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Mechanical Ventilation in Swine Buildings– Pork Industry Handbook
Michigan State University Extension Service
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Issued August 1979
8 pages

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pork industry handbook

COOPERATIVE EXTENSION SERVICE • MICHIGAN STATE UNIVERSITY

Mechanical Ventilation of Swine Buildings

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A well-designed and managed ventilation system is an essential part of any confined swine production building. Mechanical ventilation involves many factors, and these must be understood if the system is to be designed to function properly. It's a complete system of matched components—insulated building, supplemental heat, fans, inlets, controls, etc.—tailored to the environmental needs of the swine production building. Omitting any part of the team of components will result in unsatisfactory performance. For example, adding fans without providing adequate insulation will not provide the desired results.

Controlled ventilation will perform the following functions:

- Removes moisture, gases, odors, dust and air-borne disease organisms.
- Provides fresh air and distributes it uniformly without creating drafts.
- Modulates air flows according to needs so that temperatures can be controlled in winter and summer, assuming supplemental heating or cooling is available to handle temperature extremes.

Building Construction

Insulation in the walls and ceiling, and along the foundation and floor, is essential to keeping the building warm and preventing condensation. Using adequate amounts of insulation reduces heat losses and minimizes condensation in cold weather. Conserving heat in winter increases air temperature in the building, enabling the air to absorb and remove more moisture as it moves through the building's ventilation system. Insulation reduces solar heat gain in summer. Check other Pork Industry Handbook publications for information on this topic.

Unplanned openings such as cracks around doors, windows, and hog doors can nullify the benefits of a well-planned ventilation inlet system by changing the distribution and velocity patterns of air coming into the building. For this reason, mechanically ventilated swine buildings must be tightly constructed. Many operators are eliminating windows to reduce this air infiltration and heat loss through the windows.

Ventilation Principles

During cold weather, the air flow requirements of a swine building are based on the moisture produced in the building and on the expected moisture content of the air entering and leaving the building. Figures 1 and 2 show the total moisture produced by hogs including the respired water vapor and the water evaporated from floors. The ventilation system is expected to remove this moisture and to maintain a relative humidity between 50 and 80 percent. Higher humidities may cause condensation and respiratory problems, while lower humidities may also cause respiratory problems.

During cold weather, the outside air entering the building contains very little moisture, as shown in Table 1.

Table 1. Moisture holding capacity of air at 100% relative humidity.

Temperature degrees F.	Grains* moisture/lb. dry air	Grains/ft.[3]
-20	1.8	.16
-10	3.2	.28
0	5.5	.48
10	9.2	.78
20	15.1	1.25
30	24.2	1.95
40	36.5	2.88
50	53.6	4.12
60	77.6	5.82
70	110.7	8.09

* 7,000 grains of moisture equal one lb. moisture.

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1P-3M-8:79-UP, Price 25 cents.

Michigan State University Printing

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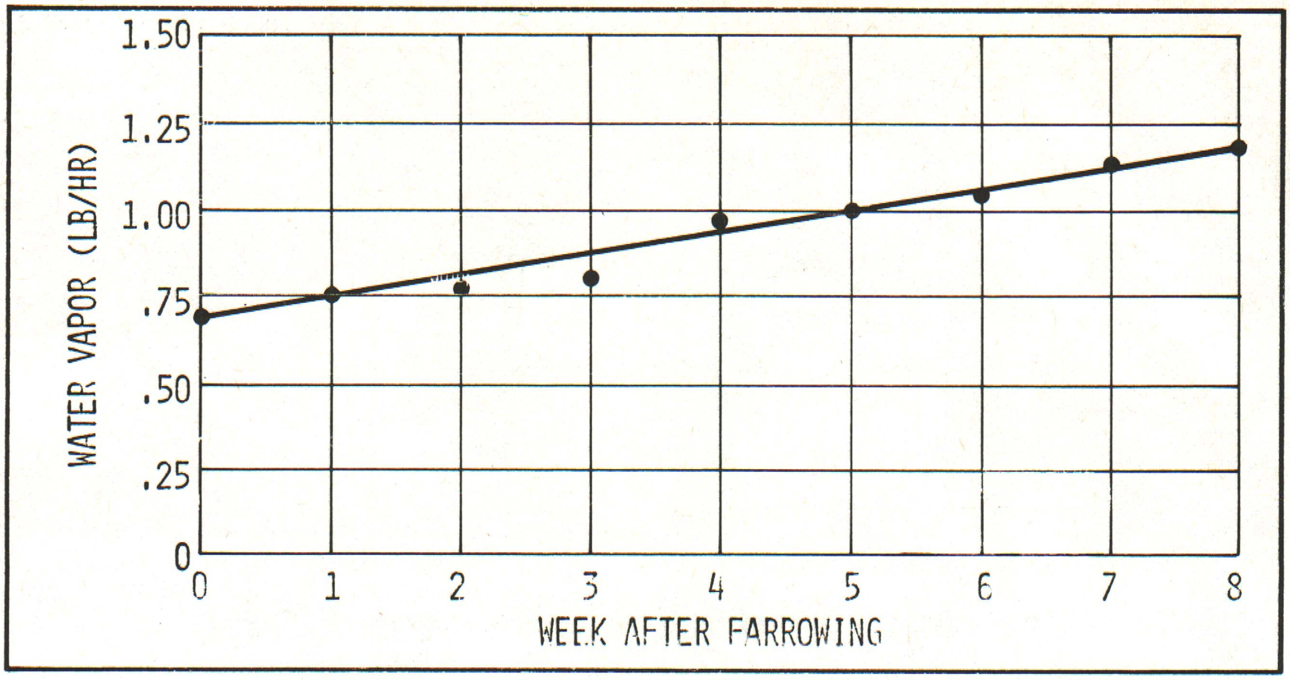

