COOLING PERFORMANCE CURVE FOR THE NEBRASKA MODIFIED ROOF POND

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ABSTRACT

A Cooling performance curve for the Nebraska Modified Roof Pond is presented in this paper. For a given fixed pond temperature the generated curve is a plot of the total deliverable Cooling versus the ambient outdoor temperature. This Cooling performance curve occurs for a fixed water temperature of 21.1 °C (70.0 °F). Each test point requires one complete night of testing. The peak Cooling capacity for the test period exceed 6 kilowatt-hours per square meter of roof pond area for an 8.5 hour interval when the pump is on.

INTRODUCTION

The 21.1 °C Cooling performance curve represents work performed by the Passive Solar Research Group during the summer of 1986 when the roof pond itself was effectively decoupled from the test room, Figure I shows the altered configuration for the 1986 summer experiments. The goal of the summer research was to measure the Cooling capacity directly by keeping the pond temperature constant with thermostatically controlled heaters that turned on whenever the pond went below its minimum preset temperature. Thus the monitored hat input represents the Cooling capacity for the preset pond temperature. One will note that in addition to the floating cement coated insulation, the pond is itself surrounded with a 9.2 cm (4.0 inch) layer. of rigid insulation.

The Nebraska Modified Roof pond is an evolutionary design by Richard Bourne of the Davis Energy Group and Bing Chen who is at the Solar Energy Research Institute on sabbatical from the University of Nebraska at Lincoln. In contrast to the original roof pond concept as developed by Harold Hay the Nebraska Modified Roof Pond eliminates the need for moving roof shutters and utilizes convection and evaporation as an integral part of the Cooling process. For climates requiring heating the Nebraska Modified Roof Pond employs passive Solar heating in either direct gain or thermosiphon modes thus avoiding the need for a skylid. Thus the building is blazed along its Southern exposure as is shown in Figure 1.

EXPERIMENTAL TECHNIQUE

Each experiment consisted of keeping the pond temperature fixed over the entire test period by the use of water bed heaters which are immersed within the pond. Heat loss due to evaporation/convection and radiation occurs at night when water is pumped over the cement coated floating insulation. The water then migrates downwards via cracks in

between the various members of the floating insulation and reenters the pond as shown in Figure 1. In order to maintain a fixed pond temperature monitored electrical energy is delivered to the immersed water bed heaters. This monitored energy represents the pond's effective Cooling capacity at that fixed pond temperature for the particular weather conditions encountered.

Experiments were carried out for different @ond temperatures which included 15.6 ℃ (6OoO ℉)t 21*1 ℃ (7OeO ℉)t 26o7 ℃, (80.0 ℉) and 29.4 ℃ (85.0 ℉). Cooling performance curves for these forementioned temperatures are not presented due to several critical factors including nonuniform spray distribution patterns upon the roof and in some cases an insuf f icient number of data points. When the pump rate was doubled at 21.1 ℃ (70*0 ℉) the flow distribution of the water was now uniform. This set of experiments contains the largest data base. It is from these experiments that the performance curve was generated. Each of the data points in the performance curve consist of the accumulated and averaged results form one entire night of testing. During each night the pump which is timer controlled is turned on for an 8.5 hour period.

The pond has a total area of 2.6 square meters. During the test period the pond was filled to a depth of 34.3 cm (13.5 in.). A submersible pump was used which has a flowrate of 1375 liters per hour per square meter. Solar radiation measurements were made with a PSP Eppley pyrradiometer and a Fritschen WEATHERtronics #3040 pyrradiometer (for night sky measurements). An evapograph, wind velocity sensor and dew point meter (all from WEATHERtronics) provided data most of which went to an Instrulab #2000 data logger. Dipped, type T thermocouples provided temperature data.

EXPERIMENTAL RESULTS

There are 139 days of data collected for the summer 1986 experiments. For the generated performance curve, the 21.1 ℃ (70*0 ℉) at 1375 liter/ml-hr has the largest data set. For each night the ambient temperature and water temperature are averaged. The input energy to maintain the pond temperature is integrated and the nightly summed total represents the Cooling capacity for a day which is provided by the 8.5 hour cycle during which the pump was on each night. The difference between starting and ending water temperatures is also taken into account for the Cooling capacity.

Due to problems caused by wind and humidity instrumentation failures, we were formed to rely on north 6 Omaha weather station data. In addition to wind and humidity information the cloudiness factor data was also obtained form the weather station.

Figure 2 displays the Cooling performance for the 21.1 ℃ fixed pond temperature. The Cooling capacity is shown in kilowatt hours per square mete per night and is plotted against the average ambient outdoor temperature for , the night. Each data point represents one night's performance given different conditions for humidity, wind speed, cloudiness factor and rain conditions. Refer to Table 1. In spite of this limped parameter base of diverse weather conditions there is a discernible pattern that emerges from the data. The Cooling capacity of the pond decreases as the ambient outdoor temperature increases.

