Dew and Frost Deposition on Pyranometers

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ABSTRACT

The formation of dew or frost on the outer glass hemisphere of pyranometers was found to cause erroneous values of incident hemispheric solar radiation. An air flow system was designed to continually ventilate the instrument and thereby prevent moisture formation on the outer hemisphere. Comparison of instantaneous early morning readings from ventilated and non-ventilated pyranometers indicate that substantial errors can occur because of dew or frost. Since the moisture from dew or frost naturally evaporates by mid-morning, daily totals of solar energy are not likely to be significantly affected on clear days.

1. Introduction

During a continuing program of hemispheric solar radiation measurements in central North Carolina, early morning dew or frost was observed to form frequently on the outer hemisphere of pyranometers. In fact, on roughly two out of three non-precipitation days, dew or frost was noticed on the instruments at 0800 local time (the beginning of normal daily working hours). Both Eppley precision spectral pyranometers and Spectrolab model SR-71 pyranometers were used in this measurement program and the following results are applicable to both types of sensors.[2] The dew formation is largely the result of the climate of the area, i.e., frequent clear nights and generally high humidity. After heavy dew had formed on a clear or mostly clear day, it typically persisted for 2–3 hr after sunrise before all the moisture evaporated.

The effect of dew or frost can be qualitatively viewed through the voltage output of a pyranometer monitored continuously on a strip chart. When moisture is wiped

[1] On assignment from the National Oceanic and Atmospheric Administration, U. S. Department of Commerce.

[2] The mention of company or product names is not to be considered as endorsement or recommendation for use by the Environmental Protection Agency.

from the instrument, an abrupt voltage change usually can be seen on the chart trace. Casual observations indicated that during the first hour after sunrise errors of 50–100% occasionally occur. However, the effect of dew or frost on incoming radiation is rather erratic and even the sign of the radiative change is variable. All energy passing through the hemisphere, that directed both toward and away from the sensing element, is subject to reflection and refraction by the moisture. The amount and sign of the effect on radiation apparently depends on the amount of dew or frost formed, its placement on the hemisphere, and solar elevation. For example, with dew drops only on the top of the dome or with a general coating of frost, the amount of energy detected was usually increased during very low sun angles.

2. Air flow system

In an attempt to eliminate the difficulty causing these erroneous radiation measurements, an air flow system was designed which would ventilate only the outermost hemisphere of the pyranometers. A continuous flow of air was directed at the hemisphere through four jets attached to the edge of the white radiation shield. The jets were positioned as close as possible to the hemisphere without actually protruding above the horizontal plane of the thermopile. A pyranometer with the air flow system attached is shown in Fig. 1.

The air flow system basically consists of a diaphragm pump (a Thomas model 907CA20 was used for this experiment) which generates 1.5 ft^3 min^{-1}, and a 17-ft helical polypropylene tube of 0.22-inch i.d. connected to four cellulose acetate $\frac{3}{16}$-inch i.d. jets. The jets and their connectors are painted white and aimed directly at the hemisphere. The connecting tubing and jet mounts are clearly shown in Fig. 1.

The pump used in this experiment caused a warming of the forced air of about 10C between the inlet and outlet of the pump. However, the air was reduced in temperature to about 1C above ambient during its course through the 17-ft tube. It is estimated that the complete air flow system could be purchased for less than $50.00. The cost of the pyranometer itself is roughly $1000.00.

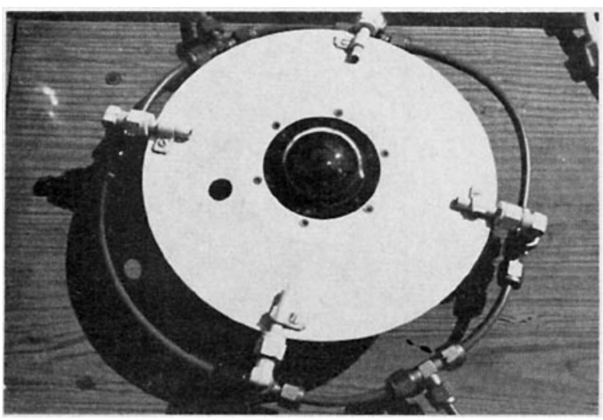

FIG. 1. Photograph of pyranometer with air flow system attached.

After the construction of the air flow system, ventilated and non-ventilated pyranometers were operated side by side for several weeks. The ventilation system was quite efficient in preventing the formation of dew and frost on the instruments. Only on the days of heaviest dew or frost formation was any moisture at all evident on the ventilated instrument; then only a few drops were present on the very top of the dome. As a beneficial side effect, the system also greatly enhanced the evaporation of rain drops from the hemispheres and thereby reduced the time of erroneous data due to this phenomenon.

