pork industry handbook

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Cooling Swine

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Hot weather reduces swine performance more than cold weather, resulting in significant economic loss to the pork producer. This occurs because buildings in much of the U.S. are designed for cold weather while producers are often content to "wait out" hot spells. Hot weather does not usually result in death losses, but it can cause conception problems and subtle reductions in feed intake that result in significant drops in production.

The purpose of this publication is to suggest practices which minimize animal production losses to heat stress through the use of effective, energy-efficient cooling systems. Discussed first are the ways in which swine give off excess body heat. This is followed by a discussion of the various types of cooling systems based on these different heat dissipation principles. This information provides a basis for evaluating your present system or selecting one that best fits your situation.

Heat Dissipation

Larger swine (animals in gestation, farrowing, breeding and finishing phases of production) begin to feel the effects of heat stress at about 70°F. If temperatures remain above 85°F for more than a short period of time, substantial losses in performance and in reproductive efficiency can result unless some type of cooling relief is provided. Swine dissipate little moisture through their skin—certainly not enough to rid themselves of excess body heat. Therefore, to relieve heat stress they must depend upon heat dissipation to their environment in one or more of the following ways: radiation, conduction, convection, or evaporation through the respiratory tract (panting). Evaporative cooling from the body surface is also possible if some type of artificial surface wetting is provided along with adequate air movement.

Radiation

The surface of an animal's skin is constantly radiating heat to or receiving radiant heat from its surroundings. In a building, if the surrounding wall, ceiling and floor surfaces are cooler than the skin, there will be a net loss of heat from the animal, making it feel cooler. Radiant heat loss is directly related to the insulation level of the building. Insulation keeps inside building surfaces cooler in the summer, especially the roof or ceiling. Radiation typically accounts for about 20% of the total animal heat loss in the summer, but if building surface temperatures are above that of the animal, there will be a net heat gain by the animal.

Conduction

Conduction heat loss occurs when the animal's skin is in direct contact with a cooler surface. Conduction usually accounts for only 5-10% of the total heat loss in hot weather, because only about 20% of the animal's skin is in contact with the floor's surface, even less if the floor is slotted.

Conductive heat loss to a cool ground surface under a shade in a pasture or lot can be significant. However, it is not as important in concrete-floored confinement buildings, because higher building insulation levels and a greater concentration of animals maintain a warmer floor surface temperature. Insulation placed specifically under the floor or along the foundation to control winter heat loss further reduces summer conductive cooling.

Convection

Convection heat loss results from air movement over the animal's body. This is an effective means of cooling, provided two conditions are met: (1) the air velocity is at least 2 mph, and (2) the air temperature remains at least 10° F below the animal's body temperature (102 ± 1°F). At air temperatures in the range of 80-95°F, swine can dissipate up to 30% of their body heat by convection to the surrounding air.

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Evaporation

Evaporation heat loss from the animal's breathing process is important, particularly at high temperatures. For every pound of water evaporated, about 1,000 Btu of heat is required. At 80°F, panting accounts for nearly 40% of the total heat loss. Consequently, in providing relief from hot weather, it is important to keep the air around the animal's head as cool and dry as possible. This is the basic premise behind the concept of snout cooling of sows.

Shade Cooling

The use of sun shades in pastures and outside lots is an effective method for helping livestock keep cool (Figure 1). Shades can cut the radiant heat load from the sun by as much as 40%. They work by blocking out the sun's direct rays and providing a cooler ground surface on which the animals can lie.

Shades should have their long axis oriented in an east-west direction. High shade height maximizes the animal's exposure to the "cool" northern sky, which will help maximize radiant heat loss from the animal.

From a cooling standpoint, shades with straw roofs are best because they supply a high insulation value as well as a reflective suface. However, uninsulated aluminum or bright galvanized steel roofs are also good. Painting the upper surface white (or with a reflective paint) and the lower black improves cooling by about 10%. Wood snowfencing, a common shade material, is about half as effective as straw or painted metal. Greenhouse shade cloth works well and is reasonably durable when exposed to the sun and wind.

Shades are most effective if they are placed on high ground where they can catch the summer breezes. Lightweight shades must be well anchored to prevent overturning in strong winds. Locating them at least 150 feet downwind from a wooded area or lush vegetation helps cool the breeze.

