



Natural or Tunnel Ventilation of Freestall Structures: What is Right for Your Dairy Facility?

Curt A. Gooch, P.E.
Senior Extension Associate
Department of Biological and Environmental Engineering
PRO-DAIRY PROGRAM
Cornell University

INTRODUCTION

Many dairy producers ask the question, "Are we better off ventilating this structure naturally or by using tunnel ventilation?" The answer to that question is site specific and depends on a number of variables. First, let's discuss the basics of ventilation and then we can look into the question of natural or tunnel ventilation in detail to determine what system will be right for your dairy facility.

VENTILATION BASICS

Ventilation of any dairy housing structure, whether it is a newborn calf shelter or a lactating cow shelter, is of paramount importance. Emphasis here is placed on fresh air! Dairy cows need a constant source of fresh, clean air to achieve their production potential. High moisture levels, manure gases, pathogens, and dust concentrations present in unventilated or poorly ventilated structures create an adverse environment for animals. Stale air also adversely affects milk production and milk quality.

Proper ventilation consists of exchanging barn air with fresh outside air uniformly throughout the structure. The required rate of air exchange depends on a number of variables, including the conditions of the outside air (temperature and moisture level) and animal population and density. A properly designed and managed system results in shelter air that is nearly equal in quality as the outside air on a year-round basis. The shelter air concentrations of manure gases, dust, and pathogens should be low and the relative humidity should be about the same level as that of the outside air. **Fans hanging over stalls or alleys do not provide air exchange and are not a substitute for well-designed and managed ventilation system.**

Air exchange can be accomplished with either a natural ventilation system or a mechanical ventilation system.

NATURAL VENTILATION

The natural ventilation process relies on a combination of key shelter characteristics and their management coupled with natural air movement in order for air exchange to happen. Shelters need to be properly located and oriented to maximize natural ventilation—ideally with the sidewall perpendicular to prevailing summer winds. Shelters need adequate sidewall, endwall, eave and ridge openings for air to enter and exit. Sufficient space must exist between a shelter and any windward breeze blocking objects so naturally moving air



has the opportunity to enter the shelter. The minimum distance between nearest sidewalls of adjacent shelters should be at least 80 feet. For large structures, a distance of 100 feet or more is recommended.

Let's look more closely at the shelter attributes that are important to a successful natural ventilation system.

Shelter Location and Orientation

This is of primary importance. Animal housing shelters should be sited so that prevailing summer winds are not blocked by natural or man-made structures. Ideal locations are on the highest ground available on the farmstead. Other structures, such as silos (both uprights and bunkers), other barns, and natural wind barriers should be located on the leeward side of the shelter.

Research shows that orientation of the shelter should be in such a manner that the prevailing summer winds intersect the shelter perpendicular to the sidewalls. With this orientation, air entering the shelter through the curtain sidewall travels the shortest distance possible to exit the shelter through the opposite sidewall. This improves the rate of air exchange in the shelter and consequently enhances the cows' environment.

Sidewall Openings

Sidewalls of naturally ventilated shelters can be the air inlet or the air outlet depending on the wind direction. For proper ventilation to take place, the sidewalls of the shelter must be fully open in the summer, moderately open in the late fall and early spring, and partially open in the winter.

Sidewall heights should be a minimum of 12' for 2- and 3-row barns and 14 to 16' for 4- and 6-row barns. With these sidewall heights, large volumes of air can enter and exit the shelter. High sidewalls accommodate a larger volume of dilution air in the shelter during periods of little or no natural air exchange. This postpones the point at which "stagnant air" in the shelter becomes "stale air".

Producers must be careful not to block the openings provided by high sidewalls with excessive curtain hardware or support materials. For example, using $\frac{3}{4}$ " by 1" wire mesh as curtain support is better than using expanded plastic safety netting, which has an increased surface area. Similarly, storage of curtains on a split curtain system that "bundles" instead of rolls up in the middle during the summer months reduces the effective opening. Raising the top curtain to immediately below the eave and up against the structural header keeps the curtain cleaner and minimizes wind blockage.



