G83-651 Nebraska's Solar Heated Modified-Open-Front Swine Nursery

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Nebraska's Solar Heated Modified-Open-Front Swine Nursery

This NebGuide discusses the design features of this unique swine nursery, including ventilation, heating and energy conservation factors, and manure handling systems.

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A warm environment is essential for young pigs. High fuel costs and the practice of heating entire buildings brought about the design and testing of solar heated nurseries on several farms.

Adjustable air outlets (upper slot openings) and large openable air windows/air inlets ensure a healthful environment for the animal year-round.

The Nebraska nursery design incorporates concepts of both the modified-open-front (MOF) building and solar heating to provide a thermal environment suitable for smaller pigs. It uses increased insulation, passive and active solar collectors, an in-floor heat distribution storage (IFHDS) system, and hovers.

Solar Collector Systems

Solar radiation entering through the passive solar collector panels or windows along the high south wall is absorbed by the concrete floor and partitions in the front part of the building (*Figure 1*). The concrete floor and partitions act as a thermal mass to store solar energy for release inside the building at night. Since the passive windows also serve as summer ventilation openings, they must be constructed and installed to provide a continuous 3-foot high opening the full length of the building.

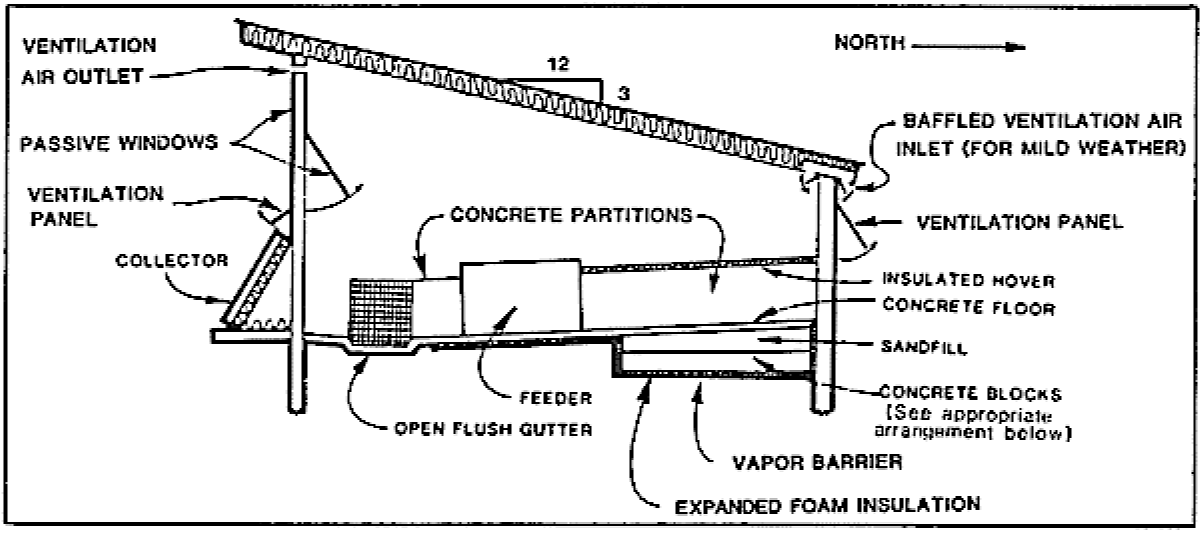
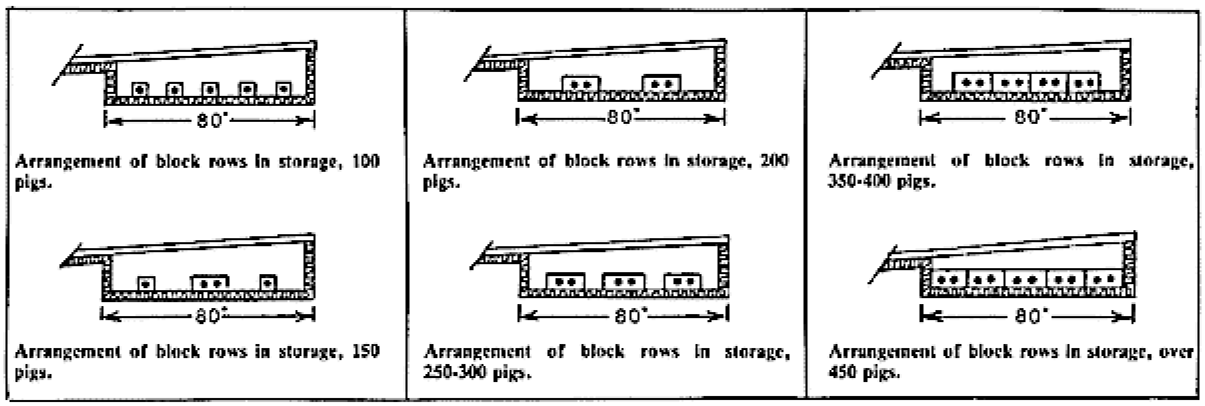


Figure 1. Cross section of the Solar MOF Nursery. Details omitted for clarity.



