THE ARK PROJECT
R. R. #4, SOURIS, P. E. I.

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ABSTRACT

Both active and passive solar heating systems are employed at the P. E. I. Ark. An active drain-down system, which stores heat in water located in 70,000 litre concrete tanks, supplies heat to the living area. Domestic hot water is heated by a thermosiphon drain-down solar system coupled to a wood cookstove. Environmental design of the Ark allows for maximum use of passive solar energy. The passive system supplies the majority of the heating load on sunny days, while wood stoves supply the back-up heat. The performance of the active system has required high maintenance because of problems in the mechanical and electrical systems. This, coupled with the high initial cost, has not made the system cost effective. The 178m^2 commercial greenhouse uses a hybrid system with both active and passive systems. The active system employs a fan to draw air through rock storage. The passive system employs the high thermal mass of the deep soil beds, a concrete slab, and most importantly, 53,200 litres of water in translucent tanks. These tanks are then used for fish rearing and are the basis for a solar hatchery. The greenhouse has performed very well, producing crops year round since 1976.

INTRODUCTION

The Ark Project at Spry Point, Prince Edward Island, is an experiment in alternatives which focusses on indoor and outdoor food production, alternative architecture and the examination of alternative ways of providing energy. The common theme throughout is an integrative approach to greater self-reliance. Occupying approximately 490m^2, the Ark contains a home, two greenhouses, an aquaculture facility and office/laboratory space. The entire structure relies on a unique combination of active and passive solar systems plus supplementary wood stoves to provide heat for its occupants; namely--people, plants and fish.

The Ark, built in 1975-76, was one of the first solar installations in Canada. As a result, this "solar infant" has suffered growing pains with both equipment and general design. This paper documents some of the experiences with these systems for the benefit of those who follow.

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SYSTEMS AND RESULTS

Monitoring

Recording of environmental and performance data for the first two years of the Ark was on strip charts. These are cumbersome and difficult to read and analyze. In November, 1978, a MICROLOG Computer System was installed. This system was designed specifically for New Alchemy Institute by MICROLOG, Guilford, Connecticut, to operate in the variable temperatures and high humidity environments found in the Cape Cod and P. E. I. Arks (1). The system displays and records data on temperature, solar radiation and dissolved oxygen which allows for monitoring of the performance of the active solar space heating system, the greenhouse and aquaculture system. This system was debugged and tested during the winter past with the unfortunate result that critical data, most notably that on greenhouse performance, is considered to be unreliable.

Passive Solar Heating

The passive solar system supplies most of the heat to the living area of the Ark on sunny winter days. Heat is collected in the living area through south and west-facing, glass doors and through the attached kitchen greenhouse. Rocks, concrete and water add to the thermal mass aiding in heat storage. Passive use of solar energy involves proper orientation to the sun and wind. A berm of earth was bulldozed into position on the north side of the Ark thus deflecting prevailing winter winds over the Ark's sloping roof. Walls and roof are tightly built and well insulated. R20 fibreglass insulation is used in the walls and R40 in the roof. Although the Ark sits low to the north, it rises high on the south to meet the sun. It is long on an east-west axis, to provide maximum southern exposure. While no detailed monitoring has been carried out in the living area, preliminary estimates suggest passive design supplies over 50 percent of the heating requirements. On some sunny winter days with outside temperatures -10°C to -20°C, heat has to be dumped through rooftop vents or an open door. The planned addition of vents from the living room to upstairs bedroom/offices should remove the need for venting of the excess heat and solve the problem of poor heat distribution to these rooms. The efficiency of the passive system will be improved during 1979-1980 by the installation of a reflective curtain made of aluminized fabric. This is expected to halve the nighttime heat losses.

In spite of the large area of south-facing glazing surface, the Ark does not overheat during summer days. The high profile and strategic location of windows and vents create positive internal pressure which aids ventilation and causes the building to be passively cooled. This process is aided by the high wind speeds found at this exposed coastal location.

