Ventilation: Why, When, and How

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Why do we ventilate animal housing?
A ventilation system has three roles it must fulfill to be successful. It must provide fresh air, remove excess moisture and gases, and control the temperature. If the system does not complete these three functions it will fail!

Properties of Air
To understand ventilation of animal housing, first there are some properties of air that need to be understood. First is temperature. This should need no explanation; the dry bulb temperature is used to evaluate and control the ventilation system. Second is relative humidity. This is a percentage value of the amount of water presently in the air versus the amount of water the air can hold at a given temperature. A very important property to understand is that as the temperature rises the relative humidity will fall unless moisture is added to the air. The third property is air density. Air density is measured in pounds per cubic foot of air. As the air temperature rises its density decreases making the air lighter. This phenomenon is known as "Thermal Buoyancy".

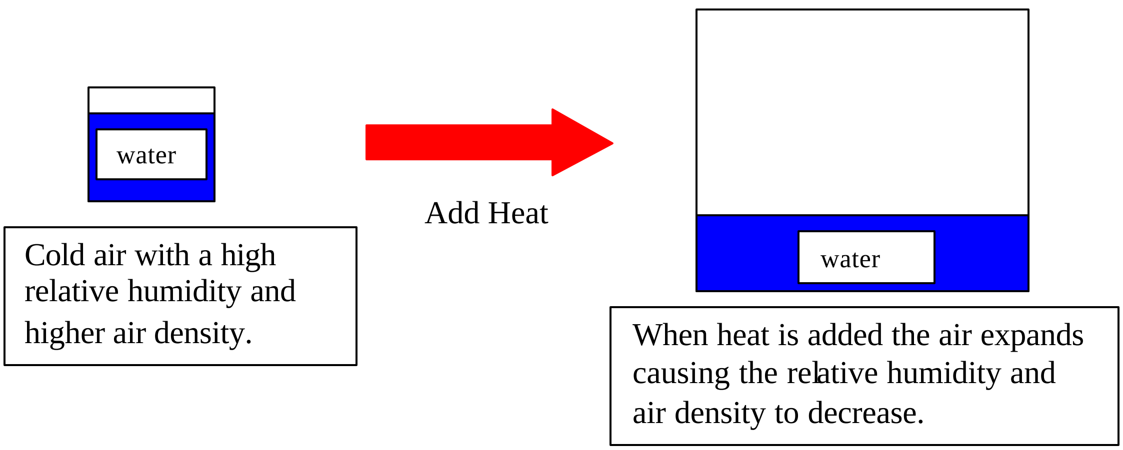

Figure 1. The effect of adding heat on relative humidity and air density of a pound of air.

Ventilation Theory

Animals produce heat, moisture, and other gases that must be removed from the environment to maintain healthy conditions. So a properly operating ventilation system must: 1) Bring fresh air into the building through planned openings 2) Thoroughly mix outside and inside air, picking up heat, moisture, and air contaminants, while lowering temperature, humidity, and contamination levels, and 3) Exhaust the moist, contaminated air from the building. Therefore a ventilation system must have two things, an inlet and an exhaust.

