

# RP\_PERFORMANCE: A DESIGN TOOL TO SIMULATE THE THERMAL PERFORMANCE OF SKYTHERM NORTH ROOFPOND SYSTEMS

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## ABSTRACT

This article introduces a new design tool to simulate the thermal performance of Skytherm North roofpond buildings. *RP\_Performance* is an interactive Microsoft Excel™ spreadsheet that allows users to modify relevant parameters that influence the thermal performance of Skytherm North roofpond buildings. This design tool provides users with a ten-day temperature chart for a roofpond, energy-conserving, and reference building for any desired month. In addition, *RP\_Performance* provides the Solar Savings Fraction (SSF) by comparing the roofpond against the reference building, and the heating and cooling energy costs for the roofpond, energy-conserving, and reference building.

To simplify the use of *RP\_Performance*, a companion *Weather Database* (Microsoft Excel™ file) containing climatic data for 34 North American cities is provided along with information on how to incorporate additional locations.

This article also presents a calibration study of *RP\_Performance* using experimental results obtained over a period of nine months (December of 2002 through August of 2003) in a 128 ft<sup>2</sup> Skytherm North roofpond test-room located in Muncie, Indiana.

## 1. RP PERFORMANCE DESCRIPTION

*RP\_Performance* is an interactive design tool that allows its users to investigate relevant parameters that influence the thermal performance of Skytherm North roofpond buildings (e.g. pond area and depth, glazing type and slope, R-value of the movable insulation, etc.). Because of its user-friendly interface, the program lets users look at year round performance and multiple optimizations in a very short

period of time, making it therefore a powerful design tool for the early stages of the design process.

*RP\_Performance* uses a spreadsheet structure based on the work developed by Lord (1999) to investigate flat roofponds with a glazed cover. However, *RP\_Performance* departs from previous work as it specifically addresses the variation in solar radiation gains due to the skylight area, surface orientation, tilt angle, and glazing type.

In addition, *RP\_Performance* targets a type of roofpond (Skytherm North) that has received little attention in the literature but that can, like the better studied Skytherm South, solve 100% of the heating and cooling needs of buildings located in areas where snow loads are significant.

The accuracy of *RP\_Performance*, as shown in the validation study, allows it to be used for parametric studies that help to quickly identify meaningful variables in any given location. Therefore, *RP\_Performance* allows for the optimization of a design configuration by providing its users with a ten-day temperature chart for any desired month for the Skytherm North roofpond, an energy-conserving building, as defined by Balcomb et al (1984), and a reference building that meets ASRAE Standard 90.2-2001. In addition, *RP\_Performance* provides the Solar Savings Fraction (SSF) when the Skytherm North roofpond is compared against the reference building along with the heating and cooling costs for the three buildings simulated (roofpond, energy-conserving, and reference).

## 2. RP PERFORMANCE VALIDATION

The *RP\_Performance* design tool was validated using experimental results from a test-room with a floor area of

128 ft<sup>2</sup>. The test room, located in Muncie, Indiana, has a roofpond design based on the Skytherm North system developed by Harold Hay and tested in St. Paul, Minnesota. The system consists of a “ceiling pond” with eight inches of water under a pitched roof conventionally insulated on the north side (R-34.6) and with 43.6 ft<sup>2</sup> of glass on the south slope (1/8” uncoated double glass with 1/2” air space). Interior movable insulation is provided by a Thermacore® garage door (R-9.31) that moves between the north and south slopes. This garage door is automated and during the heating season it was opened 45 minutes after sunrise and closed 45 minutes before sunset. During the cooling season the garage door was opened right after sunset and closed at sunrise.

The *RP\_Performance* tool was designed to generate hourly weather data for a ten-day period based on user inputs of mean and extreme temperatures, mean maximum and minimum relative humidity, and mean daily global horizontal irradiation for a particular month. Since hourly temperature, humidity, and global horizontal irradiation data were available for the validation studies, along with interior operative temperatures measured inside of the roof pond test room between December of 2002 and August of 2003, the module to generate hourly data was deactivated during the validation of the program.

Similarly, the *RP\_Performance* tool has an algorithm that acts as a “switch” that opens or closes the movable insulation depending on the need for space heating or cooling. Since the actual times in which the movable insulation was operated are known, the “switch” included in the program was disabled and instead the actual operation schedule was programmed.

