

## Natural Ventilation For Freestall Dairy Barns

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Ventilation systems in dairy barns help maintain a comfortable environment to keep cows healthy and productive. Cows continuously produce heat and moisture. Therefore, a ventilation system is necessary to constantly exchange warm, humid air inside the barn for cooler, drier air outside of the barn. This exchange must occur regardless of outside temperature or weather conditions. Fresh outside air is required even on a cold, windy night to reduce moisture accumulation inside the barn. Good air exchange also removes nuisance odors and manure gases that can have negative effects on animal health and performance.

Most ventilation problems associated with dairy barns are due to inadequate design, construction, and/or operation of the facility. Dairy barns are usually designed, built, and managed for the convenience and comfort of the producer or worker. However, for wellbeing and productivity, cows require a different physical environment than humans. For example, most cows are comfortable and can maintain high levels of productivity between 41 and 77 °F, if the relative humidity is not too high. Furthermore, cows are much more tolerant of temperatures below this optimum range than above. Cows are still productive at temperatures far below 20 °F, if they are kept dry and sheltered from the wind. Most wintertime productivity problems are the result of animals being shut inside poorly ventilated barns rather than cold temperatures.

Proper ventilation is also essential to the barn's structural integrity. Materials in poorly ventilated barns are likely to deteriorate faster than in those with good ventilation systems because inadequate air exchange keeps in corrosive gases and allows water vapor to condense on interior surfaces. The lifespan of hardware and wood structural members is often shortened as a result.

Poorly ventilated barns are easy to identify. They are damp and foul smelling and are likely to have condensation on interior building parts. However, ventilation can often be improved by increasing the size and/or number of ventilation openings to reduce these problems. This publication discusses the basic requirements of natural ventilation systems for freestall barns that should improve cow wellbeing and productivity throughout the year and extend the barn's life.

### Basic Requirements of Natural Ventilation

Even the most basic natural ventilation system requires the following items:

- Air exchange
- Control
- Flexibility
- Good barn construction

#### Air Exchange

Air exchange is the replacement of indoor air within a given space with air from outside. Natural ventilation systems are so called because natural forces (wind and buoyancy) drive air exchange.

#### Control

The ability to control or modify ventilation rates based on inside or outside conditions is essential to good ventilation. Ventilation rates can be changed by turning fans on and off and/or opening and closing sidewall and endwall curtains. Automatic control provides the best response to weather changes and the most uniform conditions inside the barn.

## Flexibility

Ventilation systems should be flexible to provide a comfortable environment for cows throughout the year. The three distinct operating conditions for ventilation systems are:

- 1. Continuous, low level air exchange.** This is the minimum ventilation condition required at all times, even during periods of sub-freezing temperatures, to remove the moisture produced by animals.
- 2. Temperature controlled air exchange.** This ventilation condition is necessary during cool and mild weather to remove excess body heat from the barn.
- 3. High air velocity and high rates of air exchange.** This is the maximum ventilation condition required during hot weather to help cows remove large amounts of heat from their bodies and the space surrounding them.

## Good Barn Construction

Good barn construction is essential to the performance of ventilation systems. Barns that rely on natural ventilation must be constructed to minimize unplanned air exchanges and have sufficient and properly located openings to take advantage of breezes and thermal buoyancy (the chimney effect).

## Freestall Barns

The primary purpose of a freestall barn is to protect cows, stalls, and feed areas from rain, snow, cold winter winds, and hot summer sun. Freestall barn temperatures do not need to be continuously maintained above freezing; cows remain productive at temperatures far below 20 °F if they are sheltered from precipitation and wind. Natural ventilation works well in most freestall barns, although fans may be required to mix inside air with air from outside and to increase airflow over cows in extremely hot weather.

Freestall barns are classified by the degree of temperature control and the amount of insulation used for the natural ventilation system. Most freestall barns are built with little or no insulation. These barns are well suited for Virginia's mild climate. Freestall barns may also be built with moderate and high levels of insulation. However, these barns are cost effective only in areas with extended periods of extremely cold weather.