Figure 1. Moisture production, 340 lb. sow and litter at 80 F. Source: *Agricultural Engineers' Handbook—ASAE.*

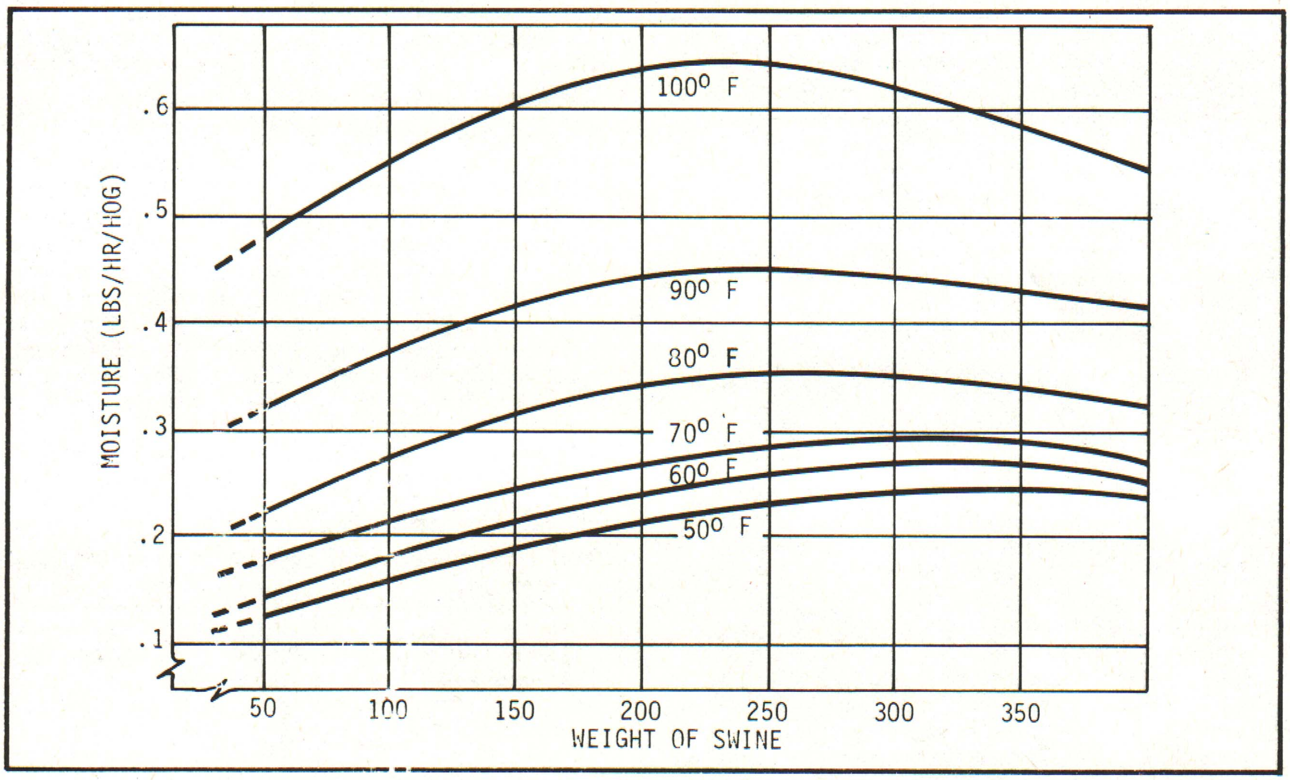

Figure 2. Moisture production of swine. Source: *Agricultural Engineers' Handbook—ASAE.*

When cold air is brought into an insulated warm building, the air temperature increases, which, in turn, increases its moisture-holding capacity. This warmed air picks up moisture and is then expelled by the fan(s). Figure 3 illustrates how expected inside and outside air conditions determine the ventilation rates for moisture removal. For example, at -20 F. a pound of air at 100% relative humidity contains 0.0003 lb. of water (2.1 grains) and occupies 11 cu. ft. If this air is warmed in a swine building to +60 F., this same pound of air expands to 13.3 cu. ft.; and if it is exhausted at this temperature and 75% relative humidity, it will contain 0.00831 lb. of water (58.2 grains). Every cubic foot, then, will remove 0.00831-0.0003 ÷ 13.3 = 0.0006 lb. of water. A 120-lb. hog produces 0.19 lb. of water per hour (Figure 2). Our ventilation rate for moisture removal for these conditions would be 0.19 lb./hr./pig ÷ (0.0006 lb./ft^3 x 60 min./hr.) = 5.3 cu. ft. per min. for each 120 lb. hog.

Because moisture removal is critical during extremely cold weather, the minimum winter ventilation rate is determined by the rate of moisture production in the building. If a rate higher than this calculated value is used, an increased heating bill should be expected. Table 2 gives the recommended rates for minimum, normal, and summer ventilation.