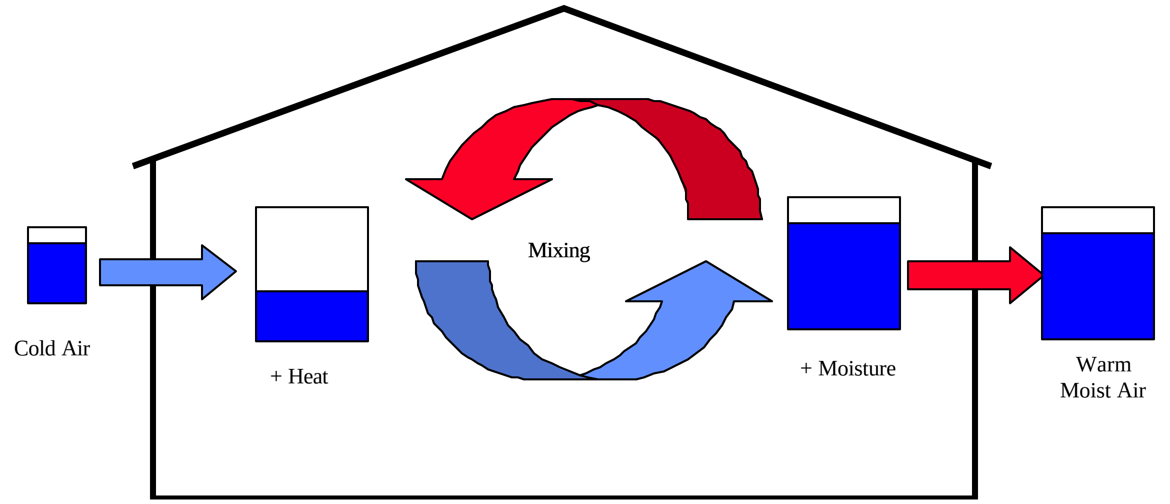

Figure 2. A properly working ventilation system.

Ventilation Rates

How much ventilation is needed? Ventilation rates are based on preferred housing conditions, climatic conditions, and the heat and moisture produced by the animals being housed. Remember the ventilation system is for the animals not for the worker. (ie Think like a cow.)

Production of dairy cattle is general not effected by cold weather. A Holstein cow's production potential remains at 100% at temperatures below 15°F. However, excess moisture must be removed from the building to maintain air quality.

Table 1 shows the heat and moisture production of a 1300-pound Holstein dairy cow. The table shows that even at temperatures around freezing each cow is still producing about one pound per hour of moisture that must be remove from the barn. The table also shows that while the moisture production increases as the temp rises the cows ability to lose sensible heat to the surrounding air is dramatically decreased. This factor is very important when considering hot weather ventilation.

Air Temperature (°F)	**Moisture Production (Lbs H_2O/hr)**	**Sensible Heat Production (BTU/hr)**
30	1.00	3830
50	1.30	3024
59	1.69	2419
70	1.69	2217
81	2.34	1209

Table 1. Moisture and heat production of a 1300-pound Holstein dairy cow. (Adapted from ASAE Standard EP270.5 DEC94)

Ventilation Seasons and Rates

The above discussion of temperature vs moisture and heat production leads to the development of ventilation rates bases on "ventilation seasons". There are three ventilation seasons to deal with: cold, mild, and hot weather. Cold weather or winter ventilation must provide fresh air while removing excess moisture and gases, and is driven by moisture balance. Mild weather or spring and fall ventilation must modify the temperature and removes moisture. This is driven by heat balance. Hot weather or summer ventilation reduces heat buildup and increases air movement in the barn. The goal is to be within 5°F of outside temperature. The increased air exchange and movement in the barn during hot weather is critical, because of the animals decreased ability to lose sensible heat during high temperatures.

Ventilation Season	**Ventilation Rate (cfm/cow)**
Cold	50
Mild	200
Hot	500 to 1000

Table 2. Recommended minimum ventilation rates for dairy housing. These values are based on heat and moisture balances with general assumptions of weather conditions.

Types of Ventilation

There are two basic types of ventilation, mechanical and natural.

Mechanical ventilation forces air exchange with the use of fans and controlled inlets. There are also three different types of mechanical ventilation systems, negative pressure, positive pressure, and neutral pressure.

Negative Pressure

When mechanical ventilation is used in dairy housing it is most often a negative pressure system. In this system fans are used to draw stale air out of the building, lowering the internal pressure, and causing fresh air to enter through well designed and distributed inlets throughout the barn.

