Energy Conservation in Ventilating and Heating Swine Buildings: Pork Industry Handbook
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Energy Conservation in Ventilating and Heating Swine Buildings

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Energy Inputs

Energy is used in swine facilities for the operation of fans, lighting, feed handling, creep heaters, water heaters, and supplemental space heaters. This fact sheet will discuss ways to save energy used for operating a ventilation system including supplemental heating. Most mechanical ventilation systems use energy to reduce the management required to maintain a productive environment. Usually, reducing energy use increases the level of management required. Some methods of saving energy may increase other production costs, such as feed, enough to offset the value of any monetary savings for energy. There are ways to reduce energy use without adversely affecting feed utilization or animal performance.

Environmental Control

Ventilation Principles. The primary goal of a ventilation system is to modify the environment to improve production while maintaining acceptable air quality levels for workers. The way ventilation systems operate has a major impact on energy use, especially supplemental heating. Ventilation systems are designed to vary air flows from minimum ventilation rates in the winter to maximum ventilation rates in the summer (Table 1).

Ventilation rates vary because there are different air exchange needs at different outside temperatures. The ventilation system must limit temperature rise during hot weather, control temperature during mild weather, control humidity during cold weather, and control odors and gases.

When the outside air temperature is greater than the desired inside air temperature, the ventilation system can only limit the temperature rise of the air as it passes through a building, unless a cooling device is used. The air temperature increases as it moves through the building because of the heat added by the animals, lights, creep heaters, motors, etc. As the outside air temperature falls below the inside air temperature, temperature control is achieved by altering the ventilation rate until the heat losses from the ventilation air and building shell equal the heat added. As the ventilation rate decreases, the relative humidity in the building increases. The ventilation rate must then be adjusted to balance the moisture removed by the ventilation air with the moisture produced in the building. During low outside temperatures, when the ventilation rate needed to control humidity is greater than the rate to control temperature, a supplemental heat source must be added to maintain the building air temperature.

Table 1. Total Per-head Ventilation Rates for Swine Buildings During Various Times of the Year.

	Cold Weather	Mild Weather	Hot Weather
		-cfm-	
Sow & litter	20	80	500
Pre-nursery pig (12-30 lb)	2	10	25
Nursery pig (30-75 lb)	3	15	35
Growing pig (75-150 lb)	7	24	75
Finishing hog (150-220 lb)	10	35	120
Gestation sow (325 lb)	12	40	300
Boar (400 lb)	14	50	300

The level of odors in a swine facility is another factor affecting the minimum ventilation rate. Odors will increase in any facility as the ventilation rate decreases. The most important energy conservation techniques are those that reduce the ventilation rate as much as possible while maintaining the minimum allowable room temperature as well as good moisture and odor control.

Effective Temperature. The ventilation rate should be managed to provide an environmental temperature that will maximize animal performance. The environmental temperature required is determined by several factors including air temperature, air speed, humidity, floor type, radiation levels, animal size and group size. Together these factors determine an effective temperature. The effective temperature for an animal is similar to the wind chill index for humans. Comfort levels must be based on the effective temperature rather than on the actual air temperature alone. For example, a nursery that has no drafts, warm walls, dry straw on the floor, and an air temperature of 70° F could have a similar effective temperature as a nursery that has drafts, cold walls, a wet concrete floor, and an air temperature of 95° F. The use of hovers in farrowing rooms is a good example of providing an area for the small pigs with a different effective temperature than the entire room. **Effective temperature is more important to animals than air temperature 5 ft above the floor.** Locate ventilation controls as close to the animals as practical to provide better control of the air temperature.

Desirable Humidity Levels. A relative humidity between 50% and 70% is desirable in most swine buildings. Higher humidities contribute to rapid equipment and building deterioration. Waterers, manure, wet floors, gutters and water vapor from an animal's lungs and skin all contribute to the moisture that must be removed. At present, there is no reliable, inexpensive device to sense and control relative humidity in the corrosive environment of swine buildings. Therefore, ventilation rates for humidity control are based on room moisture production estimates or experience. The humidity level in the building can be altered by proper adjustment of the ventilation rate. To raise the humidity level, the ventilation rate is decreased. To reduce the humidity level, the ventilation rate is increased.