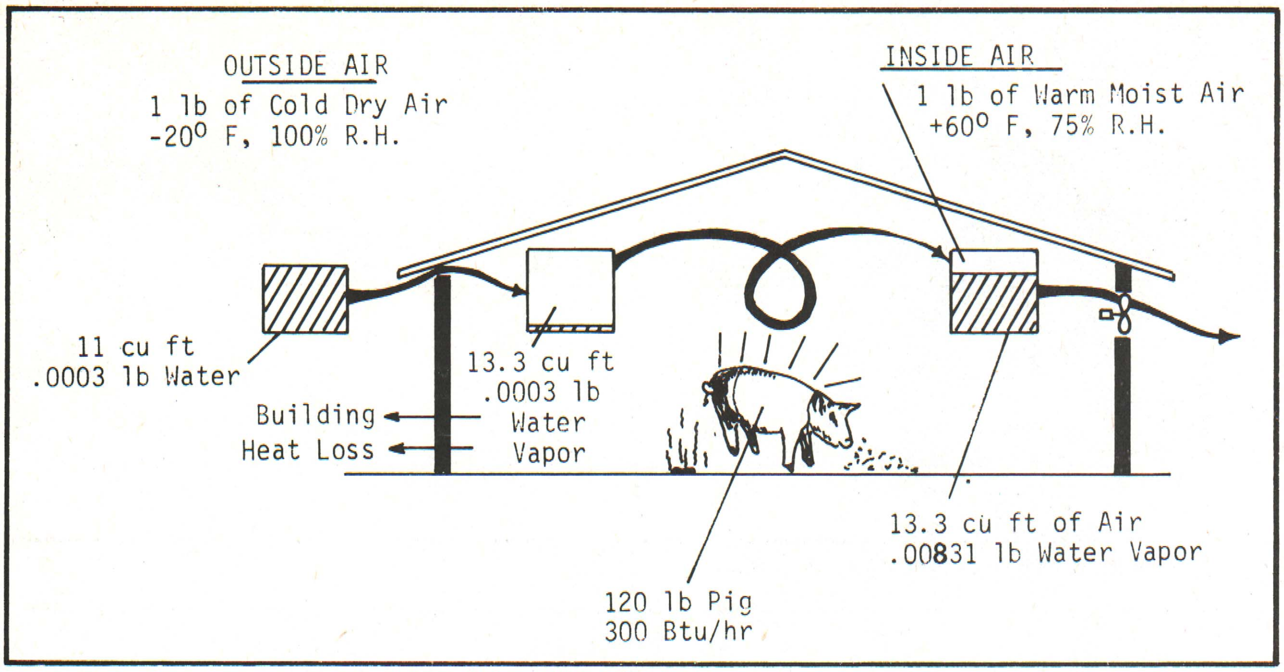

Figure 3. Winter ventilation in a controlled environment. Source: MWPS-1, *Midwest Plan Service Structures and Environment Handbook.*

Table 2. Recommended fan capacities (at ⅛ in. static pressure) per pig or sow and litter.

		Ventilation rates, cfm				
		Winter			Summer	
	Animal weight, lb.	Minimum (continuous)	Add +	Maximum†	Add +	Total†
Sow and litter	2-20	20*	(+60)	80	(+130)	210
Growing pigs††	20-40	2	(+13)	15	(+21)	36
	40-100	5	(+15)	20	(+28)	48
	100-150	7	(+18)	25	(+47)	72
	150-210	10	(+25)	35	(+65)	100
Gilt, sow or boar	200-250	10	(+25)	35	(+85)	120
	250-300	12	(+28)	40	(+140)	180
	300-500	15	(+30)	45	(+205)	250

*10 cfm continuous, 10 cfm on manual switch to control odor and humidity (may be shut off to save heat).

† Rates are cumulative totals, winter "maximum" includes "minimum," "summer" includes "winter." Example: Total winter rate for sow and litter is 80 cfm (not 80 + 20 minimum) of which 20 (or 10 and 10) is continuous. Total summer rate is 210 cfm of which the 80 cfm for winter is a part.

†† If totally slotted floors are used for growing pigs, the minimum continuous ventilation rate can be reduced to ½ the values listed.

"Minimum" Winter: Operate at least one fan at all times that the inside temperature is above 35 F. Set a thermostat to shut the fan off when the inside temperature drops below 35 F. This fan should supply the cfm rate listed under "minimum" in the table. Install this fan to exhaust the air from above any stored liquid manure.

"Maximum" Winter: Provide additional fans, thermostatically set to start in 5 degree steps from lowest desired temperature to prevent sudden drops in temperature. These fans, together with the minimum fans, provide the capacity for outdoor temperatures up to about 55 F.

Summer: Provide additional fans to supply the cfm rates listed under "Summer" in Table 2, or install large panels in the walls that can be opened for natural ventilation. Some or all of these fans or panels should be operated when the inside building temperature is above 75 F.

Types of Ventilation Systems

The two general types of mechanical ventilation systems are (1) positive pressure and (2) negative pressure (exhaust). Either system will work satisfactorily if designed, installed and operated properly.

Positive pressure systems use fans to force fresh air into the building and to distribute it by the use of lateral ducts or tubes with carefully designed outlet holes. Most positive pressure systems in use today are basically pressurized intakes, with sidewall exhaust fans to expel moisture, heat, odors and gases from the building as needed. Fan capacities in the exhaust portion of the system are sized as per Table 2 and are controlled by thermostats. A circulation 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 at the fan locations, which are controlled by the same thermostat(s) which controls the exhaust fan, open automatically bringing in fresh air from either the outside or from the loft above the ceiling. When the thermostat turns the exhaust fan off, the motorized intake shutters also close, and the fan simply circulates room air through the distribution duct or tube. Unit heaters can also be incorporated into this system, resulting in rapid and uniform distribution of heat throughout the building. Figure 4 illustrates a positive pressure intake ventilation system. This system is usually a commercially-available package which includes air circulation, heat distribution and ventilation. The system can function properly only if patterned and selected for a particular building.

Negative pressure, or exhaust, ventilation systems use a fan (or fans) to draw the air from the building, creating a negative pressure. Make-up air is drawn into the building through designed air intakes. As with any ventilation system, the incoming air must be well-distributed, properly mixed or blended so that it can remove moisture and/or heat, and do it without creating drafts. Figure 5 illustrates a negative pressure system.