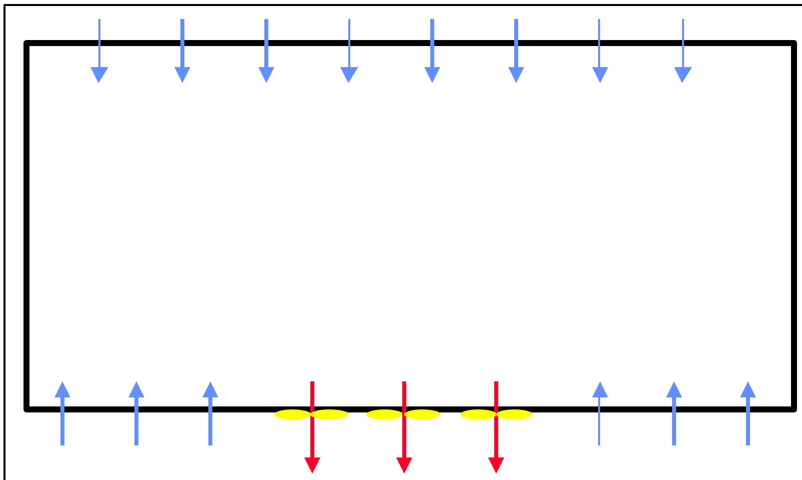

Figure 3. Typical negative pressure system.

Mechanical ventilation rates for each season are determined by heat and moisture balance to maintain healthy conditions inside the barn. Table 2 gives ventilation rates that are based on heat and moisture balances with general assumption of weather conditions. Exact fan sizes are than determined by matching these ventilation rates to the capacity of different size fans. It is recommended to use fan capacity ratings providing by the manufacture due to variation between brands. However, Table 3 gives general fan capacities based on fan size. In large building fans can be installed in banks to break up the barn into smaller ventilation "zones". Also to provide uniform ventilation there should be no more than 75ft between an inlet and a fan.

Fan Size (inches)	**Fan Capacity (cfm)**
12	1,600
14	1,800 to 2,200
16	2,400 to 2,900
18	3,500
20	4,000
22	4,500
24	5,000 to 6,000
36	10,000
48	20,000

Table 3*. Fan capacity based on fan size. (Developed from "Agricultural Ventilation Fans")
* Manufacture ratings at 0.01 inches of water should be used whenever possible.

Inlet Design and Location

Proper inlet design and placement is critical for the proper operation of a negative pressure ventilation system. Air must be brought in around the entire perimeter of the building and thoroughly mixed with the stale air inside the barn. In order to avoid cold air drafts and promote mixing inlet air is drawn through the inlet at approximately 800 to 1000 feet per minute (fpm). To reach this high air speed the design rule is to provide 1 ft^2 of inlet for every 500 cubic feet per minute (cfm) of fan capacity. As the ventilation rate increases the inlet area most also increase or the fan will become "starved" for air. The measurement of static pressure can be used to evaluated inlet sizing. Static pressure should be maintained at of 0.04 to 0.06 in of water. A common problem is the lack of inlets, they are either not there or they are improperly adjusted.

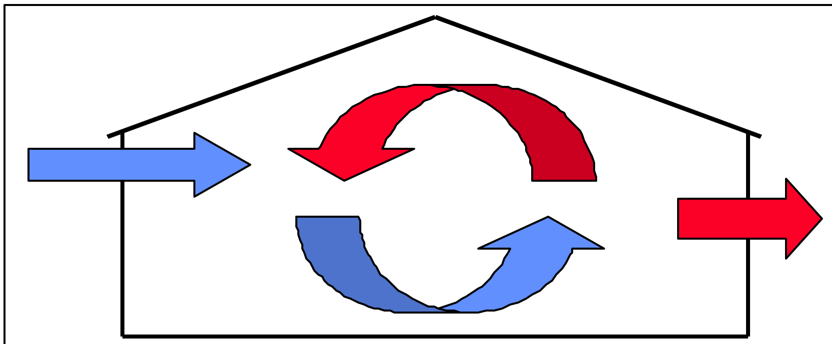

Figure 4. High inlet speeds promote mixing.

