EXTENSION BULLETIN E-1336
JUNE 1991 (MAJOR REVISION)

pork industry handbook

COOPERATIVE EXTENSION SERVICE • MICHIGAN STATE UNIVERSITY

Mechanical Ventilation of Swine Buildings

Authors
James P. Murphy, Kansas State University
Don D. Jones, Purdue University
Leslie L. Christianson, University of Illinois

Reviewers
Wallace and Denise Bradway, Salem, New Jersey
Daryl Haerther, Strasburg, Colorado
Harvey Hirning, North Dakota State University
Leon and Pat Reiner, Tripp, South Dakota
Dennis Stombaugh, The Ohio State University

A well-designed and well-managed ventilation system is an essential part of any pork production building. Mechanical ventilation involves many factors, which must be understood if it is to function properly. It's a complete system of matched components–insulation, tightly constructed building, supplemental heat, fans, inlets, and controls–tailored to the environmental needs of the animal. Omitting any of the components can result in unsatisfactory performance. Simply adding fans without providing adequate insulation and supplemental heat will not provide the desired results.

Proper ventilation should:

- Remove moisture, gases, odors, dust and air-borne disease organisms.
- Provide fresh air and distribute it uniformly without creating drafts.
- Control air flow and supplemental heat to modulate temperatures in winter and summer.

Building Construction

Insulation in the walls, ceiling, and along the foundation and floor is necessary to keep the building warm and prevent condensation. Using adequate amounts of insulation reduces heat losses and prevents condensation in cold weather. Adding or conserving heat in winter acts to increase the temperature of incoming air, enabling it to absorb and remove moisture as it moves through the building. Check the Midwest Plan Service Handbooks and Pork Industry Handbook publications listed at the end of this factsheet for more information on this topic.

Unplanned openings such as cracks around doors and windows can nullify the benefits of well-planned ventilation inlets by changing the distribution and velocity patterns of air entering the building. For this reason, mechanically ventilated swine buildings must be tightly constructed. Many operators eliminate windows to reduce air leakage, condensation and heat loss. However, emergency ventilation openings should be provided if standby power is not available.

Ventilation Principles

During cold weather, the air flow requirements of the building are based on the moisture produced in the building and on the expected moisture content of the air entering and leaving the building. The ventilation system is expected to remove this moisture and to maintain a relative humidity between 50% and 70%. Higher humidities contribute to condensation and respiratory problems while humidities below 50% may also increase respiratory problems due to dryness and dust.

During cold weather, the outside air entering the building contains very little moisture. When cold air is brought into a warm building, the air temperature increases which, in turn, increases its moisture-holding capacity. This warmed air absorbs moisture before being expelled by the ventilation system. Figure 1 illustrates how inside and outside air conditions determine the ventilation rates for moisture removal. Under the conditions shown in Figure 1, every cubic foot of exhaust air removes (0.00831- 0.0003) / 13.3 = 0.0006 lb. of water. Since a 120-lb. hog produces 0.19 lb. of water per hour, the ventilation rate for moisture removal for these conditions would be (0.19 lb./hr./pig) / (0.0006 lb./ft.^{3}) = 320 ft.^{3}/hr./pig or 320 / 60 min./hr. = 5.3 cu. ft. per min. for each 120 lb. hog.

Cold weather is defined here as periods when supplemental heat is needed, either continuously or intermittently, to maintain a constant room temperature. If a ventilation rate higher than this calculated value is used, an increased heating bill should be expected. Table 1 gives the recommended ventilation rates for cold, mild, and hot weather ventilation.

Table 1. Recommended fan capacities (at 1/8 in. static pressure) per pig or per sow and litter

		Ventilation rates, cfm		
Life Stage		Cold weather	Mild weather	Hot* weather
	Unit	------ cfm/hd (or sow + litter) ------		
Sow and litter	400 lb.	20	80	500**
Prenursery pig	12-30 lb.	2	10	25
Nursery pig	30-75 lb.	3	15	35
Growing pig	75-150 lb.	7	24	75
Finishing pig	150-220 lb.	10	35	120
Gestating sow	325 lb.	12	40	150
Boar/Breeding sow	400 lb.	14	50	300

* These rates may be reduced when supplemental cooling is available in hot weather; and may be increased when air velocities on pigs are low in summer.

** 500 cfm is the generally recommended hot weather rate in farrowing, however local recommendations range from 250 cfm in northern areas of the United States to 1000 cfm or more in the southeast and southwest.

The rate for each season is the total capacity needed. For sow and litter: 20 cfm/unit (cold weather) + 60 cfm/unit = 80 cfm unit (mild); add 420 cfm/unit for 500 cfm/unit total hot weather rate.

Cold weather rate: In some cases, this airflow needs to be adjustable, due to a change in the number of animals in the room or due to their growth. Ideally, at least one fan should operate at all times when the inside temperature is above 35°F. Set a thermostat to shut the fan off when the inside temperature drops below 35°F and activate an alarm to notify the operator. This fan should supply the cfm rate listed in Table 1 under "Cold weather rate". The fan should exhaust the air from above any stored liquid manure.

Mild weather rate: Provide additional airflow, thermostatically set to start in 3-5 degree steps, from lowest desired temperature to prevent sudden drops in temperature. These fans, together with the cold weather fans, provide the capacity for outdoor temperatures up to about 55°F.

