Non-mechanical Ventilation of MOF Swine Buildings Pork Industry Handbook
Michigan State University
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# Non-mechanical Ventilation of MOF Swine Buildings

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Ventilation is a key element in the successful operation of any swine production facility. A well-designed, manageable ventilation system enables the producer to ensure environmental conditions within the pig zone conducive to good performance.

A ventilation system removes low-quality air and replaces it with fresh, high-quality air. Excess heat, moisture, dust, odors, pathogenic organisms and irritating, noxious or toxic gases decrease air quality. Ventilation systems are judged, all too often, by air quality in the people zone—4 to 5 ft. above floor level. Accurate assessment of ventilation system performance requires evaluation of air quality in the animal zone—0 to 2 ft. above floor level. Good ventilation of the animal zone is dependent upon system design, management skill and inputs, building layout, farmstead arrangement, construction techniques, judicious use of insulation, and careful material selection.

Our goal is to provide healthful conditions for animals and personnel and to control deterioration of structural components and equipment. Given the widely varying climatic conditions encountered in most locations, there is no perfect system. Consequently, producers need to select the system which best fits their management abilities and goals with the most acceptable set of compromises. The selection process should include careful evaluation of all viable options or alternatives.

There are two basic types of ventilation systems. Both require good design and management. A mechanical ventilation system relies upon fans or other mechanical air-moving devices to achieve airflow through the building. A non-mechanical ventilation system (also sometimes referred to as "natural" or "gravity" ventilation) relies upon wind forces and the thermal buoyancy of air to achieve airflow through the animal zone. Buoyancy is the tendency of warmer, lighter air to rise and cooler, heavier air to fall or descend. This phenomenon is also referred to as natural convection.

## Building Design

Dissatisfaction with the operating cost of mechanically ventilated buildings and the performance of pigs reared in open front buildings and shelters during winter conditions resulted in producers installing doors or panels to allow partial closure of the open front during extreme weather—and the modified-open-front building or MOF was born. Research and field experience have shown reduced incidence of pneumonia and improved feed efficiency in a well-designed, well-managed MOF compared to open-front housing.

Buildings with gable or "A" roofs and those with monoslope, shed or single slope roofs can be designed and managed as an MOF. Gable-roof MOF buildings are used primarily for growing-finishing pigs though some are used as breeding-gestation facilities. Monoslope roof buildings with a southward facing high wall are often referred to as the "Nebraska MOF." Originally the monoslope roof MOF was used for growing/finishing pigs. More recently, the design has been adapted for farrowing, nursery, and breeding-gestation units. Most MOF buildings are non-mechanically ventilated year-round. Some use mechanical ventilation (often manure storage ventilation) to provide cold and a portion of the mild weather ventilation needs.

The performance and manageability of both gable and monoslope roof buildings are enhanced by adherence to sound design principles. The construction practices and techniques unique to each building style are discussed later.

## Basic Principles

*Siting*—Locate feed bins at the ends of the building or on the downwind wall relative to prevailing summer breezes. Provide at least 75 ft. separation from other buildings, windbreaks, significant geographic features that protrude above grade (e.g., hills and lagoons), and tall crops such as corn. A separation of 100 ft. is preferred. The minimum separation between non-mechanically ventilated buildings or other obstructions to airflow can be calculated from the equation

$$S = 0.4H\sqrt{L}$$

(S = minimum separation, in feet;

H = height of upwind building [building causing interference with access of wind to MOF building], in feet; and

L = length of upwind building, in feet). Examples of minimum separation distances based on this equation are given in Table 1. Closer spacings also increase the risk of major loss in case of fire.

*Building Orientation*—Orient buildings perpendicular to prevailing summer breezes. For most of the U.S., this means an east-west orientation. This enhances across-the-building airflow through individual pens, permits interception of more wind, and reduces solar heat load on the building roof. The chimney effect associated with wind pressures is also enhanced when wind strikes the side of a building as contrasted to the end.

*Roof Slope*—Best year-round ventilation of a monoslope MOF is achieved with a roof slope of 2:12 (smooth ceiling) or 2½:12 (exposed roof purlins) for growing-finishing and breeding-gestation buildings. Farrowing and nursery units built to date have 3:12 roof slopes. (Note: In a monoslope MOF, the ceiling and roofline are the same.) Gable roof buildings work best with a 4:12 roof slope and without a ceiling. The steeper roof slopes enhance movement of warm, moist air through air outlets at the high part of the roof, i.e., chimney effect.

*Insulation*—Insulate walls to at least R12, rooflines to at least R19, and building perimeter to at least R10 (to a depth of 2 ft. below grade or beneath the outer 2 ft. of the floor). Uninsulated concrete walls and masonry walls with insulation in the block cores are not adequate, except in the lower tier of southern states. Earth berming moderates extreme temperatures but does not eliminate the need for insulation. Reducing heat loss through the floor, walls, and roof simplifies management of the building environment since more heat is available for removal through the ventilation system. This allows higher ventilation rates and better control of moisture and other air contaminants without excessive lowering of building temperatures. No insulation material is totally water-vapor, fire, rodent or bird proof. Use a polyethylene (plastic) vapor barrier and interior protective liner in all cases. In colder climates, insulated curtains or sidewall panels are often used to reduce heat losses. Insulated curtains are more susceptible to rodent damage than are other vent closures.

