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Saving Energy with Passive Systems

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One of the first ways solar energy was used in agriculture was to modify climatic extremes in cold livestock housing by using passive techniques. Passive techniques are extremely cost effective because they generally add little or nothing to the cost of the structure. This guide has information on designing and locating a building to make the best use of the sun and also on storing energy in such passive systems.

Building Design and Location

Extensive research over the years has provided both graphical and mathematical expressions as to just where the sun is located at any particular instant on any day of the year. By using this information, you can design and locate a building to maximize solar effects in winter and to minimize them in summer.

For example consider an open front livestock shelter like the one in Figure 1. The general recommendation for placing this type building is to orient the long dimension of the building's ridge east-west with the open side facing south. This provides the following advantages:

- Facing the smaller wall to the west minimizes exposure to the late afternoon summer sun.
- The relatively longer south wall is open to direct radiation from the winter sun, which is low in the sky. At the same time, the shading effects of overhangs can reduce the penetration of the summer sun, which is high in the sky.

Solar penetration and shading effect for different buildings can be calculated. Refer to Figures 1 through 3 to find the penetration of sunlight into an open front building facing south:

$$HP = \frac{HO \text{ (feet)}}{\text{Tangent } \Theta}$$

Where

HP = Horizontal penetration in feet behind the edge of the overhang,

HO = Height of overhang above ground,

Θ = Vertical elevation of the sun in degrees at the time being considered.

The vertical shading effect can be similarly determined:

$$VS = LO \text{ (feet)} \times \text{Tangent } \Theta$$

Where

VS = The distance down the wall which the shadow will project at the time in question,

LO = Length of overhang.

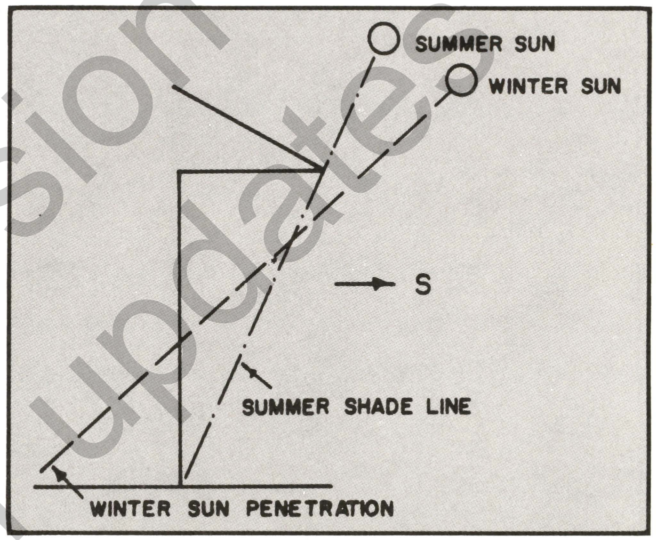


Figure 1. Seasons affect the solar angle for shade and penetration.

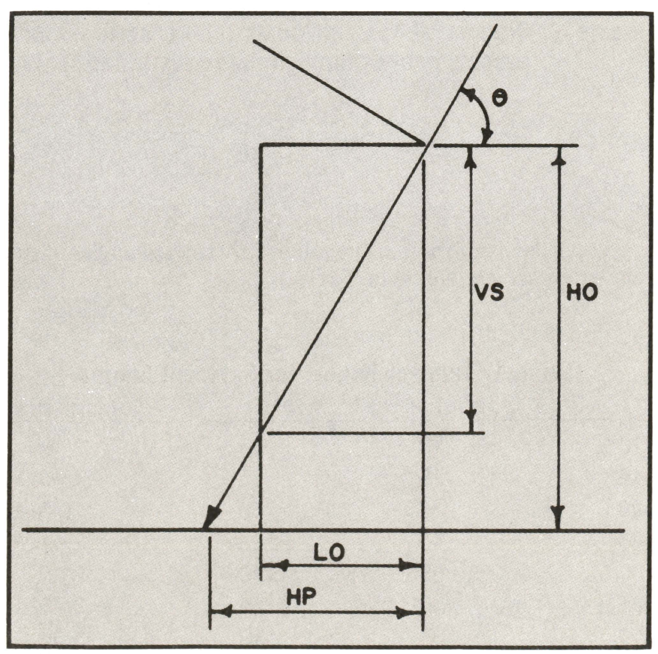


Figure 2. Seasons angle of elevation is related to solar penetration and shading height.

