Field Evaluation of a Low Energy Swine Farrowing Facility

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Disciplines
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J. D. Harmon, G. D. Christenbury, J. E. Albrecht

ABSTRACT. An energy efficient 12-crate farrowing house was designed and evaluated on a South Carolina swine farm. Pig performance was 9.2 pigs weaned per litter with 5% mortality, both were better than the national average. Energy consumption was less than estimates for a conventional 12-crate farrowing house with estimates of savings ranging between $288 and $467. Winter operation requires extra herdsman attention during farrowing periods.

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The state of the art in swine production facilities has progressed from open lots to totally confined, environmentally controlled facilities. Trends in swine production generally are set by areas of the country that produce the most swine. Therefore, the Midwest seems to lead the way in the development of innovative facility designs. One of the problems with such development trends is that typical heating degree day accumulations vary from 2800° to 4400° C-days (5000° to 8000° F-days) in the Midwest. The Southeast, as another major contributor of swine production, has heating degree day accumulations from 560° to 1900° C-days (1000° to 3500° F-days). Because of this difference, energy intensive buildings necessary for efficient production in the Midwest are not necessarily practical in the Southeast.

The Southeast has a natural energy advantage over some of the more traditional swine producing states because of milder winter weather. This advantage can be turned into a viable alternative in temperate climates. This advantage is especially true with farrowing and nursery facilities because of their high energy consumption.

Naturally ventilated farrowing houses have been shown to be a viable alternative in temperate climates. Christenbury et al. (1987) compared a totally enclosed, environmentally controlled farrowing house to a curtain sidewall farrowing room near Lake City, South Carolina. They concluded that curtain-sided buildings have more temperature variation than environmentally controlled facilities. The added cost of environmental control was not justified based on increased pig productivity in swine farrowing facilities in South Carolina. Bodman et al. (1987) experimented with monoslope open front (MOF) farrowing facilities in Nebraska. The environment was modified using supplemental heaters to maintain the room temperature around 15.5° C (60° F) and pneumatic cylinders were used to control natural ventilation inlets and outlets. A microenvironment was created for pigs using a brooder box between each pair of crates. They concluded that this housing system had no adverse effects on pig performance.

A "low energy" swine nursery design was developed and tested for use on South Carolina farms (Harmon et al. 1994). Due to widespread damage from Hurricane Hugo, a "low energy" farrowing house was developed due to requests from producers. It was then adopted by producers before evaluation was completed.

The objective of this project was to develop and evaluate the performance of a low energy (LE) farrowing house and compare it with typical energy consumption and pig performance of a mechanically ventilated swine farrowing facility.

FACILITY DESIGN

In designing the low energy farrowing house there were two main criteria: (1) utilize passive solar and natural ventilation to create a low cost and low energy consuming house, and (2) create a microenvironment for the piglets that will not adversely affect production.

The farrowing facility (fig. 1) was designed with a 3/12 monoslope roof to promote natural ventilation flow (MWPS, 1989) and to provide passive solar collection during the winter. The north side had openings in the eave and a 51 cm (20 in.) opening near the floor. Both had vent doors and were covered with hardware cloth to prevent birds from entering the building. The south side had an eave opening and a 147 cm (58 in.) opening to be covered with a ventilation curtain. During the winter, the curtain and lower north vent doors remained closed. The upper south eave remained open and various vent doors on the upper north eave were opened to regulate air flow, depending on the weather. When the plan was introduced in South Carolina, producers replaced the curtain with storm windows that could be opened from the top. They also used vent doors on the interior upper north wall rather...
Piglets require a temperature of 29.5 to 32° C (85 to 90° F) and sows are most comfortable at 15.5 to 18° C (60 to 65° F) according to methods described by MWPS (1983), this gave a maximum solar penetration at noon on 21 December of 4.8 m (15.7 ft), and complete shading at noon on 21 June.

Sows and piglets have different temperature needs. Piglets require a temperature of 29.5 to 32° C (85 to 90° F) and sows are most comfortable at 15.5 to 18° C (60 to 65° F) according to Mutchling and Stanislaw (1984). Operating a farrowing house at either of these temperature ranges may stress one of the two groups of animals. Sows may endure fairly cool winter temperatures without largely affecting production, however, they are effected by excessive heat. To reduce heat stress on the sows during the summer, the roof was insulated with a minimum of 2.5 cm (1 in.) of rigid insulation, drip coolers were employed and the sows were oriented with their head toward the north side. The insulation reduced radiant heat load, the drip coolers increased the animal heat loss by evaporation, and the orientation increased convection losses by placing the sow’s head at the location where the coolest air was entering the building. Some producers used drop ceilings with air vents in either eave while others used reflective roof insulation.

