Solar Solutions

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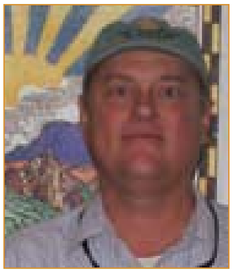

Solar thermal collector tilt

Flat plate solar heat collectors are most often mounted facing the sun at some fixed tilt and orientation. The tilt angle must allow the collector good exposure to the most useful altitude angles of the sun, while the orientation is chosen to provide good exposure to the solar azimuth angles (the sun path from east to west). For most common heating loads in the northern latitudes, the best orientation angle is true south and small variations to the east or west (plus or minus 10 degrees or so) will produce only a minor impact on the annual performance. The tilt angle, however, can be altered to produce widely different annual results, and so it is important to understand the consequences when choosing a fixed tilt.

Monthly solar climate data

To understand the solar heating climate at any location, it is helpful to inspect it month by month. A good resource for this kind of climate data is the National Renewable Energy Laboratory (NREL) website. Their "Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors" contains a handy summary for each of 239 locations across the U.S. Even though it is out of print, it can be obtained free on the web at http://rredc.nrel.gov/solar/pubs/redbook/ in PDF format, as well as ASCII Data Files (comma delimited) that can be copied into spreadsheets for solar calculations.

Each data page describes the location, presents average solar radiation values month by month for flat-plate and concentrating collectors, and gives average climatic conditions such as temperatures, heating degree-days and humidity. Data are presented by NREL for five tilt angles from the horizontal: 0°, latitude minus 15°, latitude, latitude plus 15°, and 90°. Data for a tilt of 0° (referred to as global horizontal solar radiation) show how much solar radiation is received by a horizontal surface such as a solar swimming pool cover.

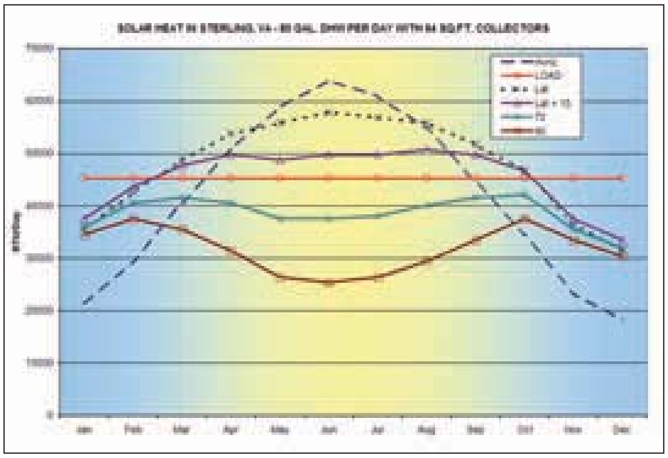

Figure 21-1

The Solar Data Manual states that the maximum yearly solar radiation can be achieved using a tilt angle approximately equal to a site's latitude and to optimize performance in the winter, the collector can be tilted 15° greater than the latitude. To optimize performance in the summer, the collector can be tilted 15° less than the latitude. Data for a tilt of 90° apply to collectors mounted vertically on south-facing walls (primarily for winter space heating) and also apply to south-facing windows for passive solar heated designs.

Consider the heat load profile

Residential domestic hot water (DHW) can often be characterized as a constant load each month when the residence is continuously occupied. For example, if 80 gallons per day are consumed with a 70° temperature rise required from the water heater, then around 46,000 BTUs are needed per day with little variation from month to month. This idealized hot water load is shown on Figure 21-1 as a horizontal line that does not vary from month to month for a sample retrofit project near Sterling, Virginia.

The tilt angle, however, can be altered to produce widely different annual results, and so it is important to understand the consequences when choosing a fixed tilt.

The residential space heating load is another matter. The 2,000 square foot house near Sterling requires 400 BTUs per hour per degree F of difference (delta T) between indoors and outdoors plus some extra heat loss due to air infiltration. So, the heat load is far from constant over the year, rising dramatically in winter and dropping to nothing but the water heater load in summer. Everybody in the heating industry knows this, of course, but when you graph it as shown in Figure 21-2 you begin to see the picture from the solar heating perspective. The space heating load is not a straight line like the DHW, but wildly fluctuating over the year with a shape not unlike the "big dipper" constellation without the handle. And, to make things even more challenging, if you choose the wrong collector tilt, the need for space heat can be perfectly out of phase with the solar heat available, off target by six months.