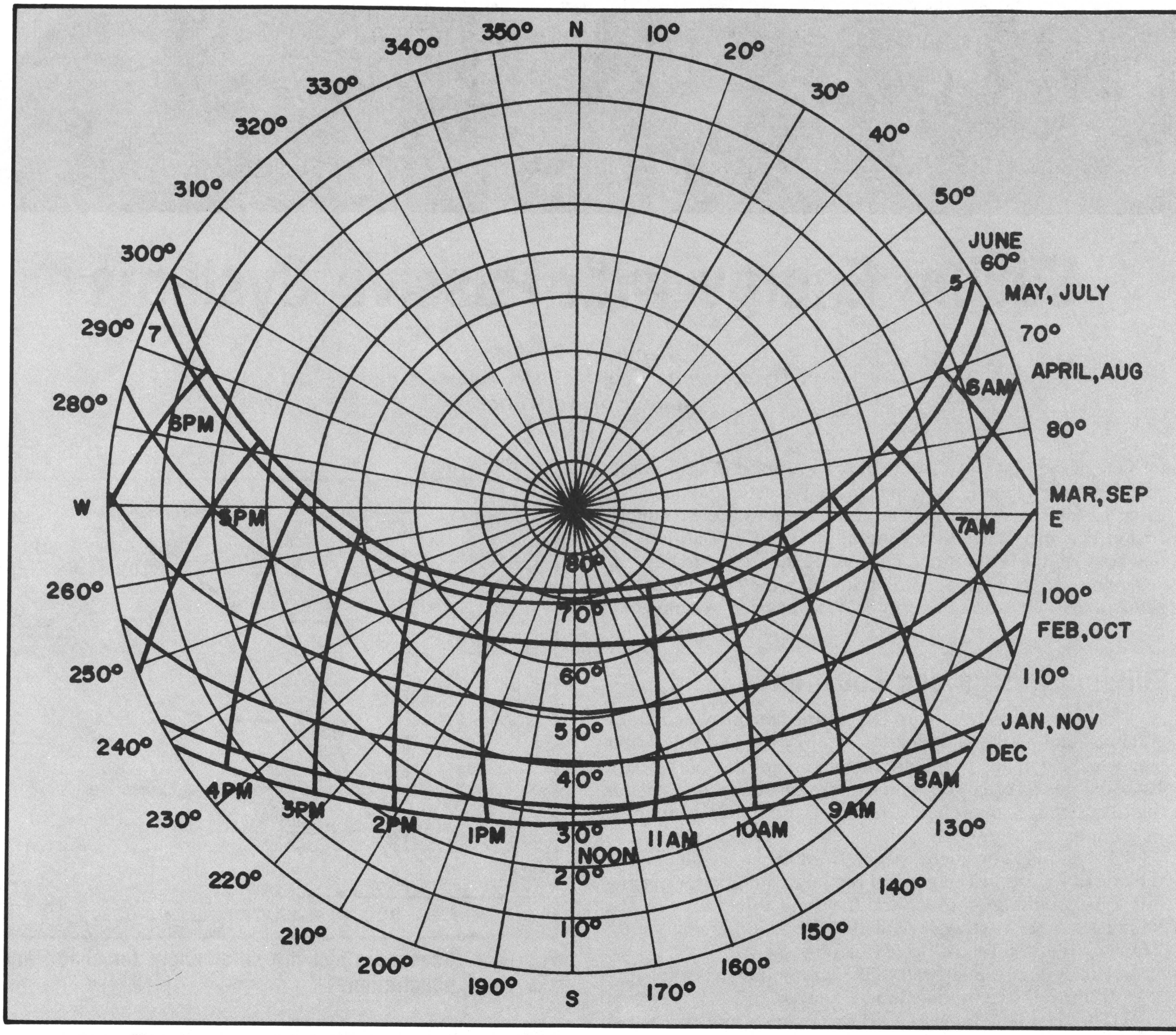


Figure 3. Diagram shows sun's path for 40° north latitude. The 40° north latitude line extends east-west through Missouri passing near or through the towns Ewing, LaPlata, Trenton, and Savannah.