Piglets, on the other hand, may not need much modification of the summer environment but require winter heating. This was accomplished using a brooder box much like the one discussed in Bodman et al. (1987). There was one box between each pair of crates. The box was 46 cm (18 in.) wide and 2.1 m (7 ft) long and divided cross-wise to give each litter a 46 cm (18 in.) x 1.05 m (3.5 ft) brooder area. Boxes were constructed of 1.2 cm (1/2 in.) plywood which sandwiched 1.9 cm (3/4 in.) of rigid insulation. Structural rigidity was added by using 2.5 x 10 cm (1 x 4 in.) boards at the edges. Flooring sections for farrowing crates were placed 30.5 cm (1 ft) apart which allowed the box to rest on a 7.5 cm (3 in.) lip on either side. A 17.8 x 35.5 cm (7 x 14 in.) opening was made to allow piglet access to the boxes. Edges were covered with flashing. A light was mounded in either side to add heat to the box. Some producers used one heat lamp mounted in the center (lengthwise) in order to use one heat lamp for two litters. Crates were located over a flush gutter for easy waste disposal to a lagoon.

**FIELD STUDY**

A farrowing house was chosen for the study that was located in Clarendon County, South Carolina, on a 300-sow, farrow-to-feeder, swine operation. The house instrumented had 12 crates. Temperature data was collected June to August 1990 for summer trials and December to February 1991 for winter trials. Herd records were used from November 1991 to April 1992 to evaluate pig performance.

**RESULTS AND DISCUSSION**

**TEMPERATURE PERFORMANCE**

To evaluate the temperature performance of the farrowing house, black globe thermocouples (Tbg) were placed within the house and within selected pig brooder boxes. Dry bulb temperatures (Tdb) were recorded outdoors, in the brooder box, and in the farrowing room. Temperatures were measured once per minute and recorded as averages once per hour. Daily averages and standard deviations for the four extreme cases appear in table 1.

During the summer test period, brooder box temperatures remained relatively close to outdoor ambient temperatures. This was due in part to the discontinuation of heat lamp use during the warmest weather as evidenced by the minor differences between brooder box black globe and dry bulb temperatures. It should be noted that ambient temperatures varied the greatest with the room and brooder box showing less variation. Therefore, the building shell acted as an insulator from ambient temperature changes and the brooder boxes, in turn, acted as an insulator from the room temperature. Therefore, the brooder boxes have

![Figure 1—Cross-sectional view of the low-energy farrowing facility design (CPS, 1988).](image-url)

### Table 1. Temperature averages and standard deviations for the low-energy farrowing house in °C (°F)

<table>
<thead>
<tr>
<th>Date</th>
<th>Brooder Box</th>
<th>Room</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tdb</td>
<td>Tbg</td>
<td>Tdb</td>
</tr>
<tr>
<td>6/7/90</td>
<td>Avg. 29.4 (85.8)</td>
<td>29.8 (85.7)</td>
<td>28.7 (83.6)</td>
</tr>
<tr>
<td></td>
<td>SD 3.1 (5.3)</td>
<td>2.3 (4.2)</td>
<td>4.4 (7.9)</td>
</tr>
<tr>
<td>6/8/90</td>
<td>Avg. 29.0 (84.2)</td>
<td>29.4 (85.0)</td>
<td>28.1 (82.6)</td>
</tr>
<tr>
<td></td>
<td>SD 2.7 (4.8)</td>
<td>2.0 (3.6)</td>
<td>3.9 (7.0)</td>
</tr>
<tr>
<td>1/22/91</td>
<td>Avg. 20.0 (68.0)</td>
<td>26.8 (80.5)</td>
<td>7.9 (46.5)</td>
</tr>
<tr>
<td></td>
<td>SD 2.7 (4.9)</td>
<td>1.7 (3.0)</td>
<td>3.8 (6.8)</td>
</tr>
<tr>
<td>1/23/91</td>
<td>Avg. 21.3 (70.3)</td>
<td>27.1 (80.8)</td>
<td>9.7 (49.5)</td>
</tr>
<tr>
<td></td>
<td>SD 2.7 (4.8)</td>
<td>1.4 (2.6)</td>
<td>5.7 (10.3)</td>
</tr>
</tbody>
</table>
the lowest standard deviation. The temperature variations from a summertime extreme that occurred on 8 June 1990 appears in figure 2.

During the winter test period, the brooder box temperatures varied less over the day than did the room or the ambient conditions. In this case, the brooder box dry bulb temperature remained 18.6 to 19.2° C (33.5 to 34.5° F) above the ambient conditions while the black globe temperature remained 26 to 24.4° C (46.8 to 44° F) above ambient. The brooder box also remained warmer and more stable than did the room temperature. This is due to the insulation of the box and the heat input of the heat lamp. The temperature variations from a wintertime extreme that occurred on 23 January 1991 appears in figure 3.