**Table 1. Absolute minimum feet between nonmechanically ventilated buildings and other buildings or obstructions to airflow (based on $S=0.4H\sqrt{L}$).**

| Windward building or obstruction height | Windward building or obstruction length, feet | | | | | |
|---|---|---|---|---|---|---|
| | 50 | 75 | 100 | 150 | 200 | 250 |
| feet | feet | | | | | |
| 8 | 75* | 75* | 75* | 75* | 75* | 75* |
| 12 | 75* | 75* | 75* | 75* | 75* | 76 |
| 16 | 75* | 75* | 75* | 78 | 91 | 101 |
| 20 | 75* | 75* | 80 | 98 | 113 | 126 |
| 24 | 75* | 83 | 96 | 118 | 136 | 152 |
| 28 | 79 | 97 | 112 | 137 | 158 | 177 |
| 30 | 85 | 104 | 120 | 147 | 170 | 190 |

* Separation distances less than 75 feet are not recommended. Closer spacings impede ventilation and risk fire. Preferred minimum separation distance is 100 feet.

*Air Inlets/Outlets*—All effective ventilation systems require air inlets and air outlets. The proper quantity of well-distributed, good quality air is necessary for effective ventilation. Provide air inlets over the desired dunging area and outlets at the high part of the roof. Outlets must allow a continuously upward flow of warm, moist air. Ventilation during warm weather requires openings on both sides of the building for across-the-building airflow. There is no physical phenomenon to make warm air move downward. Locate openings so that air enters the pig zone. Inlets should be within 32 in. of the floor and direct air down toward the floor. A single opening, such as a curtain, cannot function as both an inlet and an outlet. All inlet and outlet openings must be easily controllable. PVC pipes, concrete blocks on edge and similar wall openings provide insufficient air inlet area except during severe winter weather.

*Sidewall Closures*—Install sidewall panels (pivot or top-hinged doors) or curtains to allow independent operation of various sections of a building. This allows temperatures in different parts of the building to be varied to meet animal requirements and aids in controlling longitudinal (end-to-end) airflow. Do not try to keep one part of the building warm by allowing or encouraging airflow from one part of the building to another. Such practices accelerate the transfer of disease. All pigs require fresh air. Limit the length of curtain or panels operated by one control device and thermostat to 100 ft. Curtains and wall panel vents must be sized and installed so that they do not protrude into the ventilation opening when in the "full open" position. Open curtains should be "stored" beyond the opening. Size panels to assure the required opening is provided, considering any reduction in opening size because of the panel itself. Panels that direct air down into the pig zone are best.

*Partitions*—Provide full height room partitions at 75 to 100 ft. intervals in long buildings and between the grower-finisher parts of all buildings. Gable-style roof, partly-slatted hog buildings should use pen partitions that are mostly solid between pens (in the solid floor area) to improve performance and dunging patterns. Some airflow is desirable in all areas of the pen, but air velocity in the resting areas should be kept lower than in the desired dunging area. In gable buildings with a work-service aisle on the north side, install a walk door at each room partition location. The partitions aid in maintaining appropriate room temperatures and controlling longitudinal airflow. Match the location of curtain or panel junctions and solid room partitions. In large operations, consider separate buildings, instead of separate "rooms" for improved disease control. Multiple, smaller buildings enhance "all in all out" management and control of disease.

*Ceiling*—A smooth roofline or ceiling improves airflow, especially during calm winds. Avoid exposed purlins more than 4 in. high.

*Group Size*—Limit pen or group size to 35 animals (25-30 preferred). Smaller groups allow easier size matching of the pigs, feeder spaces, and waterers; reduce social stress; and facilitate the use of hovers over the sleeping area during extreme weather.

*Pen Arrangement*—Arrange pens to allow ventilation air to enter over the dunging area. The low north wall of the monoslope building provides a natural "hover effect" without adversely affecting cold weather ventilation. Additional hovers may be required over the sleeping area for small pigs and during extreme winter weather, especially in gable buildings.

*Pen Size*—Design pens with a width:length ratio of 1:2 to 1:4 for better definition of the sleeping, eating, and dunging areas. A combination of three pen widths (for example, 6, 8, and 10 ft.) is best in most situations to optimize animal density without overcrowding or excessive numbers of pigs per pen. This will maximize animal heat production and reduce the need for supplemental heat. Use partially slatted floors or open gutters in MOFs to provide animals a draft-free, solid floor resting area.

