understanding the physical and engineering problems related to solar pond use [2]. In recent years several laboratory size salt-gradient ponds have been built [3-6].

In our work the design and construction parameters for a 39 m^2 (415 ft^2) research pond were established with the view of building and operating a 0.5 acre (21,780 ft^2) pond to generate industrial process heat in Puerto Rico in the future. The pond instrumentation package and data acquisition system were designed to enable the investigation of automatic or semiautomatic pond operation in maintaining the salinity gradient to improve upon the presently used methods that call for manual pond operation and gradient control. Although a computer program for a HP-97 programmable calculator to determine a pond's density gradient is available, this manual pond control method is time consuming and demands the operator's constant attention [7]. The design problems of the data acquisition and instrumentation package are technically similar to those encountered in solar heating and cooling [8]

2. DESIGN

A number of theoretical models to predict a salt-gradient solar pond's thermal performance have been developed and studied. A general analytical formulation of the pond's thermal behavior that shows it to be equivalent to that of a flat-plate collector [9,10], the development of a new steady-state analytical method for pond analysis [11,12], and the use of theoretical predictions for pond sizing in heating applications [12-15] are some of the approaches that have been taken. A simple method to calculate pond parameters has also been introducted [16], and a number of solar pond computer models to predict solar pond thermal behavior in different situations have also been proposed [16-25],

The thermal efficiency of salt-gradient solar ponds strongly depends on both brine transmissivity and heat loss to the ground. The solar pond has to be designed then in such a way as to minimize the heat losses from the pond and the wetting of the soil around and underneath the pond. Wetting is basically caused by ground water movement, rainwater, or brine leakage. Keeping these factors in mind, the preliminary design of the pond was performed by using the simplified method of M. Edesses et al.[16]. These calculations were later followed up by a more elaborate computer analysis that employed the model developed by J. B. Dávila Acarón [20]. In addition to the refined steady-state analysis of A. Rable and C. F. Nielson [13] his model also takes into account the edge heat losses, bottom heat losses and the effect of surface mixing on the pond's thermal performance.

Figure 2 shows a conceptual drawing of CEER's research salt-gradient pond. The drawing indicates the three distinctive

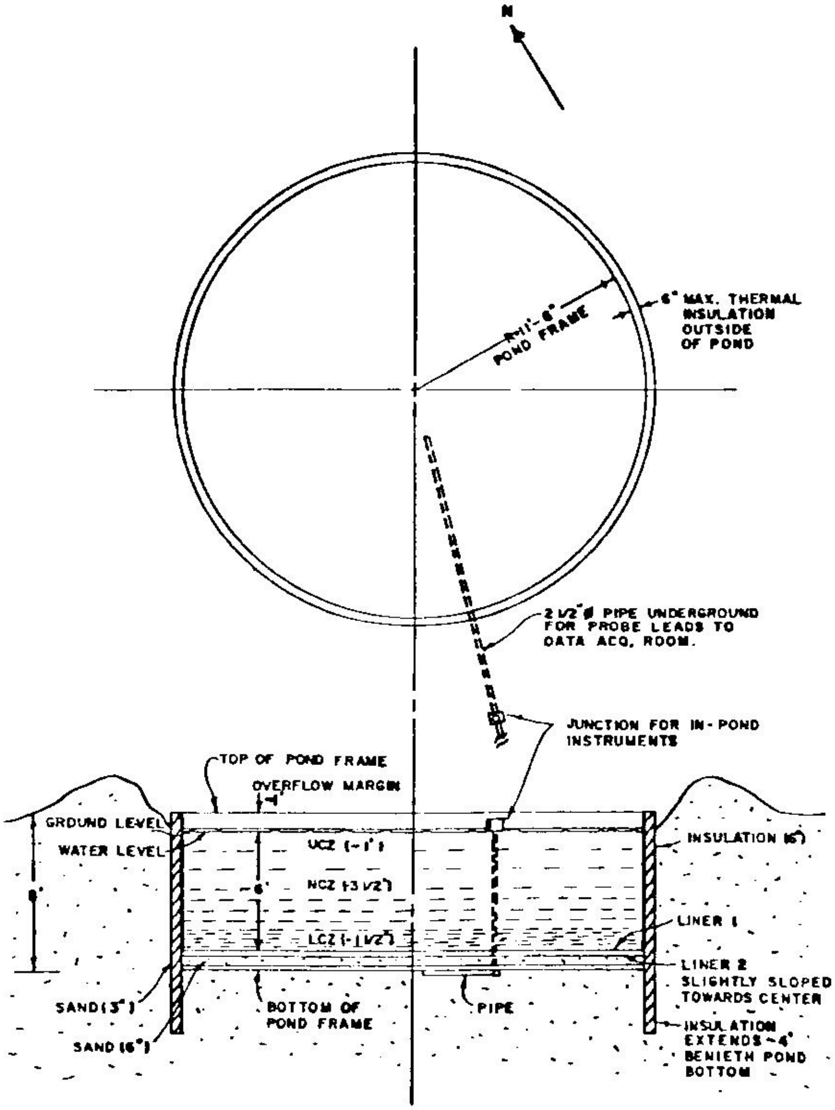


Fig. 2. Conceptual Design of Research Pond.

zones formed in the pond: the upper convective zone, the non-convective zone and the lower convective zone. The upper convective zone caused by wind stirring and surface heating and cooling is kept as thin as possible, 0.1-0.4 m (0.3-1.3 ft) in research ponds. The lower convective zone's thickness depends on the use of the pond. It is typically 0.5-0.8 m (1.6-2.6 ft) thick, with thicker zones occurring in ponds used for large heat storage. The non-convective zone's thickness depends on a number of parameters and is usually 0.2-1.0 m (0.6-3.3 ft) in research ponds.

3. CONSTRUCTION

The 7 m (23 ft) diameter pond structure will be constructed by using two 1.2 m (4 ft) high, commercially available pool frames one on top of the other (see Fig. 3). The high sun angle in Puerto Rico can cause overheating of sloping sidewalls that significantly increases heat loss via thermal convection along the walls and promotes upward salt transport by convective mixing. This problem was severe in a production pond built in Alice Springs in Northern Australia [26]. Thus, the CEER research pond walls and their supports, made of galvanized steel coated with a rust-resistant acrylic enamel finish, will be vertical. The pool comes with its own 14-gauge vinyl liner with electronically welded seams.