Fan Systems
Fan Capacities

Ventilation air requirements vary from the minimum cold weather capacity to many times this value in hot weather. Continuously-operating fans that exceed the minimum rate for moisture removal in cold weather waste heat. During the hottest weather, fan capacity is increased

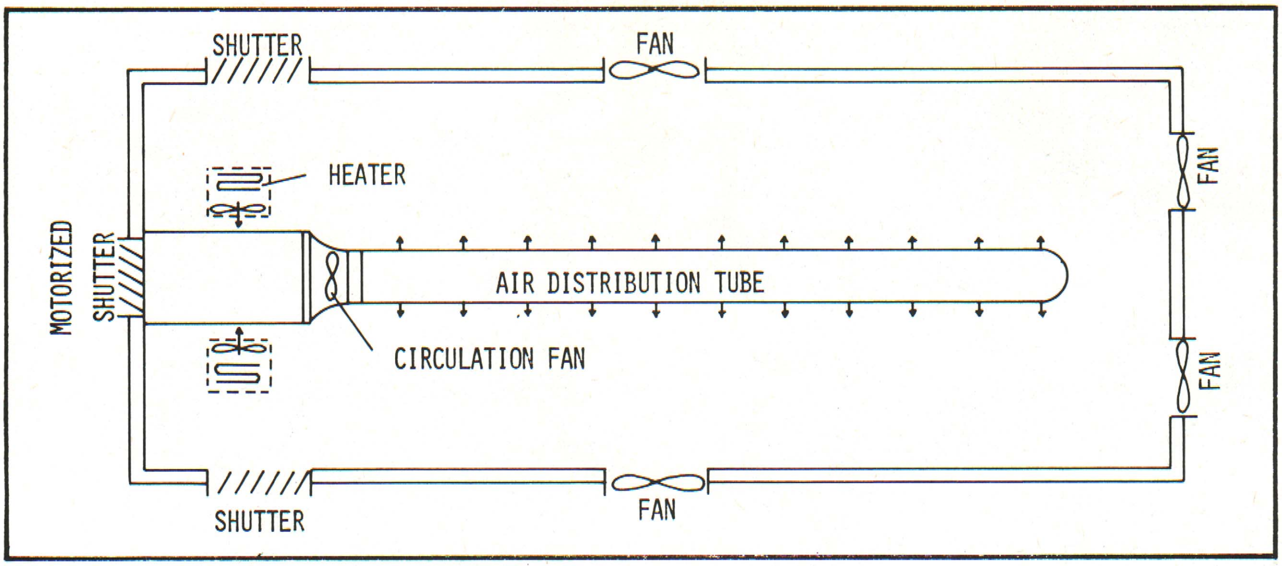

Figure 4. Positive pressure intake and air distribution.

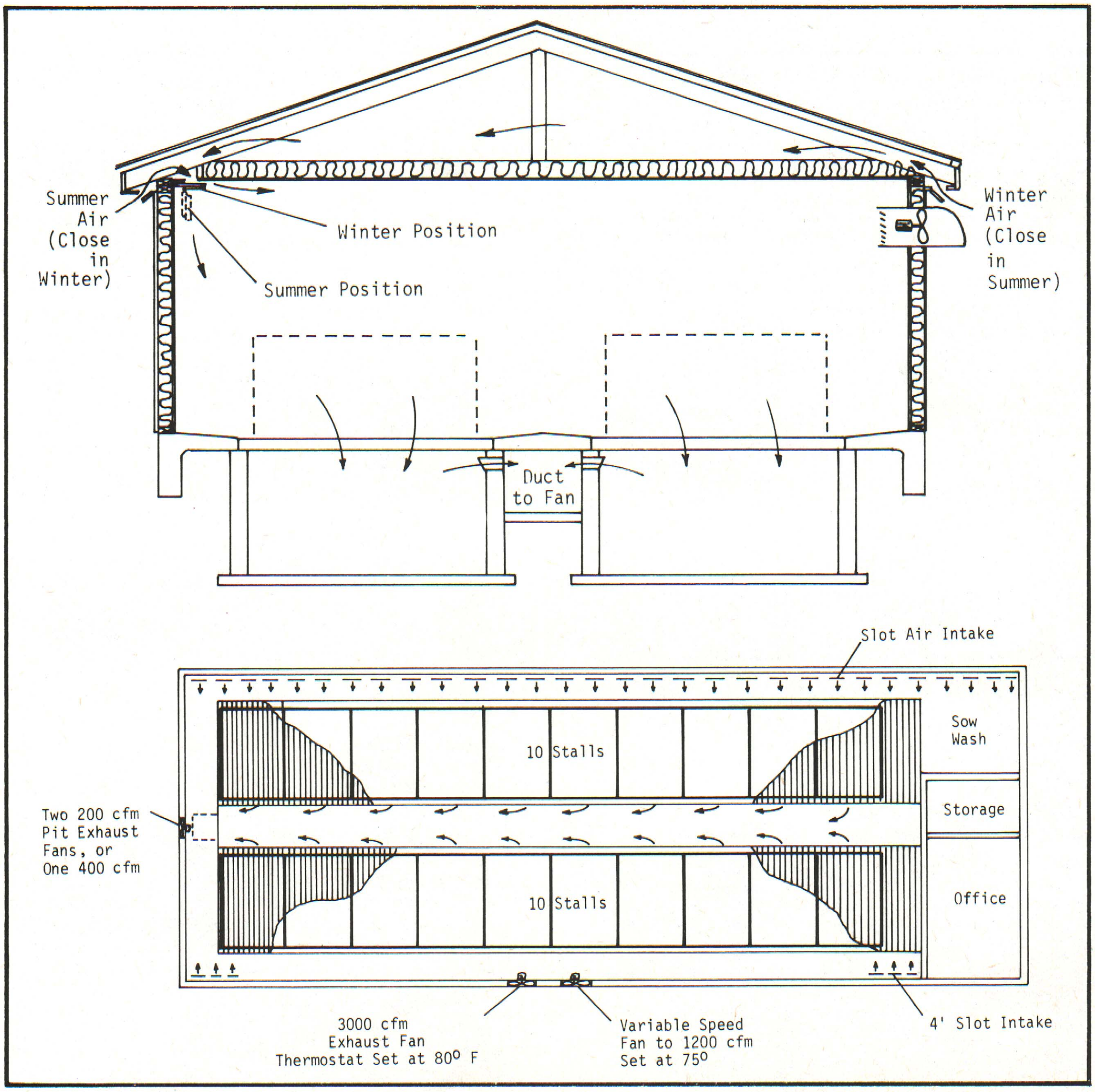

Figure 5. One type of negative pressure (exhaust) ventilation system with pit ventilation.