Measuring Humidity Levels. The most reliable and least expensive method of measuring the relative humidity level in a swine building is with a sling psychrometer. The sling psychrometer consists of two matched thermometers mounted side-by-side in a holder, with some provision for whirling the device through the air (Figure 1). The measuring bulb of one thermometer is bare, while the other is covered with a wetted cloth or wick. After being whirled for several minutes, both thermometers are read. Using these two temperatures, the relative humidity is then read from a chart or sliding scale.

Odor Levels. The level of odor in a swine facility is often the limiting factor in determining the minimum ventilation rate. Odor production varies with the type of manure handling and storage system. If odors in a facility become too great when the ventilation rate is decreased, a producer has two choices: 1) alter the manure management system to decrease the odor production rate, or 2) increase the ventilation rate to dilute the odor. For many swine buildings, the odor level will require higher ventilation rates than the minimum level allowable for humidity control. For this reason the trend is to store the manure outside the building. Under-slat, exhaust ventilation systems can aid in removing odors in some buildings with partly slotted floors.

The effect of swine building odors and gases on both swine and humans is being researched at several universities. Although limited data are available, high levels of dust and some manure gases have been shown to contribute to respiratory problems in both humans and swine.

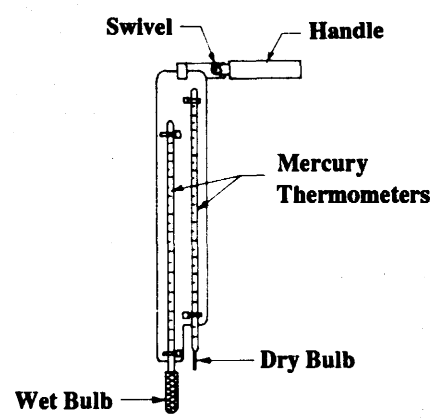

Figure 1. Sling psychrometer used to measure relative humidity.

Minimum Ventilation Rate

The minimum ventilation rate provided by the ventilation system in a swine building will have a major impact on the energy required for supplemental heat. Increasing the minimum ventilation rate in a typical farrowing building from 20 to 30 cubic feet per minute (cfm) per sow and litter would increase the supplemental heat requirement at an outside temperature of 0° F from 1300 to 2020 Btu per hour per sow (Table 2) and increase

Table 2. Effect of Ventilation Rate and Insulation Level on a Farrowing Building's Energy Use.

		Building Insulation Level					
		R-10		R-20		R-30	
Ventilation rate cfm/sow[1]	Average winter building relative humidity %	Minimum outside temperature requiring no heat °F	Supplemental heat requirement at 0°F[2] Btuh/sow[3]	Minimum outside temperature requiring no heat °F	Supplemental heat requirement at 0°F[2] Btuh/sow[3]	Minimum outside temperature requiring no heat °F	Supplemental heat requirement at 0°F[2] Btuh/sow[3]
20 (heat exchanger)[4]	67	22	520	4	60	-6	0
20	67	38	1300	28	810	26	650
30	50	46	2020	42	1560	40	1400
40	40	50	2770	48	2320	46	2160

[1]cfm/sow = cubic feet per minute per sow.

[2]Outside air temperature.

[3]Btuh/sow = Btu per hour per sow.

[4]All ventilation air provided by a 50% efficient heat exchanger. Assumptions: Twenty-crate farrowing building, animal heat only, 70°F building temperature, partly slotted floor.

the outside temperature below which supplemental heat is required from 38° to 46° F. The minimum ventilation rate can be reduced provided humidity levels are maintained at desirable levels and odor levels do not become unacceptable.

