FINAL REPORT

Covering Period : June 1,1988 to December 31,1992

Submitted to the Office of the Science Advisor
U.S. Agency for International Development

MONITORING AND CONTROLLING THE SALT GRADIENT IN THE SOLAR PONDS

Principal Investigator : Mr.Surachai Limyingcharoen
Grantee Institution : Faculty of Engineering
Khon Kaen University

Collaborators : Professor Yehuda Taitel
Professor Arkardy Tsinober
Institution : Tel-Aviv University

Project Number : 936-5544.06
Grant Number : 936-5544-G-00-8041-00

A.I.D. Grant Project Officer : Dr.Miloslav Rechcigl

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1. Executive Summary

The purposes of the project were (1) to develop monitoring instruments for the solar pond and (2) to find a simple procedure for solar pond operation for less developed countries. No substantiable progress was obtained from the laboratory work at Khon Kaen University for the first objective.The collaboration work related to the first objective was partially carried out at Tel-Aviv University,however,its application to a practical solar pond would require some further modification and testing.

Two small solar ponds with necessary accessories were constructed for the field work on the second objective.The project experienced a long period of delay such that the most experiments were not be able to complete within the project duration as scheduled.

The problems experienced during the project work,however, revealed some weaknesses for developing countries that need to be strengthened before the solar pond technology can be widely used.

2. Research Objectives

2.1 Overall objectives

This research work is an attempt to study the effects of external disturbances, especially the tropical meteorological conditions on the top interfacial boundary of the salt gradient solar pond. Results of the research should help answer the question "To what extent do the tropical weather conditions affect the upper interfacial boundary of the salt gradient zone of the solar pond?"

The overall aim of the project is to develop a simple procedure for solar pond operation for less developed countries in the tropical area. This will give LDC's with an additional energy alternative with great potential for future development.

2.2 Specific objectives

The specific objectives are the following.

i) To develop electronic hydrometer for monitoring solar ponds conditions.

ii) To identify major factors affecting the top interfacing boundary fo the salt gradient in solar ponds.

iii) To develop appropriate procedure for solar pond operation in such a way that the effects of external disturbances on the salt gradient are minimised.

3. Methods and Results

3.1 Electronic hydrometer development

The work was carried out at Khon Kaen University as well as at Tel-Aviv University.At Khon Kaen University,three different type of operating principles were investigated.The first one was the use of differential pressure transducers,the second method was the measurement of buoyancy force,and the third method measured the speed of ultrasonic wave in the salt brine.

In the first stage of development, three models of differential pressure transducers were employed in the experiments for measuring the density of the salt brine.The preliminary results indicated that the operating ranges and the resolutions of transducers were not suitable for use.In addition,the transducers were not able to withstand the corrosion of the salt brine.