## Freestall Barns with Little or No Insulation

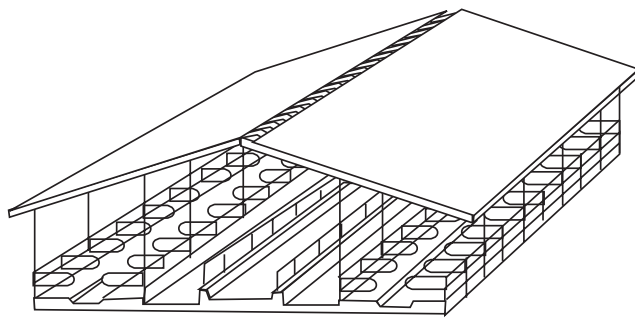
Freestall barns with little or no insulation (cold barns) have temperatures similar to outside temperatures. The open ridge allows hot, moist air to escape quickly from the roof's underside. Sidewall openings help to capture breezes that keep the warm layer of air beneath the roof farther away from the cows' stalls. A low level of insulation under the roof reduces the radiant heat load that contributes to heat stress in cows.

Curtains, removable or hinged panels, sliding doors, or hinged windows are used for sidewall and endwall closures. Material selection should be based on cost, convenience, and longevity and on the ability to provide maximum openings. Sidewall and endwall openings that require regular adjustment can be operated from a convenient, centralized location. Openings that are adjusted based on the season rather than on daily temperature fluctuations can be attached by nailing strips or other methods. Sidewall and endwall curtains can be completely rolled up during summer.

## Ventilation Requirements

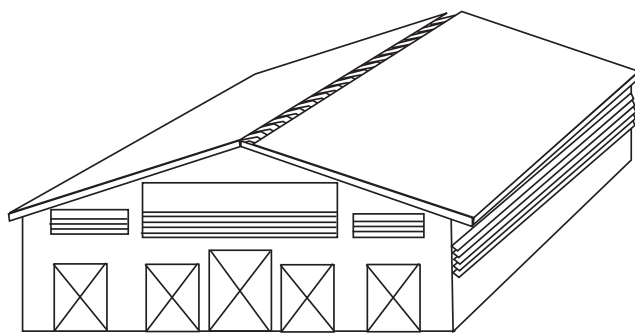
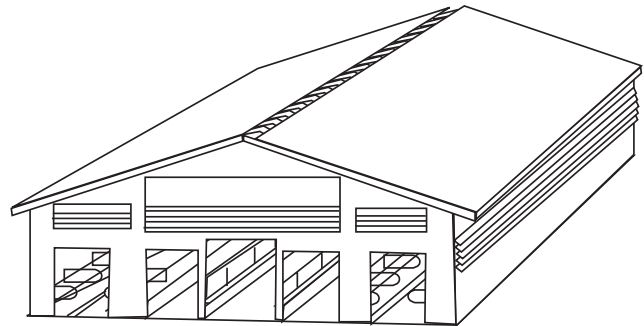
Ventilation should be maximized during hot weather to help keep cows cool. Cows start to experience heat stress when temperatures exceed 77 °F or at slightly lower temperatures if the relative humidity is greater than 90 percent. Heat stress in cows causes decreases in dry matter intake (DMI), milk production, and reproduction. In other words, heat stress reduces farm profitability. Barns should be constructed to allow for the complete removal of sidewalls and endwalls to increase air movement through the barn and to take advantage of cooling summer breezes.

In winter, minimum ventilation is required to remove moisture, odor, and manure gases from the cows' environment. The temperature difference between the inside and outside of the barn should not exceed 10 °F during cold weather. Ventilation should not be decreased to maintain inside temperatures that are comfortable for the producer or worker. Otherwise, warm, humid air will condense on cold building parts such as roof sheets, siding, and rafters. Excessive condensation accelerates barn deterioration and creates an unhealthy cow environment.



Hot weather conditions with ridge, sidewalls, and endwalls completely open.

Mild and cold winter, spring, and fall conditions with ridge completely open and sidewalls and endwalls partially open.



Very cold winter weather conditions with end doors closed and tops of sidewalls open at least 1/2 of ridge width.

Figure 1. Uninsulated or lightly insulated barn with sidewall, endwall, and ridge openings.

The following guidelines are suggested for ventilation openings during various weather conditions (Figure 1):

1. **Year round:** Continuous ridge openings. Provide a 2-inch ridge opening width for every 10 feet of building width. For example, a 90 foot wide building requires an 18-inch open ridge.
2. **Very cold winter weather:** Continuous sidewall openings. Provide an opening at the top of both sidewalls that is equal to one half of the ridge opening. For example, a 90 foot wide building requires a 9-inch opening at the top of each sidewall.
3. **Mild and cold winter, spring, or fall weather:** Continuous, adjustable sidewall and endwall openings. Provide adjustable, 4 foot high sidewall openings above cow level and adjustable endwall openings above cow level or traffic doors. Adjust openings to minimize drafts and maintain inside temperatures within 10 °F of outside temperatures.
4. **Summer:** Additional sidewall and endwall openings at animal level. Completely open sidewalls and endwalls from the ground to the roof to let in

cooling breezes during hot summer weather (temperatures above 80 °F). The barn should serve only as a sunshade and rain umbrella in the summer.

