Solar Heating Swine Buildings: Pork Industry Handbook
Michigan State University Extension Service
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pork industry handbook

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Solar Heating for Swine Buildings

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Fuel costs for heating swine buildings represent a significant—and growing—portion of the total cost of swine production. Producers are looking for alternative sources of energy to reduce these costs. Solar energy is one such energy source because it is abundant and inexhaustible. This fact sheet discusses the solar heating fundamentals and presents several systems being used to help heat swine buildings. It is not intended to be a comprehensive design manual.

Energy conservation is important especially when solar heat or any other heating system is used for swine buildings. Money must be spent to insulate a building before solar heating can be effective. Also, check the winter ventilation rate (see PIH-60, "Mechanical Ventilation of Swine Buildings") to prevent overventilating, wasting much valuable heat. In a building insulated to the standards of PIH-65, "Insulation for Swine Housing," solar energy can provide a large amount of the total energy required for heating.

The Amount of Solar Energy Available

The energy available on a solar collector surface depends on the time of day, the time of year, the weather, the latitude (location) of the collector site and the collector's tilt angle. In the Midwestern United States at noon on a sunny day in winter, the amount of solar energy striking a south-facing surface at a right angle is about 300 Btu/hr./sq.ft. of collector or 88 watts/sq.ft. Figure 1 shows the total amount of solar radiation available on a clear day for a south-facing surface located at 40° north latitude. The different curves represent various collector tilt angles measured from the horizontal. Fixed solar collectors receive the most energy if they face south, but deviations up to 15° from due south make little difference in total energy received. For maximum solar energy, set the tilt angle of the collector so the sun's rays are perpendicular to the collector at solar noon. For a fixed collector, use the average of the optimum tilt angle for each month during the heating period.

The curves in Figure 1 show that at 40° north latitude, a vertical south-facing wall receives the most energy during October through February, and considerably less the remainder of the year. A horizontal surface receives the most energy during the summer but the least during the winter. Normally, a tilt angle of the latitude plus 15°, or an angle of 55° at 40° north latitude, will give the maximum heating during the winter heating season as shown in Figure 1. A standard roof slope of 4/12 (18.4°) receives considerably less solar radiation during the normal heating season than either a vertical wall or the 55° sloped collector. The minimum tilt angle for regions with high snowfall is about 55-60° so the snow will slide off. For detailed information and monthly solar radiation data for your state, refer to Midwest Plan Service Solar Livestock Housing Handbook, MWPS-23.

Solar Economics

Will solar energy be economical for your swine building? It depends, for many things affect the economics of solar energy. Wide ranges in these factors can mean that the solar energy saved may be worth ten to twenty times as much for one pork producer as it is for another.

To reach a reasonable decision on a solar system you need to know several things:

- How much solar energy is available in your location?
- How many months can you use solar?
- How much of your fuel will a solar system replace?
- What is the cost and expected life of the solar system?
- What percent of the available solar energy will the system collect and use?
- What are the solar tax credits (federal and state), interest rate, operating and maintenance costs?

