# Solar Solutions

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## Bristol's six principles of good solar hydronic design

# Part 7: Cooling with Flat-Plate Solar Panels

In previous articles, I have been making the case that the key ingredients for solar/hydronic design and installation can be divided into six categories, listed below, roughly in order of their importance.

1. RELIABILITY
2. EFFECTIVENESS
3. COMPATIBILITY
4. ELEGANCE
5. SERVICEABILITY
6. EFFICIENCY

The success of any solar hydronic home heating installation depends on the often-conflicting balance between any of these six principles. Finding the balance between them defines the art of solar heating design.

*Figure 1. A night sky radiant cooling system installed in Taos, N.M. (Image courtesy of Cedar Mountain Solar, LLC.)*

One of the most interesting applications for thermal hydronic solar panels is also the most neglected and often overlooked, and that is night sky radiant cooling (NSRC). This type of cooling is especially interesting because it can be virtually free, if flat-plate solar heat panels already exist, and this type of cooling rates highly when evaluated according to the six principles.

Perhaps the most obvious application for using a solar panel to provide useful cooling is the example of the solar water heater running at night. This can be useful when the occupants are away from home, and no one is using the solar heated water. After a few days of solar heat collection, the water tank can become dangerously hot. But if the solar collector pump is allowed to run at night, the system "runs backwards" and delivers the excess heat from the tank to the solar panel at night, which radiates the heat away to the night sky. Some control systems can be programmed to allow this as an optional feature to prevent hot water tank over heating.

A few years ago, I was involved in a local testing program (nicknamed "Skylab") to see how much cooling we could get from the night sky using conventional flat-plate panels and how we might estimate this cooling potential using local weather records. Since then, we have installed a number of these systems for direct cooling of mass floors with encouraging results. The photo in Figure 1 shows an NSRC installation next to a small commercial building in Taos, N.M. Let's take a closer look at the NSRC phenomenon.

**What is night sky radiant cooling (NSRC)?**

In the same way that thermal radiation travels from the sun to the surface of the earth, across the vacuum of space, the heat from the earth also radiates back into space. Night sky radiant cooling is a natural process that helps the earth maintain thermal equilibrium. The effect of this radiant heat leaving the surface of the earth can easily be seen on some mornings after a clear night. A layer of frost will form on rooftops and on automobiles even though the outdoor air temperature is well above freezing. This frozen condensation is proof that the rooftops were losing heat by radiation to the night sky faster than the surrounding warmer air could replace that heat by natural convection. The roof surfaces become so cold that moisture condenses out of the air, sometimes freezing solid. The radiant cooling occurs at a slower rate on partly cloudy nights, but can still provide useful cooling. Only when the night sky is completely cloudy, does the radiant cooling effect come to a virtual stop.

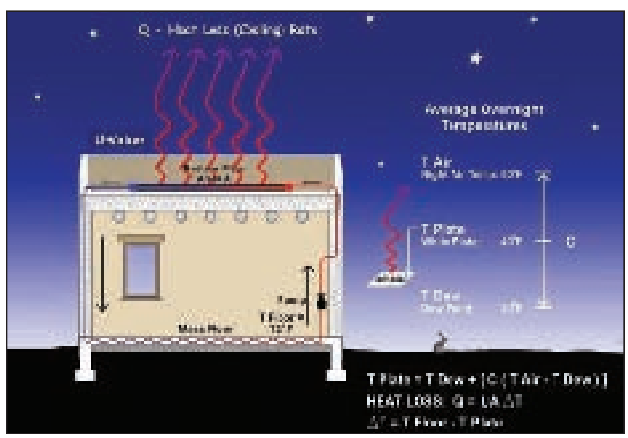


*Figure 2. The factors in effective NSRC include dew point, "white plate" temperature and air temperature. (Image courtesy Bristol Stickney and Mark Chalom.)*

The same natural mechanism that causes ice to form on car roofs can be used to cool buildings. By harvesting this radiant energy at night and storing it in the thermal mass of a

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### InSinkErator engineer honored for outstanding presentation

RACINE, WIS. — InSinkErator, a manufacturer of food waste disposers and instant hot water dispensers, announced that senior environmental engineer Michael Keleman was honored with the Wylie W. Mitchell Award for his presentation at the American Society of Sanitary Engineering (ASSE) annual meeting, held in Orlando, Fla., November 19 - 23, 2008.

