11-1987

Nebraska's Modified-Open-Front Farrowing Houses Design and Operation

Gerald R. Bodman
Extension Agricultural Engineer

Donald G. Levis
University of Nebraska - Lincoln, dlevis1@unl.edu

Duane E. Reese
University of Nebraska - Lincoln, dreese1@unl.edu

Nebraska's Modified-Open-Front Farrowing Houses Design and Operation

Gerald R. Bodman, Donald G. Levis, Duane E. Reese
MEMBER
ASAE

ABSTRACT

TWO modified-open-front non-mechanically ventilated farrowing houses with creep boxes were operated over a two year period. Annual energy requirements were in the range of 10.6 to 10.9 cents per crate per day. No adverse effects on pig performance were realized. In most instances pig performance exceeded national standards of excellent performance—survival rates in excess of 90% and 21-day pig weights of 5.9 to 6.8 kg (13 to 15 lb). The study verified that another alternative is available to producers who do not want additional mechanical equipment to operate and maintain.

INTRODUCTION

Successful operation of many Nebraska solar-heated modified-open-front (MOF) nursery/grower buildings (Bodman and Kocher, 1982, 1983; Kocher et al., 1983; Nebraska Plan No. 10.726-37) encouraged two producers to use the monoslope roof ("Nebraska Style") MOF building for farrowing. Both producers had experience with non-mechanically ventilated monoslope roof MOF growing/finishing buildings (Midwest Plan Service Plan No. 72603) and thus possessed a working knowledge of the performance capabilities and management inputs that might be required. Excellent management skills, an in-place record keeping system, and experience with farrow-to-finish swine enterprises were other common traits. Both facilities rely solely on non-mechanical ventilation and have been in operation since August 1984.

The purposes of this study were to:

1. Determine if the monoslope roof MOF style building could be used as a farrowing facility without adversely affecting animal performance. Projected savings in construction costs, anticipated reductions in energy inputs, and minimal equipment needs (fans, thermostats, etc.) were foreseen as major benefits.

2. Investigate and verify a "proof of concept" that farrowing can be satisfactorily achieved in non-mechanically ventilated buildings designed for both operator and animal comfort and convenience and that the MOF building is an alternative for the producer who doesn't want additional mechanical equipment to maintain.

Article was submitted for publication in August, 1986; reviewed and approved for publication by the Structures and Environment Div. of ASAE in July, 1987. Presented as ASAE Paper No. 86-4025.

Paper published as Journal Series No. 8439, Nebraska Agricultural Research Division.

The authors are: GERALD R. BODMAN, Extension Agricultural Engineer, DONALD G. LEVIS and DUANE E. REESE, Extension Swine Specialists, Agricultural Engineering Dept., University of Nebraska, Lincoln.

Acknowledgments: Special thanks is extended to Art and Doug Paus and Sid and Tim Burkey for their role in this study and their willingness to share their facilities and records to help prove a concept. Appreciation is also extended to the University of Nebraska-Lincoln Institute of Agriculture and Natural Resources Agricultural Research Division, Farm Journal magazine and the Nebraska Energy Office for financial support which made this project possible.

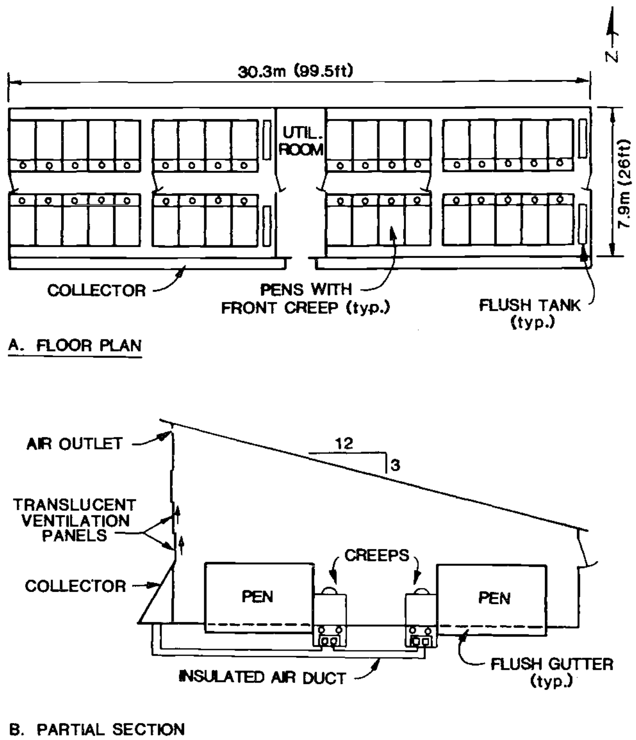

Fig. 1—Paus solar heated modified-open-front 36-sow farrowing house.