Arrangement of block rows in storage, 100 pigs.

Arrangement of block rows in storage, 150 pigs.

Arrangement of block rows in storage, 200 pigs.

Arrangement of block rows in storage, 250-300 pigs.

Arrangement of block rows in storage, 350-400 pigs.

Arrangement of block rows in storage, over 450 pigs.

The active solar collector system consists of a collector, air ducts and the IFHDS system. The flat plate collector uses air as the heat transfer fluid. This design features simplicity, ease of construction, and low operating costs.

An absorber plate, insulation and transparent covers or glazings make up the active collector. Hot air from the collector is transported to the IFHDS system at the rear of the building. General design recommendations are 0.65 to 0.75 ft^2 of active collector area per pig, and an airflow rate of 2 cfm per ft^2 of collector area. More specific recommendations regarding duct sizes, fan selection, and collector design are included with the building plans.

The active solar heating system operates in a closed loop arrangement that continuously recirculates the same air through the collector and IFHDS system. The closed loop system prevents dust and moisture from entering, thereby maintaining a high system efficiency. A good rodent control program is necessary, however, to keep rodents from entering the collector system. The collector system operates independently from the ventilation system, thus keeping both simple while allowing them to work together.

Centrifugal fans are recommended for the active solar collector system because they provide the proper balance between static pressure and airflow. Locate the fan motor out of the airstream so the motor temperature limits are not exceeded. Likewise, the fan wheel must be able to withstand air temperatures as high as 225°F. An insulated transition between the air ducts and fan inlet keeps hot air away from the motor.

Fan operation is controlled by a thermostat with a remote sensing bulb positioned at the outlet end of the collector. Locate the bulb in the upper third of the collector and 1 to 2 inches under the solid transition cover to prevent direct heating by the sun. A thermostat setting of 95°F is recommended. Manual control of fan operation is not satisfactory.

Differences in air density between the IFHDS system and the collector cause convective currents in the air ducts, resulting in heat losses when the fan is not operating. These losses can be minimized by installing a plastic flap as a back-draft damper at the outlet end of all air ducts. The plastic must remain flexible and be able to withstand temperatures of up to 200°F. Attach a piece of high temperature insulation to the plastic flap to reduce conductive heat losses.

In-Floor Heat

The in-floor heat distribution system, designed to also serve as the solar heat storage mass (IFHDS system), begins with rows of conventional concrete blocks (*Figure 1*). Each row is placed so that the cores are aligned to form air channels. The rows are arranged along the full length of the building under the hovered sleeping area (*Figures 1* and *2*). All block rows must be covered with a layer of polyethylene to prevent sand from filtering into the air channels.

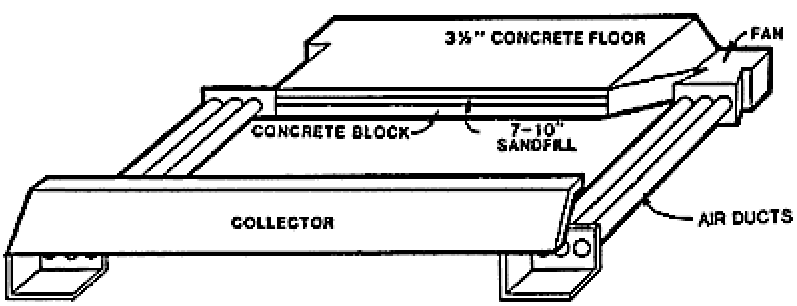


Figure 2. Schematic of the solar collector-in-floor heat distribution-storage system.

Thermal storage, provided by the solid portion of the blocks, the concrete floor, and a 7- to 10-inch layer of sand between them, lessens temperature fluctuations of the floor surface and maintains floor temperatures overnight and on cloudy days. The floor surface is kept at about 85 to 95°F, except after prolonged periods of cold, overcast weather. Auxiliary heat, such as heat lamps, may be required in the hovered areas for pigs weighing less than 20 lbs. if the floor surface temperature drops below 70°F (85°F for 10- to 15-lb. pigs) or the animals begin piling, indicating that they are cold.

