John Siegenthaler, P.E.

Do you really know what time it is?

The sun doesn't work around your watch.

Photo credit: ©istockphoto.com/Eric Gevaert

The sun is directly above a true north/south line at solar noon.

One of the first things you learn about planning and installing solar thermal systems is the importance of orientation. On a theoretically perfect clear sky day, a collector array that faces *true* south will produce the greatest heat output, all other factors being equal.

In many situations, solar pros don't have the option of facing a collector directly true south. Instead, they are constrained by the orientation of a roof, or perhaps the shadows cast by nearby objects such as trees and adjacent buildings. In these cases, using a tool such as the Solar Pathfinder (shown in Figure 1 on Page 17) can help determine the time of day and month when the location will be shaded.

The vertically oriented time arcs on the dial of the Solar Pathfinder, as well as the times on a sun path diagram (such as shown in Figure 2 on Page 17) are based on *solar time*, which can be significantly different from local clock time.

To understand why this is true, consider that a time zone spans 15° of longitude (e.g., 360° divided into 24 time zones). Clock time is the same at the east and west extremes of a time zone, yet the sun's position cannot be the same at these extremes because it is continually moving along its path through the sky. In other words, two observers within the same time zone and at essentially the same latitude (such as Boston and Detroit) will see the sun at different positions in the sky at the same indicated clock time. However, *the sun will be in the same position in the sky when the solar time at both locations is the same*. Thus, whenever you are using a symmetrical imaging device such as a solar path diagram, Solar Pathfinder or formulas that calculate the sun's position as a function of time, that time needs to be solar time.

Solar time can be calculated based on knowing local clock time using Formula 1 in combination with Figure 3 on Page 18.

Formula 1:

$$T_{solar} = T_{LS} + 4\,(L_M - L_{Local}) + E$$

Where:

T_{solar} = solar time at the location

T_{LS} = local *standard* time

L_M = longitude of the standard meridian for the time zone (°)

L_{local} = longitude at the location (°)

E = "Equation of time" (read from Figure 3; minutes)

The equation of time, as graphed in Figure 3, is a correction for slight variations in the speed at which the earth orbits the sun. Because that orbit is slightly elliptical, the earth's speed along its path is slightly faster in winter when the earth is a bit closer to the sun than in summer when the earth is farther away from the sun.

Note: The views expressed here are strictly those of the author and do not necessarily represent **pme** *or BNP Media.*

> Figure 1.

Courtesy of Solar Skies

Doing the math

Here's an example of how to convert between local clock time and solar time. Let's determine the solar time that corresponds to 10:30 a.m. March 20 in Syracuse, N.Y.

Solution: The longitude in Syracuse is 76.1478° west. Syracuse is within the Eastern time zone and the standard meridian for that time zone is 75°. Daylight saving time *is* in effect on March 20. This means the *standard time* corresponding to a clock time of 10:30 a.m. March 20 is 9:30 a.m. Finally, an estimate for the value of (E) for March 20 using Figure 3 is -8 minutes. Substituting this information into Formula 1 yields:

$$\mathbf{T_{Solar} = 9:30 + 4\,(75 - 76.1478) + (-8)}$$

$$\mathbf{T_{Solar} = 9:30 - 12:59\ minutes = 9:17\ a.m.}$$

So when a clock indicates 10:30 a.m. March 20 in Syracuse, the solar time is 9:17 a.m. In this example, the largest deviation between clock time and solar time is due to the difference between standard time and daylight saving time. To get local standard time, subtract one hour from the local clock time whenever daylight saving time is in effect. The remainder of the deviation is due to the location of Syracuse within the Eastern time zone and the slight variation in the earth's orbital speed accounted for by the equation of time.

High noon

All aspects of the sun's arc across the sky are symmetrical with respect to solar noon. The left half of a sun path diagram is symmetrical with the right half with respect to a vertical line representing solar noon. The sun also is directly above a true north/south line at solar noon. This implies the shadow cast from a perfectly vertical object at solar noon will be aligned with a true north/south line. The sun is always at its maximum altitude angle for any given day at solar noon.

Formula 1 can be rearranged to calculate the clock time that corresponds to solar noon. This rearrangement is given as **Formula 2:**

$$\mathbf{T_{LS} = T_{Solar} - 4\,(L_M - L_{Local}) - E}$$

Where:
T_{LS} = local *standard* time
T_{solar} = solar time at the location
L_M = longitude of the standard meridian for the time zone (°)
L_{local} = longitude at the location (°)
E = "Equation of time" (read from Figure 3; minutes)