*Gates and Walls*—Use "open" vertical rod gates around the intended dunging area for increased airflow and socializing. Use solid or nearly solid walls along or around the intended sleeping area for draft control. Limit solid wall height to 32 in. Let reinforcing bars extend above the solid pen partition and weld horizontal bars to them (6 in. on center) where a greater pen partition height is required.

*Electrical System Controls*—All electrical equipment such as lights, augers, and power washers as well as devices to control curtains, panels, etc. must comply with Article 547 of the National Electrical Code (NEC) (in many instances, state law). The Code requires equipment that is corrosion-resistant and water- and dust-tight. Many thermostats on the market are not UL listed and have unknown performance and safety characteristics. Failure to install equipment in accordance with the NEC could lead to higher insurance premiums or disqualification for insurance. (See Pork Industry Handbook fact sheet PIH-110 for more information.)

*Airflow Patterns*—Airflow patterns cannot be precisely predicted in any building. Variations will occur because of rate of heat production in the building, size and location of ventilation openings, inside and outside temperatures, wind speed and direction, number and location of partitions, etc. Generalized airflow patterns to be expected under different conditions are shown in Figure 1.

In addition to the cross-building airflow patterns illustrated in Figure 1, wind can also cause longitudinal or end-to-end airflow in non-mechanically ventilated buildings. The expected airflow patterns are illustrated in Figure 2. Shelterbelts, nearby buildings, grain bins, feed rooms, ventilation openings, etc. can alter these generalized patterns.

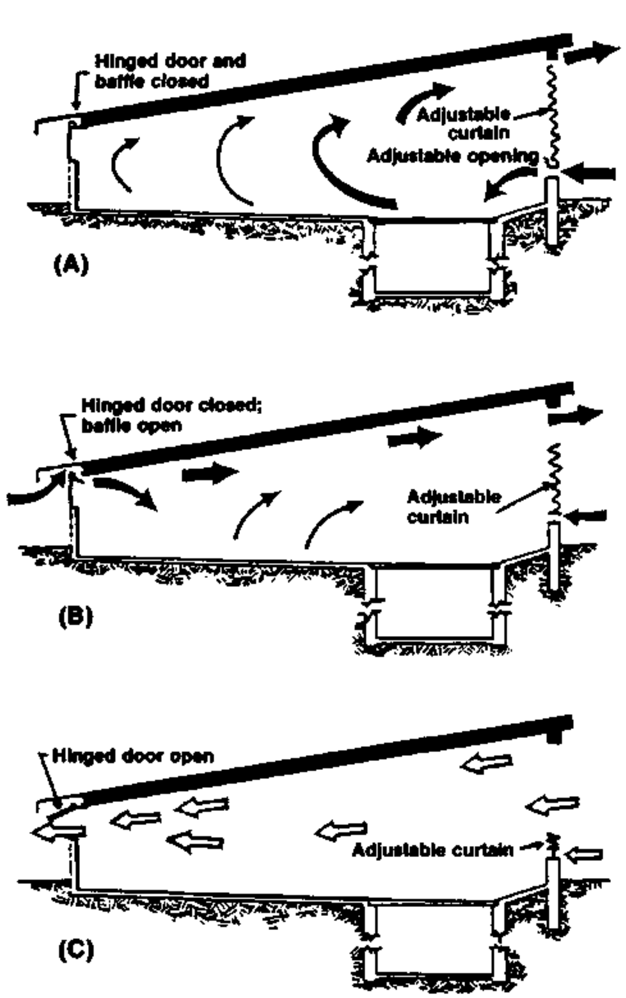


**Figure 1a. Expected airflow patterns in a monoslope-roof building for (A) extremely cold weather, (B) mild weather and (C) hot weather.**