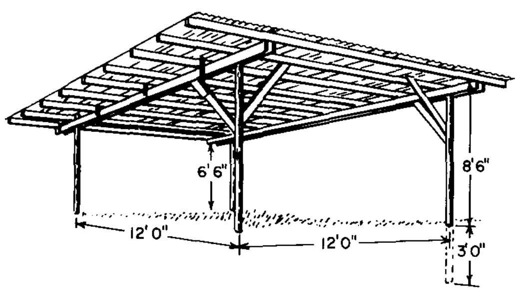

Figure 1. Shades shield out the sun's rays and provide a cool ground surface for the animals to lie on. Ideally, the high side of the shade should be located on the north to maximize radiant heat loss from the animals. See USDA Plan No. 5947 (12' x 16' shade) and No. 6257 (16' x 16' shade) available from the Agricultural Engineering Department at your state Land Grant University.

Adequate Insulation

In confinement buildings, insulation in the roof or ceiling is essential to minimize solar heat buildup in hot weather. See PIH-65, "Insulation for Swine Housing," for detailed information on insulation for swine buildings.

Sidewall insulation is not significantly beneficial for summer cooling if the building is oriented east-west since the summer sun passes almost directly overhead during the heat of the day. The attic area over a building with a ceiling should be well ventilated to prevent heat buildup and subsequent radiation of heat to the animals. Provide at least 1 sq. ft. of ridge and eave vent opening to the attic for each 300 sq. ft. of floor area. A north-south oriented building, however, should have the sidewalls as well as the roof or ceiling insulated because of the high solar heat load on the sidewalls. Sidewall insulation will be needed to control winter heat loss in most climates and in buildings which use evaporative or refrigeration-type cooling.

Ventilation Cooling Systems

Rapid air movement over the animal aids in both convective and evaporative heat loss. An air velocity below 1/2 mph is considered "still air." While low velocities are desirable in winter months to prevent drafts, an air velocity of at least 2 mph around the animal is necessary for appreciable hot weather cooling. To achieve this, the slot in an air-intake ventilation system should be designed to impart a high air entrance velocity (about 1 sq. in. of intake opening per 4 cfm of fan capacity). If possible, deflect fresh air directly onto the animals.

Summer heat is removed by a ventilation system primarily by replacing hot air with cooler fresh air. It can also reduce temperatures by using heat from the air to evaporate moisture from the floor, thus creating an evaporative cooling effect, and by taking high-humidity respired air away from the immediate vicinity of the animals.

Table 1 lists normally recommended ventilation rates for confined swine. Hot weather ventilation systems are typically designed to maintain an inside temperature that is no more than 2-5°F higher than outside conditions. Required rates will depend on climate conditions as well as the insulation level of the building. Hot weather rates recommended for larger animals (sows in farrowing and gestation, finishing and breeding facilities) vary greatly around the U.S. In the northern areas, hot weather rates which are about one-half those in Table 4 are sufficient while hot weather ventilation rates in the Southeast may range to twice the values shown.

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.

Air circulation systems, such as plastic air tubes and large diameter ceiling-hung or floor-mounted circulation fans, are often used to increase air velocities around animals. These systems are especially useful in naturally ventilated buildings and in wide (40 ft. or more) fan ventilated buildings. See PIH-41, "Maintenance and Operation of Ventilation Fans for Hog Barns," and PIH-60, "Mechanical Ventilation of Swine Buildings," for further information on the design of livestock ventilation systems. Circulation fans should be sized at about one-half the hot weather rate given in Table 1. For example, a farrowing room would be designed to exhaust 500 cfm per sow and provide circulation fan capacity equal to 250 cfm (1/2 x 500) per sow.

Water Cooling Systems

Water Supply

Animals must drink large quantities of water in hot weather if their evaporative heat loss system is to help them cool off. Table 2 lists the summer water requirements for swine. Water should be kept as cool as practical in order to achieve best weight gains in summer. Cooled water can slightly increase daily weight gains in very hot weather. Thus, water direct from a well is preferable to water stored in an above ground tank for an extended period or from a shallow farm pond.

Table 2. Typical summertime water requirements for swine.*

Type of animal	Water per head per day, gal.
Sow + litter	8
Nursery pig	1
Growing pig	3
Finishing hog	5
Gestation sow	6

*Includes water use for drinking and moderate water wastage. Water cooling systems may increase usage.

Wet-Skin Cooling

The pasture wallow has been used for many years for wet-skin cooling. In addition, the mud pack acquired helps protect the skin from the sun's rays. Wallows located under shade are more effective in improving animal comfort than unshaded wallows, because they are shielded from the sun's rays and the water remains cooler.