During the calibration study, an empirically-developed coefficient was used to estimate the heat transfer through the glazing when the movable insulation was closed during daytime. Currently, *RP\_Performance* is set to assume that 35% of the radiation incident on the glazing will be ultimately absorbed by the pond. However, this aspect of the program requires further research and the inclusion of various glazing types, colors, and materials for the movable insulation to more accurately determine the performance of the Skytherm North system during periods in which the movable insulation is closed during the daytime.

### 2.1. Validation Results

The validation of the design tool was done in two different ways. The first validation was a continuous simulation of the nine months for which data was available. The results of this validation are presented on Figure 1.

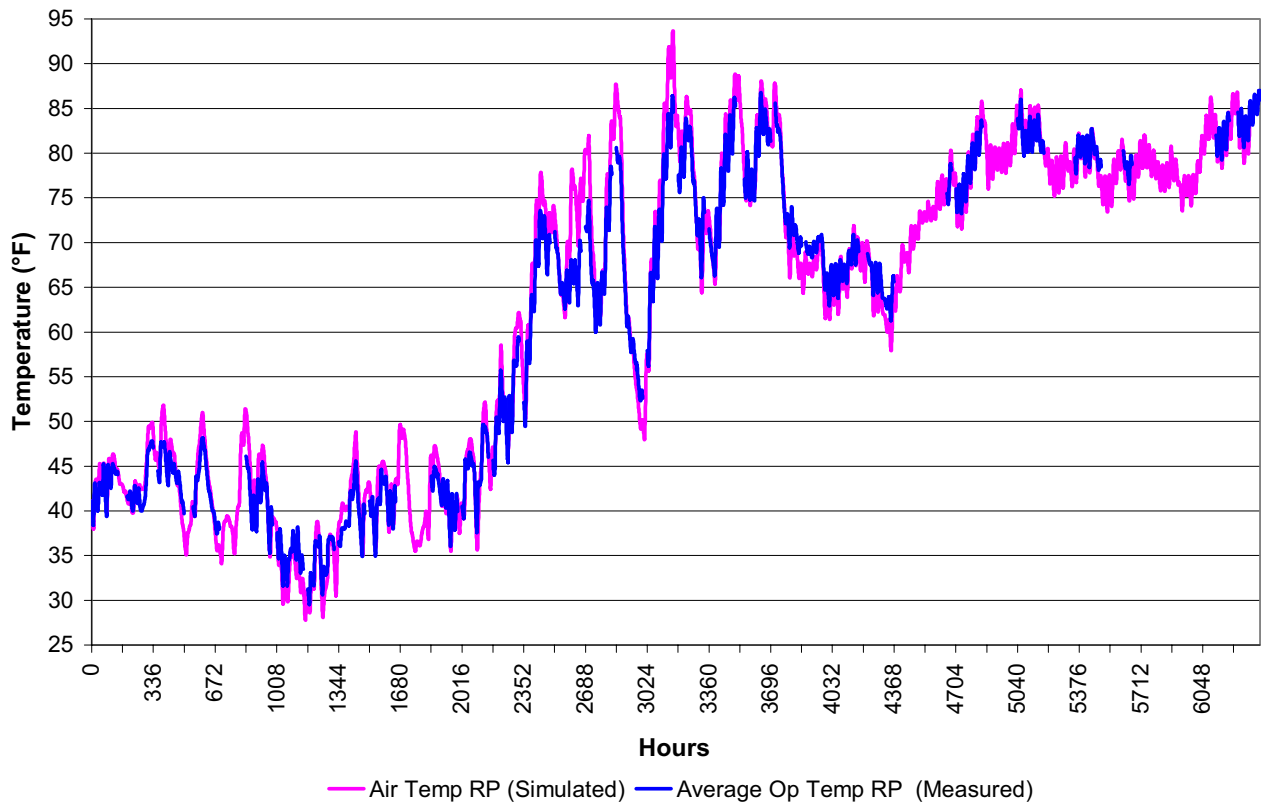


Fig. 1. *RP\_Performance* Validation using measured data from December of 2002 through August of 2003.

