Title: Ventilation Assessment Starter Kit

Author: Courtney E. Halbach, MBA

The Dairyland Initiative, University of Wisconsin-Madison, School of Veterinary Medicine

Abstract

Ventilation and appropriate air speeds are essential for cow health and productivity. Ventilation ensures the removal of dust, heat, moisture, and noxious gases from the barn, while fast moving air helps mitigate heat stress in the summer. This paper outlines the recommended ventilation rates for nursing calves to milking cows, as well as discusses the ventilation design requirements, the tools and equipment needed for a ventilation assessment, and the methods for calculating ventilation rates and air speeds.

Keywords: Ventilation, Air Speeds, Assessment

Introduction to Ventilation and Air Speed Requirements

Ventilation is the provision of fresh air into a building, which displaces warm, humid, and contaminated air from the barn. Improper ventilation puts cows and calves at risk for poor respiratory health during the winter and heat stress during the summer. Therefore, it is important to exhaust dust, moisture, heat, and noxious gases from the barn at adequate ventilation rates year-round (Table 1).

Visual and sensory signs that may indicate that a barn is not properly ventilated include streaking along the purlins, cobwebs in the ceiling, cows bunching, noticeable humidity in the air, and an overwhelming smell of ammonia. In addition, cows may be panting or have an elevated breathing rate of more than 60 breaths per minute. If more than 25% of a group of cows has an elevated breathing rate after measuring the respiration rate of at least 20 cows (standing or lying down), then a significant portion of the cows is experiencing heat stress, and the ventilation and cooling system may not be working as expected, warranting further testing. Stocking density also plays a role in the barn's poor air quality. For adult cow barns, the target stocking density is one cow per stall or 100 ft^2 (9.3 m^2) of bedded pack area per cow. Calves under 400 lb (181 kg) should be provided with 35 ft^2 (3.3 m^2) of resting space per calf. Increasing resting area decreases airborne bacteria counts in the calf pen[1]. Thus, not overcrowding the barn is essential for maintaining good air quality.

There are various design requirements that should be met based on the barn's ventilation system. If the barn or system is not designed properly, then ventilation will be compromised. Naturally ventilated barns must be free of windshadows within 100 ft (30.5 m) of the barn, have tall open sidewalls, an appropriately sloped roof pitch of 1:4, a ridge that has 2 in (5 cm) of opening per every 10 ft (3.1) of building width, and open eaves that provide an opening of 1 in (2.5 cm) per every 10 ft (3.1 m) of building width along both sidewalls. Whereas mechanical systems should have controlled inlets and outlets to exchange the air year-round to meet the above requirements and provide 1,500 ft^3/min (2,550 m^3/hr) per adult cow in the summer and cross-sectional air speeds of 500 ft/min (2.5 m/s) (cross ventilated barns with baffles only).

In addition to properly ventilating the barn, it is important to provide fast moving air in the animal's microenvironment during the summer to aid with heat abatement while preventing drafts in the winter – a concern in calf barns. Air speeds greater than 100 ft/min (0.5 m/s) are considered a draft while air speeds less than 60 ft/min (0.3 m/s) are considered to be "still air"[2]. So when checking for drafts in calf barns during the winter, the goal is to have air speeds of less than 100 ft/min (0.5 m/s), ideally around 60 ft/min (0.3 m/s), at 4 ft (1.2 m) above the floor.

For heat abatement purposes, air speeds of 200 to 400 ft/min (1 to 2 m/s) are sufficient for maintaining lying times, internal body temperature, and milk production in lactating cows located in a continental climate[3], and air speeds of 400 ft/min (2 m/s) are sufficient for thermal balance in dairy calves located in a subtropical climate[4]. Fast moving air should be provided to adult cows when the temperature-humidity index (THI) is 68, and to calves located in a continental climate at a THI of 69[5] and a THI of 65 for calves housed in a subtropical climate[4]. Fans, baffles, and positive pressure tube ventilation (PPTV) systems can be installed to deliver fast moving air in the animal microenvironment. Recommendations for fan and baffle placement can be found on The Dairyland Initiative website at https://thedairylandinitiative.vetmed.wisc.edu/home/housing-module/adult-cow-housing/ventilation-and-heat-abatement/.