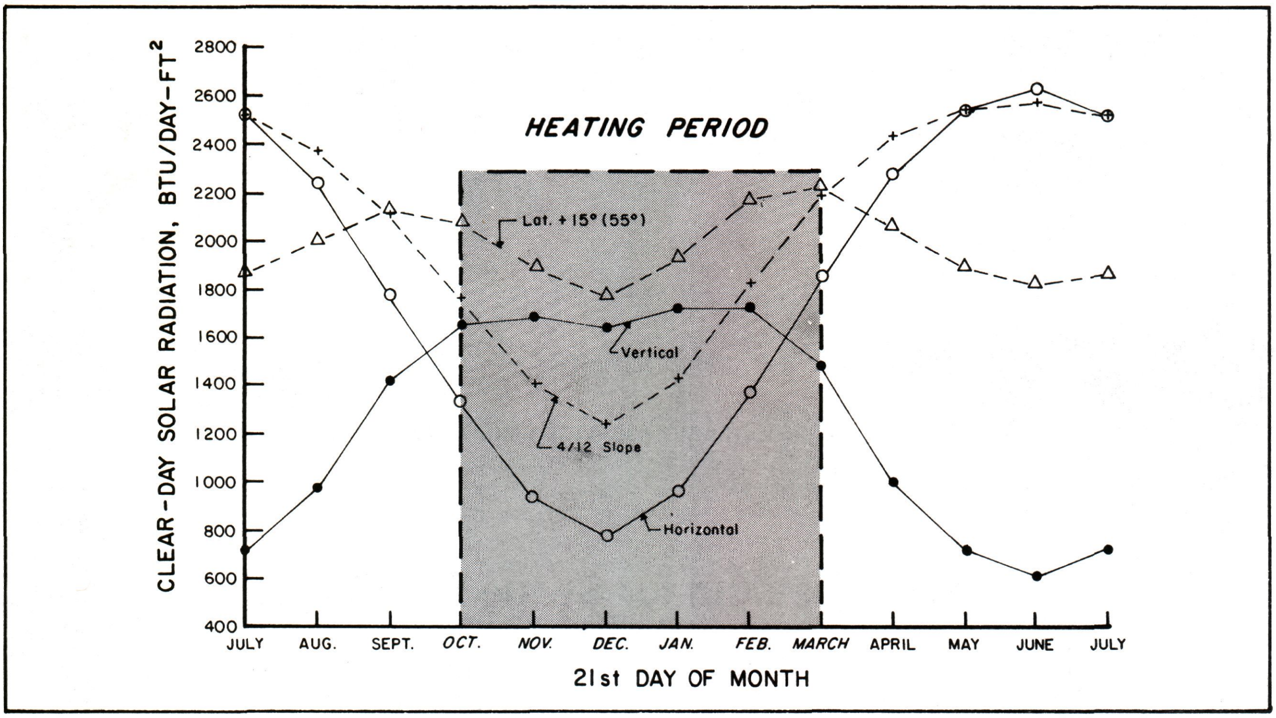

Figure 1. Clear-day solar radiation for south facing surface at 40° north latitude for different collector slopes.

Your local Agricultural Cooperative Extension Service office has information to help you answer some of these questions. You will need to estimate others, such as maintenance costs.

Types of Solar Heating Systems

Two types of systems are used to collect solar energy for swine buildings—passive and active.

Passive solar heating occurs when radiation passes through glass or fiberglass windows and is absorbed by the objects it strikes (walls, floor, pen partitions and animals). This absorbed energy in turn warms the environment. The amount of heat buildup on a sunny day may be sufficient to meet the pigs' needs during the daylight hours, but these same windows also allow heat to escape at night. During winter, the sun shines only about 6-8 hr. a day, allowing heat to escape during the remaining 16-18 hr. The result can be drastic cycling of air temperatures and excessive moisture condensation on the window surfaces during cold weather. Considerable improvement results if an insulated curtain or door is used to cover the windows when there is little or no solar heat gain.

Passive solar heating can best be used in open-front buildings. It is necessary to use a roof overhang (usually roof extension) or some other covering to shade south-facing windows in summer and still permit the sun to penetrate in winter as shown in Figure 2. Normally, to provide complete shading in July in the Midwest, the overhang should be equal to about 1/3 the vertical distance from the overhang to the bottom of the window.

Active solar systems require facilities and equipment for collecting, transferring and often storing solar energy. This allows solar energy to be collected at one location and moved by fans or pumps for use or storage in another location.

An active system may also allow for dual use of a collector. For example, the heat from a collector could be

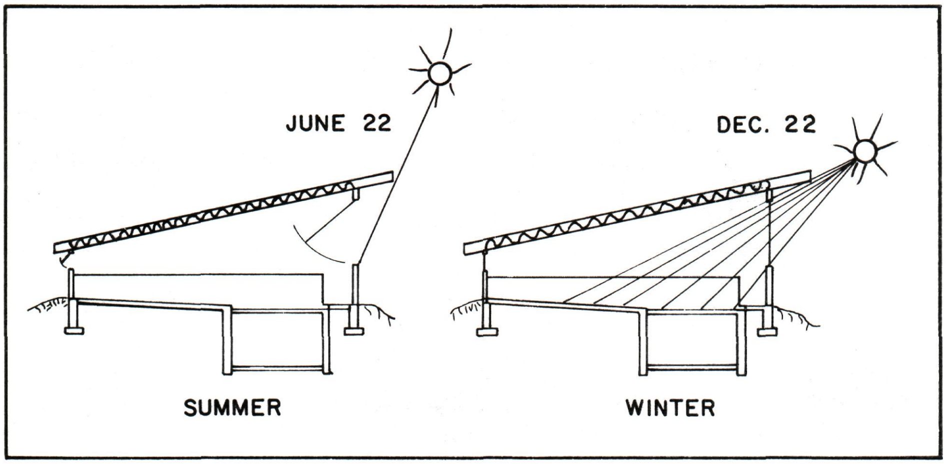

Figure 2. Passive solar system—use roof overhang to block out the sun during summer.

used to help heat the ventilation air of a farrowing house during winter, while in the fall the heat could be transferred to a nearby grain bin for drying grain. Using a collector for more than one purpose helps justify cost.

