

INTRODUCTION

Ventilation in agricultural facilities helps regulate temperature and humidity, control odor, and exhaust harmful gases. Ventilation is frequently used in animal housing, greenhouses and other plant growth facilities, packing and processing areas, and storage facilities. Energy invested in ventilating various livestock operations can vary from as little as 4% of the total in “open” cattle buildings, to as much as 64% in confined egg production facilities (5). Energy use in ventilation can be markedly reduced through the use of passive and natural ventilation wherever possible, as such ventilation requires only marginally significant energy to operate.

MINIMIZING ENERGY USE FOR VENTILATION

Ventilation system designs vary greatly depending on the application. Operating strategies are also very different depending on the type of operation. Nonetheless, there are some basic principles for reducing energy use that apply in most ventilation systems (3):

- Use efficient motors wherever possible.
- Use variable or multiple speed fans where applicable.
- Maintain ventilation equipment on a regular basis.
- Size fans to provide the actual ventilation requirements at expected static pressures (see section below).
- Use reliable equipment from reputable manufacturers and suppliers.
- Stage ventilation equipment to provide an optimum environment over a range of outside conditions.
- Design ventilation systems according to industry guidelines. Consult with professionals to optimize ventilation system performance.
- Use electronic controllers to get the best use of ventilation equipment.
- Use natural ventilation where it will provide adequate venting.

VENTILATION EQUIPMENT AND OPERATION

In building ventilation systems, static pressure difference refers to the pressure due to compression of the air, and is the difference in pressure between still air inside the building and the air outside that is created by restrictions such as inlets, louvers, breezes, etc. (2). Most agricultural ventilation uses negative pressure systems, where fans exhaust air from the building and air is introduced through some form of inlet vent. Positive pressure ventilation uses fans or blowers to introduce outside air into the building, and air is exhausted through vents. Neutral pressure systems use both supply and exhaust fans that are of approximately equal capacity.

The size of the inlet or outlet vents in relation to fan capacity determines static pressure and the velocity of

incoming air. Since fans operate most efficiently at specific static pressures, sizing vents appropriately will improve energy performance and provide optimal environmental control. In many facilities there is a benefit to maintaining relatively high inlet air velocities to provide mixing at the inlet.

There are three general categories of fans: axial, centrifugal and crossflow. Most fans in agricultural applications are axial fans with propeller type blades, which blow air along the axis of the fan. Centrifugal fans, sometimes called squirrel cage blowers, have a cylindrical impeller. The air intake is at the end of the cylinder, and the air is forced out along the surface of the cylinder. Centrifugal fans are typically quieter than axial fans of similar capacity, and can move air against greater static pressures. Crossflow, also called tubular or tangential, fans also have a cylindrical impeller in which the length of the impeller is typically significantly greater than the diameter. Air flows transversely across the impeller, entering and exiting along the length of the cylinder.

Most exhaust fans are axial propeller fans, typically mounted with a horizontal axis. Propeller fans are also used to circulate air within agricultural facilities. Horizontal Air Flow (HAF) fans are commonly used in greenhouses to provide uniform temperature and humidity. Propeller blade axial fans may be direct drive or belt-driven. Direct drive fans are typically more efficient, but noisier, and more subject to vibration. Belt drives require more frequent maintenance.



HAF Greenhouse Fan

PHOTO: NJ AGRICULTURAL EXPERIMENT STATION

Fan housings support and protect the motor and fan parts. They also generally allow for attachment of shutters and guards. The shape and size of the housing affect the overall efficiency of the fan.

Efficient ventilation system design requires balancing several different considerations. In addition to energy efficiency, these include maintaining an optimum environment, initial costs and maintenance costs.

Manufacturers often publish fan efficiency information as CFM (cubic feet per minute) per Watt. If no efficiency data is available, when comparing fans with equivalent air flow capacity the fan with the smaller full load ampere (FLA) rating is typically more efficient (1, 2). Larger diameter fans tend to be more efficient than smaller ones. Because fan efficiency is partially a function of motor efficiency, select high efficiency motors when purchasing new or replacement equipment.