Soil from the excavation piled around the entire pool will form a berm about 0.9-1.2 m (3-4 ft) high. Since the brine depth is about 1.8 m (6 ft), this leaves 30 cm (1 ft) at the top of the structure for overflow or the adjustment of zone thickness, and 30 cm (1 ft) at the bottom for sand and thermal insulation. A layer of sand a few centimeters thick will smooth the bottom ground irregularities and protect the liner from sharp stones in the ground.

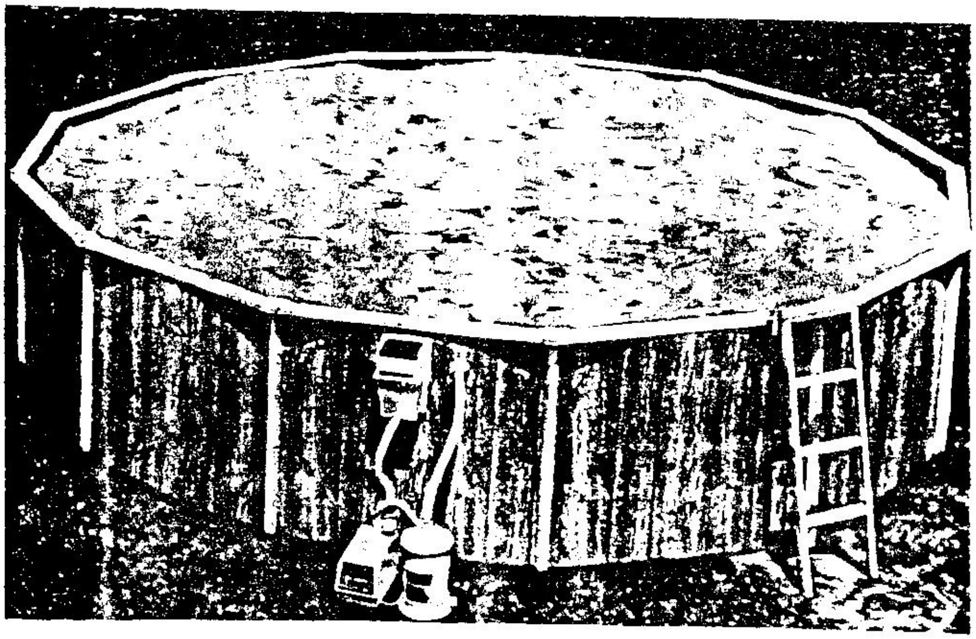


Fig. 3. General View of Research Pond Frame.

To reduce heat losses from the pond, 10 cm (4 in) thick styrofoam thermal insulation is used on the side walls of the pond and 5 cm (2 in) thick urethane board is used on the bottom. The wall thermal insulation extends 0.9-1.2 m (3-4 ft) beneath the pond bottom to reduce edge heat losses that can amount to up to 30 percent of the heat collected. A vapor barrier will be installed between the wall thermal insulation and the soil. The primary liner used in the research pond is the Shelter-Rite hypalon XR-5SP, custom cut and factory welded to fit the pond shape; the secondary back-up liner used is a 30 mil thick PVC liner.

The research pond will be operating in conjunction with an evaporative pond of the same diameter as the research pond, but with a depth of only 1.2 m (4 ft). The evaporative pond will have a single layer hypalon XR-5SP liner and thermally insulated walls. To reduce thermal interferance between the ponds, they will be built at a distance equal to the pond diameter from each other. The highest ground available on the site was selected for the ponds' construction to reduce heat losses through rain water accumulation in the soil around the ponds. Soil thermal conductivity at the pond site is expected to be up to 2.5 Watts/m°C. The pond construction is planned for FY 1984. Table I lists some of the materials selected for the construction.

Table I. Description of Selected Materials.

Material	Model/Type	Quantity	Company
Round Water Pool	7.2 m x 1.2 m	3	Sears Roebuck & Co.,Chicago,Ill
Liner	Shelter Rite XR-5SP	2	Engineering Textile Products Mobile, Alabama
Liner	PVC 30 mil thick	1	Engineering Textile Products Mobile, Alabama
Urethane Insulation Board	1 m x 1.2 m 5 cm. thick	80	McCarthy Manufacturing Co. Carolina, P.R.
Styrofoam Board	1.2 m x 2.4 m 10 cm thick	30	Refricentro Air Cond., Mayaguez, P.R.
Thermocouple Wire	T type, 24 gauge with Polyvinyl Insulation	300 m	Omega Engineering, Inc. Stamford, Conn.

4. INSTRUMENTATION

The most important physical parameters of a salt-gradient solar pond are the temperature and salinity gradients. An accurate and efficient system must be designed to monitor these two parameters. Since the CEER pond will be used for research, an elaborate instrumentation system was designed. The system will measure temperature and salinity gradients in the pond, solar radiation at the surface and at any depth, the heat losses to the ground, and the amount of heat energy extracted; it will also detect the presence of leaks in the pond liners.

The measurement of solar radiation at the surface and at various depths of the pond allows the calculation of the solar energy absorbed and provides an indication of the brine clarity. This measurement with those of heat losses through the sides and bottom, of energy removed by heat extraction, and of temperature and salinity gradients will allow the heat balance and pond efficiency to be calculated.

A weather station near the pond will measure ambient temperature, humidity, insolation and wind velocity. This data will be used to calculate the heat losses from the surface of the pond.