Each year, the Wylie W. Mitchell Award is presented to the individual speaker presenting the most outstanding paper at the E.J. Zimmer Technical Seminar, held during the organization's annual meeting. The recipient is selected by conference attendees, who are asked to critique each speaker's presentation and the overall value of the information presented.

Keleman, an environmental specialist, spoke to ASSE delegates about the role food waste disposers play in a holistic approach to food waste management and about how these widely used kitchen appliances are surprisingly overlooked and misunderstood. He provided research and technical information to support the fact that disposers are an environmentally responsible alternative to transporting food waste to landfills.

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building, the need for air conditioning or evaporative cooling can be seriously reduced or eliminated. The same equipment used for daytime active solar heating can be employed at night for "collecting" and storing the "coolth" obtained by NSRC by implementing relatively simple modifications. The heat storage mass of hydronic radiant heated floors can be used not only for heating in winter, but can be used for "cool storage" in summer. Figure 2 (on page 60) shows a cross section of a simple hydronic floor cooling installation using direct cooling of the floor mass by roof-mounted radiator panels.

While glazed solar thermal panels that are typically used for solar heating can also be used for cooling, supplementing these collectors with unglazed collector panels mounted horizontally on a building will significantly increase the cooling potential of the system.

**Skylab overview**

Night sky cooling is similar to solar heat in that it is governed by an assortment of weather variables. The indoor and outdoor temperatures, cloudiness, humidity, altitude, wind and rain all play a part in regulating the radiant cooling performance. Our challenge has been to take what we know about radiant cooling, and begin to make it more accessible to home builders and mechanical installers so that it can be put to use in the same way that solar collectors and radiant floor heating is today.

Toward that end, Mark Chalom, Kate Snyder, and I embarked on a test program a few years ago, funded by the state of New Mexico, which we referred to as "Skylab." For two summers, we set up weather instruments and data recorders and monitored the heat loss from a variety of flat-plate hydronic panels. Using these test results we developed a means of evaluating the radiant cooling potential using existing average monthly weather data, without resorting to complex computer simulations. The purpose of this simplified method is to allow any one to make a decision quickly, about the radiant cooling potential in their location by

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looking primarily at average temperature records and using only the simplest calculations.

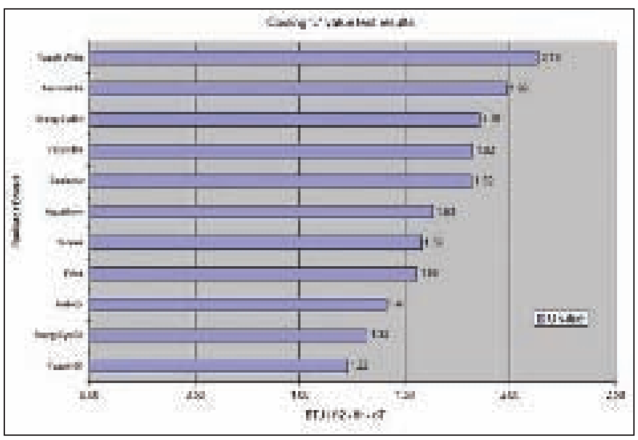
**Metal plate temperature (white plate)**

A thin metal plate exposed to the clear night sky will typically drop in temperature below that of the surrounding air. This is direct evidence of the radiant cooling effect, since the warmer air cannot be cooling the metal. The plate becomes a "sensor" that reacts to the multiple weather variables surrounding it, like wind and cloudiness, producing a cold temperature that represents the coldest useful temperature available at that moment. Using this sensor, instead of trying to correlate all of the individual weather variables, simplifies the quest for the night sky radiant cooling rate. (Steve Baer of the Zomeworks Corporation deserves honorable mention for pointing this out.)

In Figure 2, "T Plate" denotes the temperature of the metal plate.