### Mixing Fans

Mixing fans are used to reduce heat stress in cows by creating drafts across the animals' backs. These fans can be easily controlled with thermostats. Most freestall barns in Virginia have two sets of fans; one set is activated at 70 °F and the other set is activated at 77 °F. Although mixing fans provide a good draft, they do not create air exchange to make up for the lack of a good natural ventilation system.

Install mixing fans so they blow air in the same direction. Fans should be placed at a 12-foot height along the length of the barn above the freestalls. To produce a draft across the animals' backs, fans should be angled downward at about 20 degrees. Recommended distance between fans is 30 feet for 36-in diameter fans and 40 feet for 48-in diameter fans. However, distance between fans should be sufficient to provide air velocities of 200 to 300 feet per minute (2 to 3 1/2 mph) over the cows' backs

## Construction

Naturally ventilated freestall barns with little or no insulation should be serviceable for years if the following construction practices are used:

**1. Four-twelve to 6/12 roof pitch.** Lower roof pitches may cause air movement along the roof's underside to slow down. As a result, warm moist air becomes trapped against the cold roof surfaces and condensation occurs. In contrast, steeper roof pitches may cause air flow along the roof's underside to speed up. Fresh air is poorly distributed at cow level during cold weather as a consequence.

**2. Continuous open ridges.** In winter, wind blowing across an open ridge creates a suction that draws warm, humid inside air out of the building. At the same time, fresh, dry, cool air is drawn in through the sidewall openings. Trusses that are exposed to the open ridge should be coated from the ridge to the first purlin for moisture protection. Apply three coats of exterior paint or clear urethane sealer regularly (every three to five years) to seal trusses from moisture. Flashing can be installed over trusses as an alternative to coating with paint or sealer. Do not wrap trusses with metal. Otherwise, moisture will be trapped against the truss material for an extended

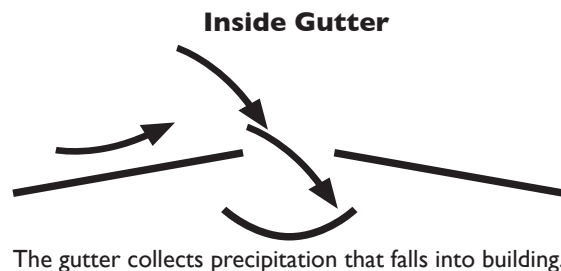
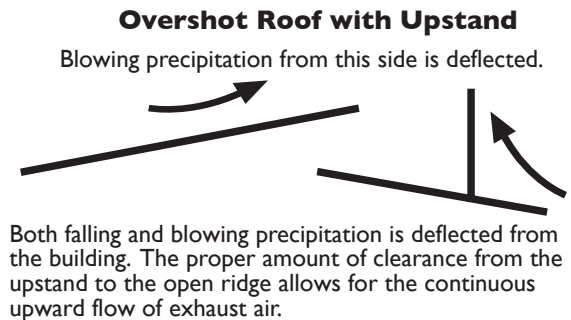
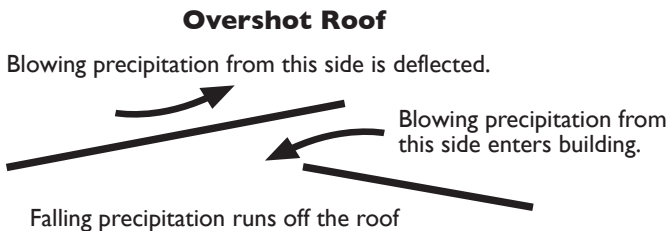
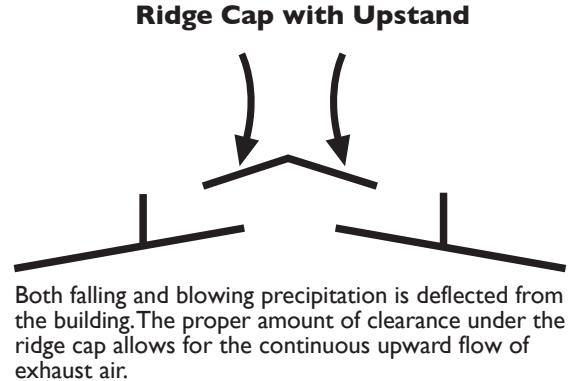
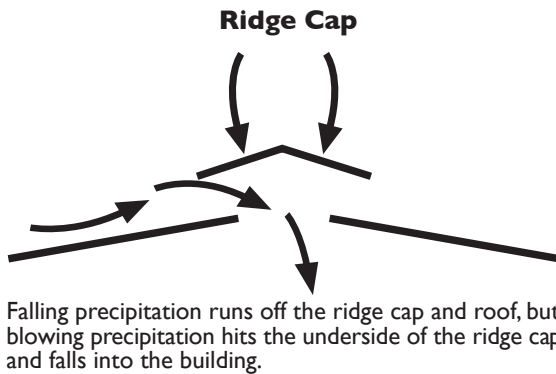
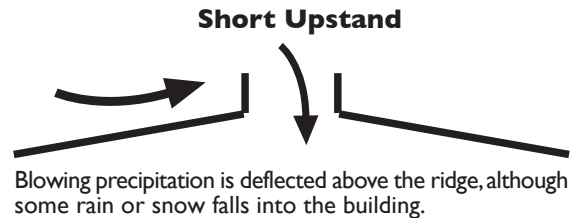
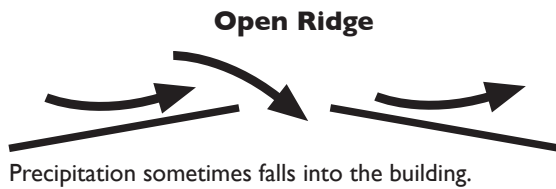