ASABE (2) provides equations for estimating operating cost savings and energy savings per year. In comparing two fans, the electric operating cost savings (ES) in kilowatt-hours (kWh) per year equals:

$$\left(\frac{AFR_1}{FE_1} - \frac{AFR_2}{FE_2} \right) \times AOH \times ER \times 0.001$$

where AFR is the air flow rate in CFM, FE is fan efficiency in CFM per Watt, ER is the dollars per kilowatt-hour charged by the electric utility, and AOH is average operating hours per year. AFR₁ and FE₁ are values for the less efficient fan.

The total lifetime cost savings in dollars is:

$$\left(\frac{RL}{AOH} \times ES \times ER \right) - (PP_1 - PP_2)$$

Where RL is the rated fan life in hours, ER is the energy rate in \$/kWh, PP₁ is the purchase price of the more efficient fan, ES is the operating cost savings given by the above equation, and PP₂ is the purchase price of the less efficient fan.



End-Wall Vents with Insect Netting

PHOTO: NJ AGRICULTURAL EXPERIMENT STATION

The relative position of fans and inlets will affect the uniformity of the inside environment and the overall efficiency of ventilation. Design guidelines for greenhouses and animal housing are discussed below. Ventilation equipment will operate most efficiently if the structure is maintained to minimize infiltration through cracks, poor insulation, and weather stripping. Doors and other openings

should be kept closed unless the ventilation system is designed for them to remain open when venting.

Ventilation equipment should be maintained regularly, at least every three months. Fans should be kept clean (dust and debris removed from all surfaces), fan belts appropriately tightened and worn belts replaced. New belts should be checked for tightness after operating for two weeks from the time they are put into service. Adjust louvers and vents to prevent air leakage and replace damaged or missing weather stripping and gaskets. Smoke generators can be used to detect leaks and undesirable air flow patterns.



Electronic Ventilation Controls

PHOTO: NJ AGRICULTURAL EXPERIMENT STATION

VENTILATION CONTROLS

Environmental controls for ventilation may be as simple as timers and thermostats. More sophisticated controls are generally needed when there is the potential for heating and ventilating systems to operate concurrently. Similarly, humidity control will typically require more complex controllers. More comprehensive controls range from single zone heating and cooling controllers to multi-zone computerized systems. Multiple and variable speed fans require controls for the specific application.

Electronic controls have several benefits including more precise control, ability to sequence and coordinate equipment operation, and interlocking heating and cooling systems. Computerized controls can provide record keeping, prompt operators to maintain equipment, and provide complex control strategies without operator intervention. Optimizing the ventilation system enhances health and growth in both plants and animals.

GREENHOUSE VENTILATION

Greenhouse ventilation serves to maintain optimum growing conditions, prevent damage to crops from overheating, and control humidity. Many greenhouses rely on natural ventilation to provide cooling. Where these designs provide sufficient ventilation and uniformity they are typically the most energy efficient way to ventilate greenhouses. Among the potential drawbacks of naturally ventilated greenhouses are non-uniform temperature and humidity, difficulty in installing effective insect screening, and limited ability to ventilate under certain weather conditions. Also, evaporative cooling using fans and pads is not an option in naturally ventilated greenhouses.

Traditional designs incorporate vents at the peak of the greenhouse, often on both sides of the ridge, but sometimes only on the leeward side (based on the prevailing winds). Single span naturally-vented greenhouses typically have inlet vents along the side walls. Sidewall venting is less effective in multiple span (“gutter-connected”) greenhouses, particularly for very wide structures; however, for such structures end-wall ventilation may be possible.

Many greenhouse manufacturers make structures in which the entire roof can open to provide ventilation (“open-roof” designs). These structures can often maintain relatively uniform greenhouse conditions at or slightly below ambient outdoor temperatures.