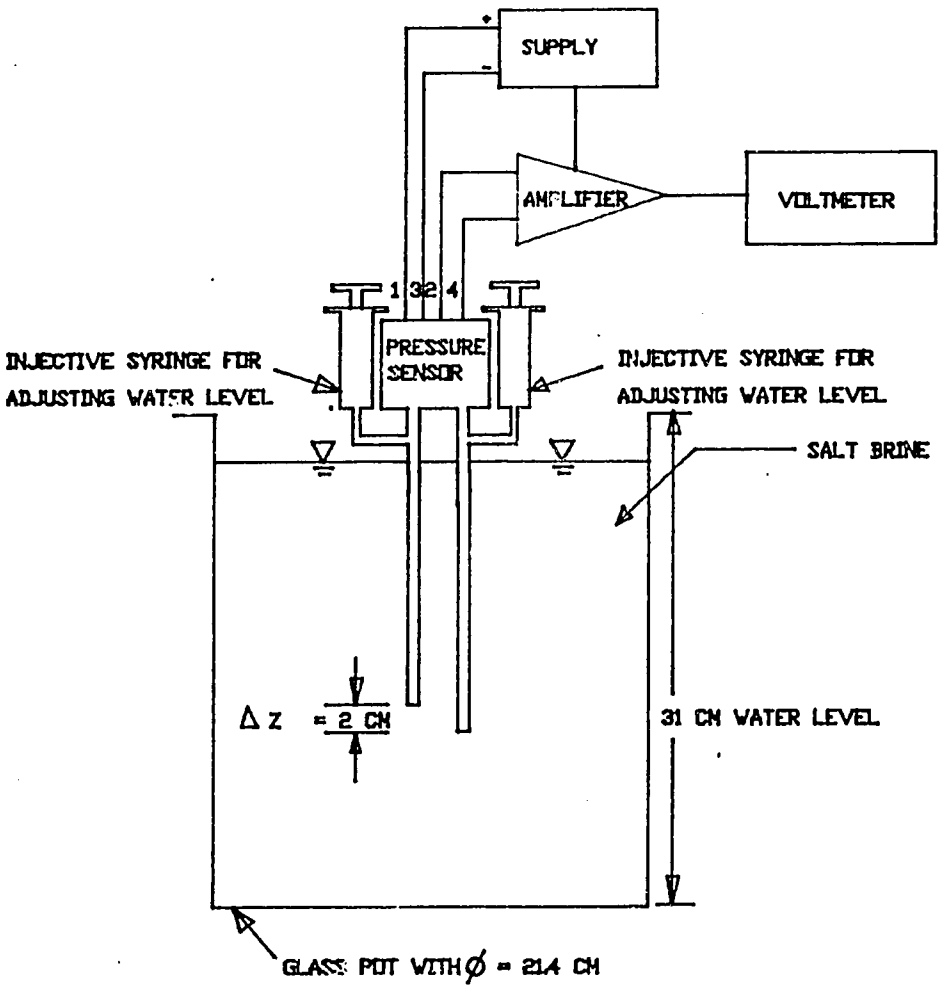

Figure 3.1.1 Field trial of pressure transducers

In the second attempt,prototype transducers for measuring the buoyancy of a glass disc (which directly related to the density of the brine) based on the principle of force balancing technique were designed.Due to the lack of precision machine tools and skilled workers in the area the prototypes did not perform as desired although the electronic components worked satisfactorily.

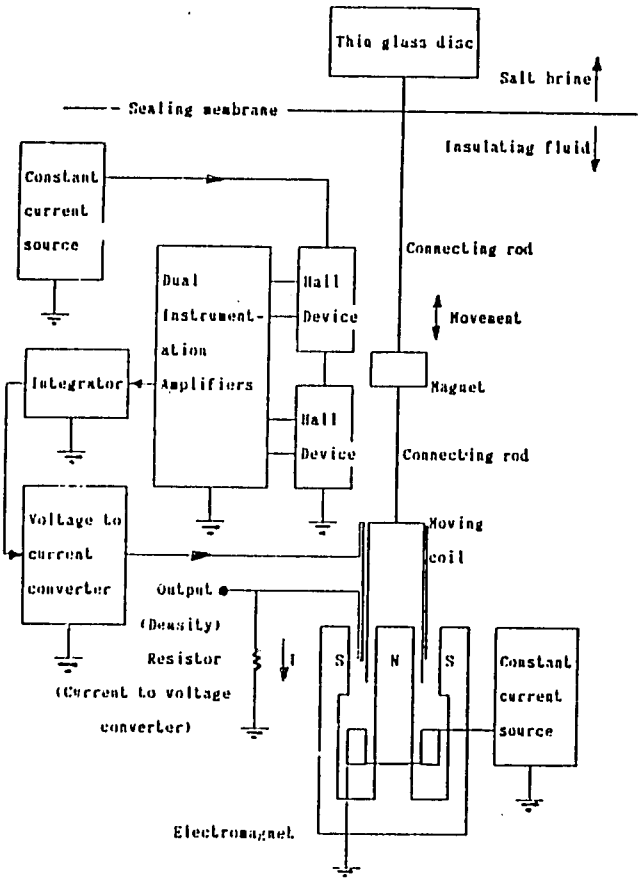

Figure 3.1.2 Schematic diagram of the density measurement system employing the principle of force balancing feedback

Following the earlier unsuccessful attempts,another method was examined.Ultrasonic transmitter and receiver pairs were used to measure the speed of sound in the brine of various densities.The activity was still in progress at the end of the project duration therefore the conclusion of the work was not available.

In parallel to the activities at Khon Kaen University, collaboration work on the development of instrument for measuring the density and temperature profiles in the KKU solar ponds was carried out at Tel-Aviv University. The instrument worked well during in-door tests at Tel-Aviv University, however, it's dimensions were not applicable for installation at Khon Kaen University.