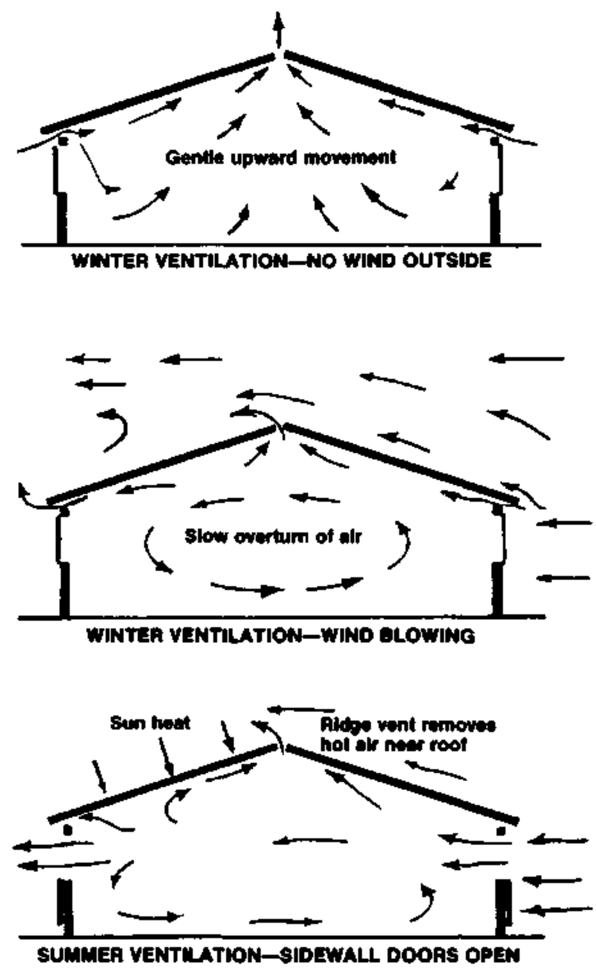


**Figure 1b. Expected airflow patterns in a gable-roof building.**

**Figure 1. Generalized airflow patterns in monoslope- and gable-roof buildings under selected conditions.**

## Monoslope (MOF) Design

*Building Width*—Limit building width to 28 ft. for growing-finishing and breeding-gestation units and 24 ft. for nursery and farrowing facilities. See Figure 3 for a typical building cross-section.

*South Wall*—Plan these openings for easy management and adjustment. They are the primary openings for winter ventilation and significantly influence summer ventilation. Provide a 3-in. (minimum) continuous full length air outlet near the top of the wall. Equip the opening with an adjustable baffle or other closure device. Two construction techniques are shown in Figure 4. These designs allow easy adjustment of the opening from floor level, have minimum components susceptible to corrosion, and use readily available materials. The opening should be "full open" except during extremely cold or windy weather. Daily adjustment is neither necessary nor recommended. A curtain that opens from the top down can serve as the air outlet if the opening is within 12 in. of the roof. Flashings, fascias, etc. must be installed so that they do not interfere with the continuous upward flow of air.

Provide an air inlet near the bottom of the wall. Masonry blocks turned on edge or PVC pipes placed in the wall are inadequate openings except during extreme winter weather, are difficult to manage, and are nearly impossible to rodent-proof. The opening should be within 32 in. of the interior floor. Excess height allows cold winter air to move farther into the pen before reaching the floor level. A curtain that is fastened at the top and that opens from the bottom can be used as an air inlet.

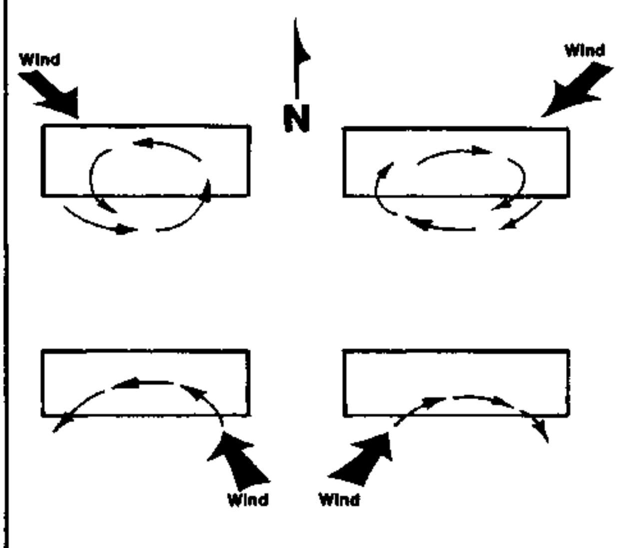


**Figure 2. Expected longitudinal airflow patterns in MOF buildings due to wind.**

Large sidewall openings are needed for warm and hot weather ventilation. A 4-ft. high continuous opening is minimum. Larger openings are desirable. A flexible curtain can function as either an inlet or outlet—but not both! If the curtain opens from the bottom up, it can also serve as the winter air inlet. Keep the bottom of the curtain opening within 32 in. of the inside floor. The curtain must be complemented with an air outlet near the top of the wall (Figures 3 and 4).

If the curtain is fastened at the bottom and opens from the top down and if the opening is within 1 ft. of the roof, it can serve as the outlet for ventilation air. An inlet must be provided near the bottom of the wall.

Install all curtains so that they do not protrude into the sidewall openings when in the "full open" position. This requires a curtain to be at least 1 ft. wider (measured vertically) than the opening being controlled and attached beyond the opening. Hemming generally reduces the actual curtain size by at least 4 in., e.g., a 6-ft. curtain is about 5′ 8″ wide. Also plan for shrinkage. Lumite-saran® curtains typically shrink about 6-10%. Lumite 50® curtains shrink about 1-2%. Non-porous curtains are preferred as they provide more positive control of airflow.

An alternative being used by several producers is a set of two curtains. Both curtains are attached about two-thirds of the distance from the front wall to the roof along the south wall. The bottom curtain is thermostatically controlled, opens up from the bottom, and functions as an air inlet in cold weather. The top curtain is either manually or thermostatically controlled, opens down from the top, and functions as an air outlet. This arrangement allows the south wall to be about 80% open for summer ventilation.

*North Wall*—Make these openings easy to adjust. They must be reasonably airtight for winter operation.