BUILDING DESCRIPTION

Paus MOF

The first unit is on the farm of Art and Doug Paus, Fairfield, NE (40° 24′ N, 98° 11′ W) who operate a 150-sow enterprise. The MOF farrowing facility consists of two 18-sow rooms in a 7.9 × 30.3 m (26 × 99.5 ft) building (Fig. 1). The 18-sow capacity was selected to match the size of sow groups. The two farrowing rooms are separated by a central service/utility room housing collector fans, electrical service, hot water heater, medication storage, on-site records, etc. Each of the two rooms is further divided by a partial partition—continuous from the north alley to the south alley—to reduce longitudinal airflow and associated drafts in the pig zone, thus forming one 8-sow and one 10-sow space. Each 18-sow room is operated independently, including heating, ventilation, manure handling and "all in/all out" movement of sows and litters. Each room is used for eight to nine farrowings per

  0883-8542/87/0302-0178$02.00

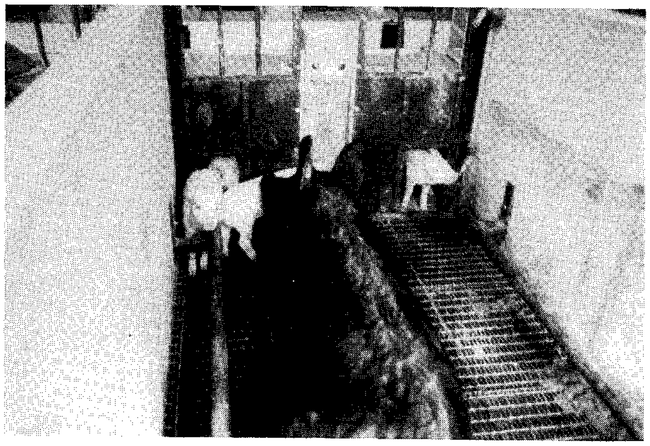

Fig. 2—The farrowing/lactation pens in the Paus unit feature woven mesh floors, concrete partitions, pipe guard rails and creep boxes in front of the pens for the pigs.

year. Sows are removed from the lactation pens when the pigs are 4 to 4½-weeks old. Two to three days post-weaning, pigs are moved to an MOF nursery/grower.

The lower 0.9 m (3 ft) of the building walls are made of insulated (RSI 2.1 [R12]) cast-in-place concrete sandwich panels. The upper portions of the walls are insulated frame (RSI 3.3 [R 19]) 3.8 × 14.0 cm (2 × 6 in., nominal). The monoslope (3:12) roof/ceiling was insulated to RSI 3.3 (R 19). A polyethylene vapor barrier was installed in the ceiling and the frame walls. The interior finish is either concrete or painted chipboard (two coats of oil-base enamel).

Sows are kept in 1.3 × 2.1 m (50 in. × 7 ft) pens with 10 cm (4 in.) concrete partitions, "open" vertical metal rod front and rear gates, woven wire floors, 5 cm (2 in.) pipe guard rails on three sides, and a 1.3 × 0.6 × 0.6 m (50 × 24 × 24 in.) front creep box (Figs. 2 and 3). The guard rails are positioned 15 cm (6 in.) out from the partitions and 20 cm (8 in.) above the floor. Manure is removed by an under-pen fresh water flush system. Manually operated flush tanks are emptied twice per day. Both sows and pigs are provided with nipple waterers (19 and 9.5 mm [3/4 and 3/8 in.], respectively).

