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Orienting solar collectors

Jim MacDonald[1/]

no. 10.615

Quick Facts

- Only a small fraction of the sun's energy is intercepted by the Earth in the form of ultraviolet radiation, infrared and visible light.
- Even on a clear day as much as 30 percent of the radiation from the sun may be reflected back into space; the radiation that penetrates directly to Earth is known as direct or beam radiation.
- The amount of direct solar radiation varies with time of day.
- A flat plate collector will perform best when it is perpendicular to the sun, or at an angle with the Earth's surface.
- Efficient angles have been determined for this locality by their relationship to latitude and season.
- The performance of a collector will not be affected significantly if it does not face exactly south; however beyond 30° the efficiency drops rapidly.
- Solar collectors do not have to be mounted on a roof, however, they should be mounted or placed in a location with full access to the sun.

Energy is generated within the sun by constant thermonuclear reactions. A large quantity of this energy is radiated into space, driven by a surface temperature of about 10,000 °F (5500 °C). The amount of energy radiated by the sun is so great that the small fraction intercepted by the Earth sustains life.

Solar radiation consists of a wide band of wavelengths, including those we see as light and others in the ultraviolet and infrared bands. Most ultraviolet radiation is absorbed by the atmosphere, so almost half the solar radiation received at the Earth's surface is in the form of visible light. Nearly all the rest is in the infrared wavelengths. Figure 1 shows the spectrum of solar radiation received at the Earth's surface.

As solar radiation penetrates the Earth's atmosphere, it is somewhat scattered, absorbed and reflected. Even on a clear day as much as 30 percent of the radiation from the sun may be reflected back into space without reaching the surface. A portion of the remaining radiation is scattered by the atmosphere and is perceived as diffuse radiation. The radiation that penetrates directly to Earth is known as direct or beam radiation.

Even with clear skies, the amount of direct solar radiation at any point on Earth varies with the time of day. The maximum is at noon, when the sun appears to be at its highest point above the horizon and when radiation encounters minimum thickness of atmosphere. The early morning and late afternoon sun must penetrate more atmosphere, with increasing reflection, absorption and diffusion.

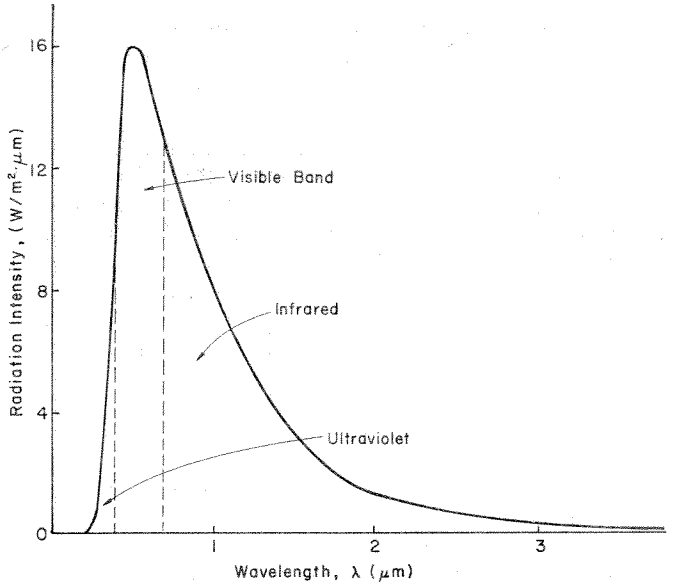

Figure 1: Spectrum of solar radiation at Earth surface.

Figure 2 represents total radiation on one part of the Earth's surface from hour to hour throughout the day.

A flat plate solar collector will perform best when it is perpendicular to the sun. Therefore, it must be installed at an angle with the Earth's surface. The increased amount of radiation intercepted by a tilted collector, compared to a horizontal one, is shown in Figure 3, which illustrates that the interception is greatest when the collector is perpendicular to the incoming radiation. As the Earth travels around the sun, the path of the sun across the sky varies during the year, so any fixed collector will be perpendicular to the sun's apparent path only two days each year. A collector would work most efficiently if the tilt angle were raised or lowered each day to follow the sun, but this is not practical for most systems.