Substantial cooling is possible by wetting the animal's skin and allowing the moisture to evaporate. Research studies measuring the performance of finishing hogs in hot weather reveal that the animals perform as well with sprinklers as they do with evaporative cooling of inlet air. Air movement across the animal increases the evaporation rate and improves cooling.

In extremely hot weather, relief can be gained by hosing the animals down once every hour or so. This requires more water and labor than a sprinkler system but can help you through a crisis.

It should be pointed out that sprinkling is preferred to fogging, which uses smaller water droplets. Sprinkling cools the skin surface by evaporation, whereas fogging cools the air and the air must then cool the animal.

Animals which are cooled with sprinklers should also be provided access to shade or shelter. Otherwise, it is possible for animals to become "sunburned."

Most sprinkler systems operate by thermostat-controlled timers that wet the animal and then allow it to dry. Sprinkler systems are usually designed to run for 1-2 min. each 30-min. period (a few operations use 1-2 min. each 10-min. period) when the temperature is above some set value (typically in the 80-85°F range).

Tables 3 and 4 provide water line and nozzle size information. Provide at least 0.02 gal. of water per hour per finishing hog (1 gal. per 50 finishing hogs) for adequate sprinkler cooling. If the available nozzles do not provide the proper amount of water at the available water pressure, either adjust the water pressure, adjust the timer accordingly or use more than one nozzle per pen. While producers often construct sprinkler systems by simply punching holes in polyethylene pipe with a 20 ga. needle, a specifically designed nozzle provides a better spray pattern and is less apt to plug.

Be sure to have an easily-cleaned, in-line sediment filter (100 mesh strainer or cartridge unit) and timer-operated solenoid valve in the line between the water source and the nozzles (Figure 2). Nozzles are an especially important component of any sprinkler system. Select non-corrosive nozzles specifically designed to furnish a solid cone of water droplets, not a mist or fog.

A recent study at Kansas State University found good results when drip irrigation emitters were mounted so that water dripped onto the neck and shoulder area of sows in farrowing crates. Each emitter provided 0.8 gal. per hr. and was operated only when temperatures were above 85°F. It should be noted that the sows in the Kansas study were on total slotted floors.

Table 3. Nozzle sizes for sprinkler system (based on operation at 40 psi).

Pigs per pen	Water requirements (gal./hr.)	Nozzle sizes 2 min./10 min.		Nozzle sizes 1 min./30 min.	
		gal./min.	gal./hr.	gal./min.	gal./hr.
10	0.2	0.017	1	0.10	6
20	0.4	0.033	2	0.20	12
30	0.6	0.050	3	0.30	18

Table 4. Water line sizes for sprinkler systems.*

Pipe size ID	Class 160 PVC	Class 200 PVC	Schedule 40	Schedule 80
3/4 in.	7 gpm	6 gpm	4.5 gpm	3.5 gpm
1 in.	13 gpm	13 gpm	9 gpm	7 gpm
1¼ in.	25 gpm	23 gpm	18 gpm	15 gpm
1½ in.	35 gpm	32 gpm	28 gpm	23 gpm
2 in.	55 gpm	55 gpm	50 gpm	45 gpm
2½ in.	85 gpm	80 gpm	70 gpm	65 gpm

*Based on maximum pressure drop of 2 psi per 100 ft. or velocity less than 5 ft. per sec.

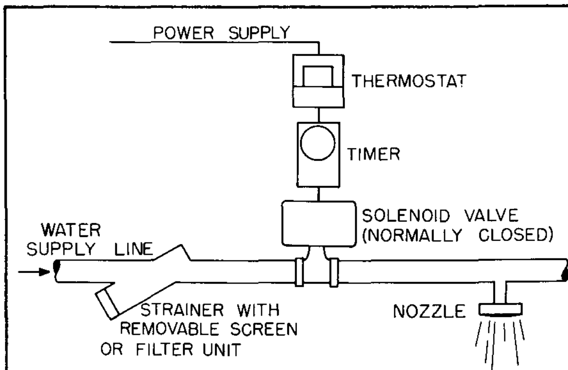

Figure 2. Sprinkler cooling systems should be equipped with a timer-operated solenoid valve, and an in-line sediment filter (strainer).

Evaporative Cooling Systems

Operation Principles

Evaporative coolers use the heat of water vaporization to cool ventilation air in the same way that water sprayed on animals evaporates and cools their skin. The incoming ventilation air is passed through a moist pad, where heat in the air evaporates moisture into the air. This raises the relative humidity while lowering the temperature of the air.