Altering Minimum Ventilation Rate. The preferred method of providing a minimum ventilation rate is to use a small, continuously running fan. The ventilation rate provided by this fan is calculated from the number and size of pigs in the building. However, the ventilation rate calculated may need to be altered because the ventilation rate calculation is based on average moisture production estimates, the calculated ventilation rate may not match airflow rates provided by available fans, and the number of animals and their weight varies. Approaches used to alter the minimum ventilation rate include multiple small fans, timer-controlled fans, variable-speed fans and a damper or sliding throttle controlled ducted fan. See PIH-60, *Mechanical Ventilation of Swine Buildings* and PIH-41, *Maintenance and Operation of Ventilation Fans for Hog Barns* for more detailed information.

Air Distribution Problems. It becomes more difficult to maintain proper air distribution as ventilation rates are lowered. Ventilation systems with adjustable air inlet baffles running the length of one or both sidewalls have difficulty providing small enough openings to allow even air distribution in the room when ventilating at minimum rates. Unplanned openings, such as poorly fitting doors, fan shutters and cracks, also hinder proper air distribution. A static pressure gauge can be used to check if the incoming air is moving fast enough to provide adequate mixing and to prevent it from settling too rapidly and thus chilling the pigs. When the baffle is properly adjusted, the static pressure gauge should read at least 0.05 inches. The surface near the inlet (within 8 ft) should be free of obstructions that could deflect the cold air onto the animals.

Some ventilation systems use a pressurized tube or duct to distribute the incoming air. These systems mix incoming air with room air to help prevent cold drafts. Since tube distribution systems use only one air inlet for the winter, they are well adapted to distributing air from some air tempering systems, such as heat exchangers, earth-tube systems, and pre-heat rooms.

Small facilities with low minimum winter ventilation rates may require small circulation fans in the animal space. The air should move in a circular pattern around the room without creating drafts on the animals.

Building Layout

Energy conservation is important during the planning of new swine production facilities. Beyond the obvious technique of additional insulation, there is often a benefit from minimizing exterior walls. The move toward smaller farrowing and nursery rooms that allow all-in, all-out operation has resulted in these smaller rooms being grouped in one larger building (Figure 2).

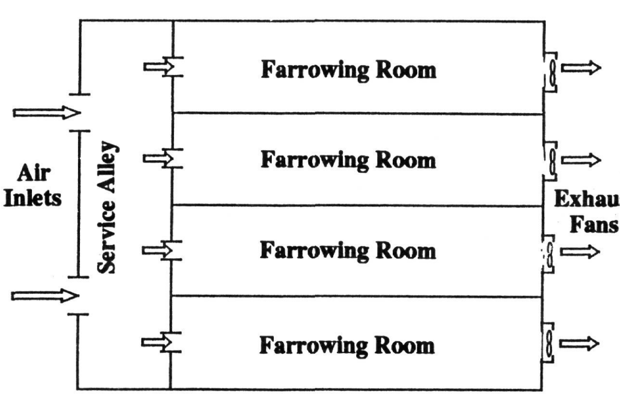

Figure 2. Typical layout of rooms grouped for energy conservation.

This grouping of smaller rooms results in a reduced area for heat loss through the walls and foundation. For example, a 24 ft x 36 ft farrowing room constructed with normal insulation levels, having two rooms side-by-side reduces the wall and foundation loss area by 30%. Placing 4 rooms side-by-side reduces this heat loss area by 45%.

Insulation

Temperature control is partially achieved by balancing heat losses to the ventilation air and through the building shell with heat gains. Reducing the heat loss through the building shell extends the temperature range over which the ventilation rate can maintain temperature control. Swine buildings should be insulated to the minimum levels given in Figure 3, using techniques described in PIH-65, *Insulation for Swine Housing*.

Minimum Insulation Level*

Climate Zone	Resistance (R)**	
	Walls	Ceilings
Mild	14	22
Moderate	14	25
Cold	20	33

*Perimeter insulation should be used to reduce heat loss through the foundation. The foundation exterior should be insulated with 2 inches of rigid insulation from below the siding to a minimum of 16 inches below the ground line.