Hot weather rate: Provide additional fans to supply the cfm rates listed under "Hot weather rate". Some or all of these fans should be operated when the inside building temperature is above 75°F. Hot weather rate airflow capacity of sows and litters and breeding animals can be reduced somewhat by utilizing drip cooling or zone cooling (water evaporation or mechanical air conditioning) of sows and boars. See MWPS-33 for detailed design information.

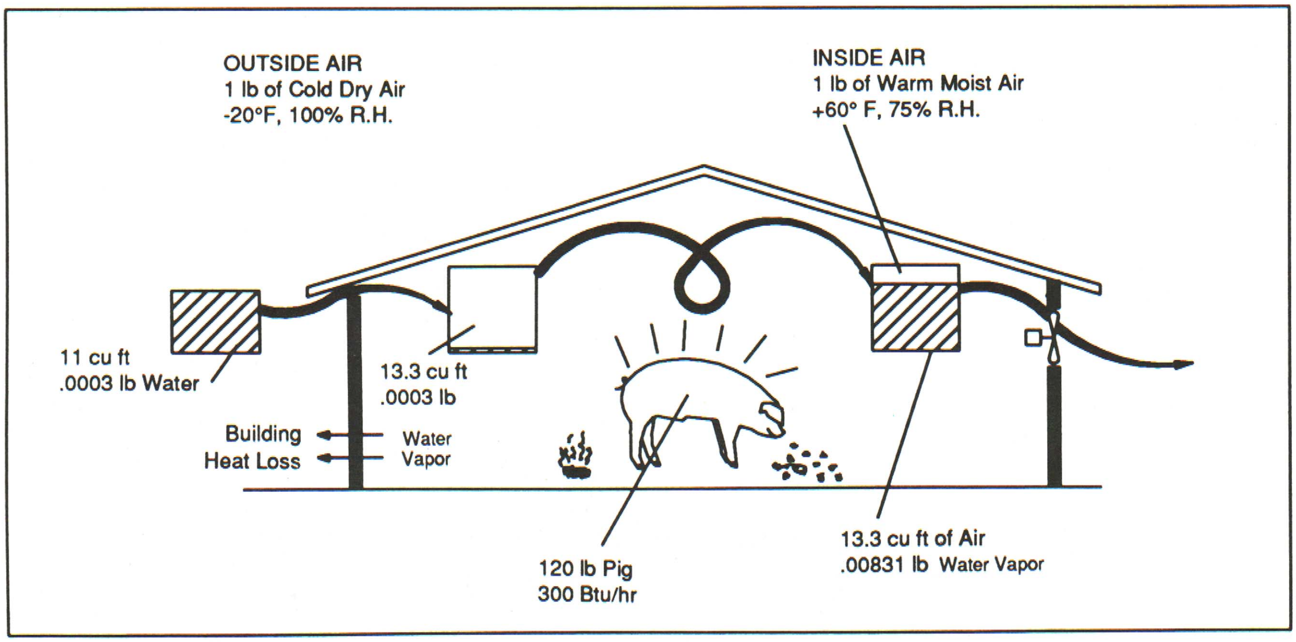

Figure 1. Winter ventilation in a controlled environment. Source: MWPS-32, Midwest Plan Service Mechanical Ventilating Systems Handbook.

Types of Ventilation Systems

There are three general types of mechanical ventilation systems: positive, negative and neutral pressure systems. Classification of the system is based on the air pressure of the enclosure relative to outside air pressure. A positive pressure system operates above normal outdoor air pressure (fans blowing into the enclosure). Negative pressure systems operate below outdoor air pressure (fans exhausting from the enclosure). Neutral pressure systems use fans both to supply and exhaust ventilation air at approximately the same rate. Any of the systems may use air recirculation ducts or fans to mix and distribute incoming air.

Figure 2 illustrates a negative pressure system with slot air inlets. Fresh air is drawn into the building through the air inlets. Like all ventilation systems, incoming air must be well-distributed and properly mixed, or blended, so that it can remove moisture and/or heat, and do it without creating drafts. Since a pressure difference must be maintained between inside and outside, it is especially important that negative pressure buildings be tightly constructed so that fresh air enters only through planned vent openings.

Figure 3 illustrates a negative pressure ventilation system with air recirculation. A recirculation fan (usually mounted near the ceiling and away from the wall) keeps the air flowing continuously through the duct or tube. The motorized wall intake shutters are controlled by the same thermostats that control the exhaust fan, opening automatically to draw in fresh air from either the outside or from the attic area. When the thermostat turns the exhaust fan off, the motorized intake shutters also close, and the fan simply circulates room air through the distri-