Pigs access the front creep boxes through two 20 × 25 cm (8 × 10 in.) openings. The tops of the creep boxes are removable to allow observation of and access to the pigs (Fig. 3). Heat is provided in the painted plywood creep boxes by an in-floor solar-heated warm air system, an auxiliary in-floor warm water heating system and heat lamps or light bulbs as appropriate. The in-floor solar heating system is a variation of the system used in other installations (Bodman et al., 1980, 1981). Except for passive solar heat entering through the translucent southwall ventilation panels, heat is added to the building only through the creep boxes. During extreme weather, ambient temperatures are sometimes in the 10.0 to 12.8 °C (50 to 55 °F) range.

Fig. 3—The front creep boxes used in the Paus facility have removable covers and provisions for auxiliary heat.

The active solar systems consist of two (one for each 18-sow room) ground level 0.9 m (37 in.) high by 12.8 m (42 ft) long collectors with painted steel absorber plates and double Tedlar® * glazing. High temperature fiberglass insulation was placed behind the absorber plates. Insulated (RSI 3.3 [R 19]) PVC pipes beneath the floor convey air between the collectors and in-floor heat distribution systems. Air is moved through the closed loop systems by centrifugal fans with an airflow capacity of approximately 0.013 $m^3s^{-1}m^{-2}$ (2.5 cfm per ft^2) of collector. Fan operation is controlled by remote bulb thermostats positioned at the outlet ends of the collectors. Solar heated air warms the floor of the creep boxes as it passes through a row of 20 × 20 × 41 cm (8 × 8 × 16 in.) 2-core concrete blocks positioned beneath each row of creep boxes. Blocks are laid on edge and cores are aligned to form air passageways. Extruded rigid foam insulation (RSI 0.9 [R 5]) was used to insulate the sides and bottom of a 0.6 × 0.4 m (24 × 14 in.) space beneath each creep. This space contained the concrete blocks and fill sand. The sand was used to fill the spaces between the insulation and sides of the blocks (2 @ 10 cm [4 in.]) and the blocks and floor (1 @ 18 cm [7 in.]). Also, the sand provided additional thermal storage mass.

The auxiliary in-floor warm water heating system is comprised of a 113 L (30 gal) quick recovery propane-fired hot water heater and two 1.9 cm (¾ in.) polyethylene pipes beneath each row of creep boxes. The water lines are positioned approximately 0.3 m (12 in.) apart and within the layer of sand between the concrete blocks and floor. Placing the water lines in the sand layer has been shown to have several advantages, including: (a) installation of the water lines (heating system) and concrete floor can be completed independently thereby spreading out the work load and allowing leak testing of the water lines as installed and under pressure; (b) floor temperature changes are less abrupt when the circulator pump turns on thereby reducing pig stress; and (c) the incidence of water line breakage due to differential expansion-contraction or cracking and differential settling of the concrete is reduced. Water is moved through the lines by a single circulator pump. Zone valves control water flow to the indivudual 18-sow rooms. In-floor thermostats control the zone valves and circulator pump. The use of a warm water system (maximum water temperature is 28.9 °C [120 °F]) allows use of low temperature water pipes and limits variations in floor surface temperatures.

Heat lamps are used to provide additional heat in the creep boxes for newborn pigs. Typically, a 125 W heat

*Mention of trade names is for information purposes only. No endorsement of listed products or discrimination against other products is intended.

lamp is used for 2 to 3 days following farrowing. The heat lamps are replaced with 75 W and 60 W bulbs during the second and third-fourth weeks, respectively. A heat lamp is positioned at the rear of the pens during farrowing to reduce the risk of pigs being chilled at birth.

Ventilation is provided by openable windows and a slot outlet on the south wall and openable panels on the north wall (Fig.1). The translucent passive solar/ventilation panels consist of three 1.2 × 0.6 m (4 × 2 ft) sections per 1.2 × 1.8 m (4 × 6 ft) unit. The bottom two sections slide up past the top section to provide a variable opening up to 1.2 m (4 ft) the length of the building. An external non-breathing flexible curtain can be lowered to reduce infiltration during windy conditions, reduce conductive heat loss during cold weather or provide partial shading for the south row of pens. A continuous and adjustable 7.6 cm (3 in.) high air outlet slot is located at the top of the south wall. The north wall is fitted with a continuous row of 0.6 m (2 ft) high insulated vent doors. All ventilation system openings and components are manually adjusted. Drip coolers are used to enhance sow comfort during hot weather.