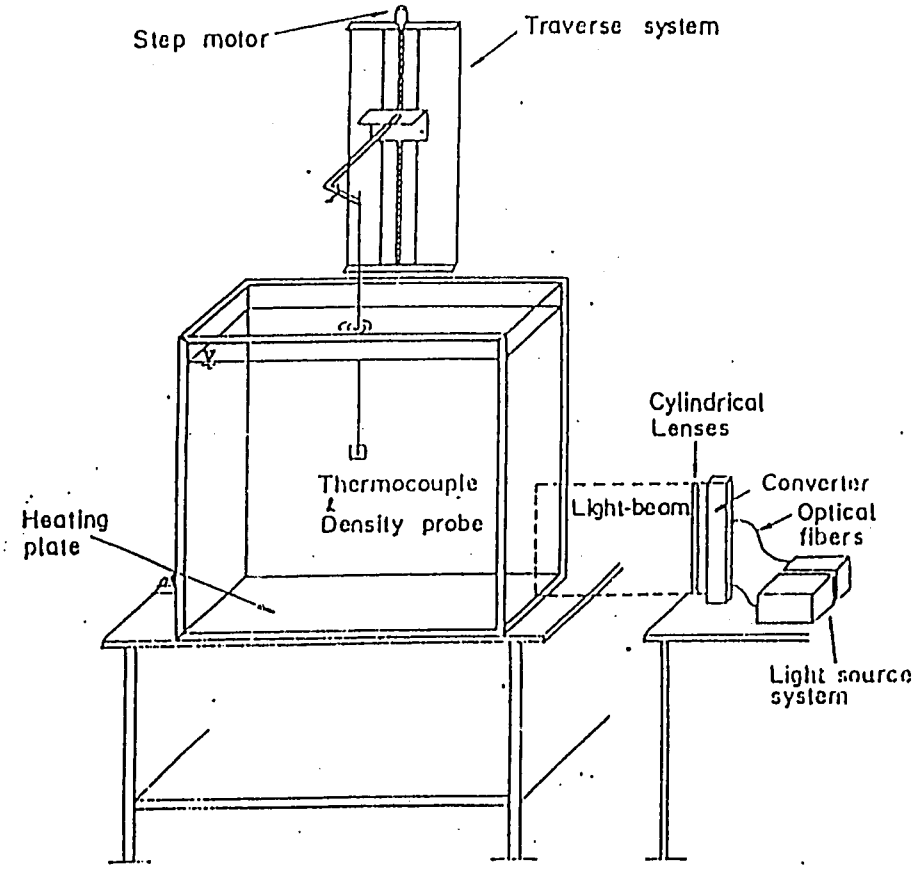

Figure 3.1.3 Shematic of experiment undertaken at Tel-Aviv University

3.2 Study of factors affecting the top interfacial boundary of the salt gradient zone

Two solar ponds each of which had a surface area of 6mx9m and a depth of 2.5 meters were contructed on the campus near the Department of Electrical Engineering of Khon Kaen University.Each solar pond was equipped with a thermocouple stand for measuring teperatures at various depth. The thermocouples were connected to mutiplexers of a data acquistition card. The signals were converted to a digital format and subsequently recorded on the hard disc of a microcomputer. Wind speed, solar radiation intensity and humidity were also recorded.