Provide a 3-in. wide continuous baffled inlet along the top of the wall (Figure 3). The inlet is used primarily during the widely varying weather of late fall and early spring when it is too warm to have the building closed tightly and too cool (especially overnight) to open the large vent doors. Without this inlet, twice-a-day adjustment of the north wall vent doors might be necessary. The inlet must be reasonably airtight during extreme winter weather.

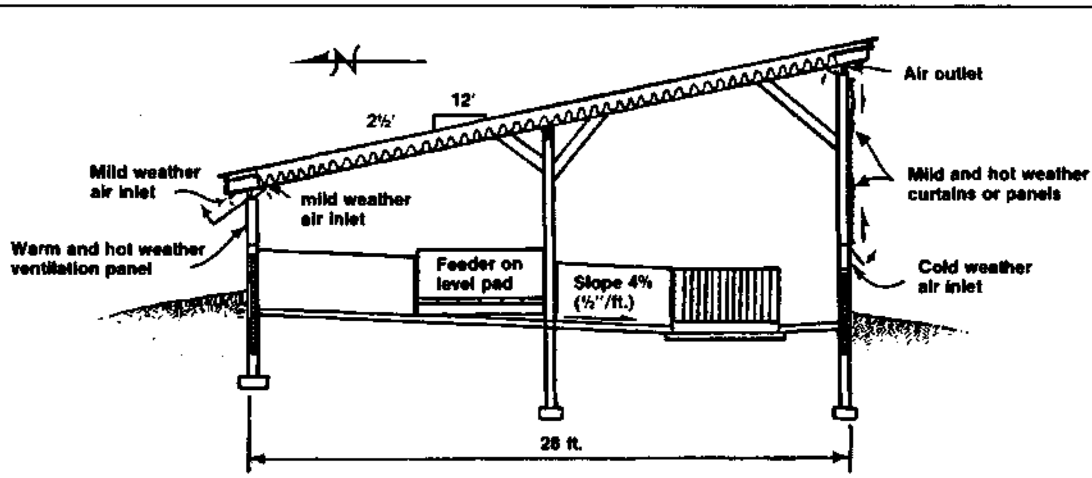


**Figure 3. Typical cross-section (schematic) of monoslope MOF.**

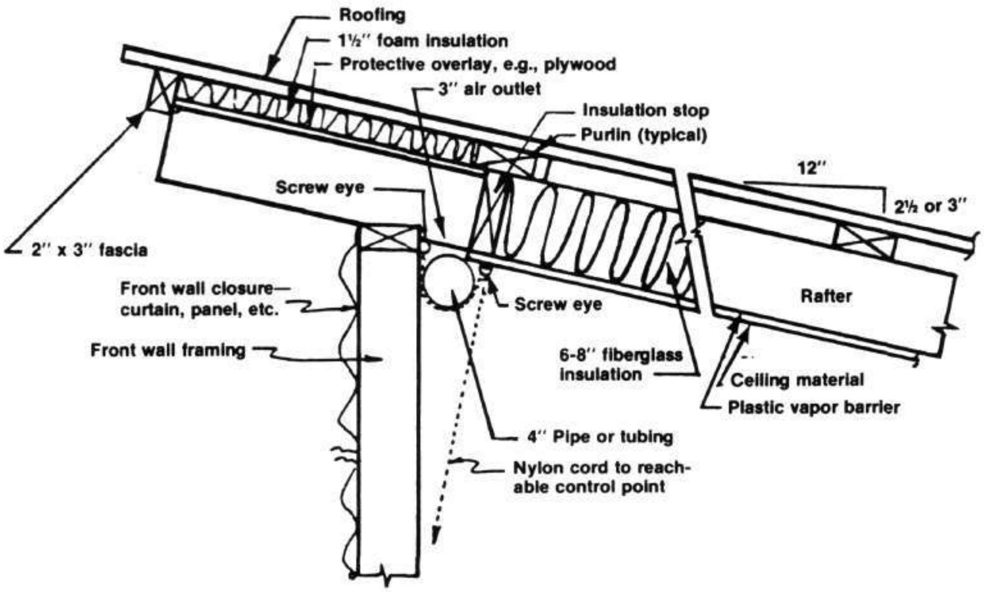


**Figure 4a. An air outlet over the plate and between the rafters requires insulation along the roof and a narrow fascia.**