The placement of these inlets is also critical. Inlets should be located so that air enters and is thrown along the ceiling allowing it to mix with the warmer air inside the barn before it settles to animal level. Inlets should be placed all along the perimeter of the building to allow for even distribution of the air. However, inlets should not be placed within 8ft of an exhaust fan. If the inlet is too close to the fan the ventilation system will “short circuit”.

Positive pressure

In a positive pressure system fans force fresh air into the building through area inlets or duct(s) creating a positive indoor pressure. Air is exhausted through doors, windows, or other openings around the building. This type of system is often used in “clean room environments”. While positive pressure systems provide good air distribution they also can force moist air into walls and attic space where moisture can condensate on colder surfaces. Ventilation rates are determined using the same heat and moisture balances as before. Provide 1 ft^2 of exhaust area per 600 cfm of fan capacity.

Neutral pressure

A neutral pressure system is a hybrid of negative and positive pressure systems. While one fan pushes fresh air into the building through a duct(s) another fan exhausts the stale air.

Natural Ventilation

Natural ventilation just doesn’t happen naturally, it must be planned for if it is to work correctly. Natural ventilation uses local natural air currents along with temperature differences between the inside and outside of the building to move air through the structure. While the desired ventilation rate is the same as in a mechanically ventilated structure it is not as simple as selecting fans. The actual ventilation rate is a function of the temperature difference between inside and outside, local air speeds, roof slope, size and placement of openings, and orientation of the building with respect to prevailing wind direction.

One of the large drivers of natural ventilation is “Thermal Buoyancy”. As the air inside a barn is heated by the animals giving off excess heat it becomes lighter and begins to rise. As the air rises and exists the barn through the ridge opening is will create a draw or slight negative pressure on the barn, much like a chimney of a fireplace, which than pulls fresh air into the building. In order to maximize the effect of this a minimum roof slope of 4:12 is recommended to help encourage the warm moist air to “drain” toward the ridge opening.

The second large driver is natural air speed. This effects ventilation is two ways; first as air crosses the ridge opening it will create a slight draw to the ridge opening thus pulling air out of the barn. Secondly as sidewall openings are increased air simply travels through the barn. For this reason it is recommended to orient a naturally ventilated barn perpendicular to prevailing winds to maximize these effects. Exposure of the barn to these local winds is also critical. Naturally ventilated barns are best located on high ground with open space around the building. It is recommended to allow a minimum of at least 50 ft from silos and 75 ft from other buildings. An obstruction can disturb airflow at a distance of 5 to 10 times its height.

During the winter season natural ventilation is driven mostly by “Thermal Buoyancy” where warm moist air is exhausted out the ridge opening and cold dry air is drawn in the eave openings.

As wind speed increases so does the negative pressure at the ridge opening, which increases the ventilation rate. Therefore wind speed is also important in winter ventilation. For winter ventilation the ridge opening should provide 2 inches to 3inches of continuous opening per 10 ft of building width, and eave openings, equal in size to the ridge opening, should be provide high on both sidewalls.

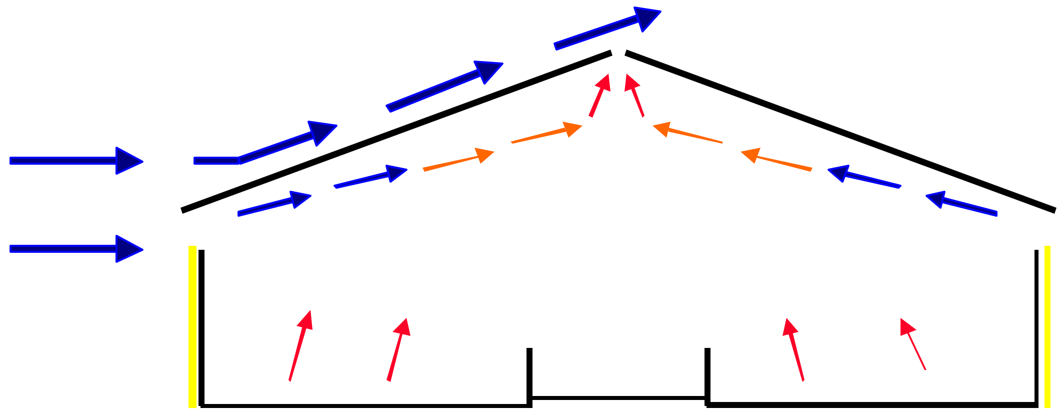

Figure 5. Ventilation in the winter is driven mostly by "Thermal Buoyancy", along with airflow over the ridge.