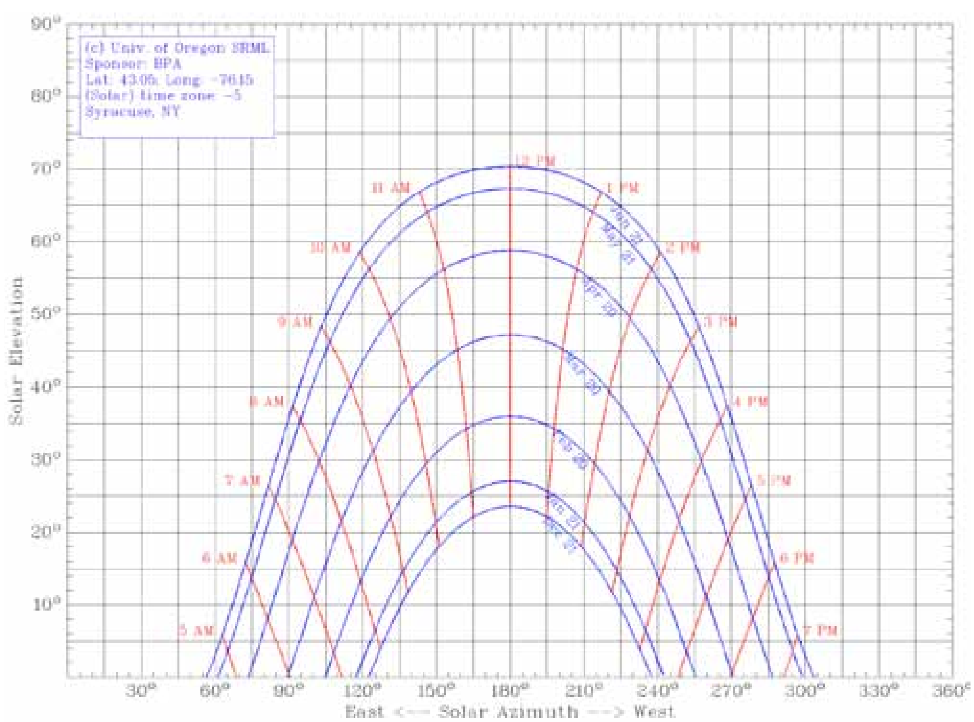
Here's another example. Find the clock time corresponding to solar noon on March 20 in Syracuse. From the previous example, the longitude in Syracuse is 76.1478°. The longitude of the Eastern time meridian is 75° and the value of E from Figure 3 is -8 minutes. Putting these values into Formula 2 yields:

$$\mathbf{T_{LS} = 12:00 - 4\,(75 - 76.1478) - (-8)}$$

$$\mathbf{T_{LS} = 12:00 + 12.59\ minutes = 12:12.35}$$

The time indicated by 12:12:35 means 12 minutes and 35 seconds past noon. Keep in mind this calculated result is still *standard* time. On March 20, daylight saving time is in effect so clock time is standard time + 1 hour. Thus, the *clock* time corresponding to solar noon is 1:12:35 p.m., which can be rounded to 1:13 p.m.

> Figure 2.



A sun path diagram for Syracuse, N.Y., prepared from the website: http://solardata.uoregon.edu/SunChartProgram.html.

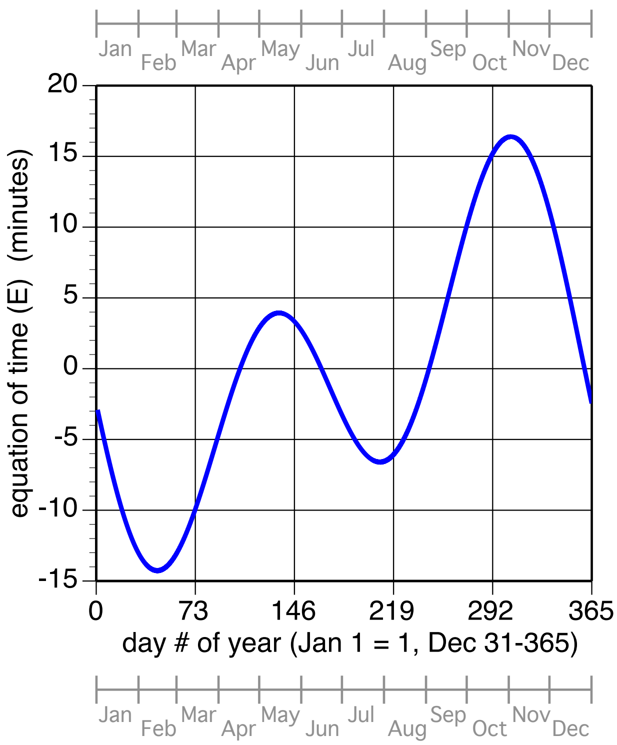
If you're not sure what the longitude of a location is, Google it. Be careful when you combine the various expressions in either Formula 1 or 2. Remember that subtracting a negative number is the same as adding. Also remember to convert between decimal minutes and seconds.

All aspects of the sun's arc across the sky are symmetrical with respect to solar noon.

Finally, take advantage of the website listed in Figure 2 to get a free sun path diagram for the location(s) you design for. It's a lot easier than using other formulas to determine the altitude and azimuth angle of the sun.

So now, with respect to the sun, you really do know (or can figure out) what time it is. **pme**

> Figure 3.



John Siegenthaler, P.E., is the principal of Appropriate Designs, a consulting engineering firm in Holland Patent, N.Y., and the hydronics editor for Plumbing & Mechanical and **pme***. Contact him at john@hydronicpros.com.*