Endwall Openings

Endwalls on freestall shelters should be able to be opened as much as possible. They provide another means of allowing air exchange to happen. Opening the endwalls is especially effective with short length shelters on days when the wind is not blowing perpendicular to the sidewalls. Open endwalls can be achieved in many ways that can be used separately or collectively as a system.

- Install curtain systems in the gable
- Install curtain systems in the endwall
- Install roll-up doors
- Install removable panels
- Install mesh fabric in lieu of metal panels

Eave Openings

Open eaves are best designed to act as the primary air inlet during cold periods with strong blowing conditions. For 2-, 3-, and 4-row barns, the effective eave opening should be a minimum of 1" per every 10' of building width. For 6-row barns, the effective opening should be at least 1-1/2" per 10' of building width. Eave air inlets should not be closed down—they are always open. Usually, the distance between the top of the sidewall truss support header and the bottom of the roofing material provides the eave opening. For cases where the soffit is totally enclosed, minimum ventilation can be obtained by making the effective height of the curtain correspondingly less than needed to totally close the sidewall.

Ridge Opening

The ridge opening provides an escape path for warming shelter air that rises due to thermal buoyancy. Effective ridge openings should be two times the effective openings of the eaves: a minimum of 2" of horizontal width for every 10' of building width. A minimum of 3" per 10' of width is recommended in 6-row shelters.

Many producers are skeptical about providing such an opening, as they are concerned with precipitation entering the shelter. Numerous methods are available handle this problem. Examples include installing a gutter system below the ridge opening or sloping the concrete feed alley floor 3" to the center of the building away from the eating surface. The best adaptation to the open ridge to help preclude the entrance of snow is to install ridge upstands. Upstand height should be at least equal to the width of the effective opening. Upstands that are two times the effective ridge opening are working well in the field. Structural members exposed at the peak of the building should be flashed or otherwise protected from precipitation.



Natural Ventilation Management Guidelines

Use these air quality guidelines to determine if you do not have adequate shelter ventilation for naturally ventilated, cold barns (those with minimal or no insulation).

- In the winter, if the inside temperature is more than 5 to 8°F above the ambient temperature, then more ventilation is needed.
- In the spring and fall, if the inside temperature is more than the outside temperature, then more ventilation is needed.
- In the summer, if the cows are heat stressed at first light the morning after a hot day, then additional ventilation is needed.
- If you detect more than a slight manure gas odor, then you need additional ventilation.

Effective natural ventilation can be achieved in many but not all cases when constructing new facilities. Many existing shelters have inadequate air exchange due to the lack of openings and/or they are poorly sited with respect to prevailing winds. Tunnel ventilation is an option available to producers constructing new facilities that might have a compromised natural ventilation system or to those with existing facilities that currently have natural ventilation challenges that cannot be overcome.

TUNNEL VENTILATION

Tunnel ventilation is a special, yet simple summertime ventilation system. Its goal is to provide **air velocity** and **air exchange** concurrently in a barn. Fans (called tunnel fans) are placed in one gable endwall of a building (see Figure 1). Fans are operated to create a negative pressure in the barn, causing air to be drawn into the opposite gable endwall opening. Once in the barn, the fresh inlet air travels longitudinally through the structure and is exhausted by the tunnel fans. For tunnel ventilation to function at its maximum potential, all sidewall, ceiling, and floor openings must be sealed to form the "tunnel."

Field measurements and experience have shown that tunnel ventilation is effective in providing predictable air exchange in freestall barns, but some challenges exist relative to maintaining viable air velocity at cow level. Research has also shown that air movement between 400 to 600 feet per minute (fpm) can successfully reduce heat stress in dairy cattle.

Limitations

Tunnel ventilation is not generally an appropriate ventilation system for use in cool and cold periods. The air speeds associated with a well-designed tunnel system can create cold, drafty conditions when operated at those times. Reducing the number of tunnel fans operating or decreasing the capacity of each fan by slowing the electrical motor will result in reduced air exchange rates that may not provide fresh air throughout the length of the barn. If some of the tunnel fans are used for cool weather ventilation, then appropriate measures must be implemented to ensure adequate mixing and to prevent serious gradients in air quality along the barn's length.