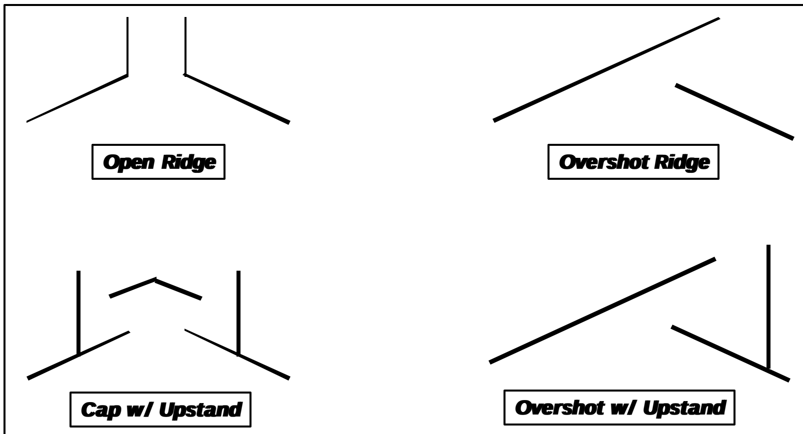

Figure 6. Various ridge treatments.

During the summer season natural ventilation is driven mostly by wind speed. Thermal Buoyancy is decreased due to the limited temperature difference between the indoor and outdoor air. Therefore during summer ventilation you need to maximize the wall openings, both sidewall and endwall. With a given wind speed of 5 mph, the ventilation rate can be doubled by going from a 6 ft opening to a 10 ft opening.

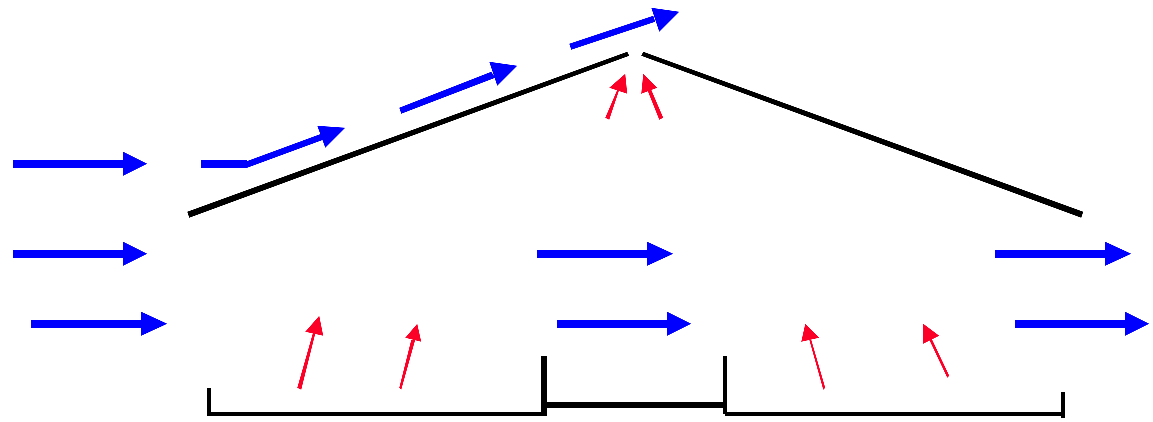

Figure 6. Ventilation in the summer is driven mostly by mostly by wind speed.