**Dew point & air temperature correlation**

When measured at night, "T Plate" will almost always be found between the dew point temperature and the night air temperature. During the testing phase of this project, we measured these temperatures every five minutes with data loggers and produced nightly averages time, and time again. The goal was to find a long-term average correlation for our climate, shown as "C" in Figure 2. "C" is shown at the midpoint between the dew point and the air. This is not a bad assumption, since our test



*Test results for various "off-the-shelf" heating collectors used as radiators. (Image courtesy Bristol Stickney and Mark Chalom.)*

results show an average of 0.441 when all our bench test data is combined, and an average of 0.488 when all the field test data is included from the summer season of 2005. On very clear nights the value is lower and during unfavorable conditions, the value is higher. But is seems that on the average, a value of 1/2 will yield reasonable results when used as a rule of thumb.

**Source temperature (mass core or reservoir)**

Heat loss to the night sky is driven by the difference in temperature between the warm radiator and the cold sky. It is not a simple linear relationship, so increasing the radiator temperature will dramatically increase the heat loss to the sky. For purposes of comparison, we chose a radiator temperature that matched the typical performance or our field tests. In these tests, we monitored the heat loss from concrete floors that were cooled with liquid, pumped through tubing embedded in the floor. The "T Floor" temperature of 73 F, shown in Figure 2, corresponds to the typical conditions seen in our field tests where radiant night cooling was typically available for 10 hours each night in summer. This type of cooling system can be engineered to operate at higher or lower temperatures if needed. They can also be designed to use water tanks for heat/cool storage instead of, or in addition to mass floors.

**Radiator performance expressed as "U Value" (heat loss from the radiator plate)**

There are a number of different types of panels readily available for use as night sky radiators. Most are manufactured by the solar heating industry, and intended to be used for the solar heating of liquid during the day. But, they can also be operated "in reverse" for cooling at night. They are available in plastic, metal and various liquid flow path configurations. Some work better than others when used for radiant cooling. Since there is no widely accepted testing and rating system for night sky cooling panels, we created methods of testing and comparing to suit the goals of this project.

The results of our radiator panel tests were reduced down to a single number for comparison. This number was intentionally derived to have the same units as "U value," which is widely used in the building industry as a heat loss rating for common building materials. "U value" is commonly expressed in Btus per hour per square foot per degree Fahrenheit. The "U value" of our radiators uses the same units, and represents the number Btus the radiator can emit to the night sky, per square foot of surface area, per hour, per degree (F) of temperature difference between the radiator surface and the white plate.

Figure 3 shows a bar graph of night sky U values for various radiator panels that we tested. The panels showing U values closer to 1 are the ones with glass covers, selective surfaces or other configurations that "hold on" to the heat at night. The panels with U values closer to 2 have bare surfaces, and good thermal radiation characteristics that lose heat better at night. The best radiators are "wetted plates" that have large surface areas in contact with the hydronic fluid inside the panel.

**Radiant cooling — hourly, nightly, monthly average**

A heat loss rate "Q" can be calculated using the formula shown in Figure 2 based on the average temperatures, the "U value" and the area of the radiator also indicated on the figure. This yields and hourly value, which represents the average cooling to be expected with this radiator under these temperature conditions, in Btus per hour. To obtain the total cooling to be delivered overnight, multiply by the number of hours the cooling pump will be run. A maximum of 10 hours per night is consistently available in our climate during the warm season. So, to estimate the maximum cooling delivered overnight, multiply by 10 hours. Then to estimate the monthly cooling total, multiply by the number of days that month (e.g. 31 days).

**Regional conclusions may vary**

This method allows you to estimate NSRC cooling potential in any location by looking up the night time dew point and air temperatures and assuming a U value for our radiator. It will get you into the right "ballpark" if you use the assumptions discussed here. This method is intended for quick initial comparisons, and no guarantee of cooling results is expressed or implied. Many design details can alter the outcome including high local winds, panel tilt, the weather data accuracy and other factors. But, this method may show you that there is more NSRC potential in your region than you thought, and for the price of running a pump, you may be able to make use of some "free" cooling. ■

*Bristol Stickney, partner and technical director at Cedar Mountain Solar Systems in Santa Fe, N.M., has been designing, manufacturing, engineering, repairing and installing solar hydronic heating systems for more than 30 years.*