The most feasible application of solar collectors would be with farrowing and nursery buildings because considerable supplemental heat is usually required in these buildings to maintain a uniform temperature in cold weather. Usually no supplemental heat is used in growing-finishing and sow buildings.

Types of Active Systems

The different types of active solar systems being used on swine farms all have the following two common characteristics: (1) a dark-colored surface to absorb the sun's rays, causing an increase in surface temperature and (2) a transfer medium, usually air or water, to pick up the heat absorbed and transfer it to the point of use or to storage. Most collectors also have a clear cover (which should be kept clean) over the absorber surface which reduces both convective heat loss caused by the wind passing over the collector and radiant heat loss. Typical air- and liquid-type solar collectors being used in swine buildings are shown in Figure 3.

The common air-type collectors are either bare plate or covered plate collectors. Most bare plate collectors (Figure 3a) use dark colored metal roofing as the absorber surface. When roof-mounted, they have the capability of preheating the ventilation air about 10°F using the regular metal roofing with a small air space (about 2-4 in.) to pull the ventilation air through under the metal roofing.

Greenhouse-grade, clear fiberglass (fiberglass-reinforced plastic referred to as FRP) is the material most often used for the cover on covered plate collectors (Figure 3b) for agricultural applications. Fiberglass transmits about 80% of the solar radiation compared to about 87% for glass, but it is more resistant to breakage. Plastic films or sheets are also used, but few types can withstand more than 1-2 yr. of the sun's rays before becoming discolored and brittle. The transmission capabilities of plastic film is high (over 90%) but 30-40% of the total can be reradiated back through the cover, compared to 5-10% reradiation with fiberglass.

Solar collectors for heating water (Figure 3c) are also used in swine buildings, usually in connection with an in-floor radiant heating system. These systems usually require relatively high investments and, consequently, should have higher returns to justify the higher costs. The finned-tubed solar panels are usually mounted on a steeply sloped roof (usually 45-50° from the horizontal).

The efficiency of a solar collector is normally measured by dividing the amount of energy collected by the total amount of energy that strikes the collector and expressing it as a percentage. However, a more meaningful indicator to measure the benefits of a collector is how much regular heating fuel is saved per dollar invested by using the collector. Actual benefit is not from simply collecting the energy—there must be a use for the energy. For example, the most energy is collected during the summer by collectors with small tilt angles, but to date there is little need for solar heating in hog buildings during the summer.

During a sunny winter day, excess solar energy may be wasted unless there is a heat storage unit to hold the heat for later use. A solar system with a storage unit helps even out daily temperature fluctuations.

Solar Attic Collector

Solar attics have been successfully used in swine buildings. A solar attic is formed when one or both sides of the roof is covered with clear fiberglass and the sun is allowed to shine through, warming the air in the attic. It is best to orient the building east-west and to cover the south half of the roof with clear fiberglass. With a north-south orientation, both the east and west sides of the roof need to be covered with fiberglass, which adds to the cost. The amount of overall energy collected is about the same for both arrangements, but the overall cost effectiveness would be better with the south facing collector. The extra cost of constructing a solar attic instead of normal roof construction will vary between $.50 to $3.00/sq. ft. of collector.