A partial listing of tangent values for selected angles of sun elevation are contained in Table 1.

Table 1. Tangent Values for Selected Angles.

Θ	Tangent Θ	Θ	Tangent Θ
10	.18	50	1.19
15	.27	55	1.43
20	.36	60	1.73
25	.47	65	2.14
30	.58	70	2.75
35	.70	75	3.73
40	.84	80	5.67
45	1.00		

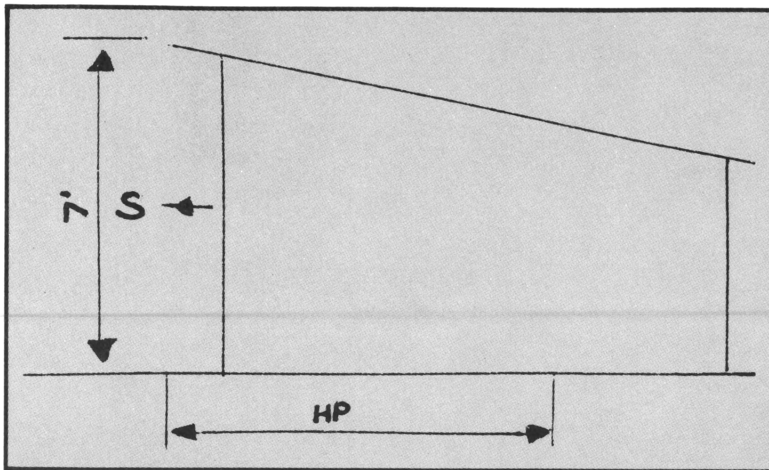
Example Problem:

1. Where is the sun located in the sky at 10 a.m. on June 15? Refer to Figure 3 and find the arc which represents June. Follow the arc to the intersection with the 10 a.m. line. Read the vertical elevation (Θ) as 59°. The compass position is approximately 112° or 22° south of east.
2. Referring to Figure 4, calculate the depth of winter sun penetration into the open-front, shed-roofed building. How will penetration change if height is reduced to 5 feet?

Almost all open-front farm buildings facing south have had some consideration given to solar angle and its effect in their design. More recently, structures have been designed specifically to take advantage of this factor.

Quantifying the positive results of passive design is virtually impossible. But years of satisfactory experience have led to the general acceptance of solar control as a design practice. Since most of these designs require no or little added investment, their acceptance is well merited.

Figure 4. Use this illustration to work the example problem.