Active Solar Space Heating System

The main heating for the Ark was intended to be an active solar system. Thirty-six "Sunworks" flat plate collectors ($65m^2$) are mounted at 90° on the peak of the building. These collectors, using water, are connected via a drain-down system to three concrete storage tanks (70,000 litres) located beneath the living room. The tanks were insulated with 10 cm of urethane foam sprayed in place and water-proofed with a butyl rubber coating (Elastron). Heat is supplied to the living area by a hot air system which draws heat from storage via a finned coil heat exchanger.

The solar system has been in operation since the summer of 1977. Problems due to failures of sensors, controllers and collectors (see table 1) have prevented it from functioning as a reliable heat supply for the living quarters. The active solar system is now supplemented by a wood space heater and wood kitchen stove.

In addition to the breakdowns, the inaccessibility of the collectors at the peak of the building prevents ready repair and accounts for the considerable down time of the system. It is also impossible to monitor the performance of individual banks of collectors and, indeed, to determine if adequate flow rates occur in the various banks. Some problems have also been encountered with the hot air circulation system. Poor mounting and lack of insulation in the air ducts resulted in high noise levels and a bearing had to be replaced. The collectors when operational do perform efficiently. Energy collection on two sunny days in January, 1979, was over 100,000 Kcal and preliminary calculations of efficiency were 62 to 75 percent. However, these calculations are only approximate because it is impossible to determine the volume of the storage tanks.

Energy collection, as expected, is much reduced during summer because of the high angle of the sun. In early July only 67,000 Kcal of heat were collected in spite of the fact that the solar radiation measured on a horizontal surface was three times that in January.

Solar Domestic Hot Water

Domestic hot water at the Ark is heated by 11.6m^2 of solar collectors, mounted at 60^o angle. Three collectors: Sunworks, Guilford, Connecticut; Solartherm, Weston, Ontario; and Hoflar, Surrey, British Columbia, are compared. These collectors were all early models produced by these companies. The system is thermosiphon drain-down (Fig. 1). During winter, a three-way solenoid valve drains the bottom when the sensor detects cooling rather than heating. Two check valves at the water tank are closed by the surge of water from the pressurized water tank. When the temperature rises again to collection temperatures, the solenoid fills the collectors again, opening the check valves. The air escapes through the vacuum breakers. During summer, the solenoid valve is overridden and the system becomes a simple thermosiphon.

Performance of the D. H. W. system has been much more reliable than the space heating system. However, there have still been problems. (See Table 2). A recent inspection of the D. H. W. collectors indicates all have lost some of the flat black or selective absorber coating. The Solartherm collectors have paint lifting where the flux was not removed during the original soldering. The fibreglass glazing on the Hoflar collector has deteriorated and discoloured. The glazing on one of the Hoflar collectors was broken when searching for leaks and is now further deteriorating. We are currently planning to replace some of the collectors with newer systems.

The D. H. W. system is not yet monitored by the computer system so we have no information on its performance. However, the solar system supplied all the hot water used at the Ark during May to November, 1978. Since then a wood cookstove with water jacket, integrated with the solar system, has served as back-up. This solar-wood system now supplies all of the hot water used at the Ark.

Greenhouse Solar System

The 178m^2 commercial greenhouse is heated by a hybrid solar system which has both passive and active features. The greenhouse, glazed with Acrylite SDP, is the solar collector. The passive system employs the high thermal mass of the deep soil beds, a concrete slab and most importantly, the 50,000 litres of water in the aquaculture tanks. A preliminary thermal model (2) of the greenhouse suggests that the water in the tanks stores about 60 percent of the winter heat. The active system uses an air-rock heat storage system. An 86m^2 bin of smooth river stones is located on the north side of the greenhouse. On sunny days it is heated by drawing the warm air accumulating at the ridge of the greenhouse down through the rock pile and forcing it back out through ducts along the growing benches just below the south windows. The only energy needed for this heat storage system is the electricity for the circulating fan, about 500kwh/month. A back-up wood-fired boiler system was installed and intended to add heat at critical times by circulating water through a heat-exchanging coil in the rock storage system duct. The boiler has been tested for short periods but was found to be inadequate.