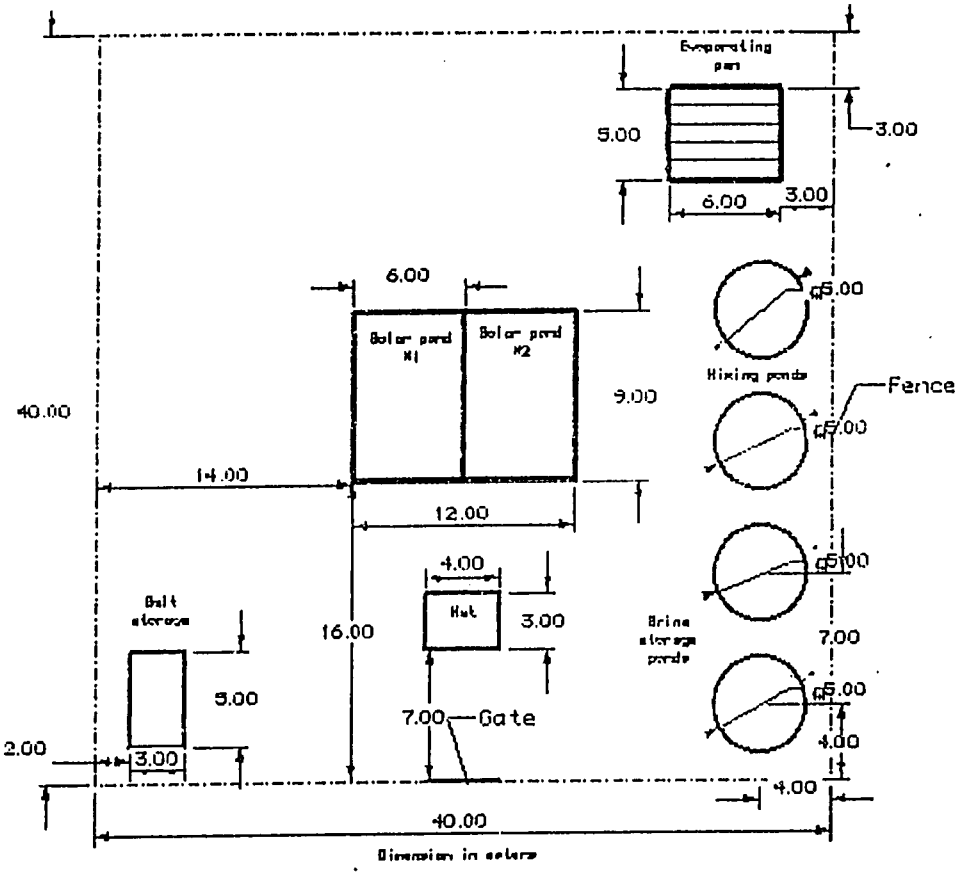

Figure 3.2.1 Layout plan for KKU solar pond site

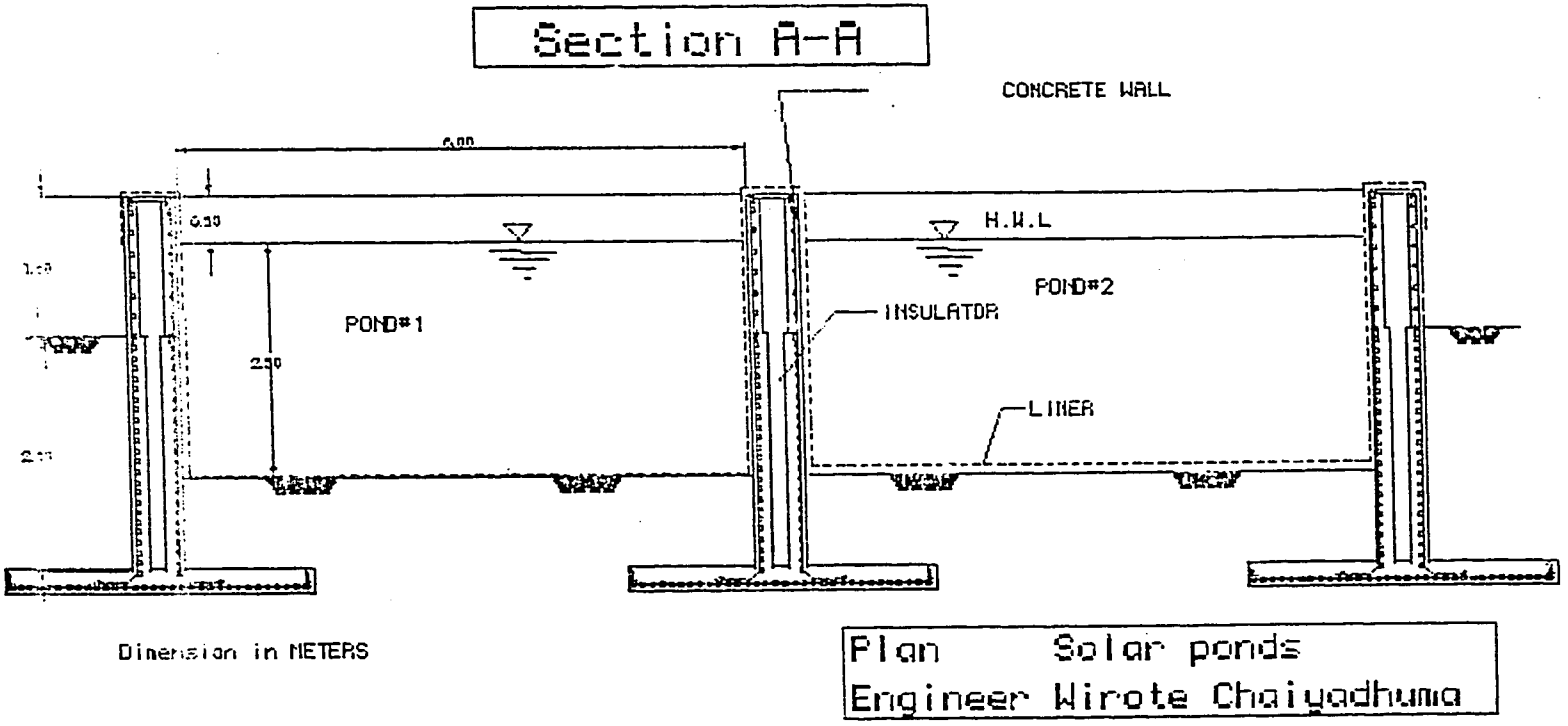

Figure 3.2.2 Sectionalised plan of the solar ponds

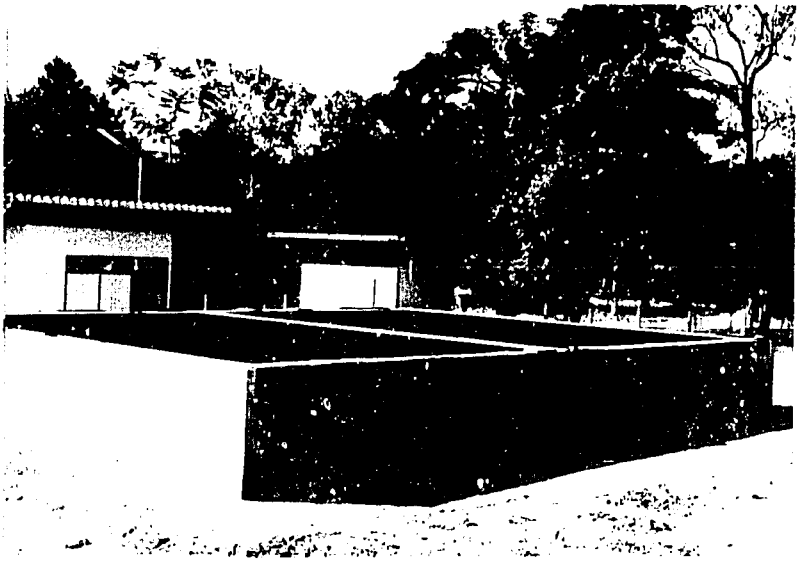

Figure 3.2.3 Photograph of the KKU solar ponds

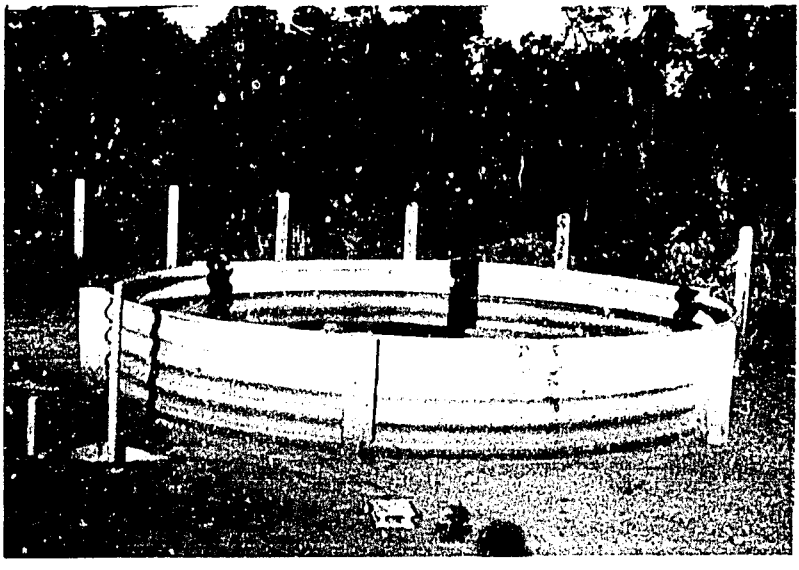

Figure 3.2.4 Photograph of a brine mixing pond

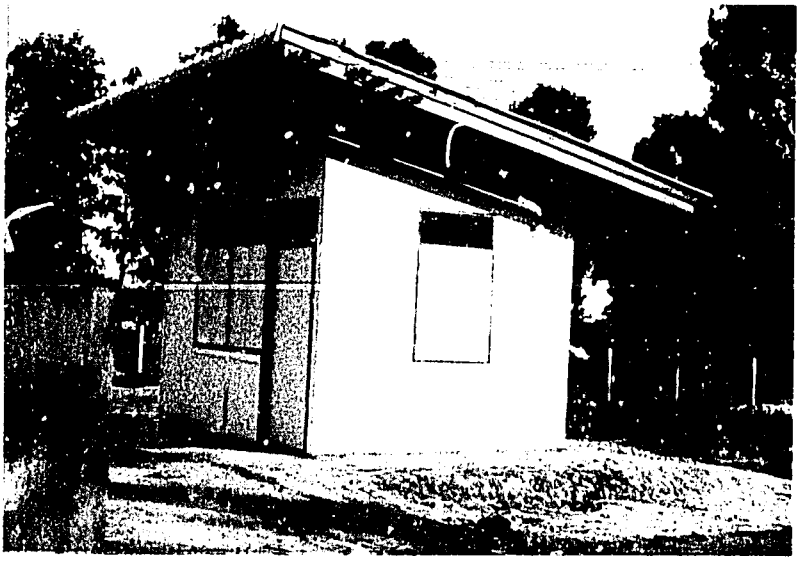

Figure 3.2.5 Photograph of the instrument hut

Figure 3.2.6 Photograph of the evaporating pan

The commissioning of the solar ponds was delayed several times due to the leakage of the lining material. The work was also temporarily suspended as instructed by USAID when the Thai Civillian Government had been overthrown by the National Peace Keeping Force. It was until the beginning of 1992 that one of the two solar ponds was ready for the establishment of the salt gradient.The density profiles obtained by taking samples of the brines at specified depths showed the deepening of the top interfacial boundary of the salt gradient despite the fact that the suface of the water was 1.1 meters lower than the top edge of the sidewalls. This would have greatly reduced the effect of the prevailing winds. A thin salt gradient layer was also observed to have been created by rain on the pond's surface.

