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 operation of fans, lighting, feed handling, creep heaters, water heaters and supplemental space heaters. This fact sheet will consider ways to save energy used for operation of the ventilation system including supplemental space heaters. Before considering ways to save energy, however, remember that most ventilation systems were designed to use energy to reduce the management required. In most cases, reducing energy use will increase the level of management required. Energy inputs used in swine production facilities are normally less than 5% of the total cost of farrow to finish production. Some methods of saving energy may increase other production costs, such as feed requirements, enough to offset any monetary savings. Even though energy expenses are a small percentage of the total production cost, there are ways to reduce energy use without adversely affecting feed use or animal performance. However, the primary objective of a ventilation system is to provide a productive environment for the animals.

Environmental Control

Ventilation Principles

It is important to understand how ventilation systems operate because ventilation rate has a major impact on energy use for 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).

These ventilation rates vary because there are different needs for ventilation at different outside temperatures (Figure 1). Ventilation rates are varied to: limit temperature rise during hot weather, control temperature during mild weather, control humidity during cold weather, and control odors and gases.

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

	Cold weather	Mild weather	Hot weather
		—cfm—	
Sow and litter	20	80	500
Pre-nursery pig (12-30 lbs.)	2	10	25
Nursery pig (30-75 lbs.)	3	15	35
Growing pig (75-150 lbs.)	7	24	75
Finishing hog (150-220 lbs.)	10	35	120
Gestation sow (325 lbs.)	12	40	150*
Boar (400 lbs.)	14	50	180*

*Use 300 per sow or boar in breeding facilities due to low animal density.

When the outside air temperature is above the desired inside air temperature, the best the ventilation system can do (without a cooling device) is to limit the temperature rise in the air as it passes through the building. The air temperature will increase because of the heat being added to the building by the animals, lights, creep heaters, motors, etc. As the outside air temperature decreases below the inside air temperature, temperature control is achieved by altering the ventilation rate until the heat losses, such as ventilation air and building surfaces, equals the heat gains listed previously. As the ventilation rate decreases to control temperature, the relative humidity in the building will increase. The humidity increase is caused by the lack of sufficient ventilation air to carry out the moisture produced by the pigs in the building. When the humidity level becomes too high, the ventilation rate must be increased to balance the moisture removed by the ventilation air with the moisture produced in the building. At low outside temperatures, the ventilation rate to control humidity is greater than the rate to control

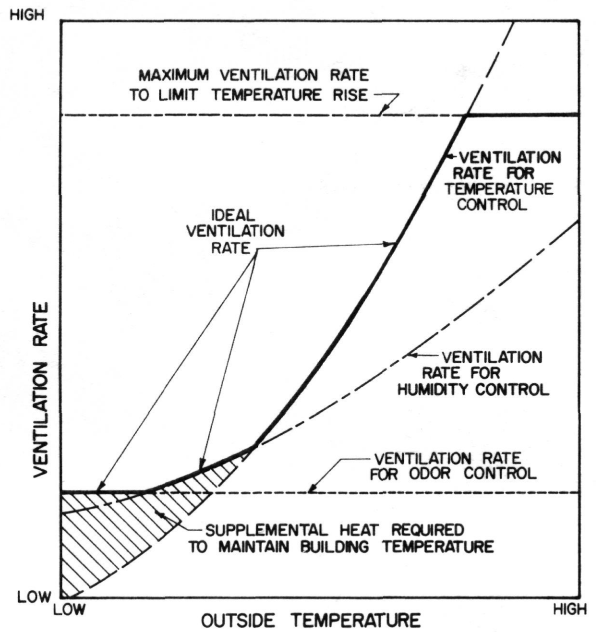

Figure 1. Typical ventilation curves for the four ventilation needs versus outside temperature.

temperature, and another heat source must be added to maintain the building air temperature. The level of odor in a swine facility is often the limiting factor in determining the minimum ideal ventilation rate. Odors are caused primarily by the animals' manure, and the odor level will increase in any facility as the ventilation rate decreases. The most important energy conservation techniques are those which extend the range that the ventilation rate can maintain temperature to as low an outside air temperature as possible.