**Total of resistances of insulation, lining and siding surfaces and air spaces.

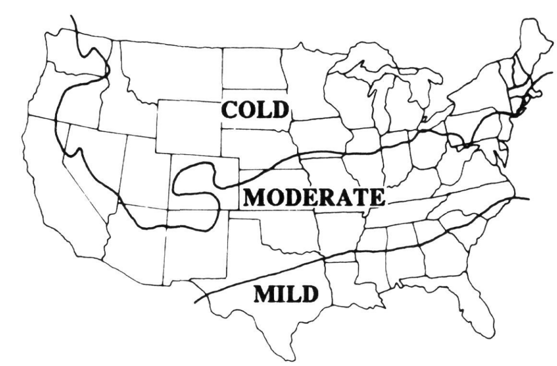

Figure 3. Recommended minimum insulation levels for controlled enviroment swine buildings.

A farrowing building can be used to illustrate the importance of adequate insulation to save energy. The higher the level of insulation, the lower the outside temperature must be before supplemental heat is required. For example, supplemental heat is required in a farrowing building with an average R-value of 10 when the outside temperature is below 38° F (Table 2). If the average R-value is increased to 20, no supplemental heat is needed until the outside temperature drops below 28° F. Note that the outside temperature below which supplemental heat is required is reduced only 2° to 26° F by increasing the average R-value from 20 to 30. Therefore, massive quantities of insulation are not economically justifiable. The majority of heat loss from an adequately insulated swine building is via the ventilation system not through the building shell.

Thermostat Setting

Lowering the thermostat setting on the supplemental heater saves energy two ways. First, it allows ventilation rate to control inside temperature at lower outside temperatures and second, it reduces the amount of supplemental heat energy required to

Table 3. Effect of Building Temperature and Insulation Level on a Farrowing Building's Energy Use.

		Building Insulation Level					
		R-10		R-20		R-30	
Building temperature °F	Average winter building relative humidity %	Minimum outside temperature requiring no heat °F	Supplemental heat requirement at 0°F[1] Btuh/sow[2]	Minimum outside temperature requiring no heat °F	Supplemental heat requirement at 0°F[1] Btuh/sow[2]	Minimum outside temperature requiring no heat °F	Supplemental heat requirement at 0°F[1] Btuh/sow[2]
60	72	22	710	12	320	8	200
70	67	38	1300	28	810	26	650
80	60	54	1830	48	1300	46	1130

[1]Outside air temperature.

[2]Btuh/sow = Btu per hour per sow. Assumptions: 20 cfm per sow, 20-sow farrowing building, animal heat only, partly slotted floor.

maintain the inside air temperature. For example, reducing the temperature in a farrowing building from 70° F to 60° F reduces the supplemental heat requirement at 0° F outside temperature from 1300 to 710 Btu per hour per sow (Table 3). In addition, the outside temperature below which supplemental heat is required is reduced from 38° F to 22° F. Cooler air can hold less moisture so as the inside temperature is reduced the relative humidity level may rise. When reducing the thermostat setting, caution should be used to insure that animal performance and health do not suffer.

Thermostats that control fans (except the minimum rate fan) should be set a minimum of 4° F above the heater thermostat setting or the preferred method is to have the heater and fan controls interlocked or operated by the same controller. If thermostats are not set properly, ventilation fans that control temperature may run when the heater is operating. This wastes energy.

Ventilation Air Tempering Methods

The range over which the ventilation rate can maintain the temperature of a swine building also can be extended by warming the intake air. Several methods, such as heat exchangers, solar walls, and earth tubes are used as air tempering systems. For example, if a 50% efficient heat exchanger is used in a well-insulated farrowing room (R-20), it would decrease the lower limit of the outside temperature from 38° F to 22° F, Table 2, above which the ventilation rate can maintain the desired room temperature. The design and economic feasibility of air tempering methods are beyond the scope of this fact sheet. However, use the energy conservation measures described in this fact sheet before considering air tempering methods. Care must be taken to insure that air tempering systems do not increase energy use or adversely affect the air quality.

