This text 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 construction. This work is sponsored by the 'Summer Student Fellow' program by Oak Ridge Associated Universities.

THERMAL energy extraction Fig. 1. Cross-Sectional View of Salt-Gradient Pond. Salt-gradient solar ponds throughout the world have been built, 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 m2 (415 ft2) research pond were established with the view of building and operating a 0.5 acre (21,760 ft) pond to generate industrial process heat in Puerto Alcs in the future. A control and instrumentation package and data acquisition system were designed to enable the investigation of automatic or semi-automatic pond operation in maintaining the salinity gradient to improve the presently used methods that call for manual pond operation and gradient control.

Although a computer program for a HP) 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 [1]. The design problems of the data acquisition and instrumentation package are technically similar to those encountered in solar heating and cooling systems.

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 methods are discussed.

Revised methods 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 introduced [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 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 groundwater 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. Davila 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 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. The 7 m (23 ft) diameter pond structure will be constructed by using two 1.2m (4 ft) high.

Commercially available pool frames are one of many options (see Fig. 3). The high sun angle in Puerto Rico can cause overheating of sloping sidewalls, which significantly increases heat loss via thermal convection along the walls and promotes upward salt transport by convective mixing. This issue was severe in a production pond built in Alice Springs in Northern Australia [26]. As a result, 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.

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-SSP, custom-cut and factory-welded to fit the pond shape. The secondary backup liner used is a 30 mil thick PVC liner.

The research pond will operate in conjunction with an evaporative pond of the same diameter as the research pond, but with a depth of only 1.2m (4 ft). The evaporative pond will have a single layer hypalon XR-5SP liner and thermally insulated walls. To reduce thermal interference 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 rainwater accumulation in the soil around the ponds. Soil thermal conductivity at the pond site is expected to be up to 2-5 Watts/m2. 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
Ground Water Pool	N/A	1	Sears Roebuck & Co., Chicago, IL

Engineering Tad Liner | N/A | 2 | Elite Packages, Mobile, Alabama
Rhainecring Tex Liner | N/A | 1 | Rhainecring, Mobile, Alabama
Urethane Insulation | 1.2m x 2m | N/A | McCarthy Manufacturing Co., Honolulu
Thermal Sensor | 80mm | N/A | Carolina's Folk, NC
Styrofoam Board | 1.2m x 2.4m | 50mm thick | Seyagder, PR
Thermocouple with wire | 2 gauge | 300m | Omega Engineering, Stanford, CT

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 a reason for the brine clarity. This measurement, along with those of heat escaping through the sides and bottom, 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.

The text appears to discuss various aspects of a system designed to monitor and control the temperature, humidity, etc., in pond environments. Here's an attempt to correct the text, but please note that some parts were too unclear to correct accurately:

"Nature, humidity, insolation and wind velocity. This data will be used to calculate the heat losses from the surface of the ponds. 4.1 Measurements. The sensors being used in meters are listed in Table 11. Measurement of the pond parameters will be done using platinum resistance thermometers, selected for measuring the brine temperature. The system’s 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 4 1/2 h.p. electric motor will circulate the brine in the heat exchanger. A shell and tube heat exchanger with a cast iron shell and 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..."

The remaining text is too garbled to correct and seems to have broken off mid-sentence. It looks like there might be some sort of encoding error or corruption that has caused the text to become scrambled.

Stage setup: The "09" is your key stage setup where you can power up the 'boards' and ensure they are functioning properly. This can be done using the Te)-fi WoT Tepow 'aer2uowauy' app which is compatible with your device. During this setup process, ensure that your power supply is adequate and stable. This will ensure that your stage setup (including any additional equipment) functions optimally.

Portions of the text need rewriting, starting with: "The pond's surface. Electrical conductivity used to determine brine density is useful, but they require calibration and re-platinizing of the electrode is desired. Pressure measurement is essential, but it can lead to large errors in field conditions and requires further development using investigative methods such as the vibrating U-tube, which looks promising. These are possible techniques for brine density measurement. In our research, a conductance meter will be used to test the pond and the density gradient 6ft (2 in) of the pond. The brine density values will be done hourly. The probe will consist of a section of PVC tube, a copper-constantan thermocouple and a conductivity sensor (preferably brass or plastic) rated at its variability per meter. The probe will circulate brine through the pond in the same horizontal plane from which it was taken by the probe. This electric conductivity measurement can be done without taking brine samples for the brine density with a salinometer. The measurement procedure calls for the samples to cool to room temperature in closed containers. Normal corrections for pond temperature are not necessary. An automatic method for scanning these collected values is described by R.P. Pynn et al. (23). A solar radiation meter will be used to measure the brine temperature, both convective and non-convective. Both data will be recorded hourly along with the temperature gradient measurements. Solar insolation data will be requested by a play integrator and printed by a digital recorder. The surface weather station will secure global and diffuse insulation every 3 minutes. An encapsulated cell can be used for brine transmissivity measurements, its spectral response is flat from the visible to approximately 1 μm in infrared. The response of this cell is indicated in the short pyranometer which will measure radioactivity in the upper circuit fashion, before being used however, the cell should be calibrated and correction factors determined in laboratory conditions. Wind speed and direction measurements will be done with a portable wind station."