Vent Actuator

PHOTO: NJ AGRICULTURAL EXPERIMENT STATION

For simple single span greenhouses (Quonset or hoop houses and high tunnels), rolling up the polyethylene film sides can often provide adequate ventilation. These systems can be manual or motorized.

Most active greenhouse ventilation systems use large diameter axial exhaust fans in combination with louvered vents or vent window inlets. Automated cooling systems will typically reduce air temperature fluctuations.

Managing the greenhouse environment, including ventilation, is a complex topic that is discussed in detail in numerous publications. The National Greenhouse Manufacturers Association provides guidelines for designing greenhouse ventilation systems, as do some fan manufacturers. See “Further Reading” items 1, 8, and 2 for suggestions.

Poorly designed ventilation systems that do not perform within recommended specifications can reduce energy efficiency and result in poor crop performance. Multiple stages of ventilation generally provide more accurate cooling, reduce energy use and improve crop quality.

The least expensive inlets for greenhouse ventilation systems are typically wall shutters. These provide a fixed-size opening, which in some conditions can lead to poor temperature distribution within the greenhouse. Vents having variable opening size can be used to maintain desired inlet flow rates, which in turn can promote better mixing of inlet air with the air within the greenhouse.

Inlets with insect screening should be sufficiently large to maintain static pressures within the operating ranges

of exhaust fans, and inlet vents may need to be modified to accommodate insect screens. The area of screening required depends on mesh size and geometry.

Many greenhouses use HAF fans to provide more uniform growing conditions. These fans will provide the best performance if they are specifically designed for this application, and installed according to the manufacturer’s instructions. For greatest efficiency, follow recommended guidelines for HAF placement within the greenhouse (Further Reading items 5, 9).

Evaporative cooling is frequently used to lower greenhouse temperatures below the range possible with ventilation alone. Common evaporative cooling methods include fogging systems and cooling pads along inlet walls. In both systems, regular maintenance and inspection of pumps as well as plumbing piping and fixtures will help ensure efficient operation. Optimal performance of evaporative cooling systems requires appropriate control strategies, calibrated sensors and functional controls.

ANIMAL HOUSING VENTILATION

Ventilation in livestock housing provides oxygen, removes moisture and odors, lowers temperatures and dilutes airborne contaminants and disease organisms. Ventilation should remove moisture and odor in cold weather and excess heat in warmer periods. Most confined livestock housing uses mechanical ventilation. Because pigs and cattle do not sweat, ventilation in animal housing is designed to provide sufficient convective cooling as well as moisture removal around the animals’ heads. Humidity control (between 50% and 80% relative humidity is important to prevent disease and preserve building materials and equipment (4). Animal housing ventilation systems must take all of these factors into consideration. A number of publications provide guidelines for ventilating specific types of animal housing (Further Reading items 3, 6, 7).

Linkages used for opening vents must be lubricated regularly. In structures with fewer than four walls, orient open sides to allow a laminar flow of air through some part of the structure. Roof vents can also help in reducing ventilation-related energy expenditures, especially where wall venting alone results in unacceptably high temperatures. High-Volume Low-Speed (HVLS) fans can be a good, energy-efficient supplement to passive ventilation, as the low speed of the blades reduces drag and turbulence, while the low generated pressure will move air across the large-area passive ventilation openings.

Keep fans clean and properly lubricated. Where possible, the use of NEMA Totally Enclosed Fan-Cooled or Wet-Location motors can reduce losses caused by the corrosive action of water and nitrogen compounds present in livestock shelters and similar facilities. Keeping a few pedestal fans around the farm can also be of great value. These fans can be moved to specific locations that need spot ventilation or cooling instead of operating the entire structure’s ventilation systems.

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High-Volume Low-Speed (HVLS) Fans

PHOTO: UNIVERSITY OF WISCONSIN EXTENSION

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