The lower the relative humidity of the incoming air, the more effective evaporative cooling is. This kind of cooler is more effective in dry western states than in the midwestern or eastern U.S. Even so, evaporative cooling can provide some relief from heat stress under most summer conditions in these areas. Relative humidity drops as the air temperature rises and is usually at its low point during the hottest part of the day. Theoretically, a temperature drop of 18°F is possible under typical midwestern summer conditions. In practice, however, a temperature drop of only about 8°F can be expected. The hot weather ventilation rates shown in Table 1 should be used to design an evaporative cooler.

Several types of evaporative coolers are available commercially for use in livestock buildings. Most were developed for greenhouse or residential use. Local greenhouse suppliers are excellent sources of information for this equipment. Most units use a circulating pump to distribute water over a fibrous pad. Air is drawn through pads into the animal area. One commercial unit uses a pad mounted on a drum which rotates through a pan of water. Routine maintenance is essential to maintain the system in proper operating condition (i.e., control algae growth and dirt build-up).

Design

Figure 3 shows a typical evaporative cooler design. The water distribution system usually consists of a rigid plastic pipe with spaced holes to allow the water to be distributed uniformly over the pads. A 2-in. pipe with 1/8-in. holes spaced 4 in. apart (4 ft. W.G. pressure head) or a 4-in. x 4-in. open gutter with 1/4-in. holes spaced 4 in. apart (2 in. W.G. pressure head) will produce about the same flow rate over 100 linear ft. of pad area, but a better practice is to size pipe diameter, hole diameter and spacing for each system individually.

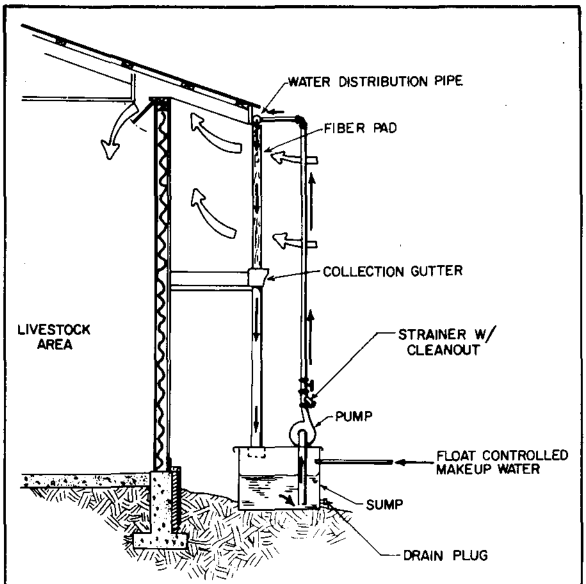

Figure 3. In a sidewall mounted evaporative cooling system, ventilation exhaust fans pull hot outside air through wet fiber pads. Heat from the air is used to evaporate the water, thus lowering temperatures but increasing the relative humidity. Consider modifying the baffle for down-the-wall air flow for maximum benefit when the cooling system is in operation.

The best procedure for sizing pad area is to follow the manufacturer's specific recommendations for his system when used in your area. In the absence of specific manufacturer recommendations, the pad area needed (in sq. ft.) can be approximated by dividing the ventilation rate (in cfm) to be cooled by 150 for aspen pads, or by 250 for cellulose honeycomb-style pads. The water sump should have a capacity of at least 0.5 gal. per sq. ft. of aspen pad, or 0.8 gal. per sq. ft. of 4 in. thick cellulose pad. The flow rate to the water distribution pipe over the pads should be at least 0.3 gal. per min. (gpm) per ft. of linear length of 2-4 in. thick aspen pad (0.4 for aspen pad under desert conditions) or 0.5 for 4 in. thick cellulose pad to ensure adequate wetting.

A gutter, sloped at 1 in. per 20 ft., is located beneath the pads to collect any water not evaporated and convey it back to the sump to prevent water wastage. Recycled water should pass through an inclined 50 mesh screen before entering the sump. The sump and open distribution gutter should be covered to shut out sunlight (to control algae growth) and to keep out insects and other debris. Make-up water to the sump is normally controlled with a shutoff float valve. Up to 1 gpm per 100 sq. ft. of pad can be evaporated on hot, dry days.

Set the thermostat so that the pump begins wetting pads when the temperature reaches 80-85°F. The pump should be wired so that it shuts off before the fans. This will allow the pads to dry out after use and minimize the buildup of algae growth.