Effective Temperature

The ventilation rate is varied to provide an environmental temperature for maximum animal performance. The environmental temperature required is determined by a number of factors which include: air temperature, air speed, floor type, radiation levels, animal size and group size. Together they produce an *effective temperature*. The effective air temperature for an animal is similar to the wind chill index for humans. Comfort levels must be based on the effective temperature rather than the air temperature. For example, a nursery that has no drafts, warm walls and dry straw on the floor with an air temperature of 70° F could have the same effective temperature as a nursery that has drafts, cold walls and a wet concrete floor with 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. The effective temperature of importance to the pigs is the one surrounding them, not the air temperature 5 ft. above the floor. It is important to locate ventilation controls as close to the animals as practical to control the air temperature for maximum performance.

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 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 confinement swine buildings. Ventilation rates used in design for humidity control are based on room moisture production estimates or experience. It is important to remember that the humidity level in the building can be altered by proper adjustment of the ventilation rate. The humidity level and ventilation rate are inversely related—as one increases the other decreases. To raise the humidity level, the ventilation rate is decreased. To reduce the humidity level, the ventilation rate is increased.

Measuring Humidity Levels

Methods to save energy when ventilating to control humidity assume that the humidity level will be measured. The most reliable method of measuring the relative humidity level in a swine building is by using 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 2). The measuring bulb of one thermometer is bare, while the other is covered by a wick which is wetted. After being whirled for several minutes, both thermometers are read and the relative humidity is determined from a chart or sliding scale. These units are inexpensive and easy to use. Producers who are trying to save energy by properly controlling the humidity level in their facilities should obtain a sling psychrometer or other humidity measuring device and learn how to use it.

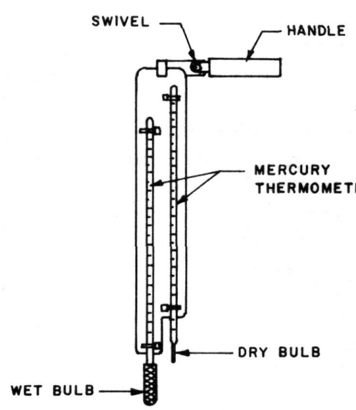

Figure 2. Sling psychrometer used to measure relative humidity.

Odor Levels

The level of odor in a swine facility is often the limiting factor in determining the minimum ventilation rate. The rate of odor produced varies with the type of manure handling and storage system. Odor production is lowest with fresh water flush systems and highest with long-term pit storage under slats. Under slat, exhaust ventilation systems can aid in removing odors. If the odor level in a facility becomes too high as the ventilation rate is decreased, a producer has two choices: 1) increase the ventilation rate to dilute the odor, or 2) alter the manure management system to decrease the odor production rate. For many swine buildings, the odor level will prevent reducing ventilation rates to the minimum level allowable for humidity control.

The effect of odors and gases on swine is an area being researched at a number of universities. Although data are limited, many swine researchers feel that odor levels unacceptable to workers are also unacceptable to swine and affect their performance. Dust and manure gases have been shown to contribute to respiratory problems in swine.

Minimum Ventilation Rate

The minimum ventilation rate provided by the ventilation system in a swine building will have a major impact on the energy use for supplemental heat. For example, increasing the minimum ventilation rate in a farrowing building from 20 to 30 cfm per sow increases the supplemental heat requirement at 0° F from 1300 to 2020 Btu per hour per sow (Table 2) and increases 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. Providing the proper minimum ventilation rate is an important consideration when trying to reduce the energy used for supplemental heat.

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 by knowing the number and size of pigs in the building. However, the calculated ventilation rate may need to be altered for the following reasons: the ventilation rate calculation is based on moisture production estimates; the calculated ventilation rate may not match airflow rates provided by available fans; and the number of animals and their weights will vary. Approaches used to alter the minimum ventilation rate include multiple small fans, a timer controlled fan, and variable-speed fans. Some of these approaches can cause problems in some facilities and should be carefully evaluated before being used. See PIH-41, "Maintenance and Operation of Ventilation Fans for Hog Barns," and PIH-60, "Mechanical Ventilation of Swine Buildings" for more detailed information.

If a timer is used with an oversized fan, the fan is on for only part of the time during which it moves an excessive amount of air. When the fan is not operating, no fresh air is provided. Facilities with ventilation openings into the attic may have problems with warm, moist air entering the attic while the fan is off. In using a timer, it is best to operate the ventilation fan at least 70% of the time. A timer should never be used on a pit fan.