4.1. Measurements

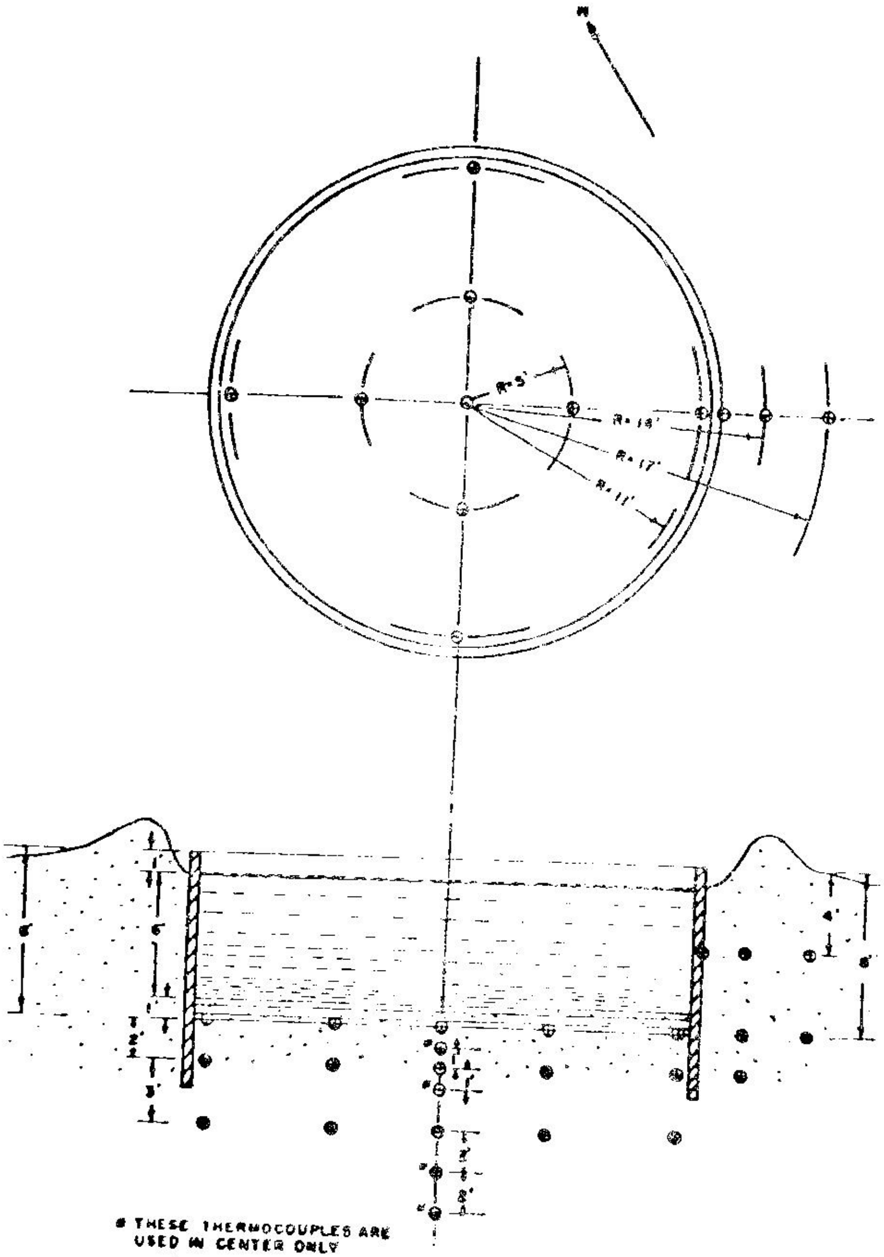
The sensors being used in the measurement of the pond parameters are listed in Table II.

Temperature measurement. Platinum resistance thermometers, e.g. 100 Ωhm RTDs, were selected for measuring the brine temperature. The system instrumentation design calls for nine RTDs with temperature gradient measurement capability every 7.5 cm (3 in). They will monitor the non-convective zone temperature distribution by scanning hourly. RTD probes will also monitor the operation of the diffuser. T type copper-constantan thermocouples in Teflon jackets will be installed in the heat exchanger piping to monitor the brine inflow and outflow temperatures during heat extraction from the pond. A pump (preferably brass or plastic) rated at 20 liters/min at zero head and driven by a 1/2 h.p. electric motor will circulate the brine in the heat exchanger. A shell and tube heat exchanger with cast iron shell and copper-nickel alloy tubes will be used. T type copper-constantan thermocouples will also be used to measure the ground temperature around the pond. The design calls for measurement at intervals of 1.3 m (4.5 ft) horizontally and from 0.3 to 0.9 m (1 to 3 ft) vertically under the pond bottom. Altogether thirty-seven strategically located thermocouples will be used (see Fig. 4). The underground thermocouples will be scanned daily and the signals will be converted to temperature readings by a data logger. Figure 5 shows the technique of installing the underground thermocouples.

A leak detection system was designed and integrated into the pond installation. This system consists of a series of T type copper-constantan thermocouples with Teflon jackets located between the liners. The sand between the liners is sloped so that the leaking brine will accumulate in the center where a sump pump

Table II. Description of Selected Sensors

Type of Measurement	No. of Sensors	Type of Sensor	Company Name
Brine Temperature	9	RTD (100 Ohm Platinum)	Hy-Cal Engineering Santa Fe, Springs, Ca.
Ground Temperature	37	T Type Copper-Constantan Teflon Insulated Thermocouples	Omega Engineering, Inc. Stamford, Connecticut
Electric Conductivity	2	Electric Conductivity Micro Cell Type 3403 and Type 3240-L10	Fischer Scientific Pittsburgh, Pennsylvania
Salinity	2	Salimeters 0° - 100°	Arthur H. Thomas Co. Philadelphia,Pennsylvania
Soil Moisture	5	Bouyoucos Gypsum Soil Block	Beckam Instruments, Inc. Cedar Grove, New Jersey
Brine Flow	2	Not Determined Yet	Not Determined Yet
Total Solar Radiation	1	Eppley Pyranometer, Model PSP	The Eppley Laboratory,Inc. Newport, Rhode Island
Diffuse Solar Radiation	1	Eppley Pyranometer, Model PSP with Shadow Band Stand	The Eppley Laboratory,Inc. Newport, Rhode Island
Brine Transmissivity	1	Eppley Underwater Radiometer,Model SUB-8-48	The Eppley Laboratory,Inc. Newport, Rhode Island
Ambient Temperature	1	T Type Copper-Constantan Thermocouples with Radiation Shield IS4	The Eppley Laboratory,Inc. Newport, Rhode Island
Wind Speed	1	Cup Anemometer, Model 014A	Met One, Inc. Sunnyvale, California
Wind Direction Measurement	1	Direction Sensor, Model 024A	Met One, Inc. Sunnyvale, California



* THESE THERMOCOUPLES ARE USED IN CENTER ONLY

Fig. 4. Location of Underground Thermocouples.

can evacuate it. Although electric conductivity probes could be used in a leak detection system, they require an A.C. bridge circuit to measure conductivity and such a circuit is not compatible with our data acquisition system. For the same reason, an electric resistance grid could not be used for leak detection in our case.

Flow measurement. A commercially available flowmeter or the flowmeter described by S. M. Gleman et al. [27] will measure the brine flow through the heat exchanger and through the diffuser. To prevent clogging and flowmeter malfunctioning a leaf trap (similar to the one used in swimming pools) and a sand filter will be used in the heat exchanger loop. PVC piping will be used with the heat exchanger and the diffuser. The flow in the heat exchanger loop will be measured and processed hourly by the data logger.