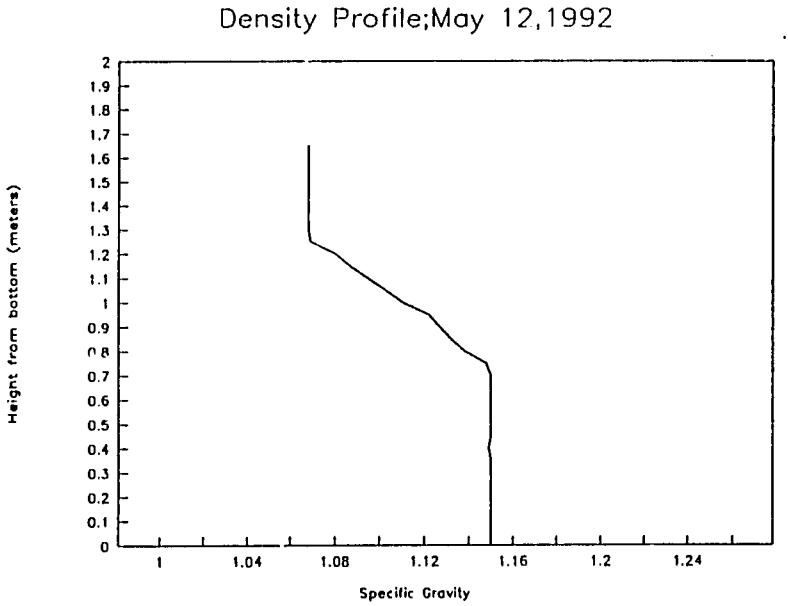

Figure 3.2.7 Density profile of the west solar pond on May 12,1992

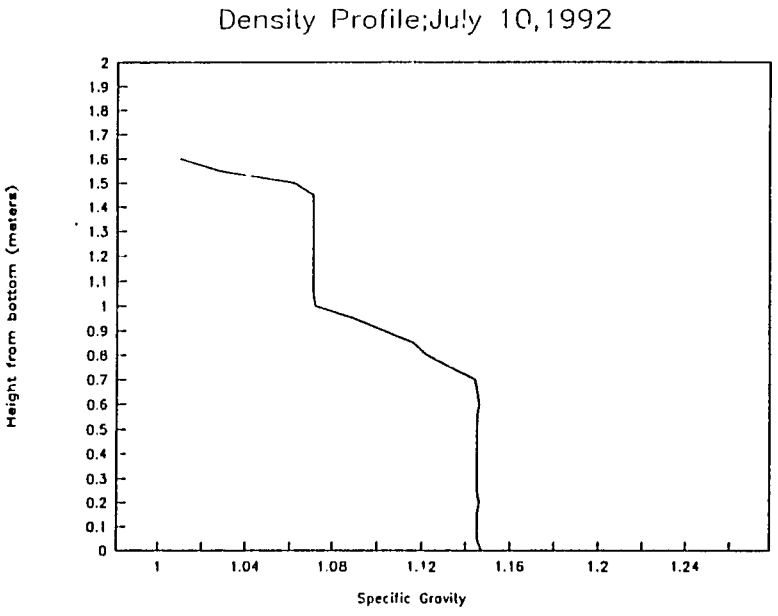

Figure 3.2.8 Density profile of the west solar pond on July 10,1992

After three months of uncontrolled operation the salt gradient deteriorated to an unacceptable level. Brine injections through a semi-circular disc shaped diffuser were carried out to restore the thickness of the salt gradient. The restoration of the gradient was completed in November 1992. Additional density profiles were obtained by regularly measuring the specific gravity of the brine samples. The data collected during this short period toward the end of the research project was inadequated to draw any further conclusion about the salt gradient. It was, however, observed that during the dry season the surface of the water was covered by a thin film of dust blown into the solar pond by the winds. The skimming off the dust film was necessary as it reduced the solar radiation that penetrated through the surface of the pond.