The second validation included a month-by-month simulation in which the initial temperature for the simulation was the experimentally measured average indoor operative temperature for the month being studied. If the measurements for a given month started after the first day of the month, the last experimentally measured temperature and corresponding date were used to initiate the simulation. The results of this type of validation are presented on Figures 2-10.

On both cases, the accuracy of the program was considered

to be acceptable for the intended uses of this program (i.e. preliminary architectural design). Additional modeling may be necessary as the design is refined and completed.

### 3. ACKNOWLEDGMENTS

This research project was done with generous support from the Evelyn and Harold Hay Fund (EHHF/SBSE) at Cal Poly State University, San Luis Obispo, the University of Nevada, Las Vegas, and Ball State University.

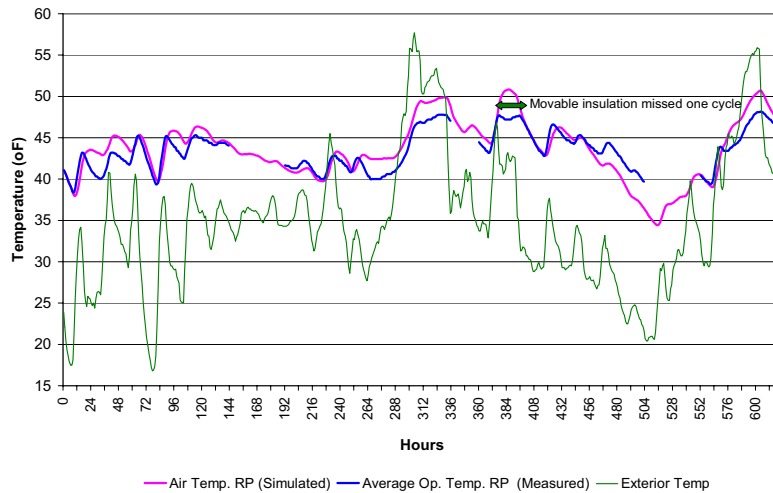


Fig. 2. *RP\_Performance* Validation using measured data from December of 2002.

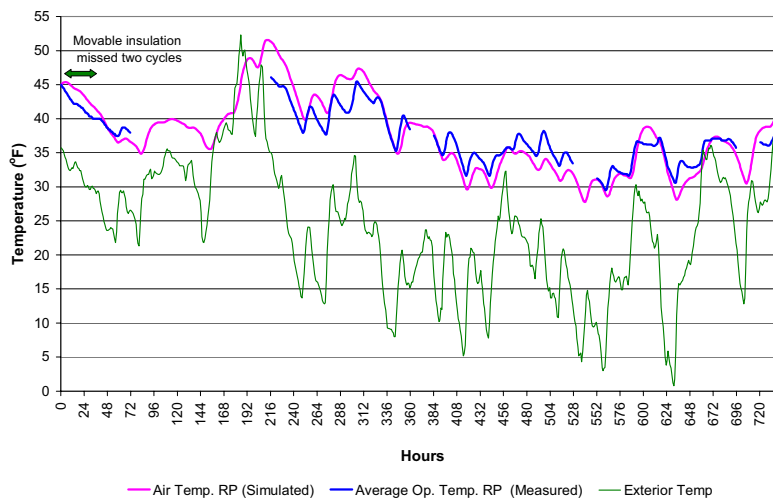


Fig. 3. *RP\_Performance* Validation using measured data from January of 2003.

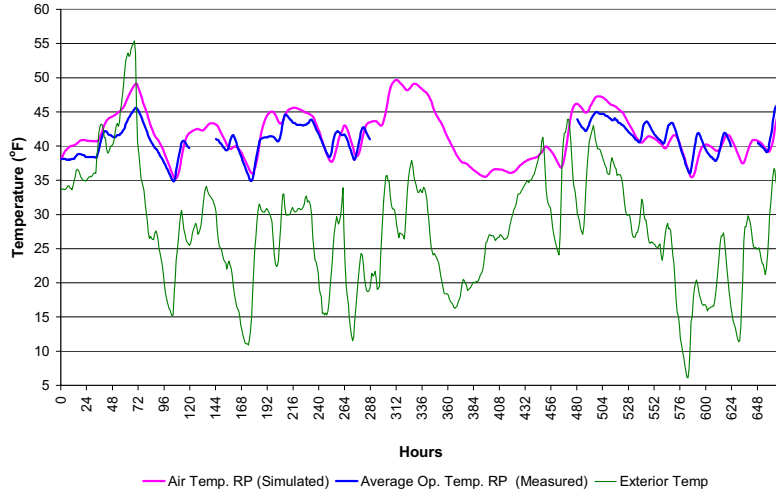


Fig. 4. *RP\_Performance* Validation using measured data from February of 2003.