The Ark greenhouse has now operated for three winters and produced crops at above-freezing temperatures. An indication of temperature performance is given in Figure 2 where data for December, 1977, to February, 1978, is presented. Minimum soil temperatures of 7^{o}C occurred in December with fairly constant temperatures being maintained in spite of cold outside temperatures. Temperatures increased abruptly in February. Reliable data for winter 1978-79 is not available as mentioned previously in the Monitoring Section. However, indications are that the greenhouse was warmer partly due to a third layer of 4mm polyethelyene glazing. Minimum night air temperatures of 5-6^{o}C were common during December - February. These temperatures are lower than those found in other commercial greenhouses but can be managed by appropriate cropping strategies(3).

DISCUSSION

It is evident that the performance of the various solar energy systems at the P. E. I. Ark have not worked perfectly. The active solar space heating system, for example, has never performed satisfactorily. However, there have been notable successes. The passive design has lead directly to the design and building of low income conserving homes on P. E. I. The greenhouse, Canada's largest total solar greenhouse, has operated successfully for three years and is now leading us into the design of lower cost greenhouses with commercial possibilities. The Ark, like some of the other pioneering solar projects, has shown that solar energy works. The challenge now is to learn from our mistakes and reduce costs to produce systems that really will bring solar energy down to earth!

REFERENCES

1. Albert M. Doolittle, Jr. 1979. Calculating Engines. The Journal of the New Alchemists, 5:14-16.

2. Joseph Seale. 1979. Where does all the Heat Go. The Journal of the New Alchemists, 5:126-134.

3. L. A. Gilkeson. 1979. Management of Solar Greenhouses. SESCI Annual Meeting, Charlottetown, P. E. I. 6 pp.

TABLE 1

PROBLEMS WITH THE ACTIVE SOLAR SPACE HEATING SYSTEM AT THE P. E. I. ARK

DATE	SYMPTOM	PROBLEM	SOLUTION
June 1977 - July 1979	Tank selection for heat collection or heat extraction not reliable.	Controllers not properly installed or adjusted.	Override automatic controls manually. Controls repaired by service technician July 1979.
January, February 1979	Tank overflow.	Controllers selecting from one tank returning to another; equalization tubes between tanks plugged with insulation.	
Winter 1977	Broken collector tube.	Wrong valve turned during winter resulting in freezing.	Solder pipe (Spring 1977).
February 1979	Broken collector tube (same collector as above).	Possible frozen pipe due to blockage and failure to drain down.	Solder pipe (May 1979).
June 1977 - Winter 1978	Collectors turning on or off at wrong time.	Automatic controls not reliable.	Temperature sensor replaced with light sensor.
Winter 1978 - July 1978	Collectors turning on or off at wrong time.	Light sensor electronics failed.	Revert to manual control.
May 1979	Collector surface browning.	Black selective coating has vaporized off some collectors.	

TABLE 2

PROBLEMS WITH THE SOLAR DOMESTIC HOT WATER SYSTEM AT THE P. E. I. ARK

DATE	SYMPTOM	PROBLEM	SOLUTION
June 1977 - June 1978	Poor drain down.	Dump valve poorly installed.	Valve remounted in different location.
June 1977 - Winter 1978	Collector draining down at wrong time.	Temperature sensor unreliable.	Manual control.
Winter 1978	Leaking collector. (Solartherm)	Faulty soldering.	Resoldered.
February 1979	Leaking collector. (Solartherm)	Pin hole in collector.	Resoldered, May 1979.