Figure 1. Tunnel fans positioned on endwall of a tunnel-ventilated 6-row freestall barn.



The maximum barn length that can be effectively tunnel-ventilated is another limitation of the system. As the inlet air moves longitudinally through a barn, it becomes increasingly contaminated with air pollutants. At some point, the inlet air is no longer "fresh" and provides limited benefit to cows downwind from this point. Limited field data collected by the author showed that temperature and relative humidity gradients between inlet and exhaust in a 600-foot long tunnel ventilated 6-row freestall barn were insignificant. However, additional research is needed to determine what the practical length limit is for tunnel ventilation in given climatic regions.

Design Procedure

The procedure to design a tunnel ventilation system consists of two steps. First, the required total fan capacity is determined. Then this value is used as an input variable to determine the size of the air inlets.

Sizing Fans

Successful tunnel ventilation system design must achieve two goals: **air velocity** and **air exchange**. Each of these goals should be considered individually during the design stage



to determine which one will ultimately govern. Experience has shown that the need to satisfy air velocity criteria will almost always control design.

The total fan capacity should be determined accordingly to achieve the desired air velocity of 400 to 600 fpm in the barn. This is accomplished by multiplying the cross sectional area in the barn perpendicular to airflow, in square feet, by the desired air speed, in feet per minute, to get a product with units of cubic feet per minute (cfm).

To check for adequate fan capacity to ensure proper summer air exchange rates, use 1,000 cfm of fresh air per cow. In order to determine the minimum required air exchange rate for summer ventilation simply multiply the number of cows in a barn by 1,000 cfm/cow.

Use the larger of the two values calculated above to determine the overall theoretical fan capacity required.

Design Example

To illustrate the design procedure, assume that a producer plans to retrofit an existing 6-row freestall barn that houses 500 cows with tunnel ventilation. The existing barn is 106' wide, which is narrow by today's design standards, and has 10-foot high sidewalls. The barn is fully insulated with rigid board insulation along the lower side of the truss bottom chords. The insulation in effect creates a ceiling in the barn. Using the ceiling as an upper boundary, the cross sectional area of the barn is calculated to be approximately 1,730 ft². Multiply the desired air velocity of 500 fpm by the cross sectional area to get a product equal to 865,000 cfm. Now, check to see if this provides sufficient air exchange in the barn.

Multiply 1,000 cfm/cow by 500 cows to get 500,000 cfm. For this example, a design based on providing the desired air velocity governs. Cumulative fan capacity should be 865,000 cfm.

Now, let's increase the number of cows in the barn to 950. Since the barn cross sectional area perpendicular to airflow does not change by adding cows (only the length), the fan capacity to achieve desired air velocity does not change. However, this number of cows requires 950,000 cfm of air (1,000 cfm/cow x 950 cows) to satisfy the requirements of air exchange. In this case, air exchange, not air velocity, governs design. For this case, cumulative fan capacity should be 950,000 cfm.

Sizing Inlets

The size of an air inlet must have sufficient opening so the required air volume can enter a barn without encountering excessive resistance to flow from friction and turbulence. Higher resistance creates increased static pressure conditions within a barn and decreases effective fan capacities. Inlets are best sized to provide a minimum of 1 ft² of area for every 400 cfm of fan capacity. Try never to exceed 700 cfm per 1 ft² of inlet area.

Using the calculated fan capacity for the example above, the minimum required inlet area can easily be calculated. For the condition where air velocity governs design, the minimum



required inlet area should be 2,162 ft² (865,000 cfm/400 cfm per ft²). If air exchange controls design, then the minimum required inlet area is 2,375 ft². (950,000 cfm/400 cfm per 1 ft²). Both of these inlet areas exceed the cross sectional area of the barn (approximately 1,730 ft²).