Facility costs, including allowance for the owner's time, was $1,110 per sow space. The solar features accounted for 15% of the total cost.

Burkey MOF

The second unit is part of a 150-sow enterprise operated by Sid and Tim Burkey, Dorchester, NE (40° 43′ N, 97° 11′ W). To complement their two existing conventional 14-sow farrowing units, a 14-sow MOF farrowing house (6.9 × 11.9 m [22.5 × 39 ft]) was constructed. The farrowing facility is attached to a breeding-gestation unit (Fig. 4). The building was sized to match existing sow groups and is used for eight to nine farrowings per year. The building shell consists of a concrete foundation with perimeter insulation (RSI 2.1 [R 12]), insulated (RSI 3.7 [R 21]) 3.8 × 14.0 cm (2 × 6 in., nominal) frame walls, and an insulated (RSI 5.5 [R 31]) monoslope (3:12) roof/ceiling. The interior finish is high density fiberglass reinforced plastic. A polyethylene vapor barrier was used in all insulated frame assemblies.

Sows are kept in raised crates with total woven wire flooring. Manure is removed by an under-crate fresh water flush system. The flush tanks are manually drained twice per day.

A propane-fired unit heater (unvented) is used to maintain an ambient room temperature in the 15 to 18 °C (60 to 65 °F) range. Plywood side creep boxes 0.4 m (16 in.) wide × 0.6 m (24 in.) high × 2.1 m (7 ft.) long are used to provide a wamer environment for the small pigs (Fig. 5). The creep boxes replace alternate crate dividers and have a partition at mid-length so each creep box services two farrowing crates. Pigs access the creep box through a single 20 × 25 cm (8 × 10 in.) opening. Additional heat is provided in the creep boxes with 100 W conventional light bulbs during the first week and with 60 W light bulbs during the second through fourth weeks. Sows are removed when the pigs are 4-weeks old. At about 5-weeks of age pigs are moved to a mechanically ventilated nursery unit.

Ventilation is provided through two continuous rows of insulated 0.6 m (2 ft) high panels along the south wall and a 0.6 m (2 ft) high row of insulated panels along the north wall (Fig. 4). Each row of panels is operated as two separate openings. Vent panel adjustment is by thermostatically controlled pneumatic cylinders. Drip coolers are used to enhance sow comfort during hot weather.

Total system costs were $1,240 per sow space. This includes a pro-rated allowance for components which are part of both the farrowing and breeding-gestation unit (e.g., air compressor to operate ventilation panels).

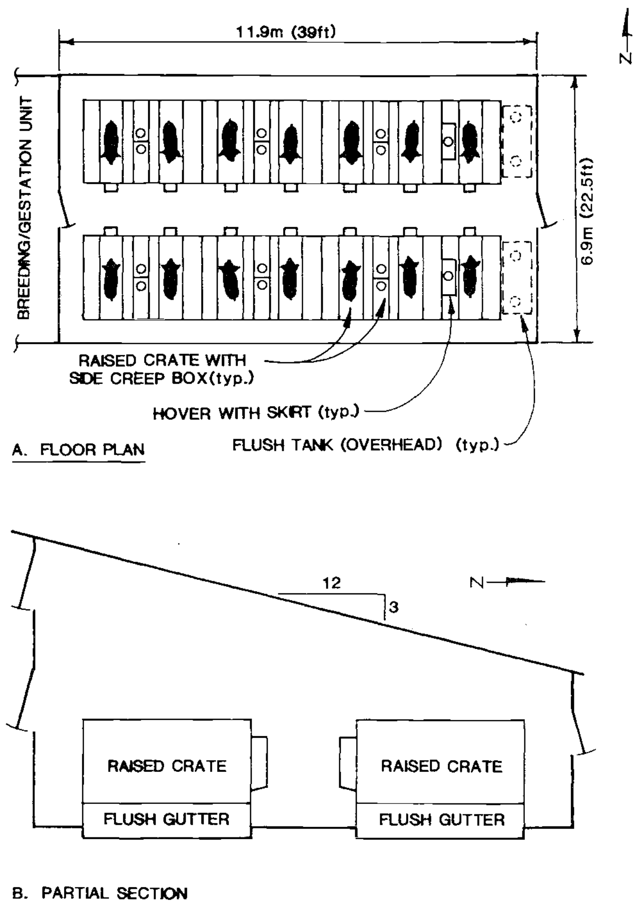

Fig. 4—Burkey 14-sow modified-open-front farrowing house.