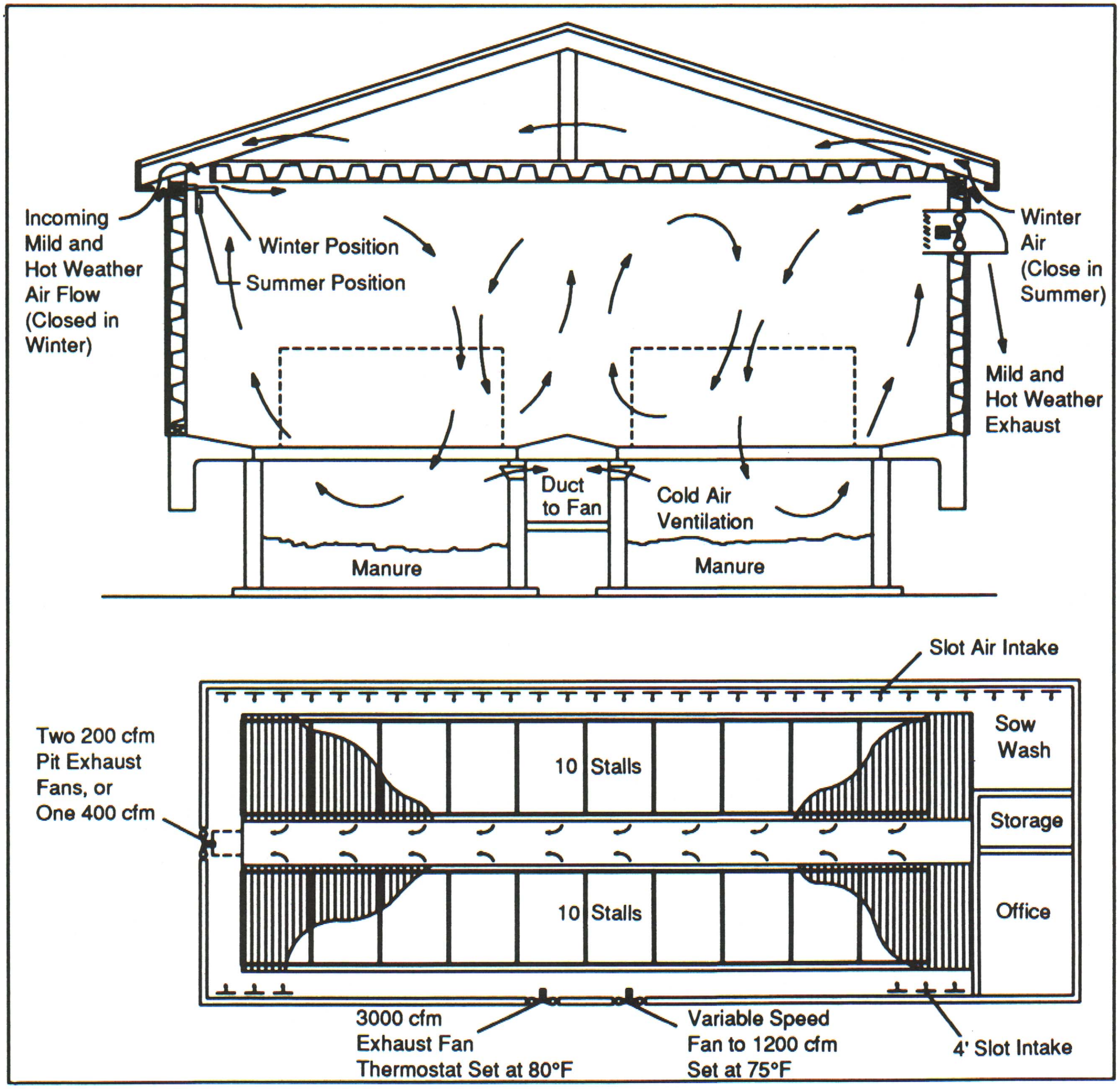

Figure 2. A type of negative pressure (exhaust) ventilation system with pit ventilation. The cold weather ventilation rate is exhausted through properly sized openings into the under-aisle duct.