However, the amount of opening is not always as they seem. Due to structural components and screening the effective opening can be reduced by a much as half. Select curtain screen that is made with thin metal wire to give a larger effective opening. Also be very careful about how stalls, curtain hardware and structural components or mounted so as not to block the opening.

During mild weather use sidewall curtains to adjust the ventilation rate dependent on temperature of the barn. Using automatic curtain controllers can help maintain a more desirable and content air quality than manual controls.

Heat Stress

There is a misconception that the environment humans feel comfortable in, cows will feel comfortable in. Therefore it has been traditional to design for winter conditions. This has lead to barns that stay warm in the winter (for workers) and are unbearably hot in the summer for anybody to work.

Dairy cattle in general prefer a cooler environment then do humans. There high body weight to surface area ratio limits their ability to give off heat. Combine this with the huge furnace capability of the rumen and it's pretty easy to see why cows like cooler weather and why summer heat is harder on their production then are the blizzards in January.

Dairy cows prefer temperatures from about 30°F to 75°F, and can hold production in temperatures below 15°F. However, cows start to experience heat stress at about 78°F, with normal relative humidity levels. Cows can stand to be exposed to higher temperatures for short periods of time during the day if they are allowed to cool off at night.

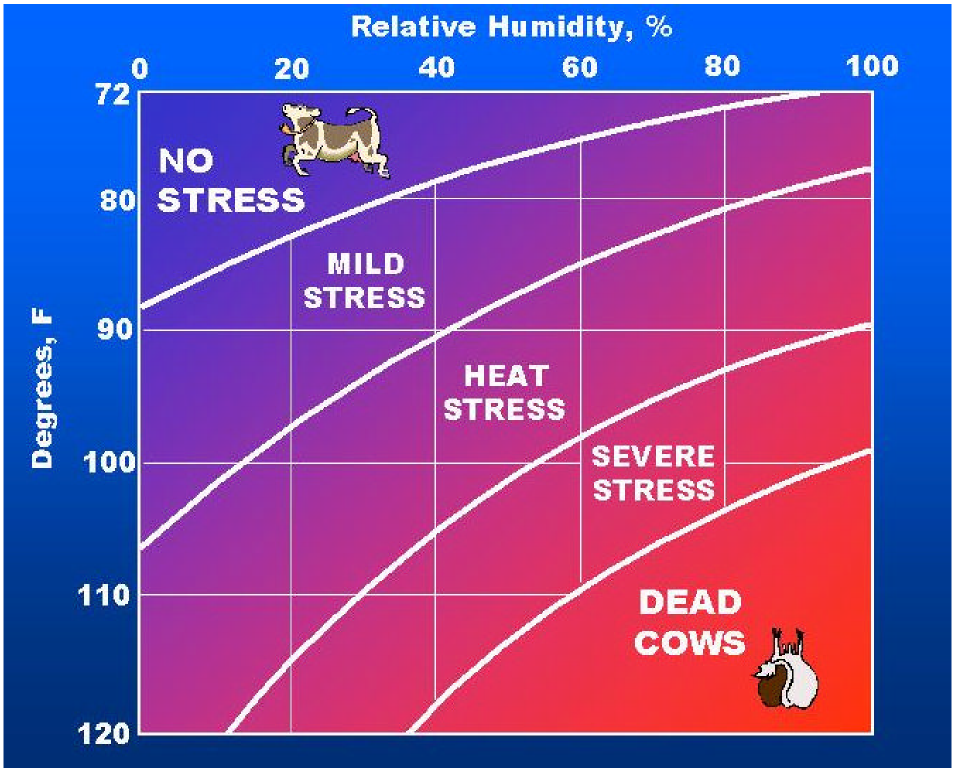

Figure 7. The Temperature Humidity Index (THI) combines the air temperature with the humidity level. This can be used to judge the potential amount of heat stress.

When Are Cows In Heat Stress?

If rectal temperatures of 8 out of the 10 cows are above 102.5° F, cows are in heat stress.
or
If respiration rates in breaths per minute are over 80 per minute, cows are in heat stress.
or
If dry matter intake and milk production drop 10% in hot weather, cows are in heat stress.