The equation for the Cooling capacity is given by;
Q 7804 -364 x TAMBIENT
where
Q: Cooling capacity per day in watt-hours per square meter

TAMBIENT: ambient outdoor temperature in degrees Celsius

The value of r2 for the data is 0.91. This value represents the square of the correlation

coefficient for the straight light generated by the individual data points.
z

For this set of data the pond flow distribution atop the cement coated rigid insulation was uniform. On an hour by hour basis the pond experienced some variations in pond temperature. This is due to the fact that the immersed water bed heaters could not keep up with the heat being lost at night.

CONCLUSIONS

1. Cooling capacity decreases in direct proportion to increasing ambient temperature. The peak Cooling achieved for the @ven 1375 liter/m'hr over an 8.5 hour pump cycle was in the vicinity of 6.4 kWh/ml- for the 21.1 ℃ fixed pond temperature.

2. For fixed pond temperatures Cooling capacity decrease as pump flowrate decreases. The optimum flow rate for maximum Cooling has not yet been determined.

3. Although wind speed, humidity and cloud cover are treated as a lumped parameter, preliminary indications show that as expected Cooling capacity is adversely affected by high levels of humidity, heavy cloud cover and low wind speeds.

4. Care should be taken in generalizing our test results. Cooling performance could be affected by a number of factors such as larger roof area, different wind profiles due to building geometries such as parapet height over the pond and the uniformity of the wetting of the pond surface.

FUTURE STUDIES

1. Data is available for an hour by hour analysis of Cooling performance which takes into account such factors as humidity, wind speed, cloud cover and rainfall.

2. A thermal model for predicting winter heating performance will be developed using existing 1987 winter data.

3. Our future analysis is aimed specifically at separating the night sky radiation from the evaporation and convection components,

4. Should resources become available there will be side by side comparison of the Nebraska Modified Roof Pond with the original roof pond concept as developed by Harold Hay.