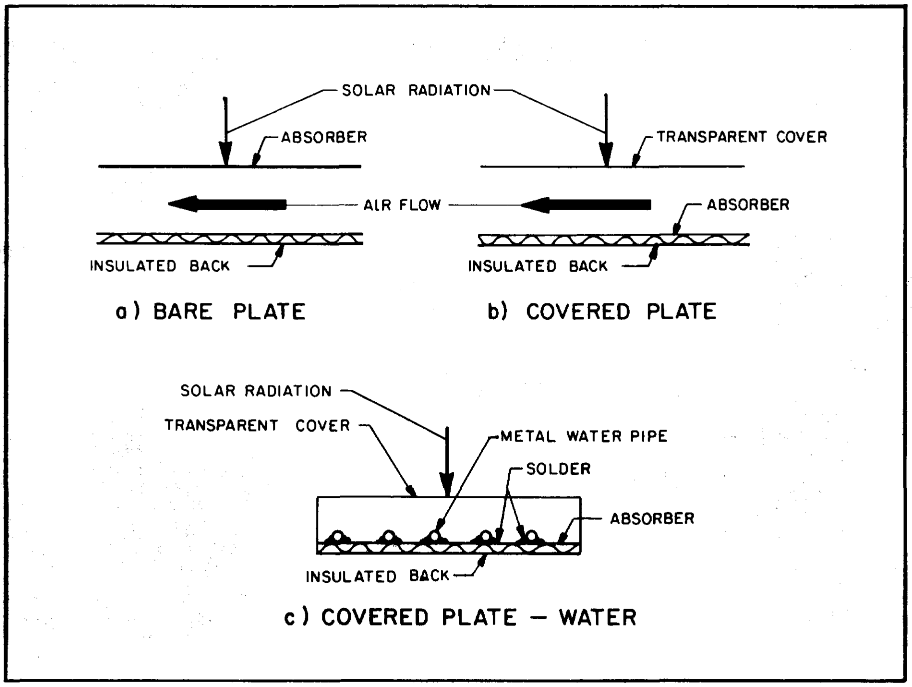

Figure 3. Types of air and water flat plate solar collectors.

When heating the ventilating air for a swine building, a major concern is to temper the air as much as possible, particularly with minimum winter ventilation rates for the pigs. Higher temperatures can be reached (and more heat saved) by dividing the attic lengthwise so the heat collecting chamber is smaller and heat loss is reduced by insulating the colder north attic section (Figure 4). In order to achieve a more desirable roof collector angle in winter, buildings have been built with a steeper roof on the south. This 50° sloping roof allows the outside air to enter the solar attic through a screened opening under the south eave. A black painted partition serves as an absorber. Less of the high summer sun than of the low winter sun strikes the absorber, which reduces maximum summer attic temperatures. The warmer air near the top of the attic is pulled down the chimney ducts into the central aisle, over a slot at the top of the aisle and into each room. It is important that a continuous running exhaust fan in the hog barn keeps a negative pressure on the attic to prevent a reverse flow of moist air into the attic. Each of the farrowing and nursery rooms can be ventilated independently because the central aisle serves as an air plenum chamber. The building must be tight with the outside doors kept closed so the regular ventilating fans can pull air through the entire system. Measurements show that during the 1980-81 winter in Illinois, 1 sq. ft. of this roof collector provided energy that was roughly equivalent to that provided by 1 gal. of LP gas. This appears to be a reasonable expectation.

The south wall can be used as a covered plate collector along with an attic collector. The south vertical wall has a good angle to the winter sun as shown in Figure 1.

In the application shown in Figure 4, the solar heated air is also ducted to the fan house of two grain drying bins and used for drying, helping to justify the cost of the solar system. Usually the grain drying season is over before the heating season begins in the hog house.

Heat Storage Materials

In a passive solar system, heat is stored in the components of the building itself, such as concrete floors, pen partitions and walls. Heat storage in an active system of a solar heated building usually uses rock, concrete or water. Another possibility is a change-of-phase material which requires a smaller volume to store equal amounts of heat. However, the cost is considerably more and there is some evidence that presently available change-of-phase materials, like Glauber's salt, will lose effectiveness over time.

A comparison of the heat storage value of various materials is given in Table 1. As a rule of thumb, for every square foot of collector surface provide at least 1 cu. ft. of rock or solid concrete, or about 2 gal. of water for heat storage. All