Heat Exchangers. Heat exchangers are designed to transfer heat from the exhaust air to the intake air. A parallel-plate heat exchanger separates exhaust and intake air by thin plates. These units can reclaim from 40 to 60% of the heat normally lost in the exhaust air. However, they have problems with dirt, moisture and freezing. Heat exchangers should include methods for easy cleaning and defrosting. Heat exchangers are most effective in saving energy at warmer room temperatures and when the outside temperature is low. For more detailed information see PIH-124, *Heat Exchangers in Swine Facilities*.

Solar Energy. Because the sun is free and provides a readily available and endless source of energy, it would seem to be an attractive energy source for swine facilities. Some facilities make use of solar collection by allowing ventilation air in the winter to enter through the attic of the building.

Solar systems for swine facilities can be either a passive or active type. Passive systems are a combination of south-facing windows and a proper roof overhang which allows the building to collect the solar energy. Passive systems in farrowing and nursery units where heating is required may need extra energy because of their large window surfaces.

Active systems require methods for collecting, transferring and storing solar energy. Active systems allow for heat to be stored in one location and used elsewhere. Without a method of storage, an active system may provide more solar energy than necessary during clear days and not enough heat energy at night. Solar systems must be properly designed as described in PIH-90, *Solar Heating for Swine Buildings*.

Earth-Tube Systems. Earth-tube heat exchangers use soil as a heat sink or source for tempering the ventilating air. Depending on the season, air is heated or cooled as it is drawn through a buried tube. The temperature 7 to 10 feet underground is nearly constant throughout the year.

Both soil characteristics and air-tube parameters affect the performance of the system. Soil characteristics include soil type, moisture content, and water table elevation. Air-tube parameters include diameter, length, depth of placement, spacing, flow rate, and the shape of the tube. Typically, nonperforated corrugated plastic drainage tile is used because it is readily available and inexpensive. The corrugations increase the surface area of the pipe and amount of air turbulence, which increases the heat-transfer rate. For more detailed information see PIH-102, *Earth Tempering of Ventilation Air*.

Animal Density. Keeping a building as full of animals as practical will keep the animal heat input as high as possible. This can generally be achieved by proper sizing of buildings or rooms during initial design to insure that the buildings fit the production schedule. Some designs have been proposed to group larger numbers of animals together to increase the heat input. An example would be a nursery in combination with a farrowing or gestation room. These designs are not recommended because they prevent the use of all-in, all-out production, may compromise the managers' ability to maintain proper sanitation, or fail to provide proper temperatures for animals of different ages.

Fan Selection

A rating system for fan efficiency is now being used by most fan manufacturers to help select energy efficient fans. Fans are rated for the amount of air moved per watt of electricity consumed (cfm/watt). The higher the number, the more efficient the fan is at moving air, which results in lower operating costs. Fan ratings typically vary from 5 to 25 cfm/watt, with larger fans generally being more efficient. Studies on 36-inch fans have shown ratings from 10 to 23 cfm/watt. Selecting fans based on their ratings reduces operating costs. During a typical summer in the Midwest, fans operate at their maximum rates approximately

2,000 hours per year. In this case, a 10,000 cfm fan with a 10 cfm/watt rating would result in 2,000 kwh's of electricity used while a 10,000 cfm fan with a 23 cfm/watt rating would use only 870 kwh's of electricity. At 9 cents per kwh, the difference in operating cost between the two fans would be $102 per year. Energy savings are possible when trying to limit temperature rise in the summer by using more efficient fans. **However, when selecting fans for use in controlling humidity levels in winter, more consideration should be given to their ability to provide the proper ventilation rate rather than their efficiency ratings.**

Summary

Energy use in swine buildings can be reduced if a producer is willing to increase the level of management of the heating and ventilation system. Ventilation systems are designed on the best information available; however, the information is for average conditions, not necessarily those in your buildings or climate. Proper management of a ventilation system to save energy includes periodic measurement of temperatures and relative humidity levels in the buildings. However, an animal zone environment that achieves the maximum production efficiency and health is more important than sacrificing the environment for energy savings.

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