ACKNOWLEDGMENT

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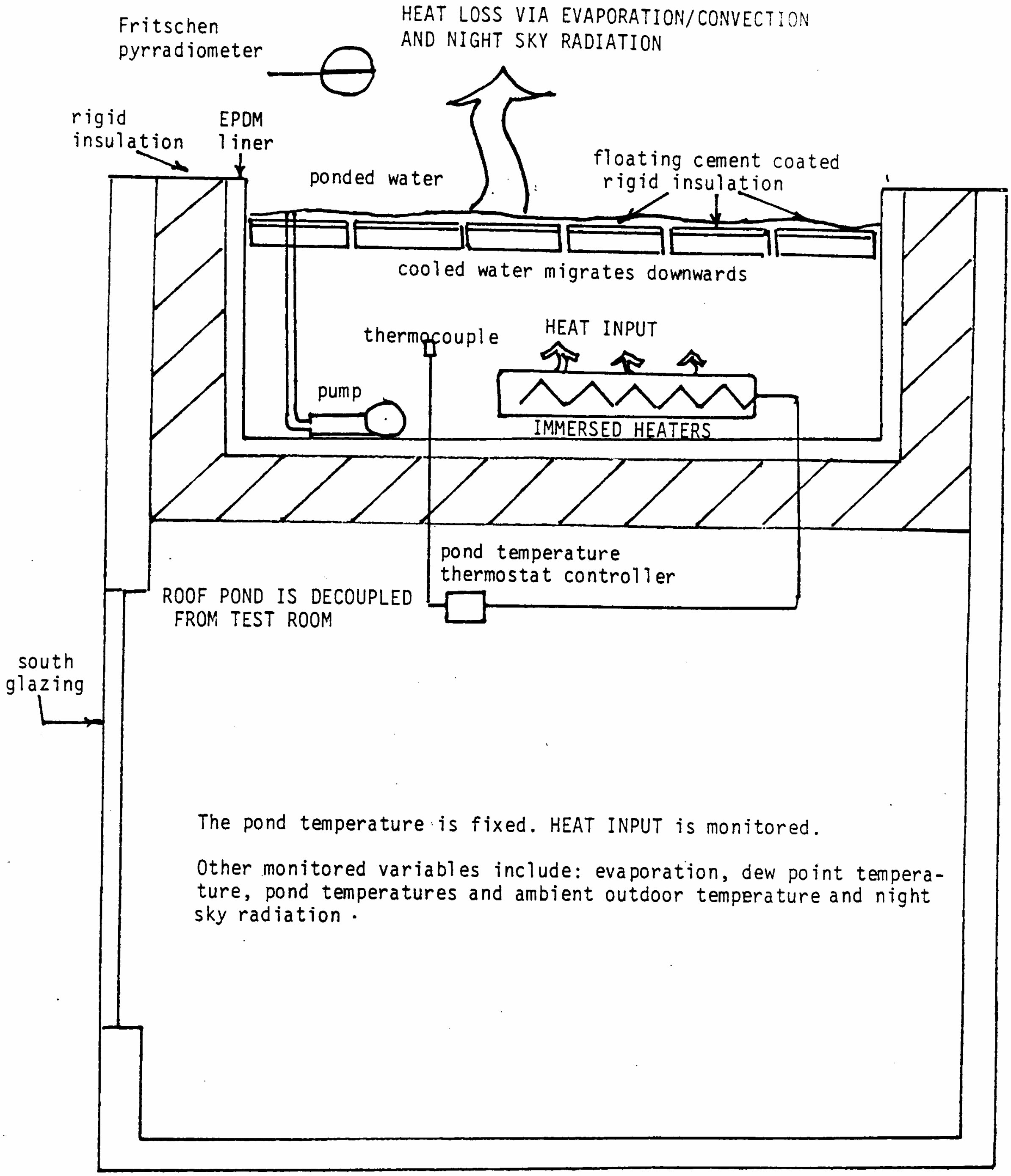
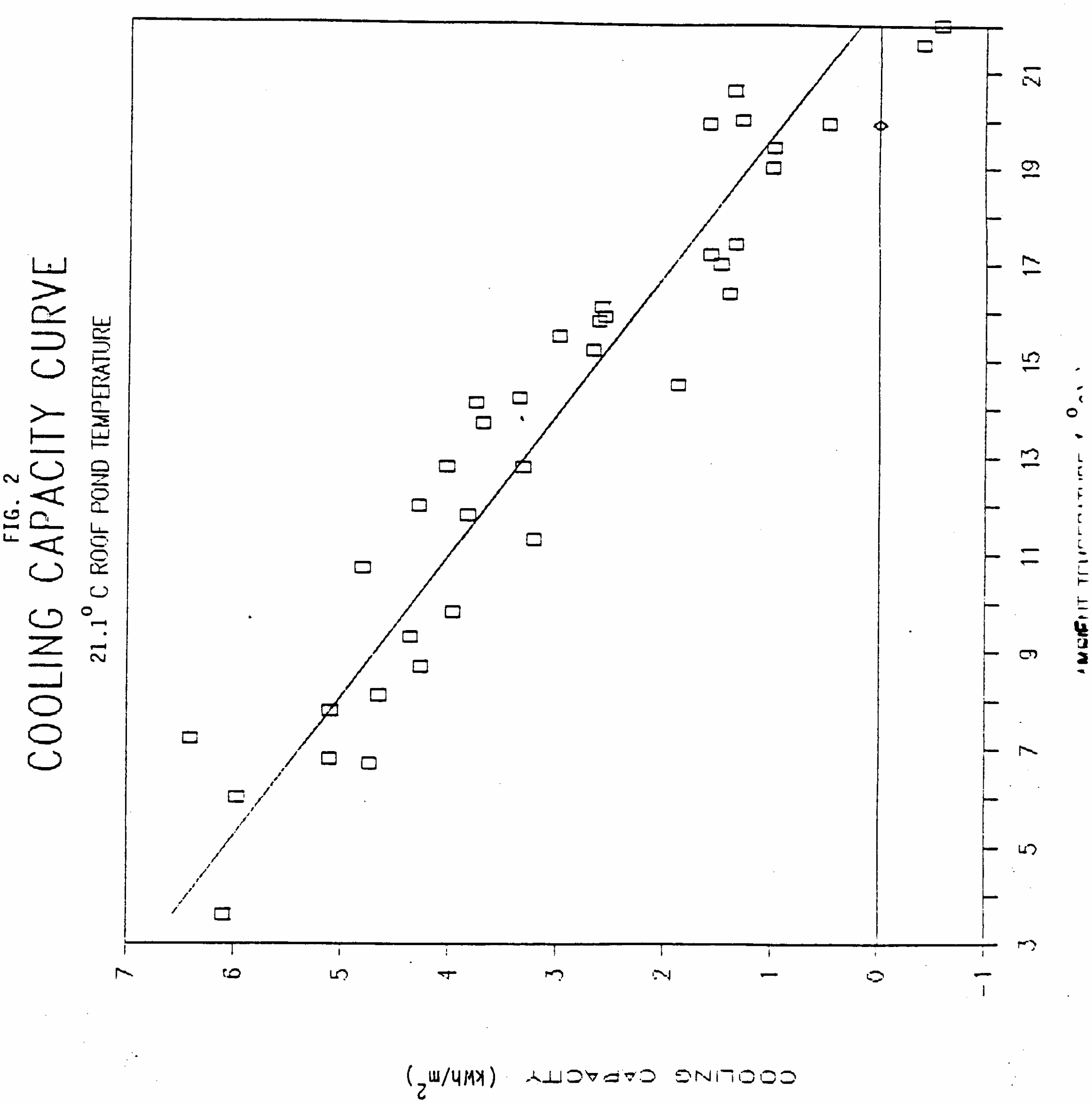


figure one

NEBRASKA MODIFIED ROOF POND
1986 SUMMER CONFIGURATION

FIG. 2


COOLING CAPACITY CURVE
21.1° C ROOF POND TEMPERATURE
COOLING CAPACITY (KWh/m²)
7
6
5
4
3
2
1
0
-1
3
5
7
9
11
13
15
17
19
21