The text appears to be about a scientific study. However, it is highly garbled and lacks clear context. Here's an attempt to correct it, but please note that specific technical terms or names might be incorrect due to the incomprehensibility of the original text:

"Section for Belk Science Station. Will he be asked to measure wind with wind sensors? The gadget that will transfer speed and direction from Met One. In this situation, the Hydrometer indicates the percentage. The concentration is directly in weight.

Table of rates:

Texenas - 103
Response - 70
Ergersene esep isvoraesg
Seg sex (door t, sex, ox)
Fazarzongunn J-Ftesaa suonters sostabod
S300Ts - 99
SS9008 Te 204
Sox ore - so
Savors sora
Spose dustaesgesTe - 8
Wore - son S
Saeots song
Sun9sF - 99
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The data will be transferred 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 S232 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		
Fischer Science Conductance Meter Model 32	1	Scientific Pittsburgh, Pa	
Bouyoucos Moisture Meter Model IPK25	1	Arthur I. Thomas, Philadelphia, Pa	
Digital WT Series U: Solar Data Printer Digital Recorder	1	Model 6240 Dayton, Ohio	
The Eppley Lab= Solar Data Integrator	Model 411	1	Laboratory Inc. Newport, Reis
Apple Computer Microcomputer Apple	1	Apple, Computer"	

Monitor Tabs Monitor Tabs Data Logger Model 9300. San Diego, CA. Flow Technology. Slave unit with 200 Channels. Phoenix, AZ. Campbell Scientific. Mode prt 1020. Logan, Utah. Campbell Scientific Micrologger Model cr2i. Logan, Utah. Campbell Scientific Model sc9sc. Flow Rate Monitor. Short Haul Calling Modem. Short Haul Answering Modem. Campbell Scientific Model sc95A. Logan, Utah.

5. DATA SCANNING SYSTEM

Figure 6 shows the two-dimensional scanning system for 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 using a combination of pulleys and electric motors, as shown in the figure. This underwater probe contains an LED platinum thermometer for temperature measurement, an electric conductivity cell, and an Eppley underwater radiometer.

Figure 7 shows the pulley and underwater probe arrangement. The scanning system would also include fixed LEDs, underground thermocouples, additional electric conductivity cells, flowmeters, and weather station instruments. The scanning would need to be done at the fastest rate needed by any one of the sensors. In this case, the fixed thermocouple data would be saved only every 24 hours, while the rest of the data would be discarded by the data acquisition system (Apple II microcomputer) until its scanning time is attained.

For a typical scanning operation, the measuring probe could be set at the bottom of the pond and then begin raising. The data acquisition system will then process the data. The scanning intervals can vary but could be as short as 30 seconds. During the operation, the horizontal position of the probe is manually adjusted.

The probe is positioned by an electric motor or a manual winch at a rate slow enough to minimize at 0.3 cm/sec. The data acquisition and signal scanning of each sensor are determined according to the needs. The data logger interfaced with the Apple II microcomputer will monitor the category as an electric motor pulls them through the water. The 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 adaptability to small size research ponds. A drawback is that the horizontal cable may be affected by wind conditions. An alternative to this system is the one-dimensional scanning system shown in Figure 2. The measuring unit, made of 5 cm (2 in) diameter PVC pipes, can only scan on the circumference of the pond by moving on the pond wire. Figure 9 shows details of the measuring unit's construction.

This system can be used in conjunction with a fixed or floating measuring platform, either manually operated or automatically operated by a cable and pulley system.

Fig. 8. One-Dimensional scanning System.

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.

The nucleus is associated with an Apple II microcomputer. A Monitor Labs 9300 data logger, when combined with an Apple II microcomputer, fulfills the function of a data acquisition system in our case. The data logger has forty channels assigned for thermocouple signal input, the twenty channels for R'D 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 48% 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 room with the Monitor Labs 9300 data logger in the foreground. Some disadvantages are inherent in this system because the Apple microcomputer can only initiate the scanning process, it cannot override the pre-set sequence. For most purposes, all the channels must be read and the data discarded.

The data logger is arranged in such a way that it can conduct electrical operations. A diffuser will calibrate salinity gradients. Figure 11 shows a detailed view of the diffuser. It maintains 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/m^2.

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, which will reduce surface water evaporation losses, it may be necessary to pump surface brine into the evaporation pond. Only small amounts of fresh water should be introduced onto the surface to build 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/m^2 (0.037 to 0.074 in/ft^2) 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. 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 is a concern. About 0.5 kg (1.1 lbs) per week of chlorine in the form of sodium hypochlorite and hydrochloric acids will be used to minimize bacteria growth in the pond by keeping the pH level at 6.5. Weekly brine samples will be taken and pH will be measured 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 bypass valve to permit periodic flushing with fresh water. For the research activities described above about 15 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 will be used to investigate the concept of pond-coupled dehumidification cooling.

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.

Acknowledgments

The authors acknowledge the fruitful comments of Dr. J. Re Mull of Argonne National Laboratory.

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