In practice, the inlet is best achieved by providing as much open area as available on the endwall opposite the tunnel fans. A well-designed inlet for a large freestall barn is shown in Figure 2. The endwall gable truss and four trusses adjacent to the endwall truss have a different design than the other trusses in the barn. This allows additional air to enter through the gable curtain below the ceiling. Ideally, additional lower endwall cladding could be removed so as much air as possible will enter at cow level.

Figure 2. Inlet for a tunnel-ventilated 6-row freestall barn.



Selecting and Locating Fans

Only quality, high efficiency fans should be selected for tunnel ventilation systems. Quality fans help ensure reliable performance. Efficient fans save on energy usage, although they typically cost more to purchase. Payback time varies based on the number of hours per year fans are operated and the cost of electrical power at the given location.

Fan efficiency, expressed as cfm/watt, is determined by comparing the volumetric output (cfm of air) to the electrical input (watts). Moderate sized fans (36 and 48 inches) will have a rating of approximately 17 cfm/watt at operating pressure. Large fans (51 to 60 inches in diameter) generally have the higher rated efficiencies—approximately 19 to 21 cfm/watt. Since airflow demands of freestall barn tunnel ventilation systems are high, large fans are recommended for all new construction and retrofit applications.



Tunnel fan capacity should be selected based on an operating static pressure of 0.15" water gauge (wg) to ensure design air velocity and air exchange rates are achieved. Large negative pressures (pressure > 0.15" wg) in barns under tunnel ventilation conditions are a good indicator of inadequate inlet area.

Fans should be located across one gable end wall of the barn. In order to maximize airflow across cows' bodies, locate as many fans as possible close to the barn's floor level. Additional fans required should be stacked above the first row, again, keeping subsequent rows of fans as low as possible. Avoid placing fans above the center door on a drive-through style barn. Fans located in this position may cause air to move down the center and high above the feed alley. This does not provide maximum benefit to the cows.

Fan Safety

Large tunnel fans are usually belt-driven by multiple horsepower motors and have heavy-duty metal or aluminum blades. Contact with rotating blades is dangerous. Care must be taken to eliminate potential contact by humans and cows alike. Removable screens, usually available from fan manufacturers, should be installed on both the inflow and outflow sides of the fans. Providing additional space between the cow zone and fan inlets creates a designated area for fan maintenance and enhances safety. This space can be incorporated into the barn design by adding 3 to 4' to the barn length and installing gates or fencing to develop a work area between the barn endwall and the cow zone.

Fan Controls

Since tunnel ventilation is a summer-time ventilation system and air ambient conditions vary significantly throughout the summer, controls should allow for adjustment of tunnel fans to accommodate changes. Successful operation is fully dependent on proper fan control. It is recommended that a pre-defined bank of tunnel fans be turned on at a barn air temperature near 65 to 68°F. (A bank is several individual tunnel fans that are controlled together.) Additional banks of fans are subsequently turned on at designated temperature intervals until all fans are operational at 71 to 74°F. This process is defined as fan staging and can be accomplished manually or automatically.

Manual Control

Manual control requires frequent attention by designated individuals who have been trained in the principles and operation of a tunnel ventilation system. System performance can be significantly compromised by human inattention or error. Changing weather conditions can require frequent or abrupt changes in tunnel stages and may happen when no trained operator is available. For these reasons, a tunnel system is better suited for automatic control.

Automatic Control

Automatic controls are more reliable from a day-to-day perspective, but require scheduled preventive maintenance to ensure proper, continuous operation. Good performance results from properly locating the sensor that provides input to the controller. Sensors



should be located so they "sense" the air that represents the condition within the barn **at cow level**. Sensors should be placed so that they are not affected by solar radiation or extreme localized conditions resulting from system short-circuiting.

Automatic control can be accomplished using off-the-shelf stage controllers available from several ventilation companies. The temperature at which the first bank of tunnel fans turn on and the bandwidth (temperature interval) between stages are a few of the variables that can be manually adjusted with most stage controllers. Also, remember that the barn's curtain system is used as the first stage of ventilation.