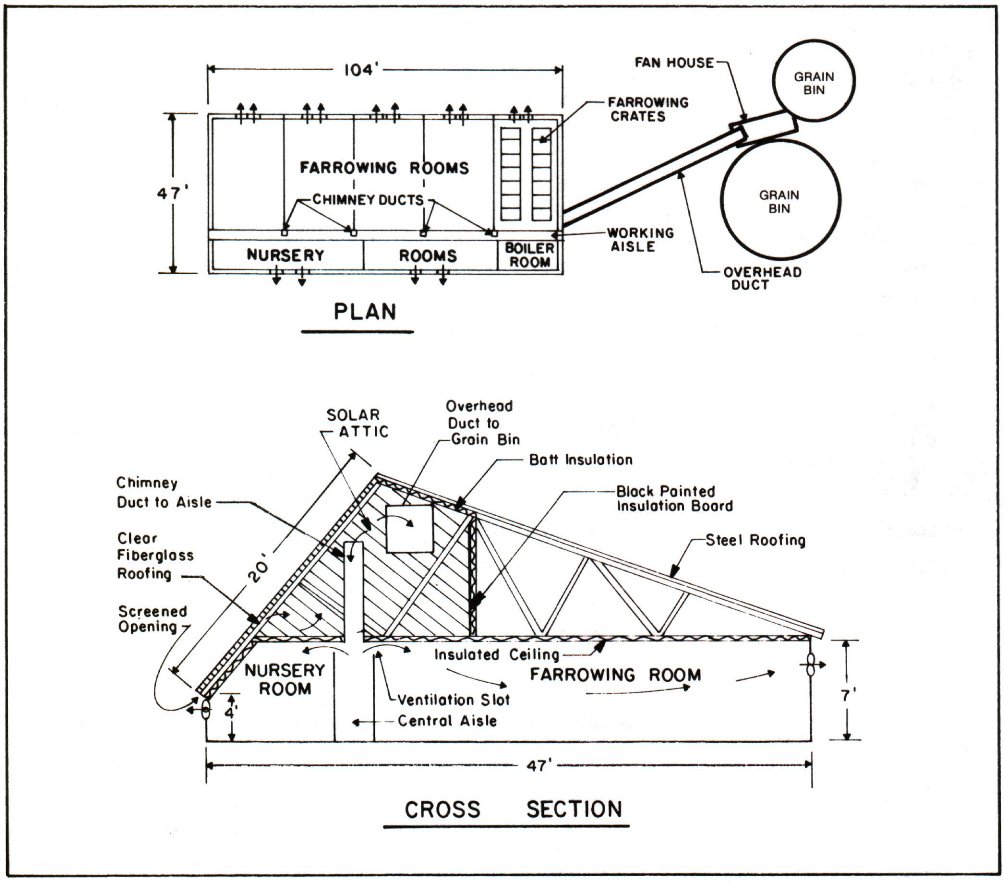

Figure 4. Modified solar attic collector for farrowing-nursery building.

Table 1. Heat storage values of various materials (for 50° Temperature Rise).*

Storage Materials	Btu/ lbs.-°F	Lbs./ cu. ft.	Btu/* lb.	Btu/* cu. ft.	Btu/* gal.
Water	1.0	62.4	50	3,120	417
Rock	.2	100	10.5	1,050	
Concrete	.2	150	10.0	1,500	

*For a temperature rise of less than 50°F, simply use a percentage of the table value. For example, a 30°F temperature rise in water storage would provide a heat storage of 30°F ÷ 50°F x 417 = 250 Btu/gal.

heat storage units should be insulated to at least an R = 15 on all sides.

Collector with Block Wall Heat Storage

A popular solar collector with heat storage uses a 16-in. thick wall of solid concrete blocks stacked along the south side of the building, a concept developed at Kansas State University. The vertical block joints are left with no mortar. Sun shines on the south, black-painted surface, heating the blocks. Ventilating air is pulled between plastic covers and through the vertical joints of the blocks, picking up heat as shown in Figure 5.

Heat is stored in the blocks during the day. The ventilating air removes most of the heat from the warm blocks at night, helping to maintain building temperature.

During the summer, the system can be used for cooling. The collector surface is covered and a separate fan pulls cool night air through the blocks and exhausts it back outdoors, thus cooling the storage. During a warm summer day, operate the system as for heating and the blocks cool the ventilating air.

The block collector and storage wall can be used as the south sidewall in a new building or constructed as a stand-alone wall adjacent to an existing building. Tests at Kansas State University show that the total energy collected from each square foot of collector (in Kansas) is equal to 1-2 gal. of LP gas per year. The energy saved depends on the building temperature maintained. In the Midwestern United States, between 15 and 20 sq. ft. of collector area is needed per farrowing crate. The cost of a collector with block wall heat storage will vary from $10.00 to $15.00 per sq. ft. of collector. Plans for a 20-sow farrowing house with heat storage wall are available from Midwest Plan Service or your Extension agricultural engineer. Ask for MWPS plan No. 81902.

Rock Storage Unit

Solar heat storage units may be located in or under the swine building or in a nearby structure. Several lean-to collectors with rock storage have been built similar to the one shown in Figure 6. The cost of this type of solar system with rock storage will vary between $5.00 and $8.00/sq. ft. of collector.