Maintenance

Pads made from woven aspen fibers must be replaced annually; however, cellulose and other types of pads with a useful life of 5 yrs. or more are now available with some units. Pads are usually mounted either on the side or end-wall, or on the roof. Wall-mounted pads are easier to maintain and, therefore, are preferred for livestock buildings. Vertically mounted pads should be checked periodically to eliminate sagging, resulting in voids which allow ventilation air to by-pass the wetted pads and enter the building without being cooled.

Pads should be hosed off at least once a month to wash away any trapped dust and sediment. Algae buildup in the recirculated water system is sometimes a problem but can be controlled with a copper sulfate solution. Some units use light-tight enclosures around the pads to help control algae growth.

Since water is constantly being evaporated, salts and other impurities build up. Constantly bleeding off 1-2% of the water (0.05 gpm per 1000 cfm of air cooled) will help flush these salts from the system as they are formed. Or you may flush out the entire system periodically; the frequency will depend on the hardness of the water used. Install removable caps or valves on the ends of the distribution lines to facilitate flushing.

Refrigerated Air Systems

Refrigeration cooling systems are seldom used in livestock buildings because of their high installation and operating cost. One reason for the high operating cost is that air conditioners are usually not installed to reuse room air because of the high level of corrosive gases and dust in the air. To prevent rapid clogging and excessive maintenance, the air conditioner must continually cool incoming fresh air in a one-pass process. Some producers use refrigerated air units for space cooling in their farrowing houses or in swine breeding units, and the systems do perform satisfactorily, except for the high operating cost.

Operation Principles

Air conditioners both cool and dehumidify the air as it passes over a cold, finned refrigeration evaporator coil. If the air is cooled below the dew-point temperature, moisture in the air condenses. The relative humidity of the air leaving the unit is higher than the relative humidity of the incoming air because of the lower temperature, but it contains less moisture because of the condensation. As this air is warmed by mixing with air inside the building, its relative humidity decreases, enabling it to pick up additional moisture.

Design

A "ton of refrigeration" is a term held over from the days of ice block cooling. It is defined as a cooling capacity of 200 Btu per min. or 12,000 Btu per hr. For a well-insulated building, use 1 ton of refrigeration for each 275 cfm of conditioned ventilation air. To determine the size of the unit needed for a specific building, refer to Table 5 and the following example.

Example: What size air conditioning unit is needed to cool a 20-sow farrowing house? From Table 5, the total refrigerated air ventilation rate is found to be 2000 cfm (100 cfm x 20 sows). Size of the cooling unit, therefore, should be about 7¼ tons (2000 cfm ÷ 275 cfm/ton).

Table 5. Per-head refrigerated air ventilation rates for confinement swine.*

Type of animal	Ventilation rate
Swine	
Farrowing sow	100 cfm
Gestating sow (325 lbs.)	40 cfm
Boar (400 lbs.)	50 cfm
Finishing hog (150 lbs.)	30 cfm

*Assumes 20°F temperature drop across evaporator.

Zone Cooling Systems

One approach to cooling confined swine is to zone cool the area around the animal's head, since, in hot weather, 50-60% of animal heat loss is through evaporation from the respiratory tract and convection from the skin surface. A supply of high-velocity air around the head enables the animal to lose more heat and thus remain cooler, but zone cooling does not satisfy all of the hot weather ventilation needs. A conventional hot weather ventilation system sized to remove air at the rate given in Table 1 is also needed.

Zone cooling is generally used only for crated or tethered animals or a small number of animals in a small pen, such as in a boar pen. In farrowing houses, zone cooling helps maintain a cool environment for the sow while allowing higher temperatures in the pig creep.

Zone cooling can use either fresh uncooled air or refrigerated air. Evaporative cooled air is NOT recommended for zone cooling systems because the high moisture content of the air prevents effective dissipation of respired moisture around the animal's head. Air cooling with earth tubes or other nonevaporative methods should be designed according to the amount of temperature drop. If cooling is as efficient as refrigeration (i.e., 20°F or more drop in temperature), the same design can be used.

Design

A zone cooling system (Figure 4) has a main air supply duct open to the outside or to the cooling unit and downspouts or drop ducts located as needed for the animals.