Staging and Louvers

It is important to note that the staging of tunnel fans, either automatically or manually, requires the use of mechanical or static pressure-activated louvers on the inlet side of each fan. Each louver should open when its fan turns on and closes when it turns off. Operating in this fashion, the louver will keep the system from short-circuiting by preventing air traveling in the reverse direction through a non-operating fan.

Sidewall Management

Since tunnel ventilation is a summertime only ventilation system, another means of providing air exchange must be in place the remainder of the year. Natural ventilation is the most logical choice. It needs to be properly designed into a tunnel ventilated freestall barn.

Natural ventilation requires curtain sidewalls to act as air inlets and air outlets. When employing tunnel ventilation in freestall barns, theoretically curtain sidewalls should be completely closed to form the "tunnel." Observation of cow response indicates that insufficient air movement may take place in the rows of stalls adjacent to a completely closed sidewall. Subsequent field measurements have shown that barns with solid sidewalls or curtain sidewalls that are fully closed have little or no air movement along the outer row of stalls and outer alley. Opening the curtain walls slightly (approximately 2 to 4") by raising the lower curtain from the bottom allows a small amount of air to enter along the length of barn at cow level. Although this is contrary to tunnel ventilation theory, opening the sidewalls is necessary in order to create some airflow along stalls on the outside walls, particularly where velocity distribution is non-uniform.

Unique Barn Needs

Some tunnel-ventilated barns have specific, unique needs to maximize air quality and air velocity at cow level depending on their initial design. These needs can include air baffles and manure gas protection.

Air Baffles

Barns with high ceilings tend to have large amounts of air movement close to the ceiling. Air initially flowing down the barn at cow level collides with cows, stalls, waterers, etc., and subsequently rises to go past the obstacle. Once the air rises, field measurements have shown that a large portion of it will stay high in the barn until reaching the tunnel fans. This



occurs unless an air deflector or baffle is installed to redirect the air back towards cow level. One barn has benefited from placing horizontal air baffles laterally across the barn at approximately 100-foot intervals. Six-foot high baffles were constructed from traditional curtain wall material and supported by a cable and turnbuckle system to create each baffle. Observation of the airflow through the barn subsequent to baffle installation indicates that the air baffles would provide even more benefit if spaced closer together.

Reducing the ceiling level will result in increased volumes of air traveling through a given cross sectional area in a given barn if the number of tunnel fans remains the same. However, a lower ceiling is not desirable with barns naturally-ventilated the remainder of the year. This suggests that dairy barn design may have to change fundamentally to year-round mechanical ventilation, if economically feasible, in order to provide a barn geometry design that addresses the severe problems in summer conditions.

Manure Gas Protection

Freestall barns with liquid manure drops to gravity gutters located below the barn floor need special attention during planning and design to minimize manure gas flow from storage back into the barn.

Gravity flow discharge pipes that are always submerged below the free water surface in storage need no additional attention. The lack of air movement through the pipe will prevent meaningful gas flow into the barn. However, gravity flow pipes that are not always submerged have the potential of transferring large volumes of gases back into the barn when they are above the free water surface. Rigid rubber or other inert material can be used to develop a flapper that will help to seal off the pipe. As an additional preventive measure, locate the discharge of a gravity flow pipe as far away as possible from designated agitation sites. Significant concentrations of gases are typically released during manure agitation, especially at the site of the agitation device.

Tunnel Ventilation Economics

Tunnel ventilation systems have measurable capital and operating costs above that of a natural ventilation system. The net return on investment for a tunnel ventilation system is a function of how well cows maintain milk production for an adequate number of days in a tunnel-ventilated barn each summer as compared to a naturally ventilated shelter. The additional cost of purchasing, installing, operating, and maintaining the tunnel system must be offset by sustained milk production in order for the investment to deliver a positive return. It is becoming more crucial to determine if an investment on a dairy farm will have a positive rate of return in a reasonable period of time.

Cash Flow Analysis

A complete cash flow analysis of a tunnel ventilation system is complex and difficult to fully quantify. While an analysis of the fixed and operating costs associated with the tunnel system can be quantified, an accurate analysis of the cow is much more challenging. The complexity of measuring a cow's complete biological response to heat stress combined



with the lack of performance data to develop economic loss predictions makes this difficult. An analysis that shows a positive cash flow projection based on sustained milk production alone would be a conservative analysis of the investment. If other less tangible benefits are realized, an increased positive impact of the decision would be seen.