With this collector and storage located adjacent to the south building wall, a triangular-shaped depression is made in the earth to a depth of about 3 ft. for the rock. A perforated metal aeration duct running the length of the storage is used for air distribution beneath the rock. A vertical duct is attached to the center of this aeration duct. A charging fan located in this vertical duct recirculates the collector-warmed air down through the rock to the aeration duct and up through the vertical duct, eventually discharging it above the rock where the air can be recirculated. Use uniform size rock with a 2- to 4-in. diameter to maximize surface area

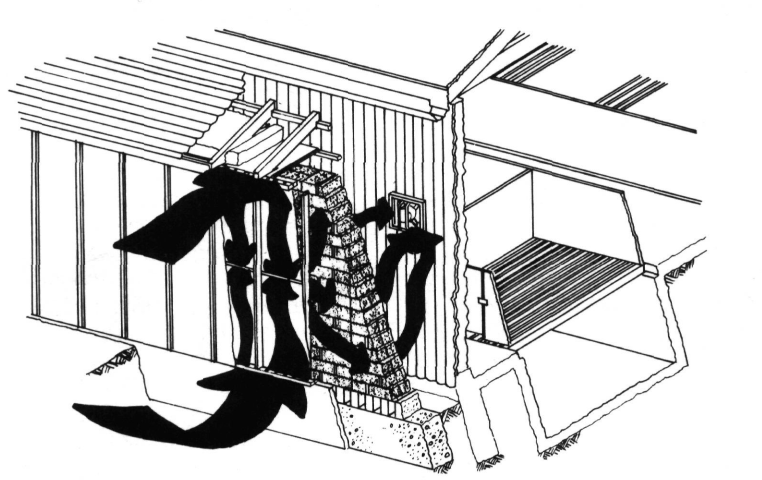

Figure 5. Solar collector with block wall heat storage.
Details for this type of construction are provided in MWPS Plan No. 81902, "20-Sow Farrowing House" available for $2.50 from most Extension agricultural engineers.

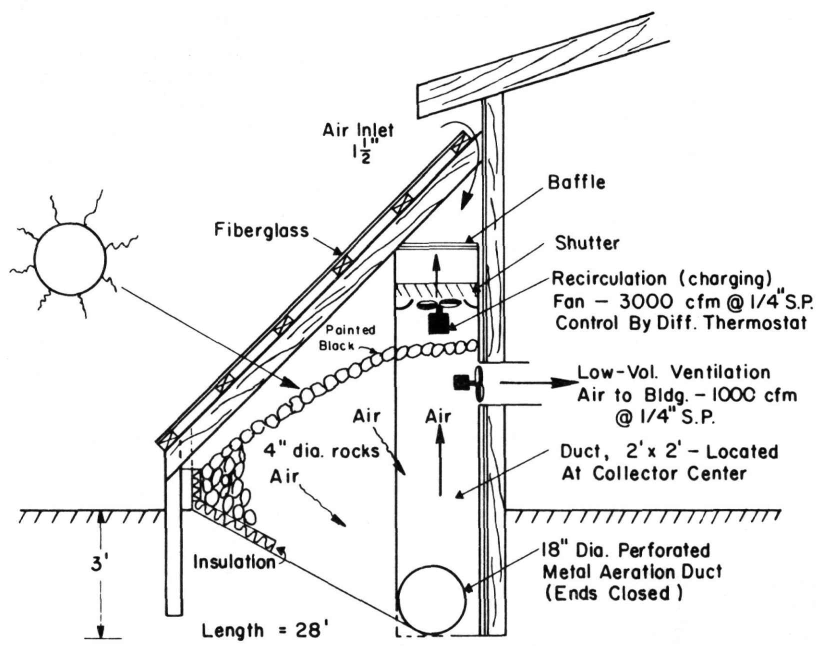

Figure 6. Lean-to solar collector with rock heat storage.

and minimize pressure losses. Smaller rocks require more energy to circulate the air because the charging fan must run against a higher static pressure. Using 4-in. rock as shown in Figure 6, the delivery of the charging fan should be based on 1/4-in. static pressure. The rock surface and the south-facing vertical wall are painted black to absorb energy. Insulate under the rock to reduce heat loss to the ground. Provide adequate drainage so water does not stand in the metal aeration duct, blocking the air flow.