Tools and Equipment

Minimal tools are needed to assess ventilation and air speeds in adult cow and calf barns. To calculate barn ventilation rates, barn dimensions such as length, width, and maximum and

minimum sidewall heights are needed, which can be collected using a standard tape measurer or laser tape measurer. Laser tape measurers that are capable of measuring beyond 200 ft (61 m) are preferred.

Air speeds can be measured with a hot-wire or propeller anemometer. A hot-wire anemometer is significantly more expensive than a propeller one, but it is capable of detecting air speeds of less than 100 ft/min, which is useful for determining drafts in a calf barn during cold weather. A propeller anemometer is sufficient for assessing air speeds of over 100 ft/min (0.5 m/s), making it ideal for assessing fast moving air. A rotating van mount and a tripod that places the propeller anemometer about 1.5 to 2 ft (0.5 to 0.6 m) above the stall surface is needed for air speed mapping in adult cow barns.

Temperature and relative humidity sensors can be placed above the stalls in a naturally ventilated barn to get an idea of what the cow is experiencing in the stall microenvironment. For mechanical ventilation systems where we are interested in the temperature difference between the inlet and exhaust end of the barn (should be no more than a 3.6°F or 2°C increase between the inlet and outlet), the sensors should be placed near the barn's inlet and outlet. The sensors should be programmed to record readings every five minutes for two hours, so it is usually best to install the sensors upon arrival at the farm. Once the visit is completed, the data can be downloaded and exported to an CSV file where the average, maximum, and minimum THI measurements can be determined. THI can be used as a proxy for what the cows are experiencing in their microenvironment. When used alongside air speed mapping, it can help determine how well the barn's heat abatement system is working.

A propane fogger with light mineral oil is useful for visualizing air flow in a barn. This piece of equipment is relatively inexpensive and has a wide range of uses. In adult cow barns, the fogger can demonstrate how air flows between circulation fans in naturally ventilated barns or between baffles and around inlets and outlets in mechanically ventilated barns. Similarly, the fogger can be used to demonstrate how air is distributed in a calf barn or if there are any dead spots. Most commonly, foggers are best for visualizing how air exits out of the discharge holes in a PPTV system. Fogging PPTV systems is best done with two people where one person stands inside the barn videoing the fogging demonstration while the second person pumps fog into the fan on the outside of the barn. Sidewall curtains and doors should be closed so that outside prevailing winds do not disrupt the course of the air jets. The person inside of the barn should take note of where the air jets are settling relative to the calf microenvironment and if air is evenly distributed along the length of the tube. This will make it easier to assess air speeds for drafts using a hot-wire anemometer. Once fogging is completed, the barn should be opened to allow the fog to dissipate.

Fogging cannot be accurately used to determine if the PPTV system is delivering a minimum of 4 ACH since the air inside of the barn is continuously mixing with fresh, incoming air. However, most of the fog should clear on its own within 20 minutes if the barn remains closed.

Ventilation Calculations

To calculate if the ventilation system is delivering the desired air exchange rate, first determine the barn volume. Next, multiply the barn volume by the desired number of air changes per hour

(typically 4 ACH in the winter and 60 ACH in the summer) and divide by 60 minutes per hour to get the total fan capacity needed in cubic feet per minute. This number can be used to compare to what is installed in the barn to what is needed.

For mechanically ventilated barns, count the total number of fans and multiply the total number of fans by the fan's capacity at 0.1 inches in H_2O static pressure (25 Pascals) to get the total fan capacity. Then divide the total fan capacity by the barn volume and multiply by 60 minutes per hour to get the total air changes per hour. Check if what is in the barn matches the required ventilation rates. This same calculation can be applied to determining the air exchange rate of the installed PPTV system. The only difference is that the fan capacity output will be at 0.18 inches in H_2O static pressure (45 Pascals).

Another calculation that can be done for mechanically ventilated barns is determining the required inlet opening to ensure incoming air speeds of 500 to 800 ft/min (2.5 to 4 m/s) for proper air mixing. The needed inlet area in square feet can be calculated by taking the total fan capacity and dividing by the average inlet air speed of 500 ft/min (2.5 m/s). An anemometer can be help up to the inlet to measure the average air speed for 30 to 60 seconds. If air speed readings are not within the 500 to 800 ft/min (2.5 to 4 m/s) range, then check the existing inlet opening measurements using a laser tape to what the calculated required inlet opening is.