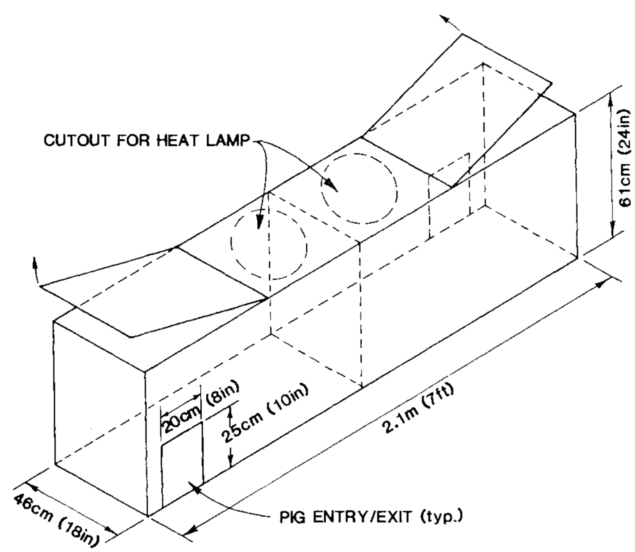

Fig. 5—Schematic of plywood side-creep boxes used in the Burkey farrowing house.

BUILDING PERFORMANCE

Temperature

Thermocouples were installed in both units to monitor indoor and outdoor ambient, collector, floor and creep box temperatures. Data were recorded hourly by Campbell CR5 data loggers. Each room was also equipped with a recording hygrothermograph. Meters were installed to measure electricity and propane usage. Installation of the utility meters was delayed by up to six months after monitoring of temperatures via thermocouples commenced. Consequently, energy use data are incomplete.

To assess variations due to location within the building thermocouples were installed at both east and west ends and along the north and south sides. Temperatures from north to south were continually within 2.8 C° (5 F°) of each other. East-west temperatures differed by 1.1 C° (2 F°) or less. The only differences between the east and west rooms at the Paus installation were those caused by room usage.

Concerns had been expressed about differences in temperature between room ambient and temperatures sensed by the sow. To assess these differences, four crates (second crate from each end of each row) were instrumented in the Burkey facility. Thermocouples were installed directly beneath the wire mesh at the sow's head, on the bottom lip of the sow feeder and above the sow (room ambient, 1.2 m (4 ft) above crate floor). Maximum temperature differences observed were 2.8 C° (5 F°).

Data from shielded thermocouples positioned below the north and south eave overhangs showed an outdoor ambient temperature range of −22.2 to +43.9 °C (18 to +111 °F) at the Paus installation and −22.8 to +45.0 °C (−9 to +113 °F) at the Burkey installation. Indoor ambient temperatures measured 1.2 to 1.5 m (4 to 5 ft) above the pen or crate floor have ranged from 10.0 to 38.3 °C (50 to 101 °F) and 1.5 to 37.8 °C (60 to 100 °F) in the two facilities, respectively. No building or animal problems attributable to these temperatures were reported by the producers. The lower interior temperatures during hot weather presumably reflect cooling associated with evaporation from the flush gutters and drip cooling system.

Relative Humidity

Relative humidity in the Paus facility was generally in the range of 55 to 65%. In contrast, the relative humidity in the Burkey unit was routinely in the range of 75 to 82%. It is speculated that the difference is due to the influence of the unvented unit heater and management styles. The Burkey unit tended to be ventilated at a lower rate as evidenced by higher relative humidity and odor levels.

Gases

Environmental gases were monitored during monthly visits with a Gas-Tec gas detection system. Ammonia levels were generally less than 3 and 6 ppm in the Paus and Burkey MOF's, respectively. On one occasion in each unit during cold weather and minimum ventilation, an ammonia level of 9 to 10 ppm was measured. At no time was there any detectable level of hydrogen sulfide or carbon monoxide. Gas measurements were taken approximately 15 cm (6 in.) above the pen or crate floor in the center alley.