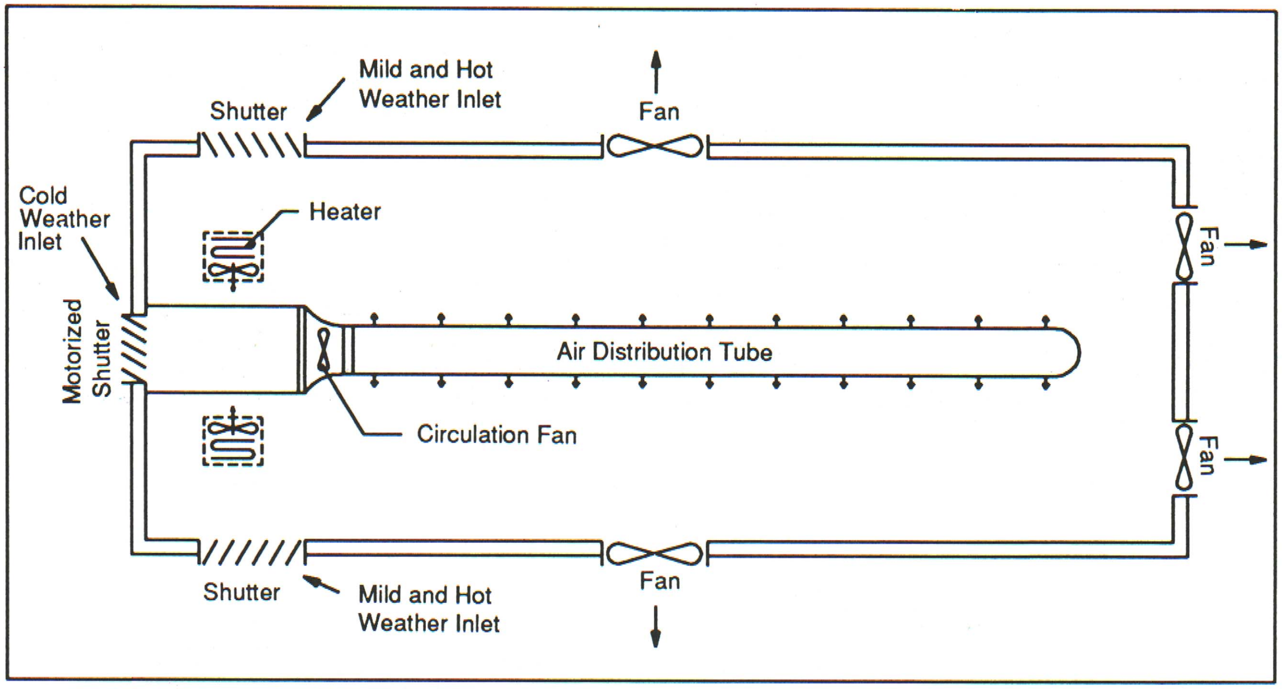

Figure 3. Negative pressure intake and air distribution. The duct is typically sized to mix one part of incoming air with four parts of recirculated air to prevent condensation on the duct during cold weather use.

bution duct, or tube. Timers are often wired in parallel with cold weather thermostats to ensure a minimum ventilation rate during cold weather especially in buildings with small animals which produce little body heat.

Figure 4 illustrates a push-pull system which operates at near neutral pressure. This design uses a fan and pressurized duct to bring fresh air into the building. Additional fans operate in conjunction to exhaust stale air.

Positive pressure systems use fans to blow fresh air into the building (Figure 5). This increases the static pressure inside the room relative to the outside causing stale air to be exhausted through vent openings. Uniform ventilation depends on proper design of the air distribution system and on proper location of exhaust vents. Positive pressure ventilation is more effective than negative pressure systems in older, less tightly constructed buildings.

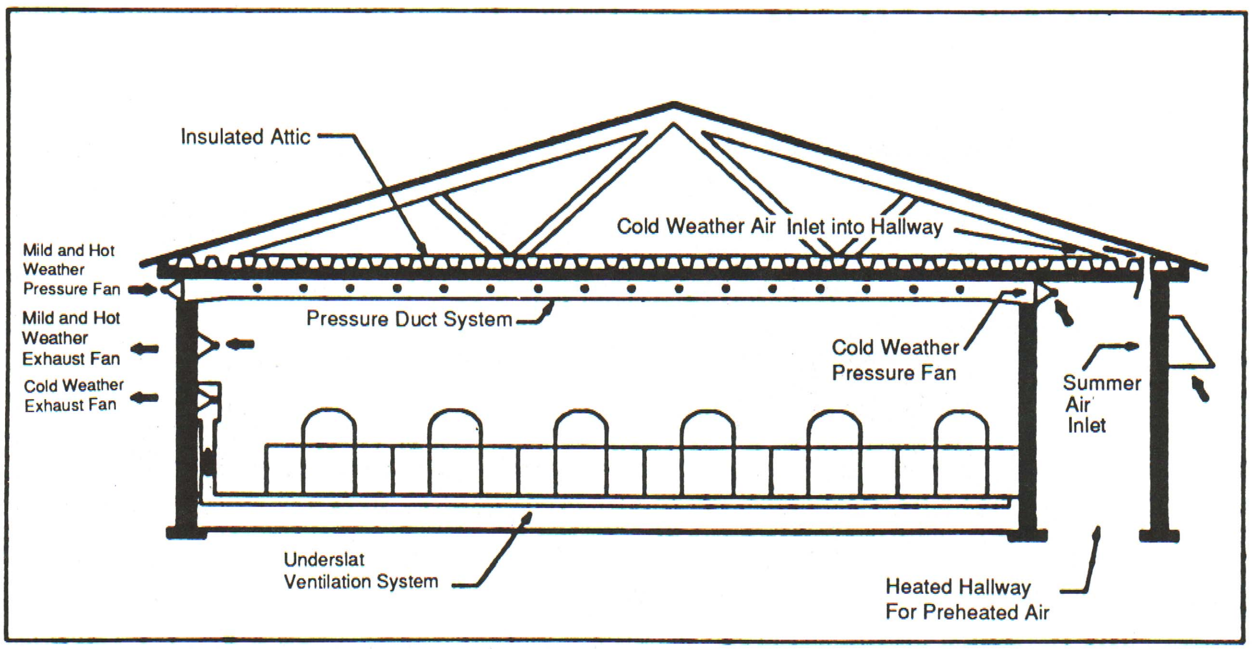

Figure 4. Neutral pressure, or push-pull ventilation. Cold weather ventilation is distributed through the pressurized duct while mild and hot weather ventilation is typically operated as a negative pressure system.

Under-Slat Ventilation

Ventilation of the space between the liquid manure and the slats is common where liquid manure is stored in pits beneath slotted floors. The cold-weather fans are located so as to exhaust air from the pit to aid in removing gases and odors.

An exhaust duct, with properly sized and spaced openings installed under the slats or alongside the manure pit walls, aids in collecting the air uniformly over the full length of the pit instead of only near the exhaust fan. Size the pit exhaust fan to handle the cold weather rate (Figure 2).

Fan Systems

Ventilation air requirements (Table 1) vary from a minimum at the cold weather capacity to many times this value in hot weather. Continuously operating fans that exceed the rate needed for moisture removal in cold weather waste heat. During the hottest weather, fan capacity is increased to the maximum rate to remove as much heat as possible and to provide more air movement around the hogs. To prevent rapid temperature changes, it is desirable to increase or decrease ventilation rates in several small increments rather than in one large increment.