Matching the heat load to the solar heat source

The NREL solar climate data described above has been plotted on the Figures 21-1 & 21-2 for our sample project in Sterling, Virginia (except that I have

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omitted latitude minus 15° and added a steep tilt of 72°). These five curves show how much solar heat is available on a typical day each month at different tilts for solar collectors of a reasonable size for the heating job. This can be compared to the heat load on a typical day each month, plotted as a red line marked with circles.

In the case of a simple solar water heater in Figure 21-1 the comparison is straight forward. The typical daily DHW heating load is seen as a horizontal line from month to month. The collector tilt that provides solar heat that most closely follows the load is the winner. Just as NREL predicts, the Latitude plus 15° collector tilt tends to match the load better in both winter and summer, providing a better match than the Latitude tilt curve which produces more excess heat in summer and a bit less heat in winter. In this example, the 64 square feet of collectors could be installed with a 100 – 120 gallon DHW storage tank to absorb the extra heat in summer while providing 80 gallons of hot water to the faucets each day.

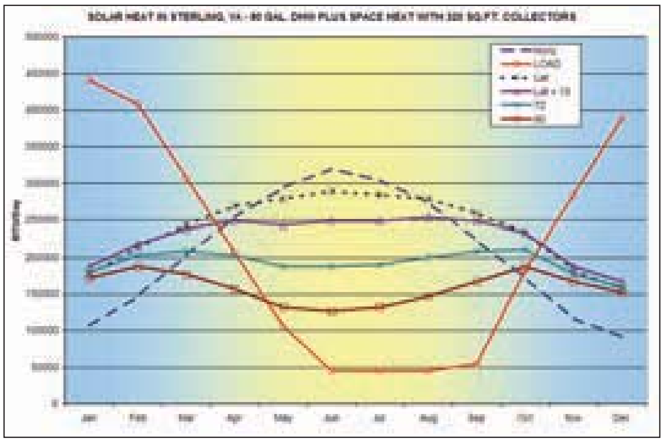

Figure 21-2

The same choices are compared in Figure 21-2 but this time applied to a much larger collector array (320 square feet) which is big enough to make a significant contribution to the space heating as well as the water heating load for this house. Notice that the familiar horizontal line from the DHW is visible in summer as a constant load. The area above this line and below the solar collector tilt line is extra summer heat, not really needed, but available for summer pool heating if a pool is nearby. In our sample project in Sterling, there is no pool, so the design becomes a balancing act of reducing the summer excess heat while maintaining the solar heat available in winter as much as possible. The data in Figure 21-2 shows that the solar collector tilt that best fits the "dipper" shape of the annual heating load is the vertical collectors (90° tilt). But when you look at the solar heat available in the spring, the Latitude plus 15° tilt works much better. Perhaps the happy medium is around 72° where heat is not cut off too drastically in the spring but does cut off pretty well in the summer.

A perfect match is not always easy or economical, which is why solar heating systems are commonly designed to take up a significant amount of the annual heating load, but not all of it. In this example it looks like 320 square feet of collectors may provide over half of the annual heating load. The size of the solar heat contribution shown here is typical of solar heating retrofits, but keep in mind this is only one example. Solar heating systems can be designed for higher or lower solar contributions depending on climate, economics, heat storage schemes, controls and many other factors.

Practical considerations

The solar tax credits and other incentives may alter the economics in favor of more collectors. When more collectors are deemed to be affordable, the designer must take more care to avoid overheating during the warm seasons. See earlier issues of this column for previous discussions about designing to prevent overheating.

Some vacuum tube collectors have a tilt limit, and may not function properly if they are tilted too close to vertical or too close to horizontal. Consult the installation manuals to be sure the solar collectors are right for the job.

Drain back collectors must be installed so they drain properly by gravity, so keep in mind that creative piping and unconventional tilts may interfere with that. When a steep tilt is required, a low profile collector may be preferable to overcome the aesthetic problem of free standing tall collectors. For example, Solar Skies and Viessmann both make low-mount collectors with internal horizontal headers.

Snow drainage takes longer at a shallow tilt and this can be a problem in some installations when collectors become covered with snow with no practical way to clean them off. ■

• *Special thanks to Dr. Fred Milder at SolarLogic for the solar climate data graphs presented here.*

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In this series of 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.