Sunlight shines through the clear fiberglass roof onto the rocks. A differential thermostat controls the charging fan, turning it on when the sun has warmed the air inside the collector and off when the rocks are warmer than the air. Air enters at the top of the fiberglass roof and is heated by the sun. As the heated air passes through the rock, it gives up heat and warms them.

A second smaller ventilation fan pulls air from the aeration duct and moves it to the entrance room of the swine building. Ventilation fans in each nursery room pull the air from the entrance room down a central duct and distribute it in each room. This small fan runs continuously, providing the minimum continuous ventilation rate needed in the building during cold weather. During summer, this ventilation fan with shutter is turned off and a motor-driven shutter located in an outside wall is opened so that fresh air can be pulled in directly from the outside.

There are times in the spring and fall when the outside air warms up considerably during the middle of the day and is actually cooled by the rock storage. Additional controls may be needed to bypass the solar system during those periods.

Water-Type Solar Collector

Typically, water-type solar collectors are built into the south-facing roof of swine buildings during construction. Prefabricated panels can also be mounted on the ground, on the roof or in other locations. The proper collector angle for liquid collectors is more critical than for air collectors. Heat is stored in an insulated tank of water, often under the service area. One type of collector panel (4 ft. x 10 ft.) has 1/2-in. copper pipes spaced 6 in. apart. These pipes are soldered to a thin copper sheet painted with a black chrome selective surface paint. The panels are connected in parallel and located so that all water will drain down into the storage tank to prevent freezing when the pump turns off (Figure 7). The typical cost of installing a commercial water-type solar collector is from $12.00 to $20.00/sq. ft. of collector.

A differential thermostat controls the pump on the collector so water circulates through the collector only when the temperature of the collector is higher than the temperature in the storage tank. A second differential thermostat controls valves directing the return water from the floor. If this return water temperature is cooler than the water temperature in the storage tank, the return water empties into the bottom of the storage tank and water is drawn from the top of the tank through the boiler to the floor. If the return water is warmer than the water in the storage tank, this return water is directed back through the boiler and no water from the storage tank is used. The temperature of the water in the storage tank must be higher than the temperature of the water in the return line from the floor before any solar heat is used. This system operates most efficiently at water temperatures about 100 to 110° F, much below the normally used 140° F. In order to accomplish desired heating with lower temperature water, design changes in the heat distribution system are required.

Heating water to be used for radiant heat in the floor of farrowing and nursery buildings has advantages over heating ventilation air. For example, hot water floor heat can be used during the warm summer months for farrowing and sow-pig nursery buildings because the heated area can be isolated for the pigs and will not appreciably bother the