Non-Mechanical Ventilation

Ventilation is necessary to remove moisture, dust, gases, odors, and excess heat during warm weather. This is done by properly distributing an adequate amount of fresh air throughout the building. The

Nebraska solar heated MOF nursery uses energy efficient non-mechanical ventilation. However, careful management of the ventilation system is required.

During cold weather, ventilation airflow must be kept low to reduce heat loss, yet high enough to control moisture and odor levels in the building. Over-ventilating removes excessive amounts of heat and may result in the heat supplied by the pigs and the solar system being insufficient to maintain acceptable temperatures.

Winter ventilation rates are varied by adjusting the small panels below the passive collector on the south wall (*Figure 1*). Air entering through these openings cools the open flush gutter area and encourages proper dunging behavior. This cool air mixes with warm interior air, picks up moisture, and rises. The now warm, moist air follows the underside of the ceiling/roof and leaves through the outlets at the top of the south wall.

Mild weather conditions require increased airflow to limit inside temperature fluctuations. Airflow is increased by opening the baffled inlet along the top of the north wall in conjunction with the winter inlets and outlets on the south wall. This rear inlet allows cooler fresh air to enter above the hovers.

Table I. Recommended locations, types and levels of insulation for the Nebraska solar heated MOF nursery.

Insulation Location	**Insulation Type**	**Insulation Level**
Ceiling/roof	Fiberglass batt	R-19
Stud wall	Fiberglass batt	R-11
Insulated concrete sandwich panel	Rigid foam board	R-13
Foundation perimeter	Extruded foam board	R-8
Beneath feeding floor	Extruded foam board	R-4
Around IFHDS system	Extruded foam board	R-8
Around solar collector air ducts	Fiberglass batt	R-11
Behind solar collector absorber plate	High temperature fiberglass*	R-8
Transitions between air ducts (PVC pipe) and collector outlet and inlet	High temperature fiberglass*	R-15
Transition between air ducts and fan	High temperature fiberglass*	R-12
Transition between fan and IFHDS system	High temperature fiberglass*	R-12
Outlet end of air ducts (back-draft damper)	High temperature fiberglass*	R-4

*High temperature fiberglass is necessary to prevent this insulation from degrading at the temperatures attainable in the collectors.

During warm weather, ventilation airflow must be high enough to prevent overheating. Airflow through the animal zone is increased by opening the passive solar collector panels on the south wall and large panels along "the north wall. Proper adjustment of the various panels is essential so that outside temperature variations do not cause significant inside air temperature changes.

Warm weather management must take into account the temperature requirements of the pigs. For pigs weighing over 25 lbs., covering of the collector may be necessary to prevent overheating the sleeping area. If the unit is used only for pigs weighing less than 25 lbs., the need for some heat on a year-round basis may require operating the collector during the summer. In those instances, the collector can be partially covered.

Energy Conservation Features

For maximum efficiency, MOF nurseries must also have other energy saving features, such as adequate levels of insulation placed next to surfaces that are exposed to the outside air or soil.

Use the right type of insulation at each different location. Improperly used or protected insulation can deteriorate or be damaged by rodents and birds. For example, settling can occur if the loose-fill variety is used in a wall; non-rigid insulations are crushed if used below the concrete blocks or floor; and using a foam insulation without proper fire protection can make the building uninsurable.

A polyethylene vapor barrier must be placed between the insulation and inside finish material on all wall and ceiling surfaces to reduce moisture movement through the insulation. Another one must also be placed between the ground and insulation under the feeding area and IFHDS system. Recommended insulation levels, types, and locations within the building are given in *Table I*.

Pen Arrangement

Solar nurseries are generally 23 feet wide, and vary in length depending on the desired capacity. Nominal 5 by 20 foot pens with a net area of approximately 100 ft^2 hold 25 50-lb. pigs. Adding 5 feet to the building length increases the capacity by one full pen, or 25 pigs.

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Openable rear vent doors and hovers over the animal sleeping area allow modification of the animal space environment as weather conditions and animal needs change.

Concentrated zone heating in the rear 40 percent of each pen is provided by the in-floor heat and hovers. This allows the pigs to choose between three thermal micro-environments within the same pen. The warmest environment is at the rear of the pen under the hover and above the heated floor. Increasingly cooler conditions are encountered as the pigs move from the hovered area toward the dunging area.

By heating only the animal zone, total energy requirements are reduced. Engineering calculations and system performance data from the field unit near Fairfield, Nebraska indicate that heat energy requirements for this building design can be reduced to approximately one-half those of a mechanically ventilated and conventionally heated nursery.

