DETERMINATION OF THE CLEAR SKY EMISSIVITY FOR USE IN COOL STORAGE ROOF AND ROOF POND APPLICATIONS

DRS. BING CHEN*, JOHN KASHER**, JOHN MALONEY**, AND
GIRGIS A. GIRGIS*
AND
DAVID CLARK*

PASSIVE SOLAR RESEARCH GROUP
ENGINEERING 236, OMAHA, NE 68182-0181

UNIVERSITY OF NEBRASKA-LINCOLN
UNIVERSITY OF NEBRASKA AT OMAHA

ABSTRACT

A primary cooling component in cool storage roofs and roof pond summer cooling applications is night sky radiation. In order to determine the amount of heat rejection into the night sky, the clear sky emissivity value should be known. This paper attempts to resolve differences in work done previously by Berdahl and Fromberg at the University of California at Berkeley and by Clark and Allen of Trinity University at San Antonio. The clear night sky emissivity (esky) is given as a linear equation related to dew point temperature.

The value of sky emissivity as a function of dew point temperature was obtained from measurements in Omaha, Nebraska and at Big Bend, Texas and is given by the equation

$$esky = 0.73223 + 0.006349\ Tdp$$

where Tpd is dewpoint temperature in $^\circ$c

KEYWORDS

cool storage roof; clear night sky emissivity; solar radiation;

INTRODUCTION

It is necessary to consider the sky radiation, whenever a solar system is to be built. The cold sky can be used as a heat sink for radiating bodies, which may be a promising alternative to conventional cooling techniques. If the emitted radiation of a surface exceeds the absorbed radiation, the surface will cool. The effective "sky temperature" is almost invariably lower than the ambient temperature because the atmospheric temperature decreases with elevation. **A** quantitative understanding of sky radiation is necessary for the design of radiant cooling systems.

The methods for estimating the thermal radiance of the sky fall naturally into two classes. The first consists of empirical methods based on direct measurements of sky radiance. For example, one can use surface temperature and humidity to predict sky radiance if a suitable correlation is available. The second method utilizes detailed profiles of atmospheric constituents, together with a knowledge of their radiation properties, to derive the atmospheric radiance. The present article gives an empirical relation for the sky emissivity to predict the sky radiance. The sky emissivity has an approximately weak ambient temperature dependence, but it depends on the amounts of water vapor in the atosphere, i.e, dew point temperature.

The development of-this study stems from interest in roof pond cooling systems. A steady series of refinements have resulted in an optimized format that minimizes water depth, utilizes commercial grade building products, improves reliability and provides year round thermal comfort. The system is referred to as the Cool Storage Roof by Richard C. Bourne of the Davis Energy Group. The primary cooling component is caused by radiation into the night sky of the heat contained within the water. Evaporation and convection also contribute to the total cooling of the system.

The authors decided to investigate the sky radiation and intend to collect a comprehensive set of measurements to further validate the findings presented in this paper.

Hemispherical radiation is given by

$$S = eo\ \sigma\ T^4 \qquad (1)$$

where

S : radiation in watts/meter2
eo: emissivity (dimensionless)
σ : Stefan-Boltzman constant 5.6697xlO-8 w/m2-°K
T : temperature of body °K

In order to compute the radiative cooling from a flooded roof the clear night sky emissivity value is needed. The sky emissivity es . s a dimensionless quantity that is a measure of the atmosp@erle's ability to transfer heat by radiation and is dependent on temperature (atmospheric and radiator) and water vapor content (cloud cover and relative humidity).

The global radiation can be read with a pyrgeometer and the ambient temperatures from a precision ASTM thermometer. Dewpoint temperature data is also taken. The clear night sky emissivity can be calculated as being:

$$esky = (S / (\sigma\ Ta^4))$$

where

esky: clear night sky emissivity
Ta : ambient air temperature

These calculations were repeated for nearly 150 data points in both Big Bend, TX and Omaha, NE. The sky emissivity was then plotted as a function of the dew point temperature. Regression analysis yields the linear relationship between sky emissivity and dewpoint temperature.

Summary of results from Berkeley and Trinity

The Berkeley equation developed by Berdahl and Fromberg is given by

$$esky = 0.741 + 0.0062\ Tdp \qquad (3)$$

where Esky is the clear sky emissivity and Tpd is the dew point temperature (in degrees Ceicius).

The Trinity equation developed by Clark and Allen is given by

$$esky = 0.787 + 0.0028\ Tdp \qquad (4)$$

Due to the discrepancy of results with both the intercept and slope it was decided that experiments be developed and conducted in order to determine the clear night sky emissivity value. Experimental data was taken by the Passive Solar Research Group of the University of Nebraska at the recently built Energy Research Test Facility and also at Big Bend, Texas.

EXPERIMENTAL RESULTS

Pyrgeometers from Eppley Labs (#26414 F3 and #28347 F3) were used in obtaining night sky radiation data. Voltage readings from the pyrgeometer's a-b output terminals were taken with a Keithley 197 digital microvoltmeter (#487329). Ambient temperature data were taken from an Ertco 63C precision thermometer (#1204) with 0.10C accuracy. Dewpoint temperature were taken with Welch and Cenco psychrometers.

The experimental results from 149 data point yield a clear sky emissivity (See attached figure) of

$$esky\ @\ 0.73223 + 0.006349\ Tdp \qquad (5)$$

with a r^2 value of 0.588.

This agrees well with the Berkeley results. The intercept is very close (0.73223 compared with 0.741) with a slope almost exactly the same (0.006349 compared to 0.0062) as the Berkeley results. It appears that our initial results confirm the Berkeley studies.

FUTURE WORK

Experiments are being designed to automate the data gathering process. In addition a chilled mirror dew point monitor from General Eastern Company with a 0.2◦C accuracy has been acquired. Ambient temperatures will be taken with AD590 sensors and will be periodically calibrated with the Ertco precision thermometer.

Cloudy sky readings will be taken by the Eppley pyrgeometer. This data will then be correlated to north Omaha weather bureau data. Cloudiness factors or sky cover are given in tenths (with 0/10 being clear to 10/10 being cloudy). An algorithm will be developed to compute a general night sky radiation predictor model based on dew point temperature and tenths of cloudiness factor for any location with weather bureau statistics.

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Fig. 1. Regression Analysis of Sky Emissivity