Creep Boxes and Hovers

To help assure that the thermal requirements of the small pigs could be met, creep boxes (Figs. 2 and 3) were installed in the Paus unit as part of the original construction. With the in-floor heat, creep floor temperatures were maintained in the range of 35.0 to 40.6 °C (95 to 105 °F). The simultaneous "air" temperature in the creep box (30.5 to 38.1 cm [12 to 15 in.] above the floor and between the creep feeder and front of creep box) was 23.9 to 36.7 °C (75 to 80 °F) with a room ambient temperature (1.5 m [5 ft] above pen floor) of 15.6 to 21.1 °C (60 to 70 °F).

Supplemental creep heat was initially provided in the Burkey installation by 250 W heat lamps with reflectors. Pig performance and observed pig behavior resulted in hovers being installed. To facilitate sanitation, hovers were made of galvanized sheet metal. Pigs were provided with a plywood floor for sleeping. The maximum measured temperature difference between hover and no hover was 0.6 C° (1 F°).

Because of the minimal improvement in thermal conditions, the sheet metal hovers were replaced with plywood hovers. The first two plywood hovers were approximately 1.2 m (4 ft) long, 0.5 m (18 in.) wide and were positioned approximately 0.6 m (24 in.) above the crate floor near the middle of the creep zone. A vertical skirt board was extended downward from each hover. The purpose of the skirts was to provide a thermal "umbrella" over the pig sleeping area while preserving the opportunity for easy pig observation. One hover had a 15 cm (6 in.) skirt and the other hover had a 30 cm (12 in.) skirt. Hence, the bottoms of the skirts were approximately 46 cm (18 in.) and 30 cm (12 in.) above the crate floor, respectively. The result was a 2.8 to 5.6 C° (5 to 10 F°) increase in pig zone temperature above ambient. Skirt length yielded no measurable difference. No attempt was made to document changes in effective temperature due to reduced air velocity.

The known performance of creep boxes in the Paus installation led to creep boxes, as previously described and as shown in Fig. 5, being installed. The result was pig zone (creep box) temperatures 8.3 to 11.1 C° (15 to 29 F°) above ambient. These higher temperatures were achieved with lower wattage light bulbs and, hence, reduced expenditures for energy.

Fuel Use

Propane and electricity were metered in both units. Differences in construction would account for some of the variation in fuel use and apparent minimal benefits of solar energy. Fuel use is given in Table 1.

The results indicate a slight reduction in fuel costs in the Paus solar heated MOF. These differences would also be influenced by variations in construction and management practices.

As an example of cold weather operation (January 1 through March 31, 1986), the energy costs per crate per day were 15.7 and 12.7 cents for the Burkey and Paus units, respectively. Differences in warm weather operating costs were less. From June 1 through September 30, 1986 the daily costs per crate using the same fuel prices were 7.6 and 6.2 cents in the Burkey and Paus units, respectively.

The data reflect a small but consistent benefit in energy use in favor of the solar heated Paus facility. With a weaning rate of 9.5 pigs per litter every six weeks,

TABLE 1. FUEL USE IN THE BURKEY AND PAUS MOF FARROWING HOUSES FROM APRIL 1985 - APRIL 1986. (FUEL PRICES: propane @ 15.85 cents/L (60 cents/gal); electricity @ 7 cents/kWh)

Fuel	Use	Use/crate/day	$/crate/day
Burkey			
Propane	759.6 L (200.7 gal)	0.149 L (0.039 gal)	0.023
Electricity	6,272 kWh	1.23	0.086
		Total	$0.109
Paus			
Propane	2700.2 L (713.4 gal)	0.205 L (0.054 gal)	0.032
Electricity	13,916 kWh	1.06	0.074
		Total	$0.106

annual energy costs per pig would be 48.2 cents for the Burkey MOF and 46.9 cents for the Paus MOF.