In theory, the variable-speed fan solves the problem of providing a small amount of ventilation air with a capability of altering the ventilation rate. However, if the wind is blowing against them, variable-speed fans may move little or no air when operating at their slowest speed. This problem can be reduced if a variable-speed fan is operated at more than 50% of its maximum rpm to achieve the minimum ventilation rate. When a variable-speed fan is used, be sure to set the minimum rpm so that it will provide the minimum ventilation rate required. The minimum rpm setting should be checked regularly with a tachometer because the rpm may vary over time with the same setting.

Air Distribution Problems

As ventilation rates are lowered, it becomes increasingly difficult to maintain proper air distribution. Systems with adjustable baffles running the length of both sidewalls have difficulty providing a small enough opening to allow air to be distributed evenly into the room when ventilating at minimum rates. Poorly fitting doors, fan shutters, cracks, etc., provide unplanned openings which also hinder proper air distribution. A static pressure gage can be used to check if the incoming air is moving fast enough to prevent it from settling too rapidly and chilling the animals. When the baffle is properly adjusted, the static pressure gage should read at least 0.05 in. The surface near the inlet (within 8 ft.) should be free of obstructions which could deflect the cold air onto the animals.

Some ventilation systems utilize a 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 utilize only one air inlet for the winter, they are well adapted to distributing air from some air tempering system, such as that provided by heat exchangers.

Small facilities with very low minimum winter ventilation rates may need to use small circulation fans in the animal space to help maintain uniform conditions. The air should move in a circular pattern around the room without creating drafts.

Insulation

Temperature control is partially achieved by balancing heat gains with heat losses to the ventilation air and through the building surfaces. Reducing the heat loss through the

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 [1]/sow	Average winter building relative humidity %	Minimum outside temperature requiring no heat °F	Supplemental heat requirement at 0°F Btuh [2]/sow	Minimum outside temperature requiring no heat °F	Supplemental heat requirement at 0°F Btuh [2]/sow	Minimum outside temperature requiring no heat °F	Supplemental heat requirement at 0°F Btuh [2]/sow
20 (heat exchanger) [3]	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 = cubic feet per minute.
[2] Btuh = Btu per hour.
[3] 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.

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" RIGID INSULATION FROM BELOW THE SIDING TO A MINIMUM OF 16" BELOW THE GROUND LINE.

**TOTAL OF RESISTANCES OF INSULATION, LINING & SIDING, SURFACES, & AIR SPACES

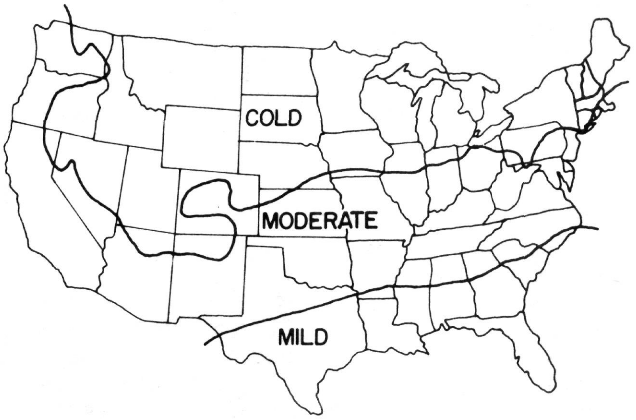

Figure 3. Recommended minimum insulation levels for controlled environment swine buildings.

building surfaces will extend the temperature range over which the ventilation rate can maintain temperature control. Swine buildings should be insulated to the levels given in Figure 3 using techniques described in PIH-65, "Insulation for Swine Housing."

A farrowing building can be used to illustrate the importance of 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. The outside temperature below which supplemental heat is required is only reduced 2° F to 26° F by increasing the average R-value from 20 to 30.

Determining an optimum level of insulation for a swine building is difficult because animal numbers and sizes change over time, and each additional amount of insulation added provides less economic benefit. Calculation procedures that can be used to determine an optimum level of insulation have been described in other fact sheets, such as ID-145, "Investing in Insulation for Farm Buildings" (available from the Mail Room, Publications, 301 S. Second St., Lafayette, IN 47905). The calculated levels are generally similar to those in Figure 3.