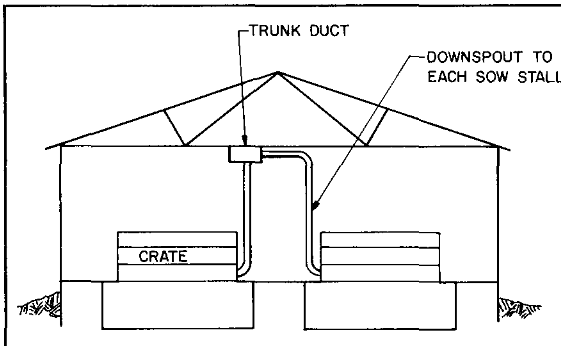

Figure 4. Zone cooling systems provide only a portion of total ventilation needs but are very effective, since high-velocity air is transported directly to the animals.

The downspouts should be placed as close as possible to the animals' heads. They should be constructed of nondestructible material and well anchored if within the animal's reach. If the duct opening is too far above the animal, the cooled air mixes with the surrounding air, both reducing its velocity and raising its temperature. Dampers can be used on downspouts to shut off the airflow when crates or pens are empty.

Table 6 gives recommended air flow rates for systems using uncooled outside air or refrigerated air. Tables 7 and 8 present supply duct and downspout sizes to accommodate various airflow rates. These suggested minimum sizes permit an air velocity of 600 ft. per min. (fpm) through the supply duct and 800-1000 fpm through the downspouts. The trunk ducts can be slightly larger but should not be smaller if good air distribution is to be obtained. Sizes shown for downspouts are more critical to maintain the proper air exit velocity and should be adhered to carefully.

Table 6. Per-head air flow rates for zone cooling for confinement swine.*

	System	
Type of animal	Uncooled air	Refrigerated air
	—cfm—	
Swine		
Farrowing sow	70	40
Gestating sow (325 lbs.)	35	20
Boar (400 lbs.)	55	30

*Systems using zone air cooling systems should still be ventilated at the hot weather rates shown in Table 1.

Table 7. Minimum supply duct sizes for zone cooling systems (600 fpm air velocity).*

Air flow rate within duct	Inside duct dimensions if: Rectangular	Round
cu. ft./min.	in. x in.	in. diam.
250	6 x 10	9
500	10 x 12	12
750	10 x 18	15
1000	12 x 20	18
1250	15 x 20	
1500	18 x 20	
2000	18 x 27	
2500	18 x 34	
3000	18 x 40	
3500	24 x 35	
4000	24 x 40	
5000	24 x 50	
6000	30 x 48	
7000	36 x 48	
8000	36 x 54	

*It is the minimum cross section area, not the actual duct dimensions given in the table, that is important. Almost any duct shape of comparable size should deliver the same amount of air.

Table 8. Recommended downspout sizes for zone cooling systems (800-1000 fpm air velocity).

Air flow rate per sow	Inside duct dimensions if: Rectangular	Round
cfm	in. x in.	in. diam.
20	2 x 2	2 1/2
30	2 x 3	2 1/2
40	2 1/2 x 3	3
50	3 x 3	3 1/2
75	3 x 4 1/2	4
100	4 x 4 1/2	5
125	4 x 5 1/2	
150	4 x 6 1/2	6
175	4 x 8	
200	6 x 6	
250	6 x 7 1/2	8

If zone cooling ducts are used to supply refrigerated air in summer or fresh air in winter (as a part of a winter ventilation system), they must be insulated (R = 6 minimum) to prevent condensation. With refrigerated air, insulation will also minimize heat gains as the cooled air passes through the duct to the animal.

The following example shows how to determine, from Tables 6, 7 and 8, the airflow and duct size requirements for zone cooling systems for a 20-sow farrowing house.

Uncooled air. From Table 6, airflow in each downspout should be 70 cfm, and in the supply duct it should be 1400 cfm (70 cfm/sow x 20 sows). From Tables 7 and 8, proper downspout size for 70 cfm is 4 in. diameter, and minimum trunk size for 1400 cfm is 18 x 20 in.

Refrigerated air cooling. From Table 6, each downspout should supply 40 cfm, while the supply duct supplies 800 cfm (40 cfm/sow x 20 sows). From Tables 7 and 8, this airflow rate requires a downspout diameter of 3 in. and the trunk size of 12 x 20 in. Note that the size of the air conditioner required for zone cooling is about 3 tons (800 cfm ÷ 275 cfm/ton) compared to 7¼ tons required to cool the entire building (see earlier example).

Summary

The lack of a cooling system is a serious deficiency in many swine production buildings. Many producers experience enough loss due to poor performance and animal deaths each summer to pay for a cooling system in a short time. Cooling systems need not be sophisticated to be effective, but they must be selected and designed for ease of maintenance. Reliability should be a primary consideration in selecting a system.

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