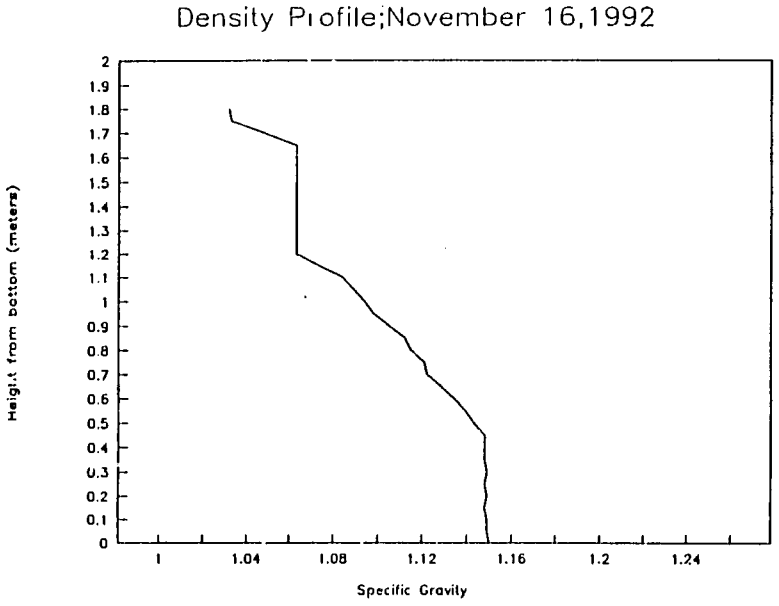

Figure 3.2.9 Density profile of the solar pond on November 16,1992

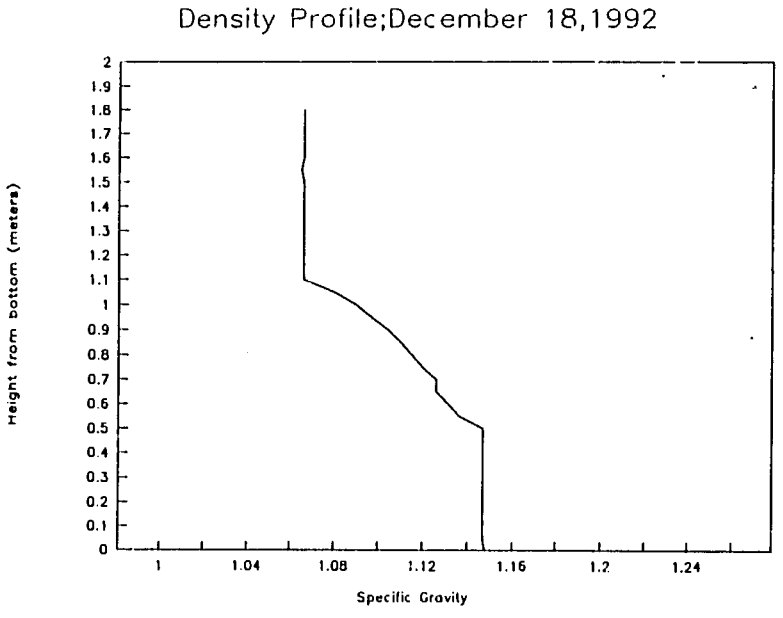

Figure 3.2.10 Density profile of the solar pond on December 18,1992

The other solar pond(the east pond) was still under test to find a minor leaking spot when the project was brought to its end.

3.3 Study of salt gradient manipulation

The study of the manipulation of the salt gradient was not possible due to the prolonged delay which was caused by the leakage of the lining material.

4. Impact,Relevance and Technology Transfer

The findings in relation to the objectives were not substantial.Nevertheless,the problems encountered during the project revealed the weakness of the local suppliers in supporting the development of the research in the solar pond.

The requirements for several types o. monitoring instruments for the solar pond especially those not commercially available were taken as topics for electrical engineering projects for undergraduate and postgraduate students. The project also provided practical experiences for several students from two technical colleges in the area. The project also provided theoretical and practical experiences in advanced electronic instrumentation for a technician of the Department of Electrical Engineering as he joined the work on a part-time basis.

The instruments that were acquired and the software for controlling the data logging system that was developed during the project will provide a foundation for advanced instrumentation laboratory. Moreover,the Faculty of Engineering decided not to abandon the solar ponds so that furthers research activities can be undertaken in the future.

The experiences that the investigators accummulated during the work on the instrumentation of meteorological data have enable them to provide consultation on the measurment of solar radiation to a reseach team of the Faculty of Agriculture.

5. Project Activities/Outputs

A lecture on double diffusive process in the solar pond was delivered to the KKU solar pond research team including interested staff members of the Department of Mechanical Engineering by Dr.Harel and Dr.Tanny of Tel-Aviv University during their visit to Khon Kaen University.

6. Project Productivity

The overall goal of the project to develop a simple procedure for solar pond operation for less develop countries in the tropical area was not accomplished because of three main causes. The first cause was the unexpected increase in the construction cost due to rapid expansion of Thailand's economy when the project began in 1988. The construction cost was the largest budget item. Its increase necesitated the reduction of the other budget items. Limiting the increase in construction cost meant limited availibilty of lining materials for the solar ponds.

The second cause was the rapid increase in salary for engineers and technicians.High economic growth rate and limited supply of engineers and technicians created a situation where private firms offerred a high salary to fill their vacancies. Since this project was not able to compete with the private firms the turn-over of the technician was high. The employment of a full-time research assistant was not possible. The continuity of instrument development was thus degraded.

The last cause was the prolonged delay which was caused by the leakage of the lining material of the solar ponds.Several firms were contacted for lining materials suitable for solar pond operation. All of them declined to import such materials for the reason of small sale volume and a specific procedure was required for installation. It was not appropriate for them to get their technician trained abroard for only one installation even if the training cost were paid by the

research project. PVC sheet which was locally available, but less suitable for conditions in the solar pond was then used. This was the consequence of the first cause.

7. Future work

The work that had not been completed during the project period especially that on the solar pond monitoring will be carried on on a reduced scale through another financial source.