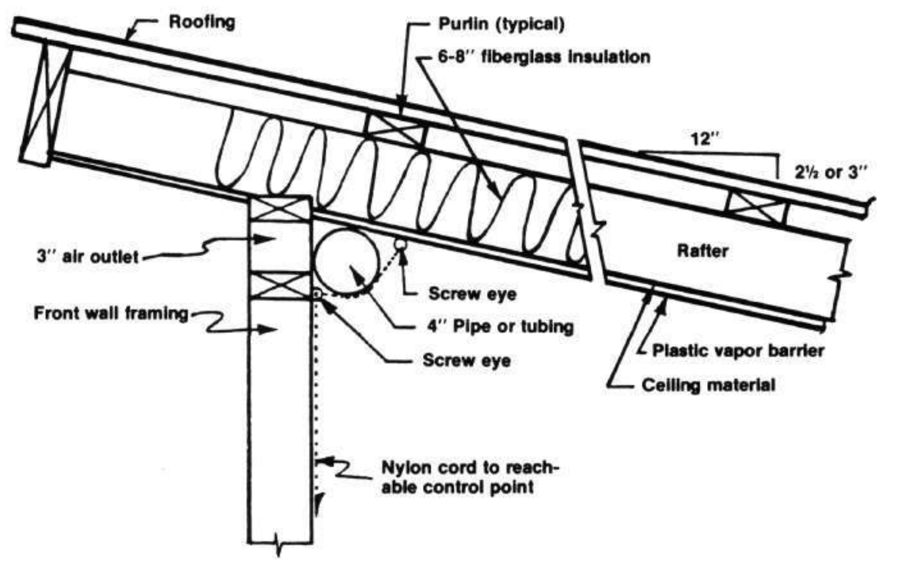


**Figure 4b. An air outlet using a double plate to form a thru-the-wall opening.**

**Figure 4. Air outlets for the top of the south wall on monoslope roof MOF buildings.**

Large doors or panels are needed for warm weather ventilation. They should provide a continuous unobstructed opening at least 2 ft. high. The bottom edge of the opening should be within 32 in. of the interior floor. Construction limitations, panel framing, and vent opening characteristics (e.g., butterfly doors or other designs that reduce the effective size of the actual framed opening) generally mandate use of panels at least 30 in. high. Install welded hog panels across the openings to control pig access to the framing materials. A non-insulated curtain can be used in some locations, but insulated curtains or panels are required for winter operation in the central and northerly parts of the U.S.

## Gable Roof MOF Design

*Building Width*—Limit building width to 50 ft. A width of 32 ft. or less is preferable. See Figure 5 for a typical cross-section. In buildings with two rows of pens, make sure the dunging areas are along the walls. Buildings with center dunging areas are very difficult to ventilate and manage.

Make the air outlet along the ridge continuous the full length of the building. The opening should be at least 2 in. wide for each 10 ft. of building width (Table 2). Equip the opening with a device to allow partial closure during adverse weather. One option is shown in Figure 6. The ridge opening should never be closed completely. If a ridge cap is installed, it must be set high enough to prevent

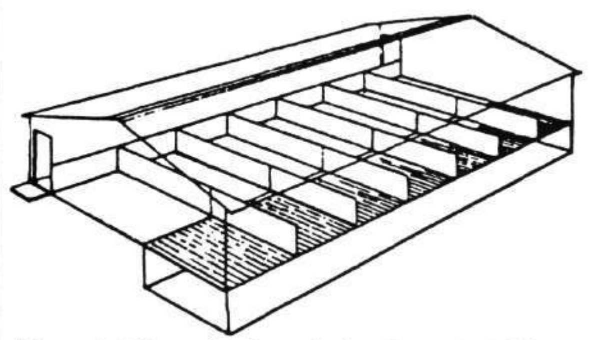

**Figure 5. Schematic of a typical gable roof MOF building.**

**Table 2. Recommended minimum openings for gable-roof buildings, plus recommended raised ridge cap dimensions.**

| Building width | Ridge opening | Sidewall opening height minimum | Ridge cap Vertical clearance | Ridge cap Width (inches) Min. | Ridge cap Width (inches) Max. |
|---|---|---|---|---|---|
| feet | inches | feet | inches | | |
| 20 | 4 | 2 | 2 | 6 | 8 |
| 30 | 6 | 3 | 3 | 9 | 12 |
| 40 | 8 | 4 | 4 | 12 | 16 |
| 50 | 10 | 5 | 5 | 15 | 20 |
| 60 | 12 | 6 | 6 | 18 | 24 |

interference with the upward flow of warm moist air (Table 2). Use extreme caution in selecting commercially fabricated ridge ventilators. Most cause significant restrictions to airflow. If rain blow-in is a problem, consider an "interior raingutter" below the ridge opening (Figure 7), rather than a ridge cap.

Provide continuous openings the full length of both sides. The openings should provide a minimum *clear* unobstructed open height of at least 2 ft. Increase sidewall opening height by 1 ft. for each 10 ft. of building width over 20 ft. Thus, a 40-ft. building should have continuous unobstructed sidewall openings at least 4 ft. high. Equip the north wall with insulated curtains or panels. If located in northern or north central U.S., install insulated or double glazed panels, double curtains, or an insulated section on the south wall also. Openings should be within 32 in. of the floor. Use a bottom opening curtain or provide a baffle inside the sidewall posts to direct incoming air down into the dunging air during cold weather.