Thermostat Setting

Lowering the thermostat setting on the supplemental heater saves energy two ways. First, it reduces the amount of supplemental heat energy required to maintain the inside air temperature at any outside air temperature, and secondly, it allows ventilation rate to control inside temperature at lower outside temperatures. For example, reducing the temperature in a farrowing building from 70° F to 60° F reduces the supplemental heat requirement at 0° F from 1300 to 710 Btu/hr./sow (Table 3). In addition, the outside temperature below which supplemental heat is required is reduced from 38 to 22° F. When reducing the thermostat setting, caution should be used to insure that animal performance and health does not suffer.

Thermostats that operate all the fans except the minimum rate fan should be set a minimum of 4—6° F above the heater thermostat setting. If thermostats are not set properly, ventilation fans that control temperature may run at the same time the heater is operating.

Ventilation Air Tempering Methods

The range over which the ventilation rate can maintain the temperature of a swine building can also be extended by warming the intake air. Several methods, such as heat exchangers, solar walls, and earth tubes, are being 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 range over which the ventilation rate can maintain the temperature from 38° F to 22° F (Table 2). The design and economic feasibility of air tempering methods are beyond the scope of this fact sheet. However, be certain to use the other energy conservation measures described here before considering air tempering methods.

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 Btuh [1]/sow	Minimum outside temperature requiring no heat °F	Supplemental heat requirement at 0°F Btuh [1]/sow	Minimum outside temperature requiring no heat °F	Supplemental heat requirement at 0°F Btuh [1]/sow
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] Btuh = Btu per hour.
Assumptions: Twenty cfm per sow, 20 sow farrowing building, animal heat only, partly slotted floor.

Heat Exchangers

Heat exchangers are designed to move heat from the exhaust air to the intake air. One type of heat exchanger is a parallel plate unit in which exhaust and intake air are separated by thin plates. These units are capable of reclaiming 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.

An alternative to passing air between plates is to use a heat sink which utilizes two small beds of rock. One is warmed while the second is cooled, and then the fan direction is reversed. This causes the intake air to be warmed as it passes over the rock. One major disadvantage with this system is finding fans and controls that will allow the fans to reverse properly. The biggest advantage of rock heat sink units is that the materials required for construction are relatively inexpensive and durable.

Solar Energy

Because the sun is free and provides a readily available and inexhaustible source of energy, it seems to be a very attractive energy source for swine facilities. Some swine facilities already make use of some 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 generally a combination of south-facing windows and a proper roof overhang which allows the building to collect the solar energy. 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 no heat energy at night. Solar systems must be properly designed as described in publications such as MWPS-23, "Solar Livestock Housing Handbook (Available from the Midwest Plan Service, 122 Davidson Hall, ISU, Ames, Iowa, 50011)."

Earth-Tube Systems

Earth tempering of ventilating air for swine buildings is being considered, but at this point, design criteria are very limited. 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 relatively 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.

Guidelines for designing earth-tube heat exchangers, such as publication Energy #2, "Earth-Tube Heat Exchangers for Swine Buildings" (available from the University of Illinois, Dept. of Agr. Engr., 1304 Pennsylvania Ave., Urbana, IL, 61801) are derived from field studies and are the best recommendations now available. However, they should serve only as a guide.

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 a farrowing or gestation room. Although these designs do increase the animal heat input, they may compromise the managers' ability to maintain proper sanitation and temperatures for different age animals.

Fan Selection

A rating system for fan efficiency is now being used by some fan manufacturers to help select energy efficient fans to limit temperature rise in warm weather. Fans are rated for the amount of air they will move per watt of electricity they use (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 in. fans have shown ratings from 10 to 23 cfm/watt. Selecting fans based on their ratings reduces operating costs. In the Midwest, fans will be operating at their maximum rates in the summer to limit temperature rise approximately 2,000 hr./yr. 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 6¢ per kwh, the difference in operating cost between the two fans would be $68 per year. Energy savings are possible when trying to limit temperature rise in the summer by using fans that move air efficiently. However, when selecting fans for use in controlling the humidity level in the winter, more consideration should be given to their ability to provide the proper ventilation rate rather than their efficiency.

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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