The range of air capacities in the ventilation system can be provided in various ways: (1) a small continuously operating fan with "minimum" cold weather capacity plus larger fans, controlled in increments by thermostats which engage fans as room temperature increases and disengage them as temperature decreases, (2) variable-speed fans operated below their full-speed capacity. Variable-speed fans are modulated by a solid-state control which regulates the voltage going to the capacitor-start, capacitor-run motor, or (3) a single-speed fan controlled by a percentage or 10-minute interval timer to allow a wide range of capacities.

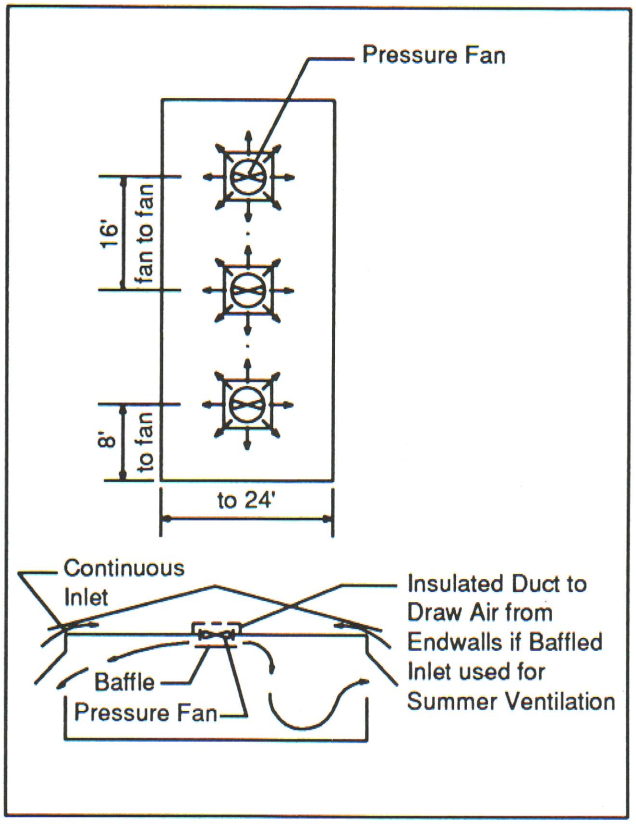

Figure 5. Positive pressure ventilation. Air outlets are sometimes located under slotted floors to provide an effective pit ventilation system.

Care should be taken to protect variable speed fans from outside wind pressure when operating the fan at low speed if a uniform ventilation rate is to be maintained. Ideally, they should not be operated below 40% of their full-speed capacity if providing the cold weather ventilation rate. Timer-operated fans also have disadvantages for cold weather use. Their "on-off" operation can cause wide temperature and humidity fluctuations and back-drafting at the intakes when the fan is off.

Fan motors should be:

- Totally enclosed and suited for use in a corrosive, moist, dusty environment.
- Rated for continuous operation.
- Sealed ball bearing type.
- Equipped with thermal overload protection.
- Wired with separate circuits from opposite sides of the 230 V service.

Air Inlets

In a mechanical ventilation system, the size and operation determine the rate of air change. The uniformity of air distribution, on the other hand, depends primarily on location, design and adjustment of the air intakes in exhaust systems or the air outlets in pressure systems. It is especially important to maintain enough inlet velocity during cold weather so that incoming air is mixed or blended with the warm room air before it reaches animal level. The opening, or cross-sectional area, of the air inlet should be based on the capacity of the fans. If the inlet area is too great, cold air enters at low velocity, causing it to "dribble" in, settle to the floor and induce drafts.

Air intakes should be designed and constructed so that a negative static pressure of 0.04 - 0.06 in. of water gauge is created at the inlet shown in Figure 6. This will assure velocities of 800 to 1000 ft. per min. A common rule of thumb is to size intakes at 1 sq. ft. for each 600 cfm of fan capacity.

Table 2 gives the rate of air flow through 1-ft. long ventilation slots for two pressure levels.

Table 2. Rate of air flow through ventilation slots one foot long.

Inches slot width	Static pressure, water gauge 0.04 In.	0.125 In.
	---cfm---	
1	50	100
2	100	200
3	150	300
4	200	400

* Source: Pennsylvania State University

Example: A 20-sow, 24 ft. x 60 ft. farrowing house is ventilated in winter with a single speed fan having capacity of 400 cfm. Additional fans will provide a total of 10,000 cfm in hot weather. What size should the slot inlets be assuming the inlet runs the full length of both side walls (2 x 60 = 120 ft. long)?