Air Speed Mapping

The main goal of a calf barn's winter ventilation system is to provide fresh air in the calf microenvironment without creating a draft. After fogging a PPTV system as described above, use a hot-wire anemometer to measure air speeds in the calf pen for 30-60 seconds at calf standing height or 4 ft (1.2 m) above the floor. It is best to take a representative sample of air speeds in a group bedded pack or measure air speeds every five pens in individual housing systems. Typically, the anemometer is placed with the notch at the end of the probe facing towards the direction of air movement and placed where the air jets from the PPTV system are settling to check that the PPTV system is not causing a draft. Air speed measurements should be taken along the length of the barn, totaling 10-20 readings. Assume the five highest readings are accurate of what the air speeds are in the calf microenvironment. If the air speeds are above 100 ft/min (0.5 m/s), then drafts are a concern and modifications to the PPTV system or where the pens are located relative to the draft should be made. If there is quite a bit of inconsistency with air speeds along the length of the tube, visually check the tube for installation issues such as the fan not being placed on the end wall, restrictions to air flow to the fan with undersized hoods, or tube fluttering nearest the fan which may indicate an inadequate fan to tube diameter ratio.

The focus for adult cow barns is to provide minimum cooling air speeds of 200 to 400 ft/min (1 to 2 m/s) at 1.5 to 2 ft (0.5 to 0.6 m) above the stall surface when the THI inside of the barn is above 68. To test air speeds in the cow microenvironment, use a propeller anemometer set up with a wind vane mounting system and attach it to a tripod that is ~1.5 ft tall (0.5 m).

Where the tripod is placed depends on the type of ventilation system. For naturally ventilated barns where the concern is about how circulation fans are spaced and angled, place the tripod in

a row of stalls between a set of three fans in line and take 30-second readings every other stall. Be sure to pick a row of stalls that is not on the prevailing wind side of the barn. This method can be replicated in a tunnel or cross ventilated facility with fans over the stalls.

Air speeds in cross ventilated barns with baffles are measured slightly differently. Instead of measuring air speeds between a row of fans, air speeds are measured before and after a baffle, every other stall, along a row. For cross ventilated barns, it is important to take air speed measurements across the entire width of the barn, traversing an end and middle of the barn, to determine how air moves from the inlet to the exhaust fans. Additional measurements to be taken in mechanically ventilated barns include air speeds at the inlet and at any barn connectors. These methods are described further in Reuscher et al. (2024)[6], and a summary of the key criteria to evaluate and their targets can be found in Table 2.

Conclusion

Providing appropriate ventilation rates year-round and air speeds in the animal microenvironment are important for maintaining the health and productivity of the herd. Visual assessments of the barn and cows can determine if the ventilation and heat abatement assessments are working properly, and tools such as foggers and anemometers can be used to demonstrate and quantify air flow in the barn. Once measurements are taken, adjustments to the number of fans, fan location, angle, and spacing, and modifications to inlet location or baffle placement can be made to improve the ventilation system.

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Tables

Table 1. Recommended air changes per hour (ACH) for cold, mild, and hot weather for all aged dairy cattle.

Age	Cold weather	Mild weather	Hot weather
	Air changes per hour (ACH)		
Animal barn, cows to nursing calves*	4-8	15-20	30-60
*Bates & Anderson (1979)[7]; Mondaca et al. (2019)[8]			

Table 2. Summary of ventilation and heat stress criteria and their targets for adult cow barns.

Criteria	Target
History of bunching	No
Moisture streaking along the purlins	No
% cows panting (observe 20 cows minimum)	None

% cows respiratory rate >60 breaths/min (observe 20 cows minimum)	<25%
Temperature increase between the barn's inlet and exhaust	<3.6°F or 2°C
% stalls with air speeds of 200 to 400 ft/min (1 to 2 m/s) at resting height (1.5 ft or 0.5 m above the stall) in the summer	>90%

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