When performing a cash flow analysis for tunnel ventilation the first step is to determine the equipment needed to outfit a barn with tunnel ventilation and calculate the cost to operate and maintain this equipment over a realistic payback period. This information then can be used to determine the threshold value of milk production required for a break-even return. The results can be interpreted by the number of fan days (1 fan day = 24 hrs. of continuous fan operation) of operation per year. A sustained production level above the calculated threshold value would lead to greater cash generation from the investment while a value below would lead to supplemental cash required from other aspects of the business to pay a portion of the investment and operating and maintenance costs.

The break-even production levels shown in Table 1 were calculated using an energy efficient tunnel fan system for common barn configurations. A fan purchase price and installation cost of \$1,170 and \$400 per fan were used. The daily required sustained production in lbs./cow/day ranges from 12.1 to 2.7 for a 2-row barn, from 16.1 to 1.8 for a 3-row barn, from 16.1 to 2.4 for a 4-row barn, and from 19.1 to 2.2 for a 6-row barn.

Table 1. Pounds of milk per cow per day required to break-even using an energy efficient tunnel fan system. Analysis based on a five-year pay back period, interest rate of 8 percent, and no changes in operating costs due to inflation. Gross milk price = \$12 per Cwt. and energy cost = \$0.10/kW-hr.

No. of Cows ¹	Extra Benefit Days ²	Barn Configuration															
		2-Row				3-Row				4-Row				6-Row			
		Average No. of Fan Days ³ /Year Operating Over 5 Years				Average No. of Fan Days ³ /Year Operating Over 5 Years				Average No. of Fan Days ³ /Year Operating Over 5 Years				Average No. of Fan Days ³ /Year Operating Over 5 Years			
		50	100	150	200	50	100	150	200	50	100	150	200	50	100	150	200
100	20	12.1	8.9	7.6	6.9	16.1	11.9	10.1	9.2	—	—	—	—	—	—	—	—
	40	9.4	7.6	6.8	6.3	12.5	10.2	9.1	8.4	—	—	—	—	—	—	—	—
	60	7.7	6.7	6.2	5.8	10.3	8.9	8.2	7.8	—	—	—	—	—	—	—	—
	80	6.5	5.9	5.6	5.4	8.7	7.9	7.5	7.2	—	—	—	—	—	—	—	—
200	20	6.0	4.5	3.8	3.4	8.1	5.9	5.1	4.6	16.1	11.9	10.1	9.2	19.1	14.5	12.4	11.2
	40	4.7	3.8	3.4	3.2	6.3	5.1	4.5	4.2	12.5	10.2	9.1	8.4	15.3	12.4	11.1	10.3
	60	3.8	3.3	3.1	2.9	5.1	4.5	4.1	3.9	10.3	8.9	8.2	7.8	12.5	10.9	10.0	9.5
	80	3.3	3.0	2.8	2.7	4.3	4.0	3.7	3.6	8.7	7.9	7.5	7.2	10.6	9.7	9.1	8.8
400	20	—	—	—	—	4.0	3.0	2.5	2.3	8.1	5.9	5.1	4.6	9.8	7.2	6.2	5.6
	40	—	—	—	—	3.1	2.5	2.3	2.1	6.3	5.1	4.5	4.2	7.6	6.2	5.5	5.1
	60	—	—	—	—	2.6	2.2	2.1	1.9	5.1	4.5	4.1	3.9	6.3	5.4	5.0	4.7
	80	—	—	—	—	2.2	2.0	1.9	1.8	4.3	4.0	3.7	3.6	5.3	4.8	4.6	4.4
600	20	—	—	—	—	—	—	—	—	5.4	4.0	3.4	3.1	6.6	4.8	4.1	3.7
	40	—	—	—	—	—	—	—	—	4.2	3.4	3.0	2.8	5.1	4.1	3.7	3.4
	60	—	—	—	—	—	—	—	—	3.4	3.0	2.7	2.6	4.2	3.6	3.3	3.2
	80	—	—	—	—	—	—	—	—	2.9	2.6	2.5	2.4	3.5	3.2	3.0	2.9
800	20	—	—	—	—	—	—	—	—	—	—	—	—	4.9	3.6	3.1	2.8
	40	—	—	—	—	—	—	—	—	—	—	—	—	3.8	3.1	2.8	2.6
	60	—	—	—	—	—	—	—	—	—	—	—	—	3.1	2.7	2.5	2.4
	80	—	—	—	—	—	—	—	—	—	—	—	—	2.6	2.4	2.3	2.2