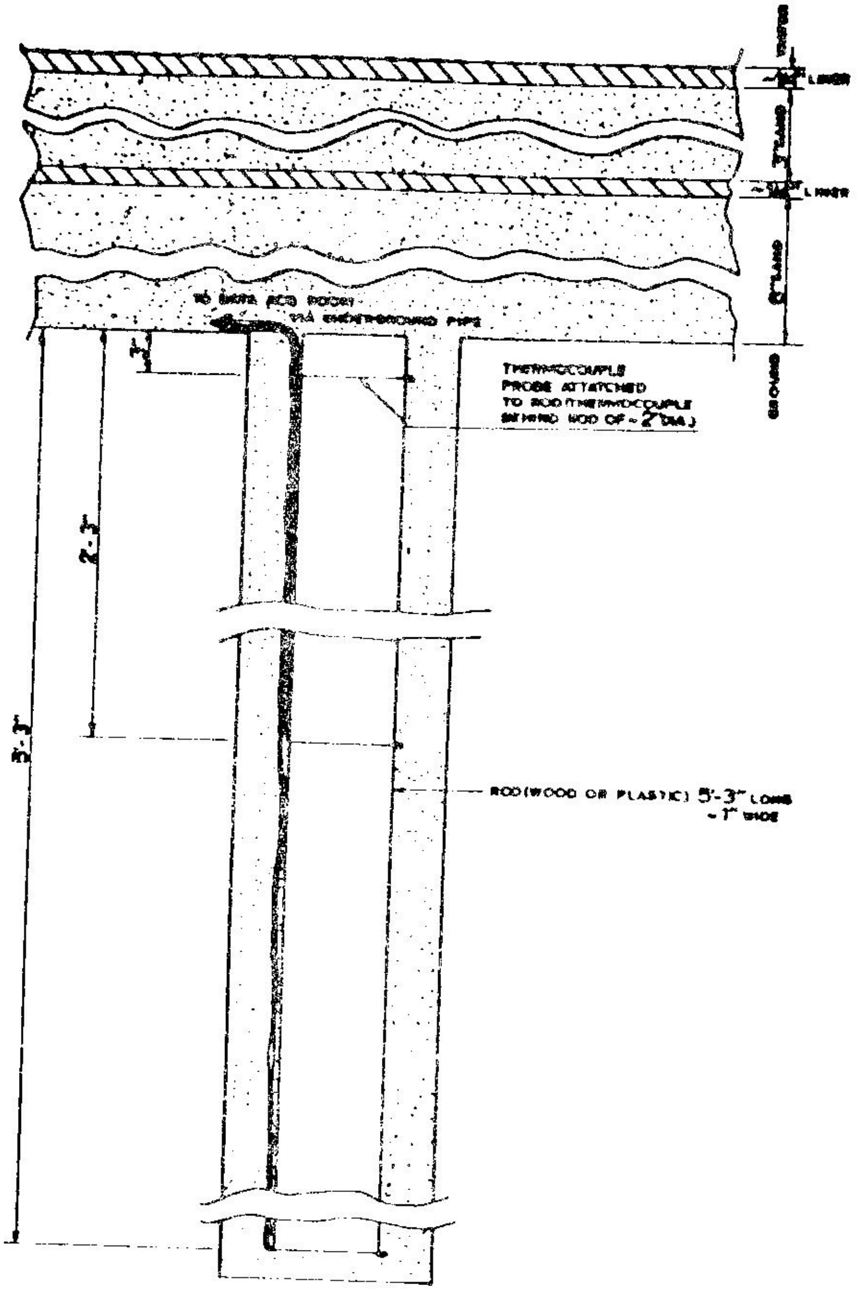


Fig. 5. Installation Technique of Underground Thermocouples.

During the operation of the diffuser, the flowmeter signals from the diffuser line will be read manually hourly at the pond site.

Soil moisture measurement. Five bouyoucos gympsum soil blocks embedded in the sand between the liners and in the soil under the pond and around the pond will measure soil moisture. A bouyoucos soil moisture meter will be read manually every 24 hours. A salinity probe can be used with this meter to measure salinity values up to 1000 ppm.

Brine density measurement. There is no ideal method to measure brine density values in a pond or to monitor the density gradient. Hydrometers are the easiest instruments to use to check the density, but the density determination process is time consuming and subject to errors. According to F. Zagrando [28], the buoyancy of a submerged object has been used successfully at SERI in laboratory conditions for accurate on site measurements. The measurement requires care, however, and does not allow measuring portions of the gradient region without starting at the pond surface. Electrical conductivity measurements to determine brine density are good, but they require frequent recalibration and replatinizing of the electrodes if high accuracy is desired. Pressure measurement as a means for density reading may lead to large errors in field conditions. Several other known methods require further development and investigation. Some of these methods such as the vibrating U-tube, magnetic float, and velocity of sound look promising. Table III lists possible techniques for brine density measurement.

In our research pond, electric conductivity cells and a conductance meter will be used to determine the brine density values and the density gradient. Scanning will be done hourly at every 5 cm (2 in) of pond depth. The measuring probe will consist of a section of PVC tube equipped with a T type copper-constantan thermocouple and a conductivity cell. A pump (preferably brass or plastic) rated at 15 liters/min at zero head will circulate brine through the probe. The brine will be returned to the pond in the same horizontal plane from which it was removed by the probe. This electric conductivity measurement loop will also allow taking brine samples for the brine density measurement with a salimeter*. The measurement procedure calls for the samples to cool to room temperature in closed containers before manual corrections for pond temperature are made from a table or graph. An automatic method for scanning electric conductivity values is described by R. P. Fynn et al. [29].

Solar radiation measurement. An Eppley pyranometer will measure insolation at the pond site. The Eppley underwater radiometer will be used to determine brine transmissivity in the upper convective and non-convective layers. Scanning of both data will be done hourly and during the temperature and density gradient measurements. Solar insolation data will be processed by an Eppley integrator and printed by a Digitec recorder. The surface weather station will measure global and diffuse insolation every 3 minutes. An encapsulated silicon cell can be used for brine transmissivity measurement if its spectral response is flat from the visible to approximately 1 μ in infrared. The response of this cell is independent of temperature if operated in the short circuit fashion. Before being used, however, the cell should be calibrated and correction factors determined in laboratory conditions.