The temperature data indicates that the brooder box temperatures were adequate during summer, but are lower than optimum on the coldest winter days. The black globe temperature in the boxes in the winter are near the optimum range of dry bulb temperatures for newborn piglets. The Tbg may be considered an effective temperature and therefore indicates a minor variance from the optimal range. However, piglets were not always within the confines of the brooder box and were, therefore, exposed to suboptimal temperatures during nursing. As piglets grow the effects of this problem were minimized.

**PIG PERFORMANCE**

Albrecht (1991) reported that the national average for number of pigs weaned per litter was 7.79, 7.83, and 7.89 for the December to February periods of 1989, 1990, and 1991, respectively. He goes on to suggest 9.2 weaned pigs per litter and a mortality rate of 8% in the farrowing house should be goals for South Carolina swine producers.

For the period of November, 1991 to April, 1992, the average weaning rate within the LE farrowing houses was 9.2 pigs per litter with a monthly range of 9.8 to 8.5. Weaning numbers far exceeded the national average and met the established goal of 9.2 pigs per litter. Mortality of piglets was approximately 5% which was better than the goal of 8%. During this same period pigs were weaned at an average age of 20.4 days at an average weight of 5.4 kg (11.8 lbs).

Pig performance data may be artificially inflated due to the fact that the farrowing houses used for this study were relatively new and probably lacked established bacterial colonies. However, the average sow parity during this period was 1.2 which would indicate that litter size and piglet size may be artificially low due to the high number of gilt farrowings included in the data. During winter farrowings the operator noted that extra attention was needed to insure that piglets were dried and found the brooder box before they became chilled.

One case of sow mortality was reported for another building site. This case was diagnosed as heat stress because crates were installed with the sow's head toward the south, thereby avoiding the cooling effect that the inlet air would have on the animals.

**ENERGY COMPARISON**

A separate electric meter was not placed on the farrowing building. The only electrical usage in this house was for lighting, which was compact fluorescent, for drip coolers and for heat lamps. One 60-W heat lamp was used for each box instead of one per litter.

In order to compare this to a mechanically ventilated structure, an estimation of fuel cost was made. Since both the conventional and low energy houses would use similar lighting and drip cooling systems, these factors were eliminated from the calculations.

A 12-crate, low-energy farrowing house uses six 60-watt bulbs. It was assumed that pigs were weaned at three weeks of age, with one week allowed for clean-out and one week for sow moving. This means that three weeks of five the heat lamps could be necessary. If during these three weeks the lamps were used constantly, then in one year they would be in service 5241.6 h. This results in a total use of 1887 kWh/year. At a cost of 7¢/kWh the total heating cost would amount to U.S. $132/year.

The conventional house was assumed to be kept at 23.8° C (75° F) with a design temperature for Sumter, South Carolina, of -4° C (25° F). The building was assumed to have an UA insulation value of 172 W/K (327 Btu/h-F) with cold weather ventilation of 0.0094 m³/s-hd (20 cfm/hd). During the period of 1 October 1990 to 1 May 1991 there were 1199° C (2158° F) heating degree days.

To estimate the cost of heating the building, the modified degree-day method was used. This method, as explained by ASHRAE (1993), is less conservative that the traditional degree-day method. The availability of daily high and low temperatures made the modified degree-day (MDD) method feasible. To utilize the MDD method, the
balance temperature was calculated using the following equation (ASHRAE, 1993):

\[ t_b = t_1 - \frac{q_k}{BLC} \]  

(1)

For the conventional farrowing house with the assumed characteristics, the balance temperature was 15°C (59°F). The number of heating degree days (HDD) were then calculated based on 15°C (59°F) using data from Bramblett (1991). This resulted in a new HDD figure of 719°C-days (1295°F-days) which was then used in the following equation to estimate electrical heating usage for a heating season.

\[ E = C BLC \cdot DD_{tb} \]  

(2)

Conversion to electrical usage yielded an estimate of 5382 kWh for an entire season. However, sows would occupy the building four weeks out of a five-week cycle so the energy usage was estimated at 4306 kWh. At 7¢/kWh, the yearly heating cost was estimated at $301.

The energy to operate the fans can also be estimated using fan duty calculations. Utilizing a three-stage ventilation system (table 2), the operational cost was estimated using a computer program from Albright (1990). This program, called DUTYFACT, outputs yearly costs based on ambient temperature distribution, ventilation rates and fan ventilating efficiency ratios (VER). Fan data was selected from Ford et al. (1993). No weather data was available for Columbia, South Carolina, so computer runs using Orlando, Florida, and Ft. Knox, Kentucky, were performed to establish an estimation. Results appear in table 3.