3. Comparison of ventilated and non-ventilated instruments

The side-by-side operation of ventilated and non-ventilated pyranometers was also used to compare the irradiances measured by the two instruments during times of dew or frost formation. As the earlier qualitative observations had indicated, no clear-cut empirical relation between the two radiometers could be established. Sometimes one sensor read high and sometimes the other. In general, however, during the first hour after sunrise, the amount of energy measured by the non-ventilated pyranometer was higher. Because the amount of dew or frost formed and its placement on the hemisphere exhibited a very wide range of different patterns, a detailed theoretical analysis of this problem was beyond the scope of this note.

Large variations in the instruments' cosine response could have caused some of the observed variations. The cosine response of the two pyranometers was checked in the laboratory using a collimated beam. The response of the non-ventilated instrument was consistently less than that of the ventilated instrument at all elevation angles; for angles $>15°$ the response of the sensors agreed within a few percent.

An example of a day during which distinct differences occurred between the two sensors is illustrated in Fig. 2. The average irradiance (ly min^{-1}) during 15-min intervals is shown from 0515 to 1215 EST. On this day (27 April 1972) clear skies were observed throughout the day at the nearby weather service office at Raleigh-Durham airport. A heavy coating of dew was observed on the non-ventilated pyranometer at 0800; by 1000 the sensor was dry. No moisture was observed on the ventilated instrument. The non-ventilated sensor read higher until 0700 but indicated substantially lower values from that time until about 0900. After all dew had evaporated, the two sensors showed good agreement.

The significance of this effect of moisture on pyranometers may actually depend on the specific ap-

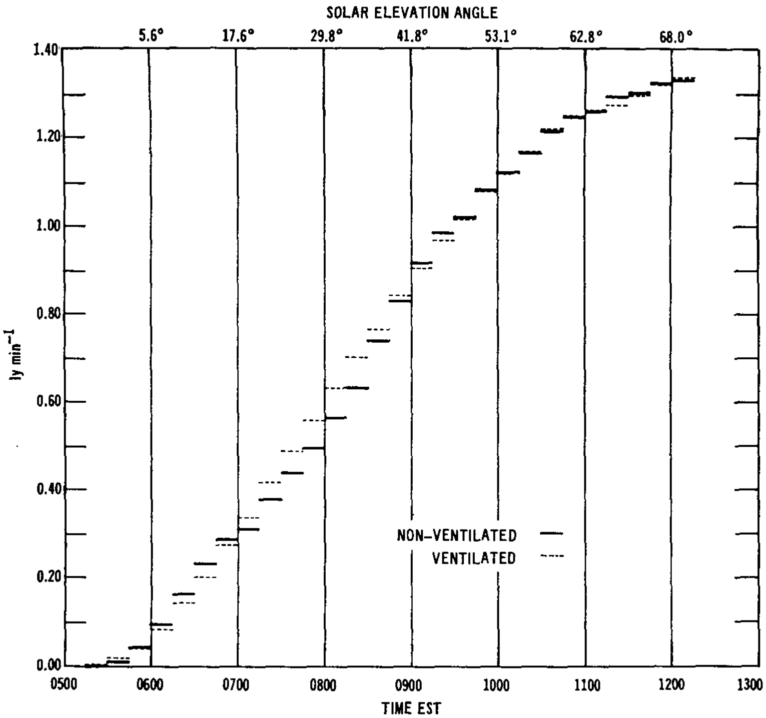

Fig. 2. Comparison of incident hemispheric solar radiation (ly min^{-1}) from ventilated (dashed lines) and non-ventilated (solid lines) pyranometers during the morning of 27 April 1972.

plication of the radiation data. For the example above, between 0700 and 0830 the non-ventilated sensor averaged only 90% of the value from the ventilated instrument. Thus, any use of the morning data on an instantaneous or short-time average basis or a comparison of morning and afternoon values could be erroneous. From sunrise (0529) until 1200, the total energy received by the non-ventilated pyranometer was only 1.2% less than that of the ventilated sensor. On a daily basis (energy indicated by the two instruments assumed equal in the afternoon) the departure would be well within the accuracy of the sensors (~1%).

The need for ventilation of pyranometers thus largely depends on the application of the data and prevailing climate. In drier and windier climates, such as in much of the middle and western United States, dew or frost formation on pyranometers may be a relatively infrequent occurrence. For example, during a one-month field experiment in St. Louis, Mo., during July and August, 1972, very little dew formed on non-ventilated sensors on top of a twelve story building in the downtown area. When heavy dew or frost does form, however, significant errors in measured solar irradiance can occur during early morning hours. Daily totals of solar energy are not likely to be significantly affected on clear days since the moisture naturally evaporates by mid-morning.

Dew deposition on the polyethylene dome of Funk-type pyradiometers and its effect on measured long-wave radiation has recently been discussed by Mukammel (1972).

REFERENCES

Mukammel, E. I., 1972: A note on dew deposition on pyradiometers. *Solar Energy*, **13**, 421–423.