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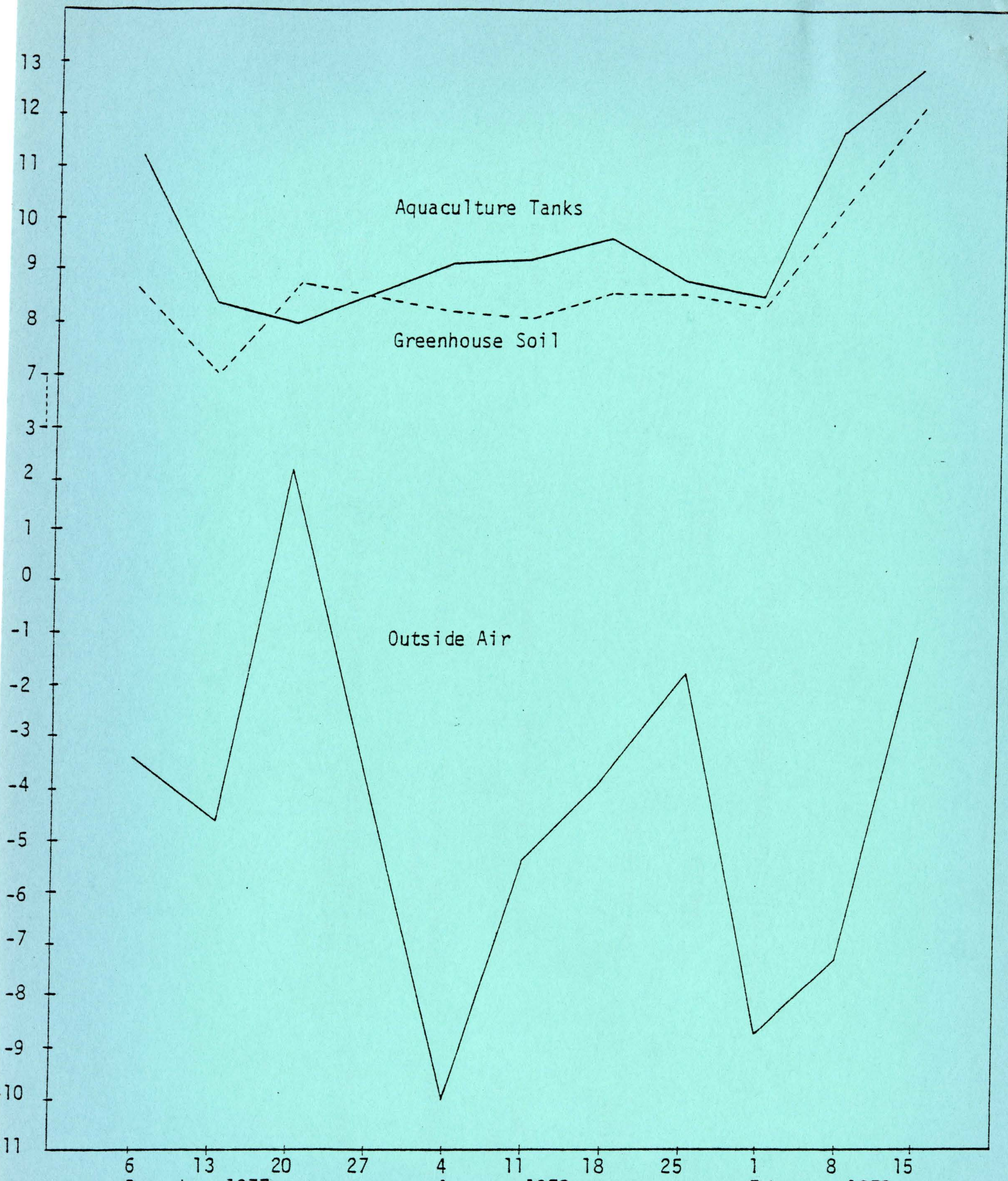

Figure 2: Average Weekly temperatures for outside air, soil and aquaculture tanks in the commercial greenhouse at the PEI Ark.(From: "Solar Energy at the P. E. I. Ark" in Solar Energy Conversion, An Introductory Course Pergamon Press, 1979.)

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