Each foot length of slot will need to provide 10,000 cfm/120 ft. = 83.3 cfm at maximum airflow. At minimum airflow, each foot length of slot opening will provide 400 cfm/120 ft. = 3.3 cfm. Assume a 1 in. slot width and an operating static pressure of 0.04 in. From Table 2, each foot of 1 in. slot will admit air at the rate of 50 cfm. The slot will require an opening that is adjustable between 83.3/50 = 1.7 in. and 3.3/50 = 0.07 in. Power-

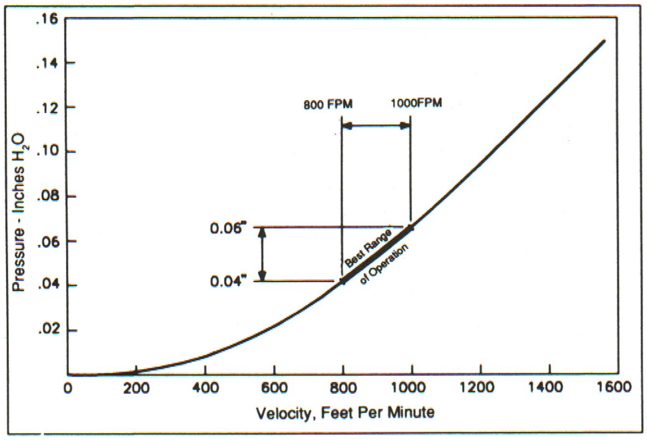

Figure 6. Air intake velocity and static pressure relationship.

operated inlet systems can automatically adjust the opening area, to maintain a preset pressure difference between inside and outside.

Adjustment of ventilation systems to provide the optimal air distribution at the various air flow rates must be understood by the operator. Several methods will work if properly installed and operated, including:

1. Separate air paths for winter and summer. This allows air to be drawn from the attic in cold weather and directly from the outside the rest of the year (Figure 7).
2. Manually adjustable hinged or vertically adjustable baffles (Figure 7) under ceiling slot intakes (Figure 8).
3. Gravity or spring-loaded curtain or damper at the inlet (Figures 9).
4. Power-operated adjustable baffles under ceiling slot intakes.

Other important considerations in planning fresh air intakes include:

1. Ensuring there are no unplanned openings into the building. All openings, including doors, windows, feed drops, cracks around doors, and other leaks should be tightly closed.
2. Providing insulated baffles under the intake slots or holes to direct the air. In winter, the incoming cold air is directed across the ceiling where it is warmed and mixed with the warmest air in the building. Make sure the ceiling liner is smooth with no obstructions that can deflect incoming cold air. This also prevents heavier cold air from dropping or settling to the floor where it could cause drafts that could chill pigs. In summer, the baffle can be lowered to deflect the air directly onto the animals.
3. Bringing air through the attic in cold weather reduces the effect of wind and allows the air to be tempered somewhat before it enters the housing area. The air intakes from the

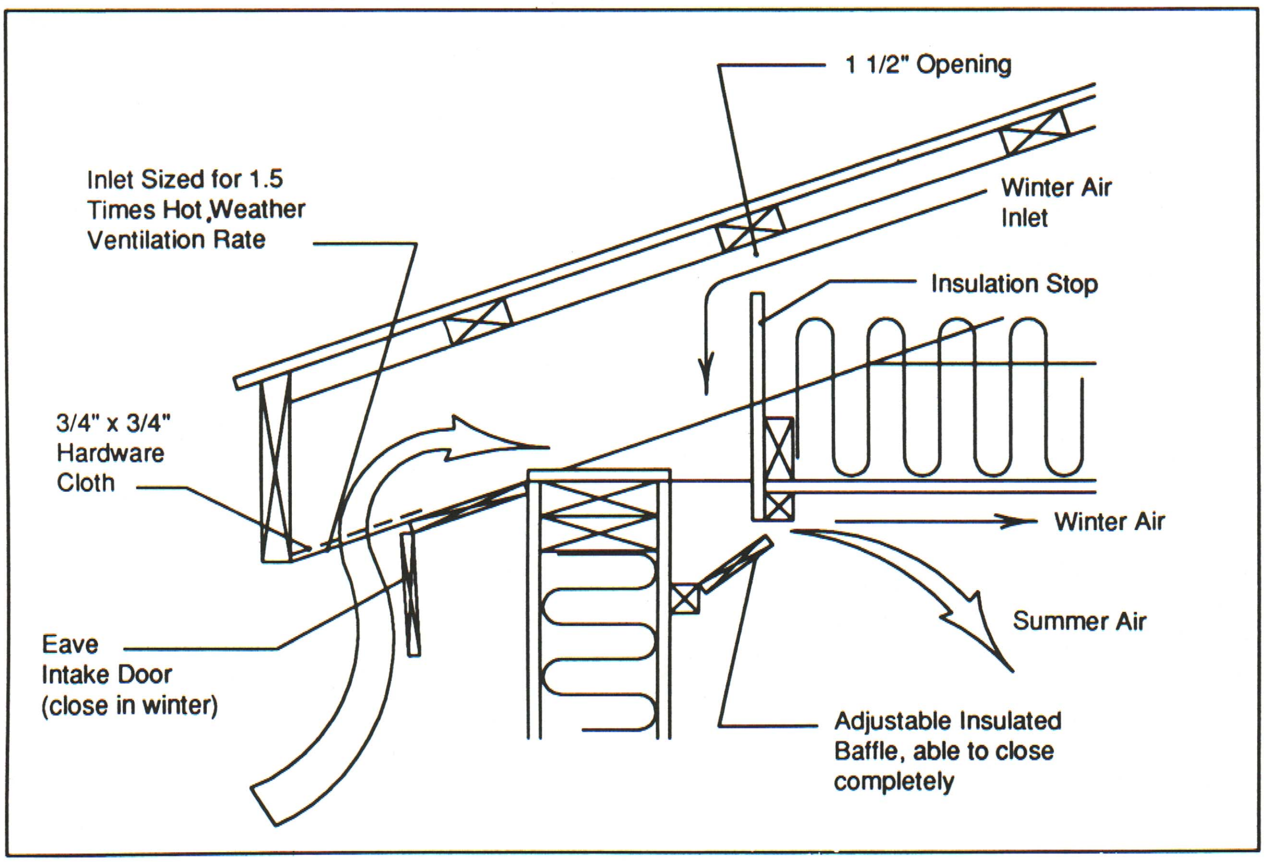

Figure 7. Typical eave and baffled slot intake. Source: Midwest Plan Service, MWPS-32, Mechanical Ventilating Systems Handbook.