SAAW

SAAW is an acronym used to remember the four basics to hot weather cow care. Providing these four basics will help the cow to increase her natural cooling ability during the summer and fight off heat stress related production drops and conception problems.

Shade is the first step to improving heat stress. Bring the cows out of the intense summer sun. This lowers the solar heat load on the animal and therefore she has less heat to lose. Natural shade, shade structures, or a well ventilated barn are all suitable.

Air velocity increases the natural cooling ability of the animal by carrying away the hot air close to the skin and allowing fresh cooler air to replace it. 308 to 440 feet per minute (3.5 to 5 mph) is the recommended velocity.

Air velocity can be increased in an open, natural ventilated barn with the use of circular fans. A general rule is that fans can throw air about ten times their diameter. Therefore the placement of fans depends on their size, 3 ft fans should be placed about 30 ft apart and 4 ft fans about 40 ft apart. Hang the fans high enough to allow equipment clearance and aim them slightly down toward the animal's backs. In enclosed structures tunnel ventilation is often used. See Penn Sate Agricultural Engineering Factsheet G-78 "Tunnel Ventilation for Tie Stall Dairy Barns" for more information.

Air exchange removes the hot, moist air from around the animal and from the building along with providing fresh air. 500 to 1000 cubic feet per minute (cfm) per animal is the recommended exchange rate.

Water is the most important ingredient in milk. During summer heat cows will increase their water intake by as much as two fold. However, this extra water is first utilized in cooling through respiration and sweating. Any left over will be used to produce milk. Add extra waterers that are easy to access and protected from the summer heat.

Water can also be used to aid in the direct cooling of cows. Two systems commonly used are misting systems and sprinkler systems. In a misting system a fine aerosol type mist is injected into the air stream where it evaporates and cools the air that is then circulated around the cow. For proper performance of a misting system it is very import that the water droplets are small enough to evaporate before hitting the animal. Therefore these systems should be operated at a high pressure (600 to 1200 psi) to insure this small droplet.

Sprinkler systems actually wet the cow to the skin and than use the BTU's produced by the cow to evaporate this water, thus removing heat directly from the cow. For more information on sprinkler systems see the article titled "Sprinkler Systems for Freestall Barns".

Conclusion

Since animals produce heat, moisture, and other gases a ventilation system must be used to remove these from the environment to maintain healthy conditions. A properly operating ventilation system must: 1) Bring fresh air into the building through planned openings 2) Thoroughly mix outside and inside air, picking up heat, moisture, and air contaminants, while lowering temperature, humidity, and contamination levels, and 3) Exhaust the moist, contaminated air from the building. If the system does not complete these three functions it will fail!

The design and operation of the ventilation system needs to be based on preferred housing conditions for the animals, climatic conditions, and the heat and moisture produced by the animals being housed. Remember this ventilation system is for the animals not for the worker. Think like a cow.

10/5/02 jtt

Ventilation Evaluation Checklist

Fill out the following checklist during a walkthrough of the barn. Areas of this evaluation that are marked no may be areas of the ventilation system that need to be addressed.

Air Quality

Evaluation Area	**YES**	**NO**
Temperature		
Inside temperature:		
Outside temperature:		
Is the temperature difference between inside the outside less than 10°F?		
Humidity		
Indoor relative humidity:		
Outdoor relative humidity:		
Is indoor humidity below 80%?		
Is indoor humidity between 50% and 60%?		
No evidence of past excess moisture (ie water stains on walls, ceiling, rafters, etc.)		
No condensation on walls, ceiling, or roof		
No “dripping” water		
Odor		
No a strong build up of odor in the barn “If it smells like a barn it needs more ventilation”- Bob Graves		
Air Distribution		
No “dead zones” of little or no air exchange		