Figure 2. Performances of various ridge cap configurations.

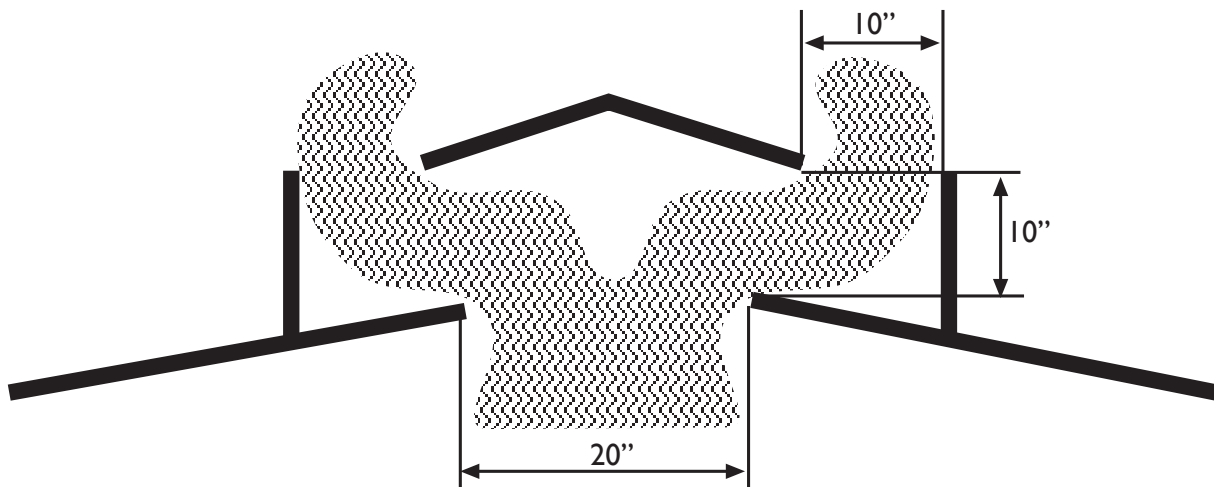


Figure 3. Performance of a properly installed ridge cap with upstands. The upstands and ridge cap must be positioned to allow for the continuous upward flow of exhaust air.

period. Use double hot-dipped, galvanized truss plates to minimize corrosion.

**3. Ridge caps or upstands.** Only minimal amounts of rain and snow will enter a properly sized open ridge when the freestall barn is fully populated. Ridge caps are not recommended for wide (50 feet or more) barns because they obstruct the air outlet provided by the open ridge and may even increase the entry of rain or snow when precipitation blows parallel to the ridge. However, an upstand that deflects rain and snow can be installed on the ridge without hindering air flow (Figure 2). Another alternative to a ridge cap is to install a rain gutter under the open ridge to intercept precipitation. A properly designed ridge cap should be used in narrow (40 feet wide) barns with one central feed aisle to keep precipitation off feed, although the ridge cap must be properly installed to allow uninterrupted flow of exhaust air from the open ridge (Figure 3).

**4. Twelve to 14 foot high sidewalls.** High, open sidewalls increase airflow for summer cooling. Use a higher sidewall (14 feet) for freestall barns that are sheltered by buildings, tall crops, or other obstructions. The sidewall height should also allow for the clearance of any machinery that may be used in the barn. A sidewall that is 16 feet high or more will make no noticeable improvement in ventilation.