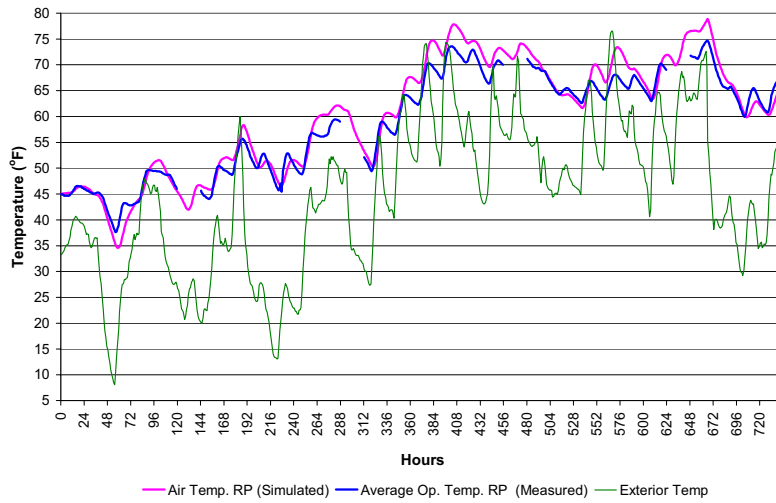


Fig. 5. *RP\_Performance* Validation using measured data from March of 2003.

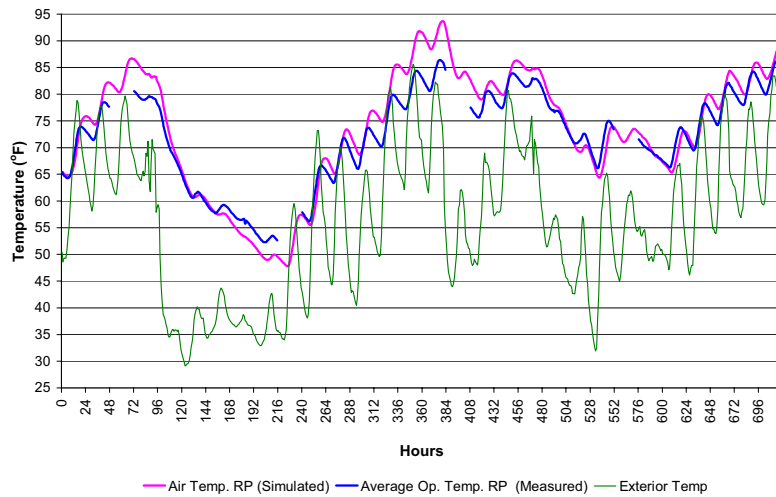


Fig. 6. *RP\_Performance* Validation using measured data from April of 2003.

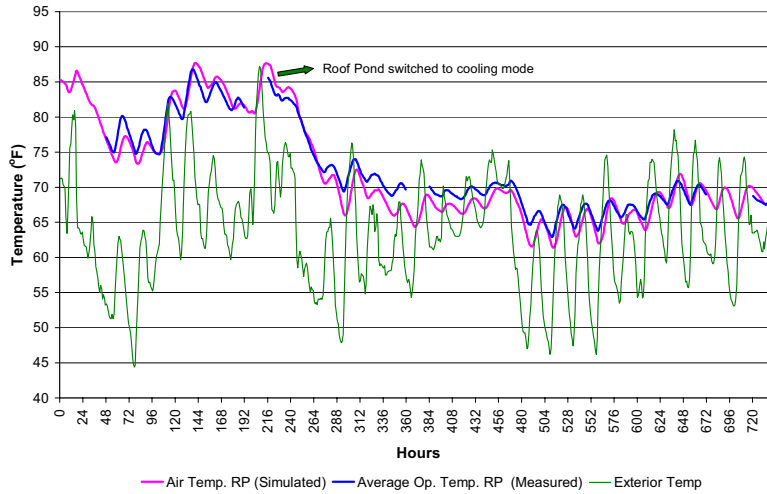


Fig. 7. *RP\_Performance* Validation using measured data from May of 2003.