Wind speed and direction measurements. A portable wind station from Campbell Scientific Inc. will be used to measure wind speed and direction. This station is equipped with wind sensors from Met One, Inc. and contains a micrologger that will transfer

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*Hydrometer that indicates salt concentration directly in weight percent.

Table III. Description of Possible Density Measurement Techniques [28]

Type of Instrument	Samples Necessary	Measure On Site	Best Accuracy (g/cm^3)	Automation Possible	Equipment Commercially Available	Remarks
Hydrometer	Yes	No	1×10^{-3}	No	Yes	Needs large sample volume;good check of density
Pycnometer	Yes	No	1×10^{-6}	No	Yes	Laborious; requires laboratory analysis skills & temperature control
Vibrating U-Tube	Yes	No	1×10^{-6}	Yes	Yes	Temperature control needed
Hydrostatic Pressure	Yes	No	5×10^{-4}	No	Yes	Temperature control needed; laborious
Buoyancy of Submerged Object	Yes	Yes	5×10^{-4}	Yes	Yes	Requires additional computation for buoyancy of support & protection from air movement
Differential Pressure	Yes	Yes	1×10^{-3}	Yes	Yes	Reproducing initial setting & equalizing both arms may be difficult
Free Floats	Yes	Yes	1×10^{-3}	Yes	Yes	Needs calibration; needs visual access to floats
Electrical Conductivity	No	Yes	1×10^{-3}	Yes	Yes	Requires frequent recalibrations; data available for several salts

the data to the Apple II microcomputer system in the data acquisition room via short haul calling and answering modems. The Apple II microcomputer will be equipped with an interface card RS232 to accept signals from the micrologger. The list of selected equipment is given in Table IV.

Table IV. Description of Selected Equipment

Instrument	Model/Type	No.	Company
Conductance Meter	Model 32	1	Fischer Scientific Pittsburgh, Pa.
Bouyoucos Moisture Meter	Model IPK25	1	Arthur H. Thomas Philadelphia, Pa.
Solar Data Printer	Digitec HT Series Digital Recorder Model 6140	1	United Systems Corp. Dayton, Ohio
Solar Data Integrator	Model 411	1	The Eppley Laboratory Inc. Newport, R.I.
Microcomputer	Apple II	1	Apple Computer Cupertino, Ca.
Data Logger	Monitors Labs Model 9300	1	Monitors Labs San Diego, Ca.
Slave Unit	200 Channels	1	Flow Technology, Inc. Phoenix, Az.
Flow Rate Monitor	Model PRI 102D	2	Campbell Scientific, Inc. Logan, Utah
Micrologger	Model CR21	1	Campbell Scientific, Inc. Logan, Utah
Short Haul Calling Modem	Model SC95C	1	Campbell Scientific, Inc. Logan, Utah
Short Haul Answering Modem	Model SC95A	1	Campbell Scientific, Inc. Logan, Utah

5. DATA SCANNING SYSTEM

Figure 6 shows the two-dimensional scanning system of temperature, electrical conductivity (density) and brine transmissivity. A horizontal cable that stretches across the pond is supported by steel pipes that are driven into the ground and held in position by guy lines. A small measurement probe attached to the cable can be moved back and forth across the pond to scan pond parameters by using the combination of pulleys and electric motors shown in the figure. This underwater probe contains an RTD platinum thermometer for temperature measurement, an electric conduc-

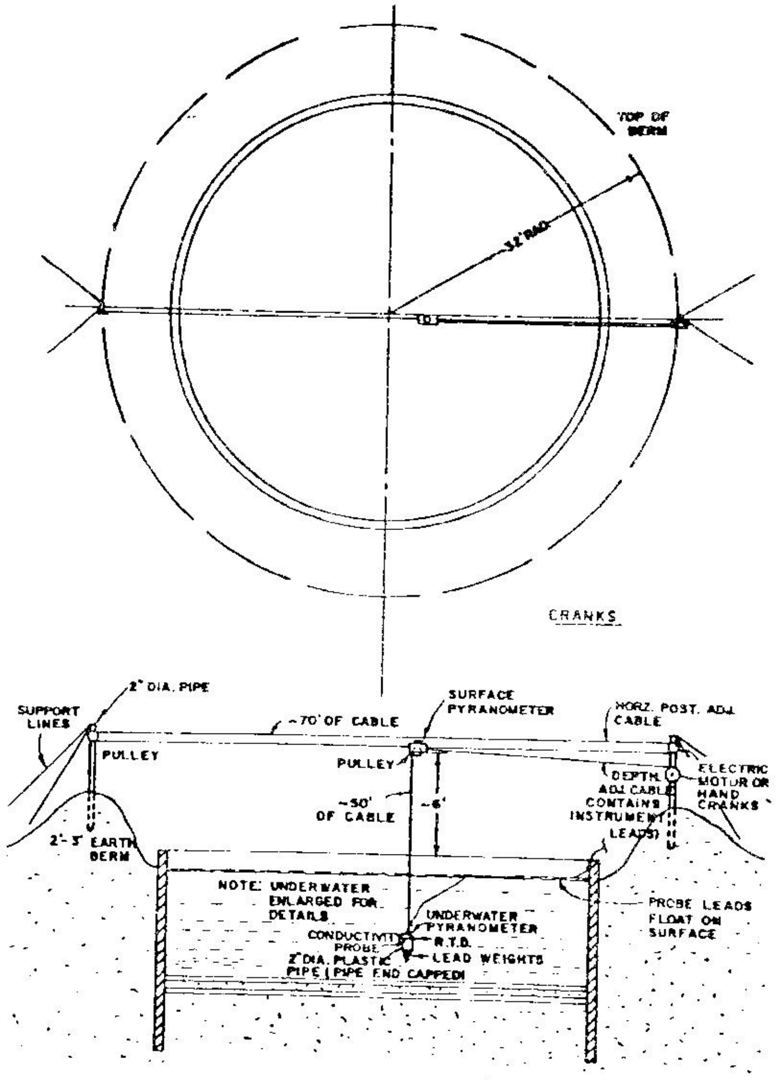


Fig. 6. Two-Dimensional Scanning System.

tivity cell, and an Epply underwater radiometer. Figure 7 shows the pulley and underwater probe arrangement. The scanning system would also include fixed RTDs, underground thermocouples, additional electric conductivity cells, flowmeters and weather station instruments. The scanning would have to be done at the fastest rate needed by any one of the sensors, in this case the fixed RTDs. The rest of the data will be discarded by the data acquisition system (Apple II microcomputer) until its scanning time is attained, i.e. the scanning might take place hourly but underground thermocouple data will be saved only every 24 hours.