to the maximum rates to remove as much heat as possible and to provide good 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" capacity plus larger fans, controlled in increments by thermostats which engage fans as temperatures increase or disengage them as temperatures decrease. (2) A single-speed fan controlled by a percentage or 10-minute interval timer allows a wide range of capacities, but is an "on-off" operation which may cause rapid temperature fluctuations and back-drafting at the intakes. (3) A single-speed fan with a motorized shutter or damper which restricts the output of the fan has been used successfully (the thermostat controls the motorized shutter which, in turn, controls the output of the fan). Sometimes one shutter is removed or shutters are partially blocked open so that a small airflow is always maintained. (4) Variable-speed fans automatically proportion air flow from a minimum of about 20% of their full-speed rated capacity. Such fans are modulated by a solid-state control which regulates the voltage going to the capacitor-start, capacitor-run motor. Care should be taken to protect the fan from outside wind pressure when operating at low speed as it does not produce much pressure and will greatly affect air flows.

The capacity of a fan to move air is expressed in cubic feet per minute (cfm). In a well-planned ventilation system, it is essential to know the exact amount of air that a particular fan will move under the expected operating conditions, or the ventilation system will not operate as designed. If the fan (or fans) moves more or less air than specified, inlet velocities will be different, and conditions in the building will probably not be satisfactory. If the fan capacity is too great, excessive heat losses will occur, wasting energy and dropping temperatures below desirable levels. If capacity is too low, a build-up of moisture, odors or heat can be expected.

Ventilation systems for swine buildings are usually designed for static pressures of ⅛-in. static pressure to assure good operating characteristics. If there are several fans in the system, this ⅛-in. rating is especially important to assure that one or more fans is not "outpulling" others and causing air to go backward through the fan. Not only do fans need to operate against the negative pressure at the intakes, but such accessories as shutters, fan guards and hoods offer some resistance and collectively may increase the static-pressure to ⅛-in. water gage. The Air Moving and Control Association (AMCA) has set up standard tests and procedures. Certified AMCA performance charts and fan ratings will assure the operator that the fan will deliver the volume of air specified for the static pressure and with accessories in place as listed or shown.

Fan motors should be:

- Totally enclosed for dust protection.
- Able to operate continuously.
- Of the sealed ball bearing type, preferably.
- Equipped with thermal overload protection.
- Wired with separate circuits.

Air Intakes

The fan, or fans, in a mechanical ventilation system determines the rate of air change, but the uniformity of air distribution depends on the location, design and adjustment of the air intakes in exhaust systems or of the air outlets in pressure systems. It is especially important to maintain enough inlet velocity in winter so that cold air is mixed or blended with the warm air. Ideally, the opening or cross-sectional area of air intake should be based on the capacity of the fans. If the intake area is too great, cold air enters at low velocity, causing it to "dribble" in, settling to the floor and causing drafts.

Air intakes should be designed and constructed so that a negative pressure of 0.03 - 0.07 in. of water gage is created at the inlet (see Figure 6). This will assure velocities of between 700 and 1100 ft. per min. A common rule of thumb sizes intakes at 1 sq. ft. for each 600 cfm of fan capacity, which makes the velocity about 1000 ft. per min. including the vena-contracta effect (the reduction in effective cross-section of an opening through which air flows). Table 3 will give the rate of air flow through 1-ft. long ventilation-slots.

Table 3. Rate of air flow through ventilation slots one foot long, including the vena-contracta effect.*

Inches slot width	cfm Static pressure 0.04 in.	0.125 in.
1	50	100
2	100	200
3	150	300
4	200	400

*Source: Pennsylvania State University

Example: A 20-sow farrowing house is ventilated in winter with a variable speed fan having minimum capacity of 320 cfm at low speed and 1600 cfm at high speed. What size should the slot inlets be?

Assume a 1 in. slot width. From Table 3, each foot of 1 in. slot will admit air at the rate of 50 cfm at 0.04 water gage. Therefore, the slot needed will be 1600 cfm ÷ 50 cfm/ft = 32 ft. long. Unless the slot is adjustable, the velocity at low volume would be: 320 ÷ [(32 x 12) ÷ 144] = 120 ft. per min. This velocity would be minimal to maintain good distribution and blending of the intake air. This installation balance between fan capacities and inlet area requires air intake control to adjust the area of intake to the capacity of the fans that are operating. An intake system that adjusts the opening area automatically, according to negative pressure sensed, is ideal for exhaust systems.

The necessary adjustments to provide the optimum air distribution at the various air flow rates must be understood by the individual operator. The methods which are used vary and will work if properly installed and operated. They include:

1. Separate inlets for winter and summer. This allows air to be drawn from the loft in winter and directly from the outside in summer, Figure 7.
2. Gravity-loaded curtain or damper at the intake, Figure 8.
3. Manually-adjustable hinged or vertically-adjustable baffles under ceiling slot intakes.
4. Power-operated adjustable baffles under ceiling slot intakes.