## Ventilation System Management

Proper management of the ventilation system by adjustment of inlets and outlets is essential so that outside air temperature variations do not cause extreme, abrupt inside air temperature changes. The goal in ventilation system design and management is to maintain animal zone conditions in the range of optimum feed intake and utilization and to maximize animal performance and comfort. The conditions provided must not pre-dispose the animal to stress, excessive risks to health, or secondary infections and illnesses. This can be achieved by distributing the air to prevent "dead air" spaces without creating drafts. Moving air reduces the effective temperature (wind chill effect). Such air currents are a "draft" anytime they produce an undesirable side-effect or reaction in the animal. (Note: The same air velocity might be considered a desirable "cooling breeze" during warm weather!) Hovers are an effective way to allow animals with different metabolic rates and reactions to air currents and temperatures to seek out conditions where they are most comfortable. Healthy, comfortable animals perform well, are less susceptible to infections from opportunistic pathogens, and lead to maximum profits. Allowing animals access to a range of environmental conditions permits them to select conditions where they are most comfortable and thus serves as a guage in managing the ventilation system.

Cold weather ventilation requires that heat produced within the building be conserved through good construction and proper use of insulation. The conserved heat is needed to maintain room temperature and to heat cold, incoming ventilation air, helping to remove moisture. Inadequate insulation usually leads to under ventilation. The result is uncomfortable conditions because of elevated relative humidity and low temperatures. A decrease in

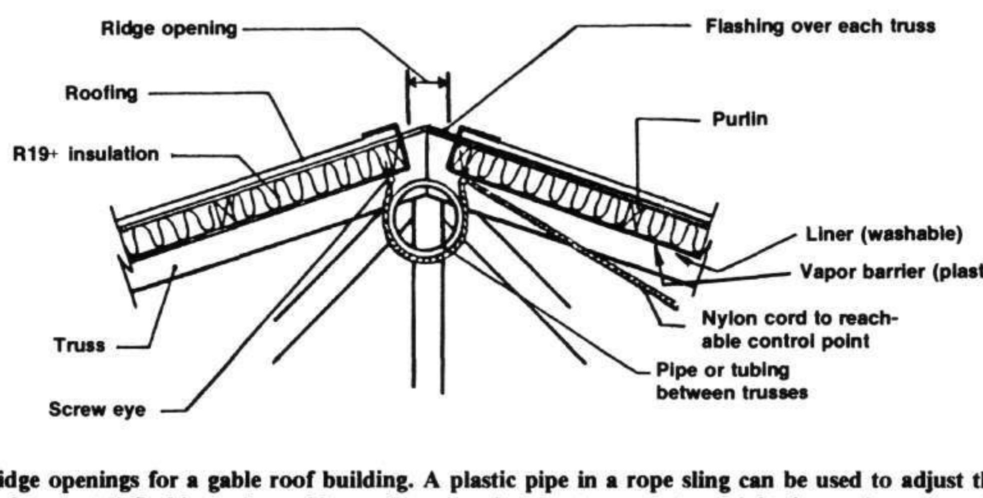


**Figure 6. Ridge openings for a gable roof building. A plastic pipe in a rope sling can be used to adjust the size of a ridge opening. Install flashings along ridge and over each truss to prevent precipitation and condensation from wetting insulation and structural members.**

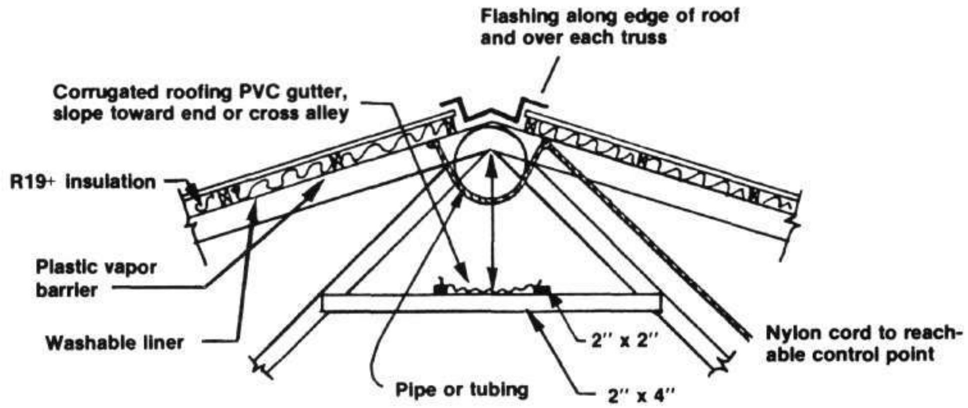


Figure 7. An interior trough or rain gutter can be added to an open ridge to intercept precipitation and prevent wet floors.