For a typical scanning operation, the horizontal position of the measuring probe could be set manually and the probe positioned at the bottom of the pond. The electric motor (or a manual winch) would then begin raising the probe at a rate slow enough to minimize the effect of thermal inertia (~0.3 cm/sec). The data acquisition system will then do the signal scanning of each sensor. The scanning intervals can be determined according to needs, and could be as short as 30 seconds. The data logger interfaced with

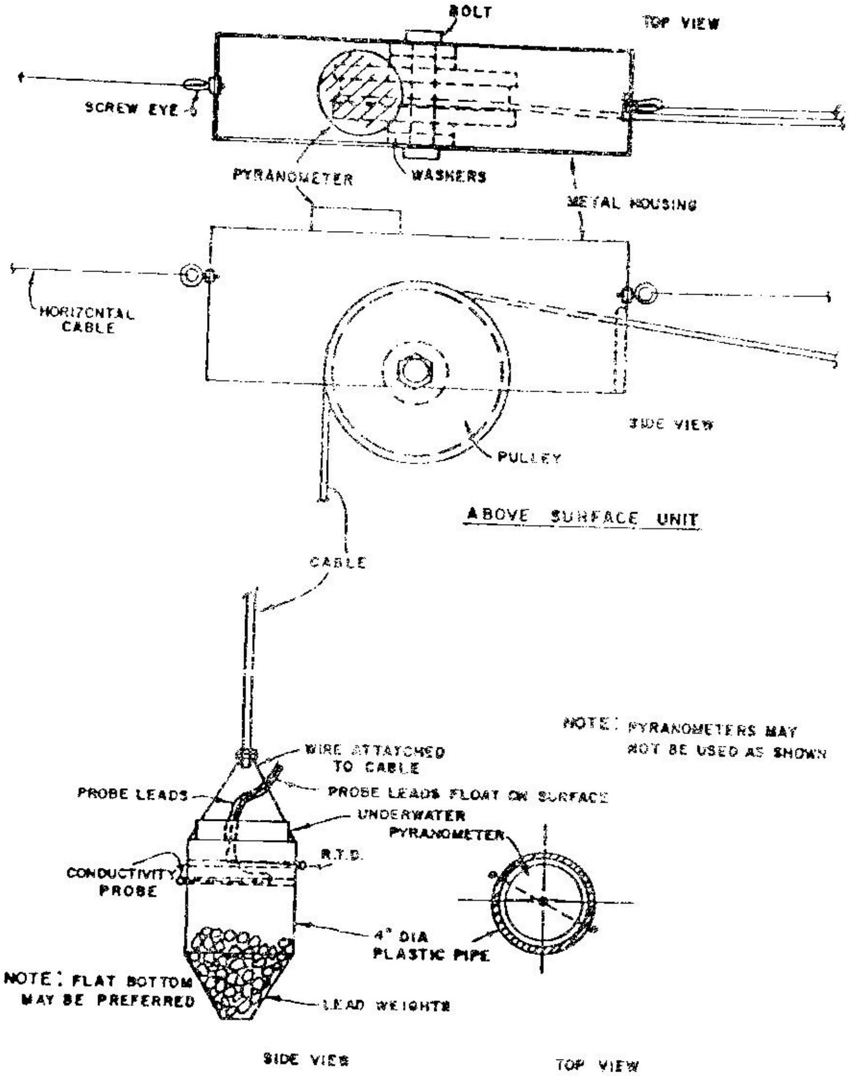


Fig. 7. General View of Pulley and Underwater Probe.

the Apple II microcomputer will monitor the scanning process. The sensors will be scanned as an electric motor pulls them through the water. An Apple II microcomputer will be placed in a loop to await the data logger's scanning signals. The main advantages of a two-dimensional cable and pulley data scanning system are its versatility, fairly low cost and particular adaptability to small size research ponds. A drawback of this system is that the horizontal cable has a tendency to sag and move under moderate wind conditions.

An alternative to the above system is the one-dimensional scanning system shown in Figure 8. As shown in the figure, the measuring unit is made of 5 cm (2 in) diameter PVC pipes. The system construction is simple and the cost low, but the unit can only scan on the circumference of the pond by moving on the pond frame. Figure 9 shows details of the measuring unit construction. This system can be used in conjunction with a fixed or floating measuring platform, more or less manually operated, or with an automatically operated cable and pulley system.

