

1994 Scoping Analysis

SolarAttic™ PCS1 Pool Heater

From the handwritten notes of the 11/29/93 “scoping analysis” performed by Professor Ephraim M. Sparrow, University of Minnesota, Minneapolis, MN.

Heat Supply To Attic Air:

1. Direct solar. Use 250 Btu/hr ft² incident normal to the sun’s rays. The angle of incidence varies throughout a given day and also depends on latitude and on the season. Use a factor of 0.7 to account for the non-normal incidence. As a best case, assume that all the incident solar is absorbed (i.e., $d_s = 1$). If a 1500 ft² roof is everywhere incident by direct solar, then

$$250 \times 0.7 \times 1500 = 262,500 \text{ Btu/hr.}$$

This would be valid for an unshaded, low-pitch roof. Perhaps a more typical roof would be half shadowed. For such a roof, the absorbed solar would be 130,000 Btu/hr.

2. Scattered Solar. Use 30 Btu/hr - ft² as a typical value. For total absorption on a 1500 ft² roof

$$30 \times 1500 = 45,000$$

3. Total solar. Range:

$$175,000 - 307,500$$

Heat Losses From Attic Roof:

1. Convection losses. Assume roof outside surface temperature is 115° F and that the air ambient is 85° F. Convective heat loss equation:

$$Q_{\text{conv}} = \frac{T}{R}, \quad R = 1/hA$$

where R is the thermal resistance without wind,

$h = 0.7 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$. So that

$$Q_{\text{conv}} = \frac{(115 - 85)}{\frac{1}{(0.7)(1500)}} = 31,500 \text{ Btu/hr}$$

For moderate wind, use $h = 2 \text{ Btu/hr-ft}^2\text{-}^\circ\text{F}$

Then,
$$Q_{\text{loss}} = \frac{(115 - 85)}{\frac{1}{(2)(1500)}}$$

$$Q_{\text{loss}} = 90,000 \text{ Btu/hr}$$

2. Radiation losses. If the diffuse sky radiation is characterized by T_{sky} , then,

$$Q_{\text{loss}} = E A (T^4 - T_{\text{sky}}^4)$$

This equation is for infrared radiation. The emissivity E is about 0.85 for both black and white roof surfaces;

$$= 0.1712 \times 10^{-8} \text{ Btu/hr-ft}^2\text{-}^\circ\text{R}^4.$$

Both T and T_{sky} are in degrees Rankine, °R = °F+ 460. Then,

$$Q_{\text{loss}} = (0.85) (0.1712 \times 10^{-8}) (1500) (575^4 - 460^4)$$

$$Q_{\text{loss}} = 141,000 \text{ Btu/hr.}$$

Heat Balance:

$$\begin{aligned} \text{Max } Q_{\text{loss}} &= 90,000 + 141,000 \\ &= 231,000 \text{ Btu/hr} \end{aligned}$$

$$\begin{aligned} \text{Min } Q_{\text{loss}} &= 31,500 + 141,000 \\ &= 172,500 \text{ Btu/hr} \end{aligned}$$

Range of losses: 172,500 - 231,000 Btu/hr

Range of solar absorbed: ($s = 1$)

$$175,000 - 307,500$$

Conclusion: There are clearly many cases where the system will work (i.e. provide = 90,000 Btu/hr), but the combination of a half or more shadowed roof and moderate wind will unable the [pool] water heating to be accomplished.