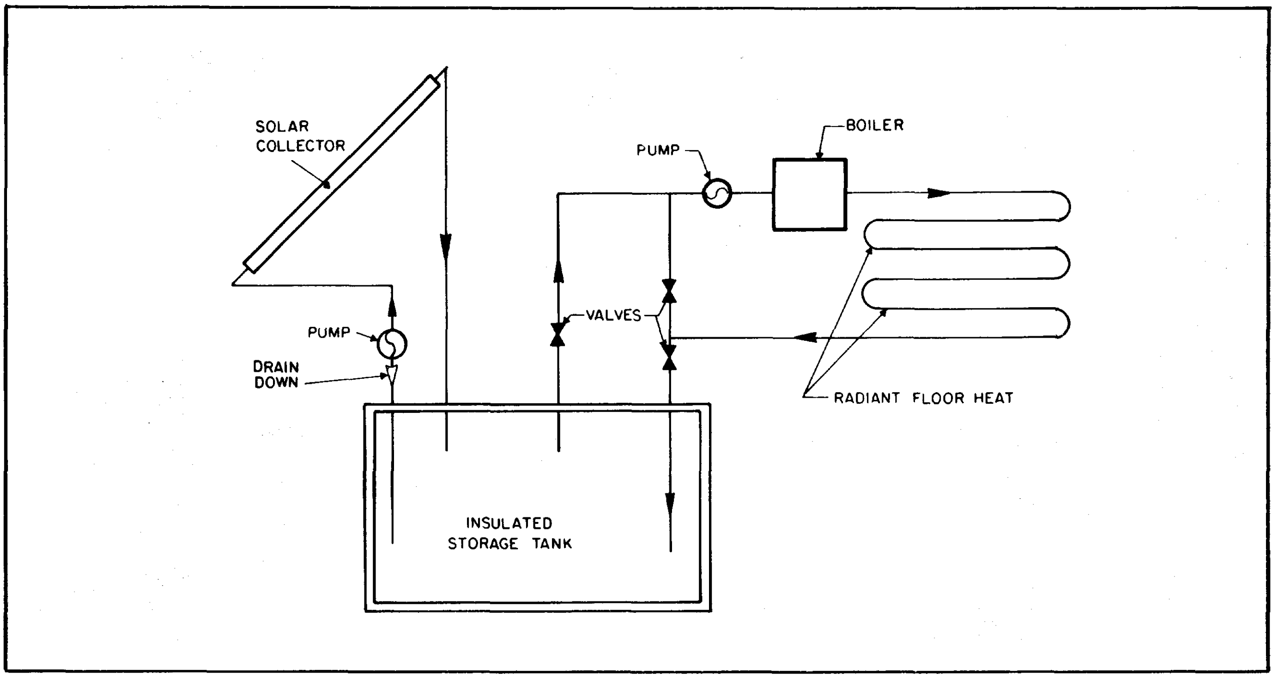

Figure 7. Hot water solar collector and storage.

sows. In contrast, warm air usually cannot be used during the summer because it is difficult to isolate from the sows, causing heat stress.

Summary of Recommendations

Be sure to weatherize and insulate the building you plan to heat to standards suggested in PIH-65, "Insulation for Swine Housing" before spending money on a solar heating system.

Position a solar collector so it faces south with an east-west axis. Generally, the most efficient slope for a collector for winter heating can be found by adding 15° to the location's latitude. For year round heating, use the angle of the latitude. If snow is a problem, use a 55-60° tilt angle for the collector. Consideration should also be given to using the south vertical wall, which has a favorable angle to the winter sun.

Avoid placing a collector behind objects that could block the sunlight. Remember small trees grow large and may eventually shade a collector.

Provide a minimum of 1 sq. ft. of collector for every 1-4 cu. ft./min. (cfm) of ventilating air to be heated. Higher airflows reduce the temperature rise but improve collector efficiency.

Use clear fiberglass with a coating to protect the cover from ultraviolet light. If a grade recommended for solar use is not available, use a good greenhouse grade. A 15-yr. written warranty for greenhouse use is a good indication of quality. However, most suppliers today will not guarantee greenhouse-grade fiberglass for solar-collector use.

When installing a fiberglass collector, it is a good idea to use hex-head, self-tapping screws with rubber gaskets to seal the air leaks. Predrill all holes in fiberglass, even when self-tapping screws are used. This avoids shattering of the fiberglass. Drill the holes slightly larger than the screws or nails to allow for expansion and contraction. A bit of silicone caulking over the top of the head after tightening down the screw will prevent leaks. Do not fasten too tightly. Screws are easier to remove than nails if the fiberglass must be replaced or dismanteled for repairs or modification.

Seal the collector against air leaks with silicone caulking or equivalent product. One tube of silicone caulking covers 75-100 linear ft. Seal the sides of the collector with sealer strips that have been preformed to the shape of the fiberglass sheet.

Screen the air inlets to make them bird- and rodent-proof and shield them so snow will not be drawn into them. Use 1/4-in. x 1/4-in. hardware cloth, not fly screen. Clean the screened area periodically or when necessary so the inlets do not become clogged with dirt or debris.

Use a black absorption surface to collect the solar energy. You can spray almost any material with flat black paint. There are also selective surface black paints available which are designed specifically for solar collectors; but regular flat black paint performs reasonably well. Selective surface paints are expensive and it is more feasible to use them on the more expensive collectors.

Avoid large pressure drops by allowing 1 sq. ft. of duct area for every 500-600 cfm of ventilating air. This will result in a maximum velocity of 500-600 ft./min. Since grain drying systems use more powerful fans than livestock buildings, you can go up to 1000 ft./min. (1 sq. ft. of duct/ 100 cfm of air). Keep the total static pressure below 1/2 in. of water (1/4 in. is better). Greater pressure drops reduce fan performance.

Insulate the back and sides of the collector with high temperature fiberglass (do not use fiberglass with organic binder) or polyurethane insulation. Polystyrene is not recommended by manufacturers for use at temperatures over 165° F.

Ventilate the collector in the summer when you are not using it by providing openings that will allow air to flow through it. A small fan can also be installed. The stagnation of air in a collector can result in temperatures over 200° F inside the collectors. Extended exposure to temperatures over 200° F will damage the fiberglass glazing and may weaken the structural members of the building.

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