From the results in table 3, an estimation of energy was made using 80% of the average (due to clean out time). This yielded an estimate of $119 (@ $0.07/kWh) or 1700 kWh per year for fan operation. From this it can be concluded that the total energy usage of a conventional 12-crate farrowing house would be approximately 6006 kWh ($420) while the low-energy farrowing house would use 1887 kWh ($132). This amounts to a savings of 4120 kWh or $288 based on 7¢/kWh.

Using estimation guidelines in USDA (1977), a farrowing house this size would use 5702 kWh/year for ventilation fans. Heating would use 670 L of LP gas (177 gal) and 579 kWh/year. Assuming electricity is $0.07/kWh and LP gas is $0.24/L ($0.90/gal), the total estimated cost would be $599. An estimated savings of $467/year is realized using this estimation technique.

<table>
<thead>
<tr>
<th>Step</th>
<th>Flow Rate (m³/s)</th>
<th>Flow Rate (cfm)</th>
<th>VER (m³/s-kW)</th>
<th>VER (cfm/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.25</td>
<td>530</td>
<td>2.8</td>
<td>5.9</td>
</tr>
<tr>
<td>2</td>
<td>0.96</td>
<td>2030</td>
<td>3.0</td>
<td>6.4</td>
</tr>
<tr>
<td>3</td>
<td>2.94</td>
<td>6230</td>
<td>3.9</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Table 2. Descriptions of the ventilation stages used for energy usage estimation

Table 3. Results of estimating fan electrical usage using DUTYFACT

<table>
<thead>
<tr>
<th>Location</th>
<th>Average Vent Rate (m³/s)</th>
<th>Duty Factor (%)</th>
<th>Yearly Cost ($)</th>
<th>Average VER (m³/s-kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orlando, Fla.</td>
<td>1.04</td>
<td>35.4</td>
<td>183</td>
<td>3.5</td>
</tr>
<tr>
<td>Ft. Knox, Ky.</td>
<td>0.62</td>
<td>20.9</td>
<td>114</td>
<td>3.3</td>
</tr>
</tbody>
</table>

FACILITY COST

The cost of the farrowing facility (as of 1991) was approximately $1,425 per farrowing crate for a complete turnkey house. This included approximately $650 per crate for the crate itself, flooring, drip cooler, and the pig box. Many producers were doing their own construction for less than this quoted figure.

SUMMARY

A low-energy farrowing facility was evaluated for temperature response, pig performance, and energy consumption. Temperatures within the brooder box remained 18.9°C (34°F) above the outdoor ambient during the coldest winter conditions during the test. Brooder box temperatures remained within 1.7°C (3°F) of ambient during summer conditions. Number of pigs weaned was approximately 9.2 litter with a mortality rate of 5%. Room temperatures dropped to 7.9°C (46.3°F) during extreme winter conditions. In such cases, it was essential that farrowings be attended.

Two methods of estimating savings yielded estimates of 4120 kWh of electrical energy or $288 (@ $0.07/kWh) and 4394 kWh and 670/L of LP (177 gal) or $467 (@ $0.07/kWh and $0.24/L or $0.90/gal), comparing the low-energy farrowing facility versus a conventional farrowing house.

CONCLUSIONS

The following conclusions were reached as a result of this study in the South Carolina.

- The low-energy farrowing facility design will maintain a microenvironment within the brooder boxes suitable for piglets in a temperate climate.
- Conditions within the low-energy farrowing facility promotes low mortality rates (5%) and high weaning averages (9.2 pigs per litter).
- Less electrical energy is used in the low-energy farrowing house than in conventional farrowing facilities without adversely affecting pig performance.
- Due to the possibility of low room temperatures during the winter, additional management is needed during sow farrowing. This is a major disadvantage because of potentially high piglet mortality rates during unattended farrowings.

ACKNOWLEDGMENT. The authors wish to extend special thanks to Harold and Judy Allan, Allan Livestock, for their cooperation in this study; and James Boone, Area Extension Agent, for his assistance.
REFERENCES


NOMENCLATURE

BLC building loss coefficient [kW/K (Btu/h-F)]
C equation constant, 86,400 s/day (24 h/day)]
DDtb degree days based on \( t_b \) [C-day/year (F-day/year)]
E heating season energy usage [kJ/year (Btu/year)]
HDD heating degree days [C-day/year (F-day/year)]
MDD modified degree day method
\( q_g \) heat generated excluding supplemental heat [kW (Btu/h)]
\( t_b \) balance temperature [C (F)]
Tbg black globe temperature [C (F)]
Tdb dry bulb temperature [C (F)]
\( t_i \) desired inside temperature [C (F)]
VER ventilating efficiency ratio \([m^3/s-kW (cfm/W)]\)