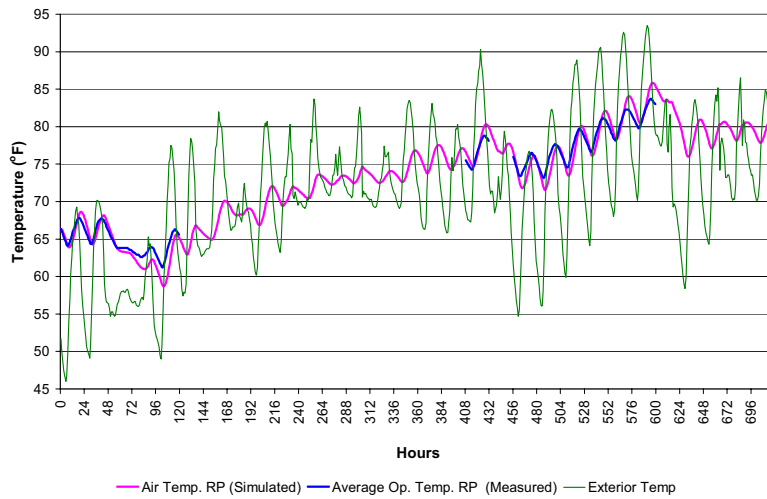


Fig. 8. *RP\_Performance* Validation using measured data from June of 2003.

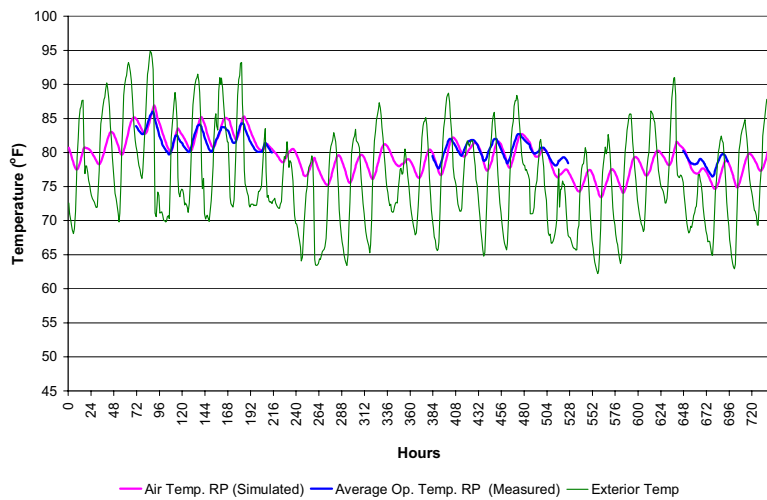


Fig. 9. *RP\_Performance* Validation using measured data from July of 2003.

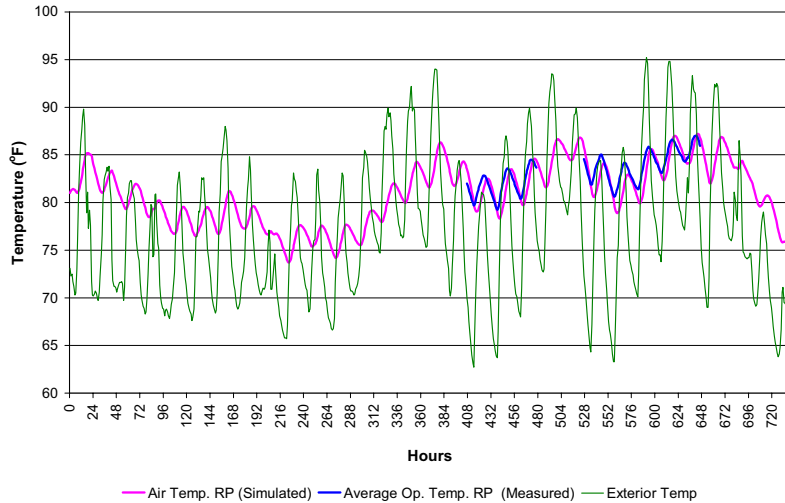


Fig. 10. *RP\_Performance* Validation using measured data from August of 2003.

#### 4. REFERENCES

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