**5. Bird protection.** Roosting or perching birds foul building parts, feed, and animals with bird droppings. Birds also destroy insulation by pecking and burrowing into the material. Although bird elimination is difficult, try the following tips:

- Minimize locations where birds can roost or perch, especially over feed aisles.

- Use plastic bird netting to exclude birds from truss areas. Increase ridge opening by 20 percent to account for air blockage if netting is placed over the open ridge.
- Use steel or wooden beams or arches instead of open trusses.
- Protect exposed insulation surfaces, ends, and joints with solid barriers.

**6. Adjustable sidewall openings.** Construct sidewalls that can be adjusted for changing weather conditions and completely opened to increase air flow during hot weather. Curtains, placed above cow level, are highly recommended for use as sidewalls because they can be easily adjusted or rolled up completely.

**7. Adjustable endwall openings.** Construct endwalls that can be adjusted for changing weather conditions and completely opened to increase air flow during hot weather. Roll up doors or curtains are highly recommended for use as endwalls because they can be easily adjusted or rolled up completely. Install large, adjustable ventilation openings in the gables to increase the flow of hot air from under the roof to outside.

**8. Minimum insulation.** Minimum insulation ( $R = 2$ ) under the roof sheets reduces solar heat loading on hot, sunny days. Use water-resistant, plastic-type insulation and protect it from birds. A 5/8- to 3/4-inch wooden roof deck with asphalt shingles is an alternative to manufactured insulation.

**9. Minimum 3-foot roof or eave overhang.** A properly sized roof or eave overhang minimizes the entry of sun, snow, and rain through open sidewalls. The overhang also protects rolled up curtains and keeps snow that slides from the roof farther from the barn. A general rule is to extend the roof to 1/3 of the sidewall height.

## Summary

Naturally ventilated freestall barns that are properly designed, constructed, and managed provide an excellent environment for dairy cattle. The primary purpose of the freestall barn is to protect cows, freestalls, and feed areas from, rain, snow, cold winter winds, and hot summer sun. Freestall barns must always have some portion of the sidewalls open and an open ridge to allow air exchange for the removal of large quantities of moisture and heat produced by cows. Barns that are closed too tightly allow condensation to form on interior surfaces and become damp. These conditions are unhealthy for cows and accelerate building deterioration.

Managing a barn to maintain certain temperatures for the convenience and comfort of the worker or producer often results in poor conditions for cows. The temperature difference between the inside and outside of a freestall barns should not exceed 10 °F. Otherwise, air exchange will be compromised and cows will be uncomfortable.

The bottom line regarding ventilation is whether cows are comfortable. Properly ventilated freestall barns are continuously filled with fresh, outside air that provides a healthy environment for cows. As a result, cows will maintain productivity throughout the year and farm profitability will not suffer during hot summer or cold winter weather.

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## For Additional Information

### On Dairy Freestall Housing

MWPS-7 “Dairy Freestall Housing and Equipment” (\$22.00)

### Publication Modified from:

Graves, R.E. and M. Brugger. 1995. Natural Ventilation for Freestall Dairy Barns. G 75. Penn State Cooperative Extension, The Pennsylvania State University, University Park, PA.

*Reviewed by Bobby Grisso, Extension specialist, Biological Systems Engineering*

NRAES-24 “Dairy Freestall Housing” (\$30.00)

NRAES-37 “Planning Dairy Stall Barns” (\$6.00)

NRAES-63 “Dairy Reference Manual” (\$20.00)

NRAES-76 “Guidelines for Planning Freestall Dairy Barns” (\$8.00)

NRAES-129 “Dairy Freestall Housing and Equipment: Managing and Planning for Profitability” (\$30.00)

To order MWPS or NRAES publications, contact your local Virginia Cooperative Extension office.

### On Dairy Freestall Idea Plans

NRAES-85 “Penn State Dairy Housing Plans” (\$15.00)

### On Heat Stress in Dairy Cows

VCE 404-200 “Reducing Heat Stress for Dairy Cattle”

### On Natural Ventilation for Dairy Housing

MWPS-33 “Natural Ventilation Systems for Livestock Housing” (\$5.00)

### On Ventilation for Dairy Tiestall Housing

NRAES-119 “Natural Ventilation for Dairy Tiestall Barns” (\$3.00)

NRAES-120 “Tunnel Ventilation of Dairy Tiestall Barns” (\$3.00)

### On Virginia Cooperative Extension

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