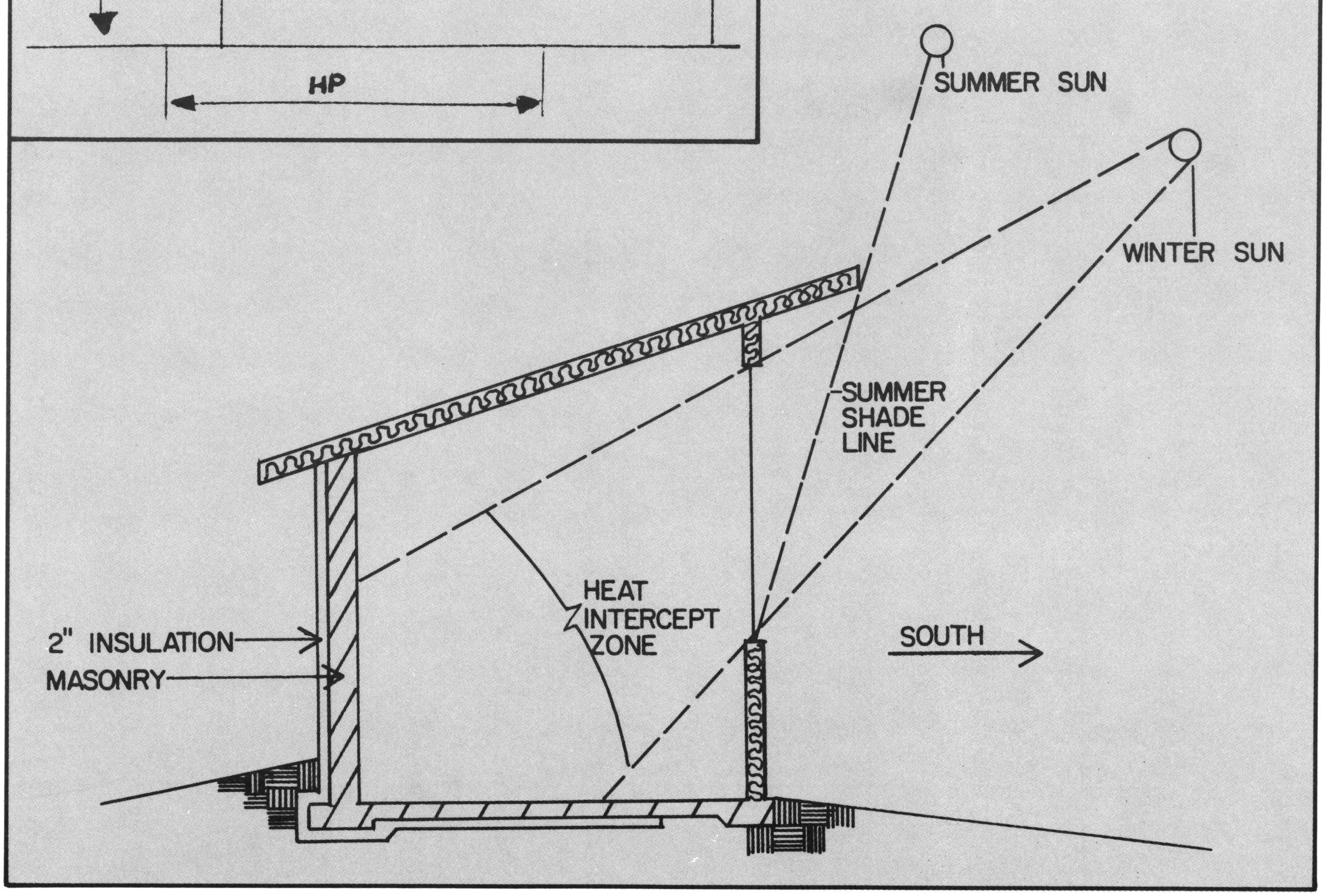


Figure 5. Shed-type structure shows elements of passive solar design with storage.

Storing Energy

A major problem with all solar systems is that of storing energy for night time and cloudy day use. Active systems with storage generally use some type of insulated container holding water or rock to absorb heat during periods of sunshine. This heat is then extracted from storage during periods of no sun.

Several years ago, a Frenchman named Felix Trombe patented a system for providing solar energy storage in passive systems. Known generally as the Tombe wall, this system involves placing a massive structure in a location where it will both intercept solar energy directly and then release it directly to the building at night.

You can incorporate Trombe design features in farm structures by placing high mass (masonry or concrete) building components where they will intercept the sun's energy directly. The most common elements are concrete floors and walls. To provide maximum effectiveness, place some type of waterproof insulation between the storage unit and the ground. A two-inch thickness of expanded polystyrene (R=8) is sufficient for this purpose.

Predicting exactly how much energy a particular design will store is difficult. The specific heat of solid masonry is approximately .2 Btu per pound per degree Fahrenheit. Concrete has a density of 150 pounds per cubic foot or 50 pounds for every square foot of a four-inch thick floor. This means that if you increase floor temperature 15 degrees during a sunny day, it will release approximately 50 x 15 x .2 = 150 Btu of heat energy as it cools during night hours.

Figure 5 shows how passive solar collection and Trombe type storage might be incorporated into a simple shed-type building.

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