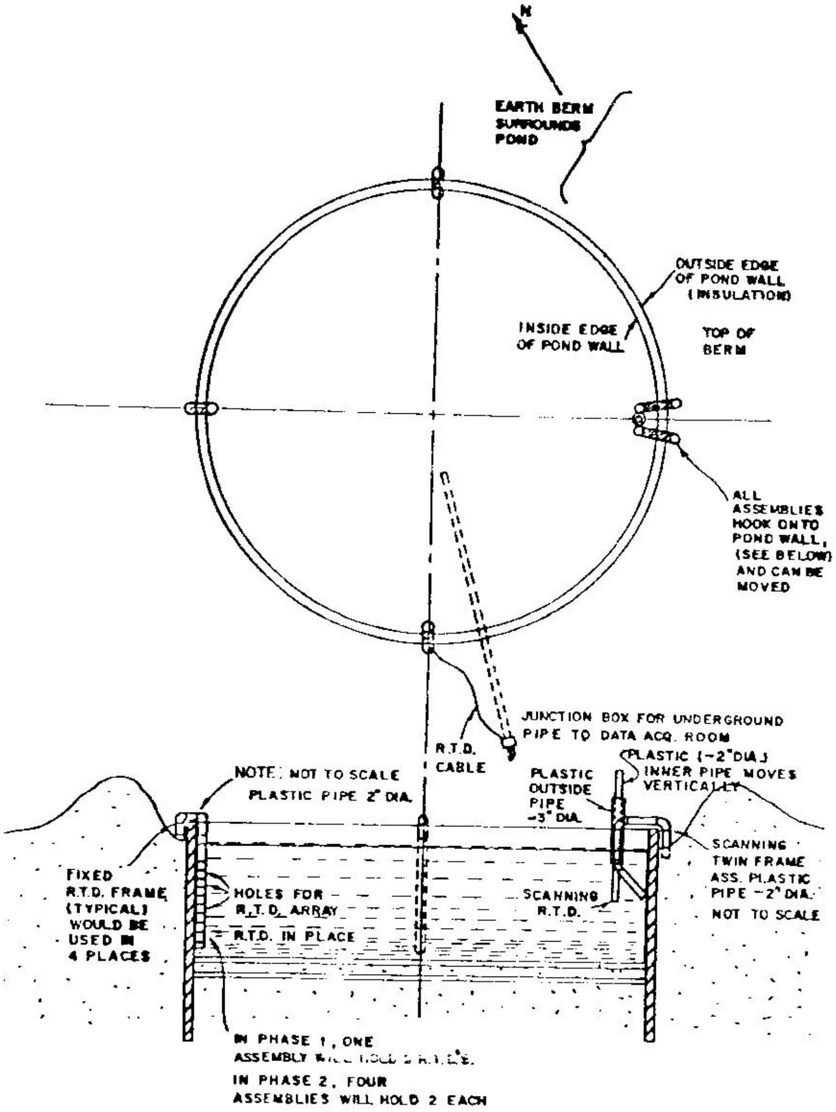


Fig. 8. One-Demensional Scanning System.

6. DATA ACQUISITION SYSTEM

A microprocessor should serve as the nucleus of a dedicated data acquisition and monitoring system. Through its parallel input/output ports it can perform several operations such as control data acquisition via pre-programmed scanning, process data, make decisions, execute maintenance instructions, and provide feedback between implemented instructions and data which resulted from their implementation. The main advantage of a microprocessor system is its versatility; this feature will be considered in future research on the automation of pond maintenance and operation.

However, since a data logger was available, it was decided to use it as the system nucleus in association with an Apple II microcomputer. A Monitor Labs 9300 data logger combined with an Apple II microcomputer fulfills the function of a data acquisition system in our case. The data logger has forty channels assigned

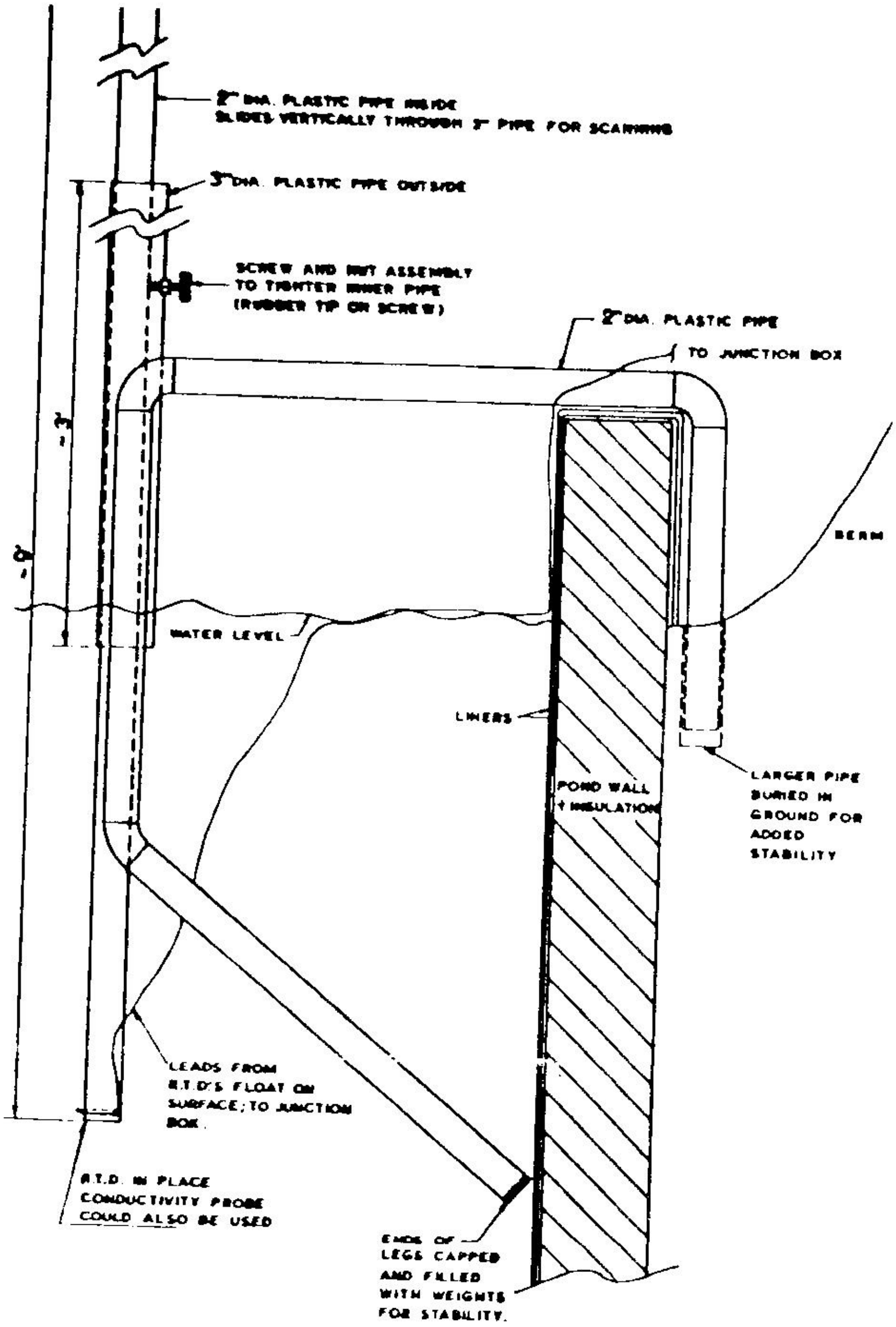


Fig. 9. Detailed View of Measuring Unit.

for thermocouple signal input, the twenty channels for RTD input; eighty more channels could be added. The Monitor Labs 9300 data logger accepts two independent scanning rates, is equipped with time averaging features and has an internal clock and printer. A 200 channel-capacity Monitor Labs slave unit works in tandem with the data logger. The Apple II microcomputer has 48K memory and is equipped with a disk drive, a video monitor and an interface card to the data logger. With the Monitor Labs-Apple II interface, the microcomputer initiates the scanning process of the data logger and stores the data received. Once stored, software programs can provide data analysis and gradient modification instructions. Figure 10 shows the data acquisition room with the Monitor Labs 9300 data logger in the foreground.