Fence-line feeders are recommended because they cause less interference with pig movement between the sleeping and dunging areas. The suggested manure handling system is an open flush gutter located along the south end of the pens. This system reduces ventilation requirements for odor control by removing manure from the building, assists in the development of a good dunging pattern, and usually results in cleaner pens and pigs. Although the open flush gutter system does not use pumps for handling manure, it does require a sizable volume of flush water. A well designed lagoon is required for the flush water and manure. You can also use a deep pit under slats. However, manure storage in the building increases the probability of odor and toxic or noxious gas problems. Make provisions to remove these gases before they enter the animal zone.

Pig Management

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The end of the building where the solar heated air enters the IFHDS system has a warmer floor (85 to 95°F) than the remainder of the building. Put the smallest pigs in this first one-third of the building.

The open, fresh water flush gutter aids in maintaining a clean, healthful environment for the animals.

Floor temperatures of the pens in the middle third of the building are cooler (75 to 85°F) because less heat is available from the air going through the IFHDS system. Pigs weighing about 25 to 35 lbs. effectively use this area as they do not require high floor temperatures for efficient growth. Put heavier pigs in the final third of the building. They do not need high floor temperatures, but still benefit from the in-floor storage.

Field Operations

Three solar MOF nurseries have been built and field tested in Nebraska. Owners have reported success for pigs weighing as little as 8 lbs.

A 23 × 116 foot unit near Fairfield has been operating since October 1979. The building capacity is 550 pigs weighing between 15 and 60 lbs. The open flush gutter manure handling system has worked well with these pig sizes. Hand-scraping of pen floors has not been necessary and no auxiliary heat was required during the first two years. Heating costs for those two years were $10 and $20, respectively--the cost of the electricity needed to operate the fan in the collector system. The estimated annual heating cost for this building if heated by conventional techniques is $1540, assuming that propane, at $0.56 per gallon, is the heating fuel. This estimate also assumes mechanical ventilation and heating the entire volume of the building, rather than using only in-floor heat.

A 300 head capacity nursery, measuring 23 × 60 feet, has been operating since October 1981 near Ceresco. It was designed for pigs ranging from 10 to 50 lbs., but pigs as small as 8 lbs. have been started and reared in the unit. No problems have been encountered with use of the open flush gutter system.

Pig performance tests conducted in this building yielded feed conversion ratios ranging from 2.33 lbs. of feed per lb. of gain (0.69 lb. gain per day) to 1.85 lbs. of feed per lb. of gain (0.77 lb. gain per day). Death losses were less than one percent.

Due to construction delays for this nursery, the heat storage was not properly preheated during the first winter of operation. This, coupled with the fact that the building was not filled to capacity, led to reduced floor temperatures. This created a temporary need for straw bedding to better meet the thermal requirements of the small pigs. This bedding had to be removed or changed by hand. Experience during the second winter indicates that straw bedding is not required when the heat storage has been preheated and the building is filled to capacity.

A 24 × 25 foot nursery near Stuart has been in operation since November 1981. Building capacity is 125 pigs weighing between 15 and 50 lbs. This building features a deep pit under slats for the manure handling system. Non-uniform distribution of air through the width of the in-floor blocks is suspected since the pigs lie near the front of the heated area, indicating that this portion of the floor is the warmest.

Revised IFHDS system design recommendations as presented in *Figure 1* should prevent this problem.

These units operated successfully through the winter of 1981- 82, which had the fourth coldest January in more than 100 years. Solar radiation levels were about one-third below normal during much of the winter, yet building performance remained acceptable with the use of some auxiliary heat. Heat lamps were provided for the smallest pigs in each building, but heating expenses were still only 1 to 3 percent of conventional nursery heating costs.

Construction costs of these nurseries ranged from $54 to $105 per pig. This variation reflects differences in material and labor costs, a deep pit versus open gutter flush manure handling system, experience of the builder, and an economy of scale factor. These costs include the complete solar systems. Material and labor costs for the solar collector systems, including collector, fan, thermostat, and storage, represent approximately 15 percent of the total building cost.

Plan

The plan for the Nebraska solar heated MOF nursery (Plan No. 10.726-37) is available from the Agricultural Engineering Plan Service, Room 215, L.W. Chase Hall, Department of Agricultural Engineering, University of Nebraska, P.O. Box 830727, Lincoln, NE 68583-0727. The plan packet includes details on many facets of the nursery design, including insulated concrete sandwich wall construction, fan size and model suggestions, sources for materials, general information about solar energy collection and use, and overall building construction details.

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