Other important considerations in planning fresh air intakes include:

1. Make sure there are no unplanned openings or holes that will interfere with the planned air intake system. All openings, including doors, windows, hay chutes, cracks around doors, etc., should be closed.
2. Provide insulated baffles under the intake slots or holes to direct the air. In winter, the incoming air is directed across the ceiling where it is warmed and mixed with the warmest air in the building. This also prevents heavier cold air from dropping or settling to the floor where it could cause drafts and, in turn, chill pigs. In summer, the baffle can be used to direct the air to the floor.
3. Bringing winter air through the attic reduces the effect of wind and allows the air to be tempered somewhat before it enters the swine housing area. This can be accomplished by slot inlets under the eaves or by screened

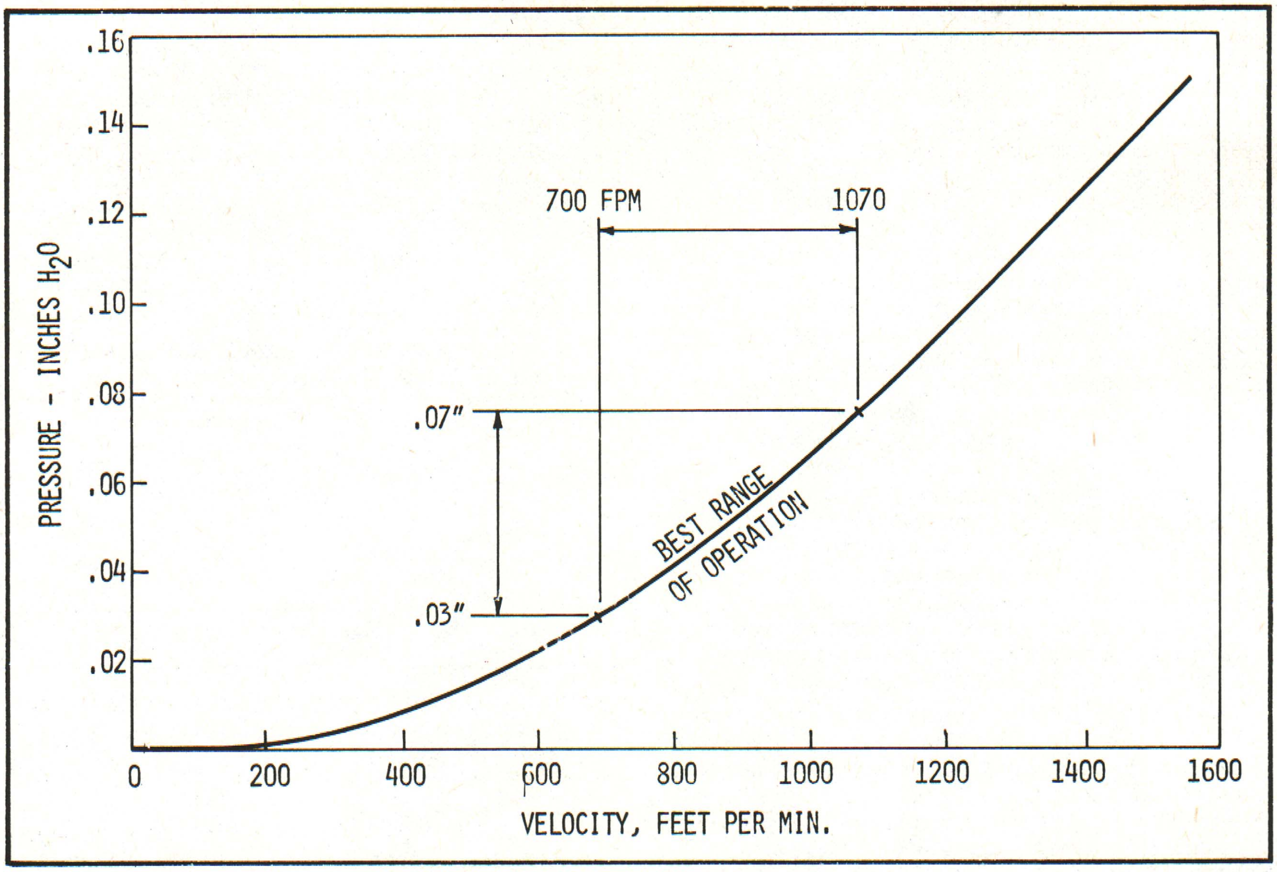

Figure 6. Air intake velocity and static pressure relationship.