¹ No. of cows = total no. of lactating cows in the barn.

² Extra Benefit Days = additional days of sustained production; the number of days subsequent to tunnel shut down that positively affect the cows' milk production.

³ A fan day is defined as all fans operating in the barn continuously for a 24-hour period.

The maximum and minimum values from Table 1 based on a percent of daily milk



production are shown in Table 2 for various daily herd averages. High producing cows, which have the potential to be more adversely affected due to heat stress than lower producing cows, require less sustained milk production to achieve a break-even investment.

Table 2. Percent of total production required to break-even for daily production levels ranging from 70 to 100 lbs./day per cow using the range of values shown in shown in Table 1.

Barn Configuration	Required Production From Table 1.		Daily Average Production For The Herd							
			70 lbs./day cow		80 lbs./day cow		90 lbs./day cow		100 lbs./day cow	
	(max)	(min)	(max)	(min)	(max)	(min)	(max)	(min)	(max)	(min)
2 - Row	12.1	2.7	17.3	3.9	15.1	3.4	13.4	3.0	12.1	2.7
3 - Row	16.1	1.8	23.0	2.6	20.1	2.3	17.9	2.0	16.1	1.8
4 - Row	16.1	2.4	23.0	3.4	20.1	3.0	17.9	2.7	16.1	2.4
6 - Row	19.1	2.2	27.3	3.1	23.9	2.8	21.2	2.4	19.1	2.2

Unanswered Questions

Continued industry interest in employing tunnel ventilation for large freestall barns is evident. Tunnel ventilation system designers have a unique challenge since complete design information is not available. Dairy producers and ventilation system operators need additional guidelines that will allow them to make better-informed management and operational decisions. Pertinent questions that currently are unanswered include:

1. What is the practical length a barn can be tunnel-ventilated?
2. How can uniform air velocity at cow level in the barn be best maintained?
3. What are the optimal settings for automated controls?
4. What is the true cost/benefit ratio for tunnel-ventilated barns?

Other Considerations

Producers using tunnel-ventilated freestall barns should consider an appropriately sized standby power source to provide back-up power to the tunnel fans and their control system during power outages. Standby power generators are normally needed on dairy farms to ensure uninterrupted electrical service to milk harvesting and cooling equipment. Including the electrical loads of the tunnel fans when sizing back-up generators will help to ensure continuous fan operation during periods of lost utility power.

Another consideration is to install an alarm system that alerts farm employees if electrical service is interrupted to the tunnel fans. Alarm systems are highly recommended for any barn that relies on mechanical ventilation year round. Cows in these barns are subject to adverse air and temperature conditions soon after tunnel fans stop running. An evacuation plan should be in place to remove cows from the barn if needed. Minimally, automatic curtain drops need to be in place in the event of mechanical power failure. This is standard and required equipment on modern poultry houses.



SUMMARY

Determining the most appropriate ventilation system for your facility is specific from structure to structure, just like balancing rations vary from cow group to cow group. A naturally ventilated structure that provides adequate air exchange and is outfitted with cooling fans placed over rows of stalls and feeding area remains the preferred system at this time. However, new and existing structures alike can greatly benefit from the implementation of tunnel ventilation that would otherwise provide poor cow environmental conditions. Tunnel ventilation can be cost effective for all common barn layouts that house an adequate number of cows, making it economically feasible.