Pig Performance

Both producers maintain and use a complete herd production record keeping system adapted to computer storage and analysis. Individual sow as well as whole herd performance data are used in making management and economic decisions. Representative pig performance data are presented in Tables 2 and 3. Data for the 12-month period coincident with the energy-use data are not available due to a *Strep. sp* infection in the Paus sow herd and re-population of the Burkey herd as part of the Nebraska SPF (specific pathogen free) program. Neither situation was pre-disposed by the physical facilities. The blocks of data presented are typical of data gathered during the entire project. Variations between sows and groups of sows still occur but no seasonal correlations are evident since installation of the creep boxes in the Burkey unit.

TABLE 2. PIG PERFORMANCE IN BURKEY MOF FARROWING BUILDING (CREEP BOXES INSTALLED DECEMBER 1984)

Date	Number of pigs			Pre-weaning survival %	Average 21-day pig weight	
	Born alive	Weaned	Weaned/litter		kg	lb
8/84-12/84	445	346	8.2	77.7	6.1	13.4
1/85-11/85	786	707	8.8	90.0	6.0	13.1
6/86-8/86	301	273	9.8	90.7	5.9	13.0

TABLE 3. PIG PERFORMANCE IN PAUS MOF FARROWING BUILDING

Weaning date	Number of pigs			Pre-weaning survival %	Average 21-day pig weight	
	Born alive	Weaned	Weaned/litter		kg	lb
2/85	442	388	8.8	87.7	6.3	13.8
3/85	491	439	8.8	89.4	6.5	14.2
4/85	398	357	8.7	89.7	6.1	13.5
3/86	141	132	10.1	93.6	6.4	14.1
5/86	203	193	10.2	95.1	6.5	14.2
6/86	403	374	10.1	92.8	6.5	14.2
8/86	395	372	9.8	94.1	6.8	14.9
9/86	374	363	9.8	97.1	7.0	14.0
11/86	426	365	9.6	85.6	6.8	15.0
1/87	456	402	9.4	88.2	6.4	14.1
4/87	286	248	9.2	86.7	6.9	15.2

The data show pig performance consistent with industry standards considered "excellent" (Mayrose et al. 1985) in most instances since installation of creep boxes in the Burkey MOF (12/84). The number of pigs weaned per litter and 21-day pig weights were in the "excellent" category in all cases. Performance is slightly better than the "high profit" group of farms reported by Mobley (1986). Over 50% of the farrowings reflected in Tables 2 and 3 were 1st parity females. The number of pigs weaned by 2+ parity sows was typically 1 to 1.5 pigs per litter greater than for the gilts.

SUMMARY

Building and pig performance have clearly demonstrated that non-mechanically ventilated MOF buildings can be used for farrowing. Creep boxes or some other method to provide a warm thermal environment in the pig area are an essential part of the system. Construction and energy costs can be reduced compared to many conventional facilities without compromising pig performance. As with all swine enterprises, good management is required.

References

1. Bodman, G. R., J. A. DeShazer, M. F. Kocher and J. A. Lamb. 1980. In-floor storage of solar heat. ASAE Paper No. 80-4514, ASAE, St. Joseph, MI 49085.

2. Bodman, G. R, J. A. DeShazer, M. F. Kocher and D. D. Schulte. 1981. Concrete floors for storage and distribution of solar heat. In: Modelling, design and evaluation of agricultural buildings. Proceedings of CIGR Section II Seminar, Aberdeen, Scotland. pp. 221-230.

3. Bodman, G. R. and M. F. Kocher. 1982. Solar heating of on-farm livestock structures demonstration project final report. In: On-farm demonstration of solar heating of livestock structures. USDA.

4. Bodman, G. R. and M. F. Kocher. 1983. The Nebraska solar MOF nursery—Design and operation. ASAE Paper No. 83-4564, ASAE, St. Joseph, MI 49085.

5. Kocher, M. F., J. A. DeShazer and G. R. Bodman. 1983. Thermal performance of an in-floor solar heat distribution-storage system. ASAE Paper No. 83-4030, ASAE, St. Joseph, MI 49085.

6. Mayrose, V. B., D. H. Bache and G. Libal. 1985. Performance guidelines for the swine operation. Pork Industry Handbook Fact Sheet No. PIH-100. Purdue University, West Lafayette, IN.

7. Mobley, E. 1986. ISU swine enterprise records summary. Iowa State University, Ames.