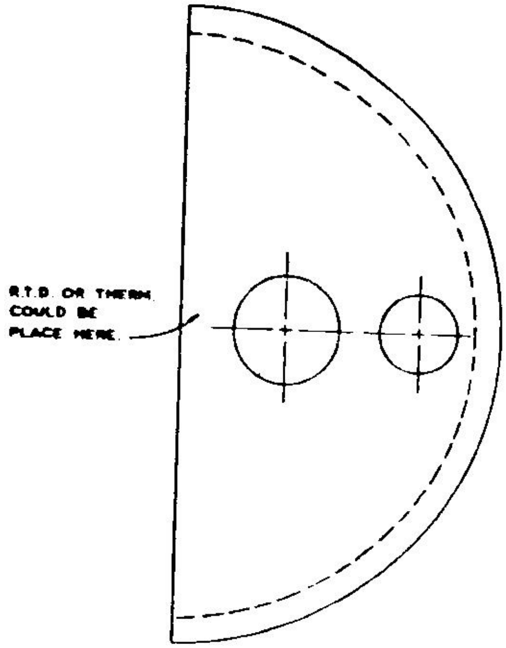
Some disadvantages are inherent in this data acquisition system because the Apple microcomputer can not control the data logger, it can only initiate the scanning. The channels which perform the scanning must be pre-set on the data logger and the computer can not override the pre-set sequences. This means that for most purposes all the channels must be read and the unnecessary data discarded. Consequently, the scanning speed is being imposed by such an arrangement. Another disadvantage arises from the fact that the data logger can not operate a multiplexer because the electric conductivity cells being used need an A.C. bridge circuit. A separate bridge is needed for each channel, and the electric conductivity data will have to be monitored manually using a conductance meter.

Fig. 10. General View of Data Acquisition Equipment.

7. OPERATION AND MAINTENANCE PLANNING

A diffuser will be used to establish and maintain the vertical salinity gradient [30]. The diffuser will be made of two 0.40 m (1.3 ft) diameter half discs of 2.5 cm (1 in) thick plexiglass. Figure 11 shows details of the diffuser construction. For small size research ponds, entire layers of brine can be removed or injected without disturbing the pond's stability as long as the flow speed is kept fairly low (in the order of 0.1 m/sec). For large experimental ponds, the gap between the discs and the brine flow rate should be such as to assure a liquid velocity from the gap of 1.0 m/sec (3 ft/sec). The diffuser will be moved to any position in the pond by the cable and pulley system.

The normal operation of a salt-gradient solar pond requires



TOP VIEW

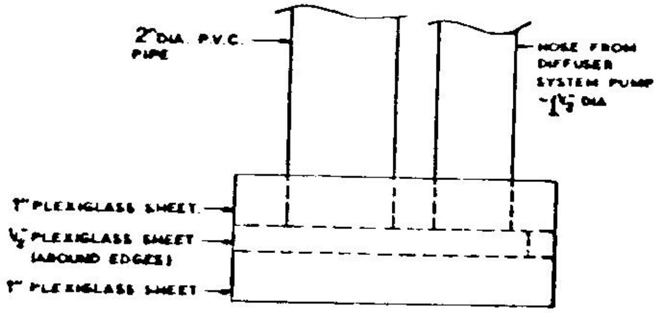


Fig. 11. Detailed View of Diffuser.

maintaining the non-convective zone (gradient zone) thickness constant by injecting fresh water at the zone surface to replace evaporative losses, and by injecting concentrated brine near the pond bottom to replace the salt. The salt slowly diffuses upward through the solar pond gradient zone at an average annual rate of about 10 kg/m² (2 lb/ft²). During the diffusion process the upper convective zone slowly gains more salt and the lower convective zone loses salt. Because of the high rainfall rate at the pond site will reduce surface water evaporation losses, it may be necessary to pump surface brine into the evaporation pond, and to introduce only small amounts of fresh water onto the surface to built up the upper convective zone thickness to the design level. Concentrated brine from the bottom of the evaporative pond or free salt in the amount up to 120 kg (264 lb) per month may have to be introduced to the bottom of the research pond to replace the salt that has migrated upward through the diffusion process and been discarded with the surface brine. The salt-gradient maintenance in a pond will be a continuous process.

To combat evaporation losses usually a surface wash in the amount of 1.0 to 2.0 cm/m² (0.037 to 0.074 in/ft²) of fresh water per day is sufficient depending on the evaporation rate and rainfall on that day. Any device used on the pond surface for controlling the upper convective zone must also be effective in reducing evaporation that may be instrumental in causing mixing by convective overturn [31]. One way to control the evaporation rate is to install windbreaks that would act to reduce both surface wind stirring and evaporation. Surface oil films are also being tried in research size ponds on an experimental basis. Wave suppressing devices will not be used because it is anticipated that wind action will not have a negative effect on the operation of a pond of this small size.

Brine clarity in a salt-gradient solar pond is important because radiation falling on the pond must be able to penetrate through the pond's upper convective and gradient zones to the lower convective zone. Chemical treatment of solar pond brine assures the pond's high transmissivity by controlling the bacteria, algae and minerals content in the pond. Controlling the pH level through chemical treatment also minimizes corrosion of pumps, heat exchangers, and piping. About 0.5 kg (1.1 lbs) per week of chlorine in the form of sodium hyperchloric and hydrochloric acids will be used to minimize bacteria growth in the pond by keeping the pH level 4-6.5. Weekly brine samples will be taken and pH will be measured by using a pH meter. A diffuser loop will be used to adjust pH at a specific depth of the pond. A small quantity of copper sulphate (~1 kg) will be put in the pond at the beginning of its operation to control algae growth.

Since mostly dirt, especially sand, will fall to the level of the lower convective zone and stay there, a sand filter similar to the one used in swimming pools will be used. The filter loop will be equipped with a by-pass valve to permit periodic flushing with fresh water. For the research activities described above about 18.5 tons of sodium chloride will be used in the research pond and 5 tons of salt in the evaporation pond. Calcium chloride or a mixture of various salts [32] will be used to investigate the concept of pond coupled dehumidification cooling [33].

8. CONCLUSIONS

The design, construction, instrumentation and operation/maintenance of a research salt-gradient solar pond has been described to provide a basis for studying pond automation and scaling up. It is apparent that the automation of pond operation and maintenance has not been addressed adequately and needs to be studied as an important part of salt-gradient solar pond development and application. The use of a dedicated microprocessor should be planned for future pond automation research to obtain data on a pond-microprocessor integrated system.

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