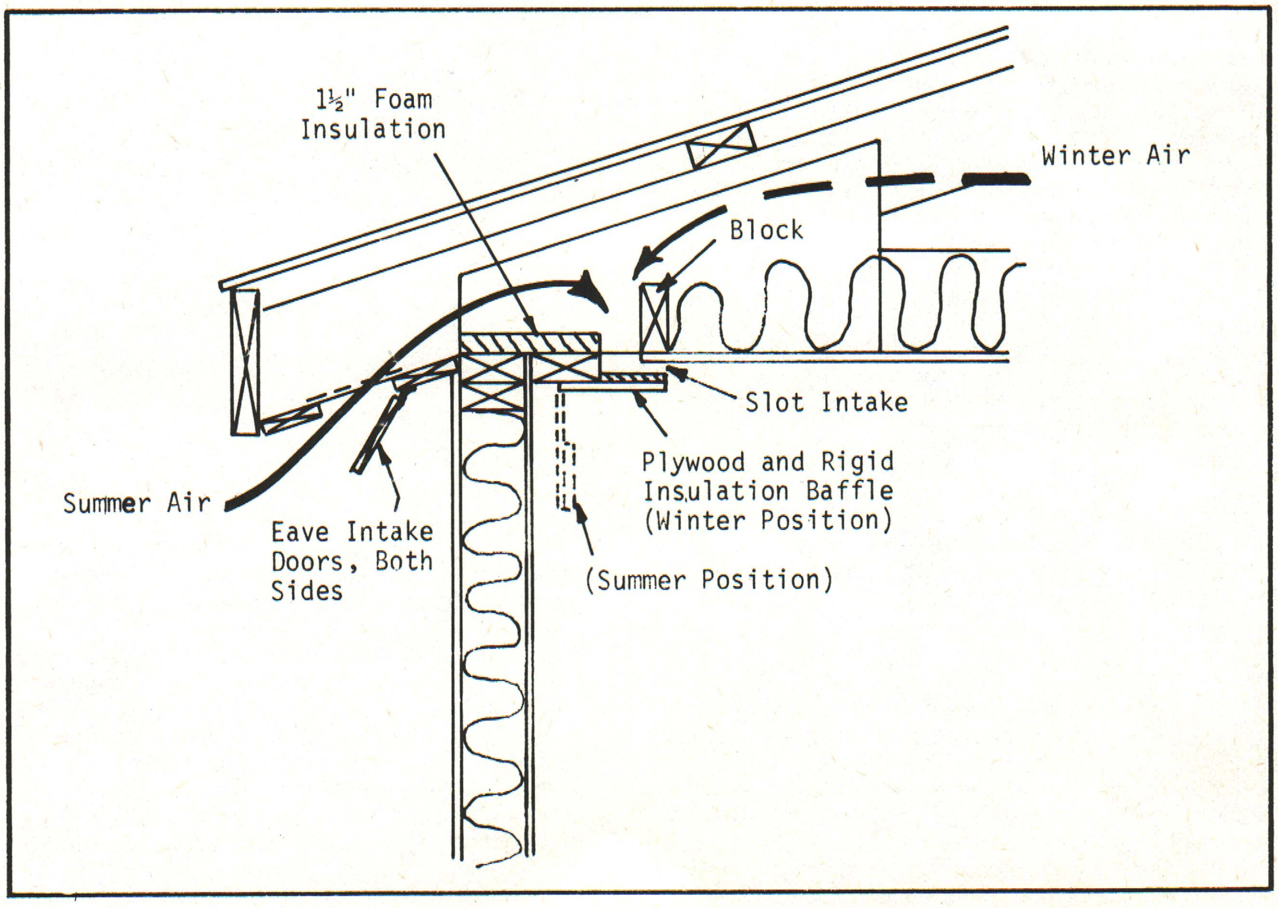

Figure 7. Typical eave and baffled slot intake. Source: Midwest Plan Service.

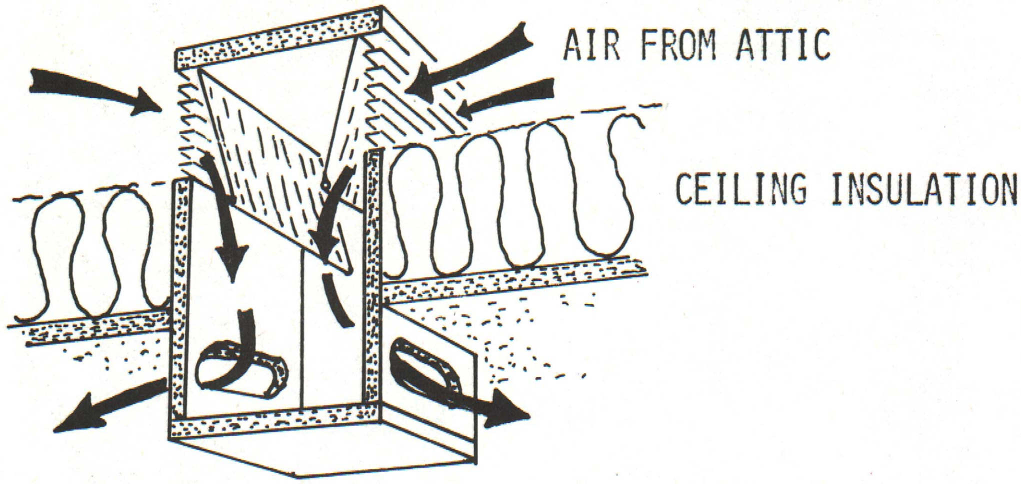

Figure 8. Rectangular ceiling area intake with self-adjusting damper.

louvers at the gable ends. The air intakes from the outside to the attic should have a net free area of 1½ - 2 sq. ft. for every 1,000 cfm of fan capacity.

Controls

Good accurate sensing controls are necessary for the satisfactory and automatic operation of a ventilation system.

The most common control has been the line thermostat which contains a temperature-sensing element and a switch. The sensing element is usually a bi-metallic strip which expands or contracts to activate a switch which opens or closes the electrical circuit to the fan motor or motorized shutter. The thermostat is a relatively simple, economical and reliable control. However, it is important to use a good quality thermostat designed especially for livestock buildings. It should also respond rapidly to temperature changes and have accuracy to within a few degrees.

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

Ten-minute interval timers, sometimes called percentage timers, are often used in conjunction with thermostats to provide minimum ventilation rates even though the building temperature may be lower than the thermostat setting. Interval timers are adjustable to operate any desired percentage of time, such as two minutes out of ten, or 20% of the time.

The control for the newer variable-speed fans consists of a solid-state electronic speed control and a thermistor heat sensor. The control regulates the voltage to the fan motor, reducing voltage and fan speed as temperature in the swine 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 reaches maximum speed at about 4 F. above the setting and minimum speed at about 4 F. below the setting. A safety thermostat should be incorporated with the variable-speed control to turn the fan off completely when the temperature declines below the minimum to be maintained in the building. This could occur if the supplemental heater fails or has insufficient capacity.

Locate controls where they will sense the average normal conditions in the room being ventilated. Never locate controls on outside walls or where they may be affected by sunlight, drafts from air intakes, heating devices or other abnormal conditions. Accuracy of temperature-sensing controls can be checked with a thermometer located next to the control. Controls should be located out of reach of animals but where the operator can easily read the temperature setting and adjust it. The controls may be grouped in a bank in a convenient location.