1/Jim MacDonald, Solar Energy Applications Laboratory (4/1/82)

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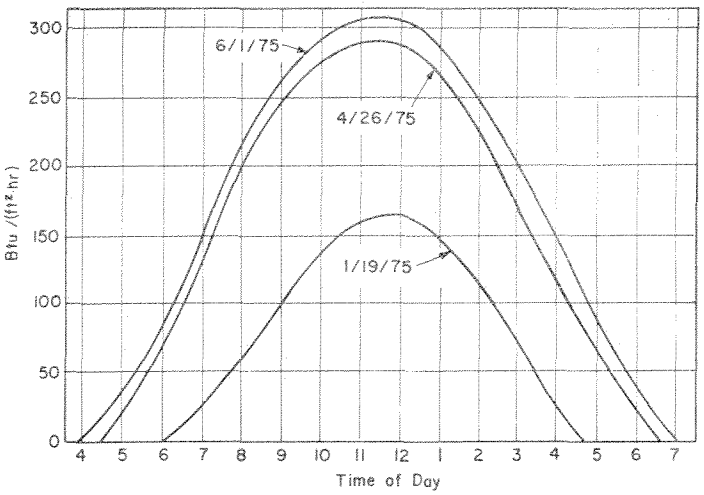


Figure 2: Hourly record of clear day radiation on a horizontal surface at Fort Collins, Colorado (data from Solar House 1).

Since the collector normally is mounted at a fixed tilt, an angle should be chosen that will have the collector nearly perpendicular to the solar radiation during the coldest part of the year. This angle will be dependent upon the latitude. (See Figure 4.) The sun is at its lowest path across the sky on December 21. To face the collector perpendicular to the sun's radiation on this date, it would be mounted at an angle to the horizontal equal to the latitude plus 24°. Since the coldest part of the winter is during January and February, however, a smaller angle would be better. This angle has been determined to be the latitude plus 15° for winter heating.

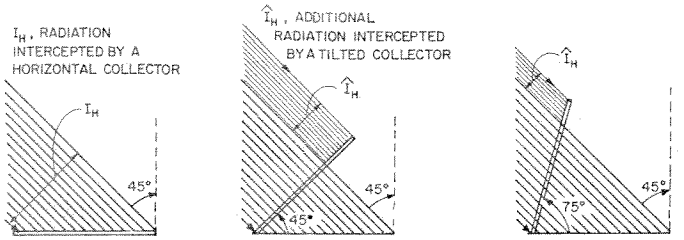
In Denver, which is at 41° north latitude, the best tilt angle for winter heating would be 56°. For summer applications, the best angle would be somewhat less than the latitude. For equal winter and summer use of the solar collector, as with a solar domestic water heating system, it should be mounted at an angle approximately equal to the latitude. The exact tilt angle is not a critical factor in the performance of a solar heating system, since the flat-plate collector will respond to diffuse radiation as well as direct.

In addition to the amount of direct radiation intercepted by the collector, there is another factor in the relationship between collector angle and performance. This is the reflection of solar radiation from the transparent surface of the collector. The greater the angle between the solar radiation and the collector the greater this reflection will be. At noon each day the sun is directly south, so a collector should be mounted facing true south for maximum performance.

The performance of a collector will not be affected significantly if it does not face exactly south. The intensity of solar radiation does not vary greatly between 10 a.m. and 1 p.m., standard time, so nearly maximum performance will be achieved if the collector faces the sun during that time frame. Experiments have shown that if a flat plate collector faces away from south by as much as 30° in either direction the performance will be reduced by 5 percent or less. Beyond 30° the efficiency begins to drop rapidly.

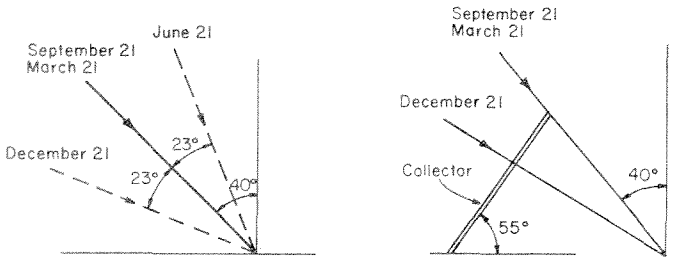
Solar collectors do not have to be mounted on the roof. They are usually mounted there to avoid shade and to allow solar heat to be brought directly into the building. They can be mounted anywhere that guarantees full access to the sun if a south-facing roof surface is not available. To avoid heat loss, however, collectors should be mounted as close as possible to the building to be heated. If only winter heating is desired, collectors can be mounted vertically on a south-facing wall, with some reduction in potential performance.

Collectors should be protected from the wind as much as possible. For this reason, the best installation is flush mounting into a roof built at or near the optimum angle. If this is not possible, the collectors may be supported by a framework attached to the roof, but the back of the collectors should then be protected from wind. If the collectors are to be mounted against the surface of a roof, they should be separated from the roof by a couple of inches to avoid ice and moisture buildup between the collector and the roof.



(a) Collector tilt angle 0°. (b) Collector tilt angle 45°. (c) Collector tilt angle 75°.

Figure 3: Effect of tilting the collector on energy interception.



(a) December 21, sun 23° below latitude angle from perpendicular; June 21, sun 23° above latitude angle from perpendicular; September 21 and March 21, sun at latitude angle from perpendicular.

(b) Collector tilted at latitude +15° maximizes winter collection.

Figure 4: Collector angle will be dependent upon latitude.