Natural Ventilation

Evaluation Area	**YES**	**NO**
Building Location		
High ground		
Open to wind		
No surrounding building within 50 ft		
Sidewall height		
10 ft minimum		
12 ft for lower density building		
14 ft to 16 ft for high-density building		
Sidewall opening		
Open from eave to floor		
Minimum wire size for max opening of bird netting used		
Minimum blocking by stall or building structure		
Easily opened and closed for spring/fall season adjustment		
Ridge Opening or Chimney		
2” per 10ft of building width for lower density		
3” per 10ft of building width for high density		
If chimney vents used do they provide 1ft^2 open per 100ft^2 of floor area and spaced no more than 50 ft apart		
Endwalls		
Can they be opened for summer ventilation?		

Mechanical Ventilation

Ventilation Rate Worksheet

Season	**Rate (cfm/cow)**	**No. cows**	**Total cfm**
Cold	50		
Mild	200		
Hot	1000		

Inlet Sizing Worksheet

Season	**Inlet Needed (1ft^2/500cfm)**
Cold	
Mild	
Hot	

Evaluation Area	**YES**	**NO**
Fan Size		
Fans properly sized to match the needed ventilation rates		
Inlet Size		
Inlet properly sized to match ventilation rate		
Inlets are adjustable		
Fan Location (distribution)		
No more than 75 ft from inlet		
Fan Maintenance		
Are fan shutters and blades clear of dirt and debris? Dirty shutters can reduce fan performance by 40% and also increases power usage by 40%		
Is belt tension properly adjusted (if applicable)?		
Inlet location		
Located around perimeter		
Not within 8 ft of fan		
Controls		
Controls located in an area of the barn that is representative of the barn		
Thermostats working as set		
Are fans properly staged to match ventilation rates?		
Static Pressure		
Static pressure (inches of water):		
Is static pressure between 0.06" and 0.10" of water?		
Fans not "starved" for air		
Doors not "pulled" from your hand and are easy to open.		
Air Distribution		
No "dead zones" of little or no air exchange		

Heat Abatement

Natural Ventilation with Fans

Evaluation Area	YES	NO
Natural Ventilation		
Maximum side and endwall openings		
Ridge vent open		
2” per 10 ft of width for low density		
3” per 10 ft of width for high density		
Fans		
Spaced no more than 10 times their diameter		
Located over every row of stalls and feed bunk		
Located and adjusted to move air over cows back		
Tilted down to hit the cows		

Tunnel Ventilation

Ventilation Rate (cfm) = Width (ft) x Height (ft) x 308 fpm

____________________ = _________ x _________ x 308 fpm

Inlet Size (ft^2) = Rate (cfm) x 2.0ft^2 ÷ 1000cfm

____________ = _________ x 2.0ft^2 ÷ 1000cfm

Evaluation Area	YES	NO
Fan Size and Location		
Are there enough fans?		
Is there a minimum of 1000 cfm per cow?		
All located at one end of the barn		
Fans Properly Maintained		
Free of dirt		
Belt adjustment		
Louvers cleaned and maintained		
Inlet		
Is minimum inlet size provided?		
Entire inlet located at opposite end of the barn from fans		
Sidewall and ridge closed		
Baffles installed at ~30ft intervals in applicable		

Cooling Systems

Misting System

Evaluation Area	YES	NO
Fans are in use when system is on		
No or little dripping from nozzles		
Producing fine mist		
Mist is evaporated into the air and DOES NOT hit animals or floor		
System can be shut down during high humidity nights		
Filter(s) on system maintained		

Sprinkler System

Evaluation Area	YES	NO
Fans are in use when system is on		
Timer used to cycle sprinklers on and off to save water		
Large drops that penetrate cow's hair coat		
Not over wetting the cows		
System evenly covering cows in sprinkler area		
System can be shut down during high humidity nights		
Filter(s) on system maintained		

Tunnel Ventilation with Evaporative Cooling Pads

Evaluation Area	YES	NO
Tunnel ventilation system is working properly		
Inlet area is larger. (4.0ft^2 per 1000cfm)		