Maintenance of the System

Good quality fans, inlets and controls do not require a lot of attention. However, regular 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. Further information is available in PIH-41, "Maintenance and Operation of Ventilation Fans for Hog Barns" and in MWPS-8, "Swine Housing and Equipment Handbook."

Information on installing a warning system or emergency ventilation when the power fails is available from equipment suppliers, power suppliers and State University Extension Agricultural Engineers.

Rust and corrosion are inherent problems in confinement swine ventilation equipment. Some manufacturers have developed and are producing fiberglass housings for their fans (see Figure 9). Others are using stainless steel for the fan frames and hoods, and some are using special protective coatings to prevent rusting and corrosion. Keeping the fan, housing, hood, shutters, etc., clean and performing regular maintenance will minimize deterioration and increase the performance and life of the equipment.

Under Slat Ventilation

In swine buildings with liquid manure stored in pits below slotted floors, ventilation of the space between the liquid manure and the slats is recommended. The "minimum" continuous winter fan (or fans) is located to exhaust air from the pit to aid in removing gases and odors. Warmer slat floors and less convective drafts are also benefits of under slat ventilation.

An exhaust duct, installed under the slats or along side the manure pit walls with properly sized and spaced open-

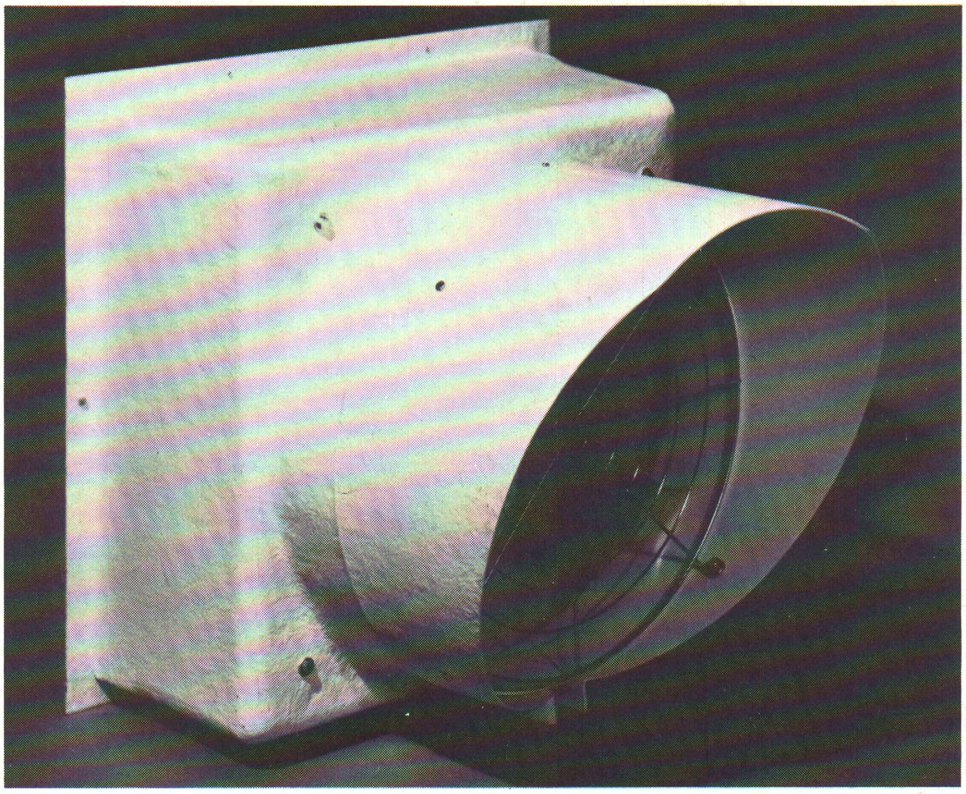

Figure 9. Materials used for fan housings and hoods, such as fiberglass, stainless steel, and special surface treatments on steel, are more resistant to corrosion and rust than ordinary painted or galvanized steel. They still require periodic cleaning, however, to operate effectively.

ings to the manure pit, will aid in collecting the air uniformly for the full length of the pit. An exhaust fan with the "minimum" ventilation capacity then expels the exhaust air from the duct (see Figure 5).

To reduce the negative pressure against the exhaust fan, the duct should be sized so that the maximum air velocity is approximately 600 ft. per min. The equation below can be used to determine the size of the duct.

$$A = \frac{Q}{V}$$

Where Q = quantity of air in cubic feet per minute.
V = air velocity in feet per minute.
A = area of duct in square feet.

Properly sized and spaced openings from the pit to the duct allow the exhaust air to flow through each opening from the pit into the duct. Opening size and spacing must be designed if reasonable distribution is to be obtained. The size of these openings is determined by allowing an entry velocity of 800 ft. per min. through each opening.

Operator Checklist

1. Fan capacities should modulate or adjust to provide the range of air movement needed for the various conditions in the swine building throughout the year.
2. Select fans accordng to their capacity at ⅛-in. static pressure to assure rated delivery even though other fans are operating in the system.
3. Install and adjust inlets to maintain good distribution of fresh air without causing drafts.
4. Ventilation system should be at winter "minimum" level before supplemental space heat is added to the building. Heating and ventilating system controls should be coordinated to prevent unnecessary heat removal by the ventilation fans.
5. Consider planning the ventilation system for adaptation of solar heat at a future date. For example, orient the building east and west to provide a good solar collector area for heating incoming ventilation air.
6. Set up a regular ventilation equipment maintenance schedule.
7. Keep all fan information and warranties in a separate file. Complete packaged systems should have an "owner's and operator's manual."

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.