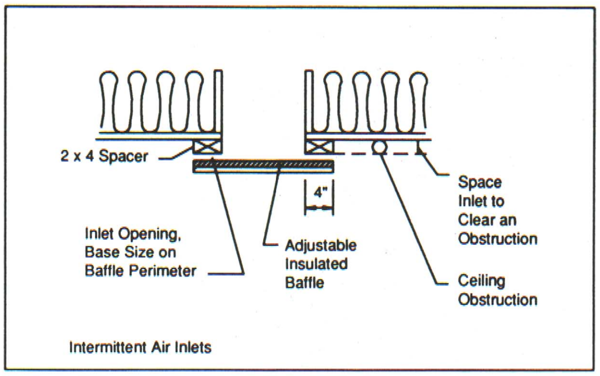

Figure 8. Baffled air inlets for "across-the-ceiling" airflow. Do not mount pipes or lights within 4 ft. of inlets–a smooth ceiling prevents cold air from being deflected down onto animals.

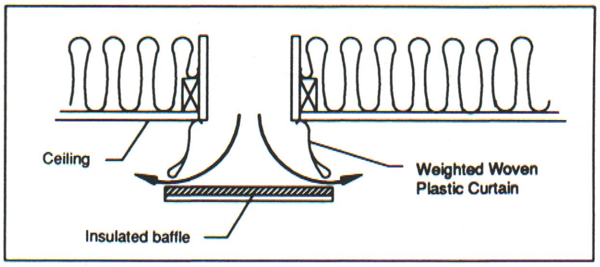

Figure 9. Gravity curtain inlet. The curtain is weighted in order to restrict the air inlet size and thus maintain a high incoming air velocity to promote mixing and distribution of fresh air.

outside to the attic (accomplished by slot inlets under the eaves or by screened louvers at the gable ends) should have a net free area of 1 1/2 - 2 sq. ft. for each 1,000 cfm of fan capacity (Figure 7).

Controls

Accurate, properly located sensors and controls are necessary for the satisfactory and automatic operation of a ventilation system.

The most common control is the line thermostat which contains a temperature-sensing element and a switch. The sensing element is usually a gas-filled coil or a bimetallic strip that expands or contracts to open or close the electrical circuit to the fan motor or motorized shutter. The thermostat is a relatively simple, economical and reliable control. Controls used in livestock buildings should be corrosion resistant, watertight, dust-tight and UL listed.

Humidistats, which have an element sensitive to the moisture content of the air, are not suitable as a fan control device in livestock buildings unless maintained on a frequent basis since dust accumulations on the sensing element greatly affect their accuracy.

Ten-minute interval timers, sometimes called percentage timers, are wired in parallel with thermostats to provide an average ventilation rate equal to the desired minimum rate. Interval timers are adjustable to operate for any desired percentage of time, such as two minutes out of ten, or 20% of the time. Timers are unpopular with many engineers because their larger capacity and on-off operation result in either overventilation or underventilation at all times.

The control of variable-speed fans is accomplished with a solid-state electronic speed control and thermistor heat sensor. The control regulates the voltage to the fan motor, reducing voltage and fan speed as temperature in the building declines, and increasing voltage and fan speed as the temperature increases. At the temperature setting on the control, the fan will be operating at about one-half capacity. It typically reaches maximum speed at about 4°F above the setting and minimum speed at about 4°F below the setting.

A safety thermostat can be incorporated with the cold weather fan to turn off the fan when the temperature declines below the minimum to be maintained in the building. This should only occur if the supplemental heater fails. Properly designed standby power and an alarm system that can alert the manager should activate quickly if this happens. Information on installing a warning system, or emergency ventilation, in case of power failure is available from equipment suppliers, power suppliers and state university Extension Offices.

Locate controls where they will sense the average conditions at animal level. Never locate controls on outside walls or where they may be affected by sunlight, drafts from air intakes or outside entrances, heating devices or other abnormal conditions. Accuracy of temperature-sensing controls can be checked with a thermometer located next to the control. Sensors should be located within the animal zone but out of their reach. Locate controls where the operator can easily read the temperature setting and adjust it. The controls may be grouped in a convenient location, often in a central aisleway.

Proper electrical design is required for dependable performance and often is a prerequisite for building insurance. Select sensors and controls that will hold up in a moist, dusty, corrosive environment. See MWPS-28 and PIH-110 for information on recommended farm wiring practices.

Maintenance of the System

Good-quality fans, inlets and controls do not require a lot of attention. However, regularly scheduled maintenance will provide more efficient performance and longer life of the equipment. Periodic cleaning, lubrication and adjustment will assure reliable performance of the system.