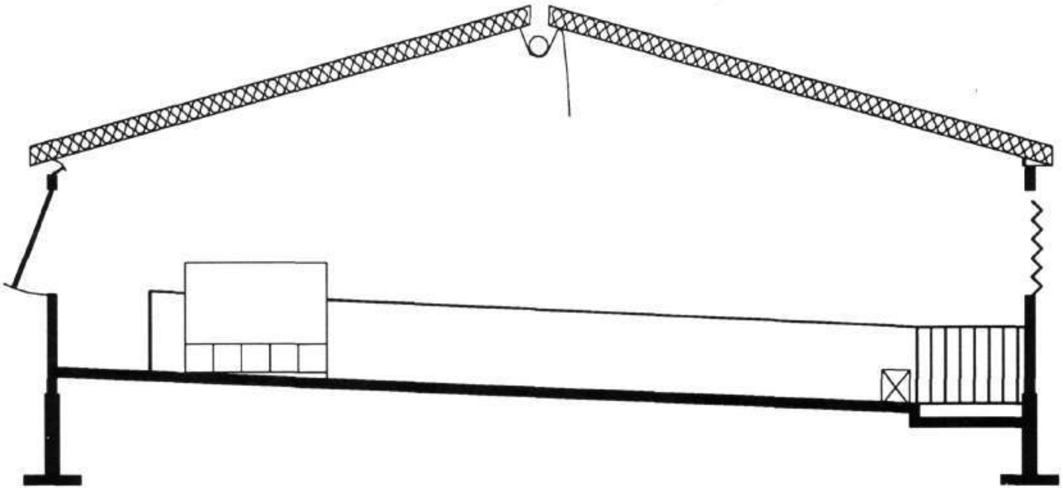

Figure 8a. A building with a single row of pens requires a winter inlet on one side only (above dunging area).

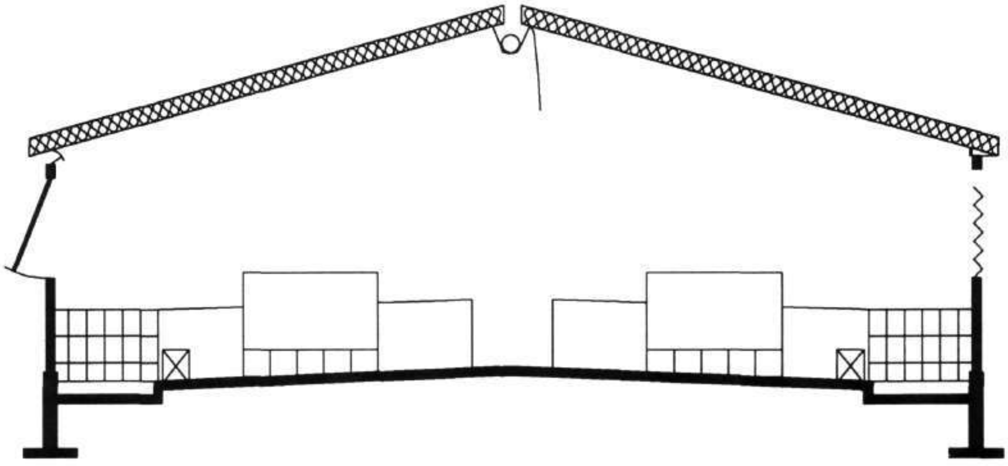

Figure 8b. Buildings with two rows of pens and dunging areas along the walls require inlets along both sides.

Figure 8. The location of inlets in a gable roof MOF is dependent upon the number of rows of pens and location of the dunging area(s).

animal health and productivity frequently follows because of chilling or respiratory ailments. The recommended range of relative humidity in livestock buildings is 50-65%.

Non-mechanically ventilated buildings should be near capacity during cold weather. Lightly loaded buildings or mostly small animals may require supplemental heat to maintain proper ventilation rates and temperature.

The distribution of ventilation air is determined by the design and location of inlets and outlets. Ventilation rates are varied by manual or automatic adjustment of inlets and outlets. Allow cold air to enter through openings near the floor to cool the desired dunging area and encourage proper animal behavior. As the cool air mixes with warm interior air, it picks up moisture and other contaminants and rises as it becomes "used." The warm, moist air follows the underside of the roof and exits through the outlets at the high point of the building.

The outlets should be the last opening closed or restricted and the first opening to be re-opened. Restrict the outlets only when outside conditions are so severe as to prevent maintenance of the desired interior conditions by adjustment of inlets only. Observe the pigs and check conditions in the animal zone before restricting outlets.

Mild weather conditions require increased airflow to limit inside temperature rises. Airflow through the building can be increased by adjusting sidewall inlets. The outlets should be full open.

During hot weather, ventilation airflow rates must be high enough to prevent overheating. Increased airflow through the animal zone is achieved by opening the large panels or curtains on both the south and north walls. The air must move through the animal zone to be effective in cooling the animals.

## Summary

Proper design will allow energy efficient non-mechanical ventilation of buildings for any phase of swine production. Management of non-mechanically ventilated buildings is fairly easy if good construction practices are followed and appropriate openings are incorporated. Non-mechanical ventilation systems require a thorough understanding of the principles of ventilation and "natural" airflow. Management inputs to properly operate an MOF are slightly greater than with mechanically ventilated designs. Usually, however, this simply means taking time to observe the building and animals and making appropriate changes during morning and evening chores.



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