Rust and corrosion are inherent problems in ventilation equipment. Some manufacturers provide fiberglass housings for their fans, (Figure 10). Others use stainless steel or polyethylene for the fan frames and hoods, or special protective coatings to prevent rusting and corrosion. Keep controls, fans, housings, hoods, shutters, and other components clean and perform regular maintenance to minimize deterioration and increase the performance and life of the equipment.

Operator Checklist

1. NEVER operate a mechanically ventilated building with power provided to only a single fan. ALWAYS provide some backup ventilation protection, so that if a single fan or circuit fails, an increase in temperature will quickly activate another fan.

2. Fans should be selected and operated to provide the range of air movement needed for animal comfort throughout the year.

3. Select fans according to their AMCA (Air Movement and Control Association) capacity at 1/8 in. static pressure to assure rated delivery under all weather conditions.

4. Install and adjust inlets to maintain uniform distribution of fresh air without causing drafts.

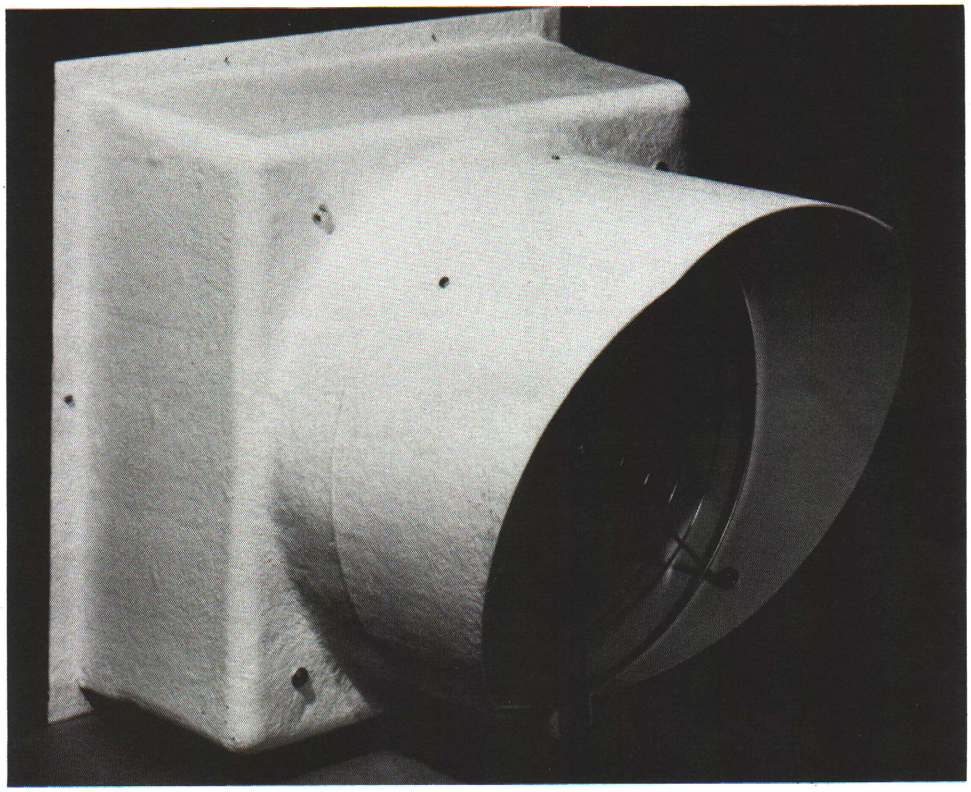

Figure 10. Materials used for fan housings and hoods, such as fiberglass, stainless steel, and special surface treatments on steel, are more resistant to corrosion and rust than ordinary painted or galvanized steel. They still require periodic cleaning, however, to operate effectively.

5. Add supplemental space heat only when operating the ventilation system at the cold weather rate. Heating and ventilating system controls should be coordinated to prevent unnecessary heat removal by the ventilation fans.
6. Set up a regular ventilation equipment maintenance schedule.
7. Keep all fan information and warranties in a separate and accessible file. Complete packaged systems should have an "owner's and operator's manual."

See Pork Industry Fact Sheets for information related to ventilation.

PIH-41, Maintenance and Operation of Ventilation Fans for Hog Barns.
PIH-54, The Environment in Swine Housing.
PIH-84, Troubleshooting Mechanical Ventilation Systems.
PIH-110, Electrical Wiring for Swine Buildings.
PIH-120, Non-mechanical Ventilation of MOF Swine Buildings.

Information and engineering designs for swine ventilation systems are available for a nominal charge from the Midwest Plan Service, 122 Davidson Hall, Iowa State University, Ames, Iowa 50011.

MWPS-8, Swine Housing and Equipment Handbook.
MWPS-28, Farm Buildings Wiring Handbook.
MWPS-31, Heating, Cooling and Tempering Air for Livestock Housing Handbook.
MWPS-32, Mechanical Ventilating Systems Handbook.
MWPS-33, Natural Ventilating Systems Handbook.

Reference to products in this publication is not intended to be an endorsement to the exclusion of others which may be similar. Persons using such products assume responsibility for their use in accordance with current directions of the manufacturer.

Issued in furtherance of Cooperative Extension work in agriculture and home economics, acts of May 8, and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Michael J. Tate, interim director, Cooperative Extension Service. Michigan State University, E. Lansing, MI 48824.

Maj. Rev. 6:91 1.5M-KDP-RP, Price 50¢, for sale only (destroy previous editions).