Convective Cooling to Reduce Heat Stress

Dairy Barn Cooling Factsheets

Key points

- A Minimum Cooling Air Speed (MCAS) of at least 1 m/s (200 fpm) at the cow resting height is required to reduce heat stress but a target air speed of 2 m/s (400 fpm) will be more effective at higher Temperature Humidity Index (THI)
- The goal is to have 100% of the free stall resting area with the target air speed at the cow resting height of 0.5 m (1.5 ft.)
- Fan spacing and angle determine uniform air speed in the cow resting area
- Turn fans on at 20°C (68°F) or a THI of 68
- Fans are important in the holding area and special needs area as well as for the dry cows and heifers
- 40 to 50 air changes per hour is recommended for tunnel ventilated barns in summer

Introduction

The most effective way to reduce heat stress in dairy cattle is by increasing the air speed over the cows, referred to as convective cooling. Convective cooling involves using fans to increase the air speed over the cow's body surface to improve conduction of body heat. Research has shown the minimum air speed for effective cooling is 1 metre per second (m/s) or 200 feet per minute (fpm), referred to as the Minimum Cooling Air Speed (MCAS). However, a study done in the Fraser Valley during the heat dome of 2021 showed improvements in milk production with a higher air speed of 2 m/s (400 fpm).

Achieving the MCAS requires the strategic placement of fans over top of the free stall area to direct air into the cow resting area, and not just over their backs (Figure 1). Fan spacing and angle are very important to achieve uniform air speed. In naturally ventilated barns fans are important, as there is often very little wind to create air speed in the barn during the hottest weather.

Fans are also necessary in many tunnel ventilated barns to direct the air into the free stall resting area rather than being short circuited down the feed alley.

Minimum Cooling Air Speed (MCAS)

The MCAS was determined from research by Kimberly Reuscher et al. published in 2023. They studied the effect of different air speeds at cow resting height in the free stalls on cow behaviour and their response to heat stress. The research looked at lactating groups with no fans, fans operating at 60% of their capacity, and fans operating at 100% of their capacity. The study showed that increased air speed:

- Protected lying time
- Kept body temperatures normal
- Protected milk yield

Figure 1. Place fans over free stalls to direct the air into the cow resting area.

Figure 2 shows how increasing fan speed protected against a drop in milk production compared to the control of no fans. This demonstrates the importance of having a MCAS.

Increasing the fan speed from 60% to 100% doubled the electricity cost and only showed an incremental improvement. The researchers noted that the improvement may be greater at higher Temperature Humidity Indexes (THI). The goal then is to have 100% of the resting area with at least 1 m/s speed (200 feet per minute), but a target speed of 2m/s (400 fpm) is more appropriate for the Fraser Valley with its higher THIs.

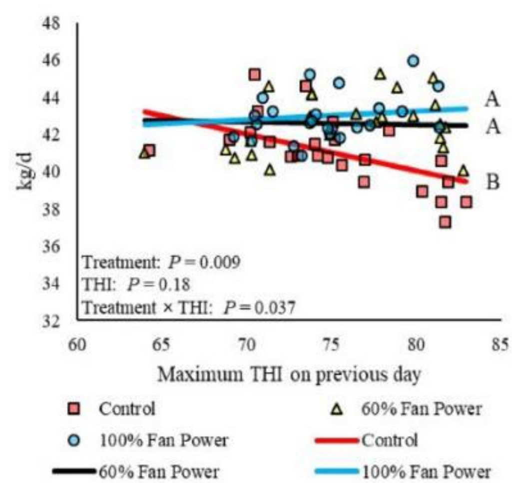

Figure 2. Milk yield response to increasing THI with different air speeds. Reuscher et al. 2023

Fan placement – Spacing and angle

To reduce heat stress, correct fan placement is required to provide the Minimum Cooling Air Speed (MCAS) in the free stall area. Fans should be spaced and angled to push air down into the cow lying area and not to just blow air over them. Air leaves a fan in a cone shape and as a result there is an area for about 3 to 6 m (10 to 20 ft.) beneath the fan where there is no air movement. Therefore, when fans are in a row it is important to angle the fan to direct air to the base of the next fan in line (Figure 3). The goal is to provide fast moving air for all free stalls. Typically, fans are 122 to 140 cm in diameter (48 to 55 in. dia.) and should be spaced 7 to 9 m (24 to 30 ft.) apart:

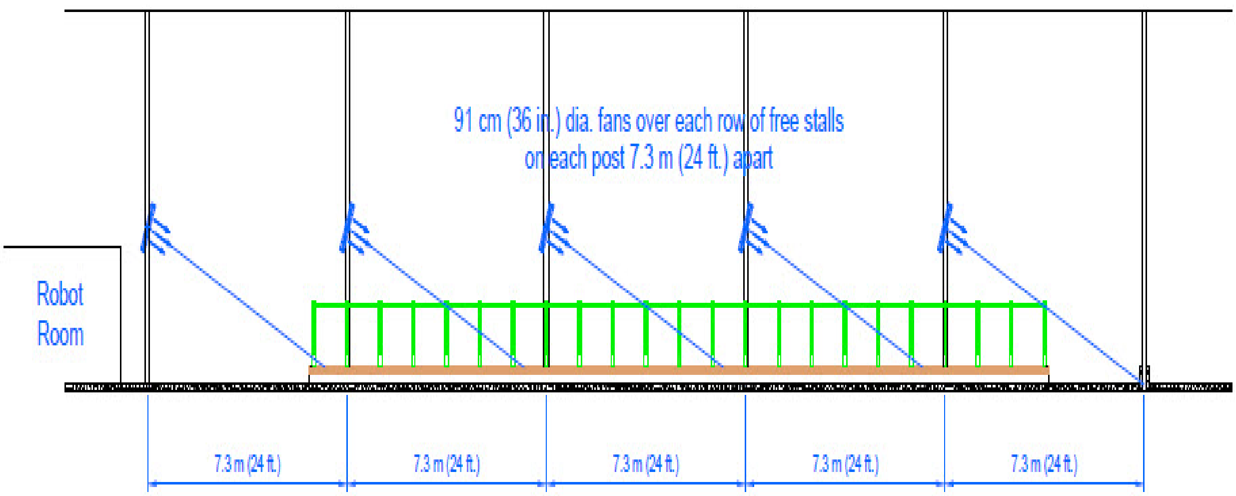

Figure 3. Fan spacing and angle are very important for uniform air speed.

However, this is only a guideline as there is a great variation between fan make, model, and size. The only sure way is to measure the air speed in the stalls. A smoker (insect fogger) can also help to observe the air pattern.

Doubling fans over rows of head-to-head stalls will also affect the throw distance. "Cyclone" style fans (Figure 4) may be placed 12 to 15 m (40 to 50 ft.) apart and still provide an air speed of 1 m/s (200 fpm) in the free stall area. Cyclone style fans should be angled and the vanes positioned to direct air in one direction and into the free stall area.

Figure 4. "Cyclone" style fan used to blow air into the free stall area.

Fans should be programmed to turn on at 20°C (68°F) or a THI of 68. Some producers will even start them at 18°C (65°F).

Holding areas

Convective cooling using fans should be considered in the milking parlour holding area. It very difficult to release body heat when the cows are crowded together two or three times a day for milking. Fans should be installed to blow air into the holding area to cool the cows. The fan system should be capable of providing 1,700 m^3/h per cow (1,000 cfm/cow). The ventilation rate is based on the total number of cows in the holding area.

Special needs area

It is very important to reduce heat stress for the cows in the special needs area as well. It may be difficult to blanket the whole bedded pack areas with fast moving air, but strategically positioned fans will create areas for cows to rest in fast moving air. Dry cows and heifers will also benefit from fast moving air to reduce heat stress.

Dairy barn ventilation

The goals of all ventilation systems are to remove odours, excess moisture in the winter, and excess heat in the summer. Reducing heat stress for cattle requires high speed air movement in the cow area at resting height.

Heat is removed from a dairy barn in the summer through ventilation. There are primarily two forms of ventilation systems, natural ventilation which relies on wind forces and animal body heat to provide air exchange and mechanical ventilation which uses exhaust fans to provide the power to exchange air.

Natural ventilation

The most common way to ventilate dairy barns is to use natural ventilation. In the summer, natural ventilation relies on the natural forces of wind and the thermal properties of air to function properly, and needs to be designed to work in a crossflow mode. The barn needs to be orientated perpendicular to the summer winds so that they can blow across the narrowest cross section of the barn. The barn also needs to be located on the farmstead so that the winds are not restricted from reaching the barn for proper ventilation by other buildings. Parallel buildings should be at least 30.5 m (100 ft) apart. Any adjacent buildings will cause a downwind effect of a distance of 10x their height.

In a naturally ventilated barn, the entire sidewall should be adjustable curtain if possible. Use a bird screen with the largest opening size and thinnest fibres that will keep birds out. Producers often use bird screens with wide mesh webbing that significantly reduces airflow.

A suitable ridge opening is a necessary part of a natural ventilation system to allow for heat release in hot weather. The amount of opening for a continuous open ridge is 2.5 to 5 cm per 3 m (1 to 2 in. per 10 ft.) of barn width. The continuous ridge opening usually takes the form of an offset roof line with an adjustable curtain that can be used to adjust the size of opening depending on weather conditions. If chimneys are used the minimum chimney size is .05 m^2 per 9.3 m^2 (0.5 ft^2 per 100 ft^2) of floor area. The maximum size for a chimney is 1.2 m x 1.2 m (4 ft. x 4 ft.) and it is recommended to have at least one chimney for every 185 m^2 (2,000 ft^2) of floor area.

In winter, the barn ventilates naturally by thermal buoyancy— that is, warm air rises. Heat produced from the cows will cause the air to rise, drawing in fresh air and exhausting it through ventilation openings at the ridge. Winds blowing over the ridge of the barn will work to draw air out.

In spring and fall, the ventilation is a combination of crossflow and thermal buoyancy. Inlets and exhaust have to be adjusted to make use of the wind and the natural tendency for heated air to rise.

The challenge with natural ventilation is that during the hottest days of the year, the wind often isn't blowing sufficiently to provide cow cooling. That is why some form of supplemental fan ventilation is necessary to increase the air speed in cow area to reduce heat stress.

Mechanical ventilation

A negative pressure mechanical ventilation system provides air exchange but still may require fans or baffles to provide sufficient air speed in the cow resting area. This system consists of air inlets, fans for air exhaust and a control system to regulate the rate of airflow. The use of fan power allows for a consistent calculated air exchange. Fans can also be positioned within the barn to increase air movement and cooling of the cows and to eliminate dead spots. Baffles can also be used in cross ventilated barns to increase air speed in the cow resting area.

There are three main types of mechanically ventilated barns:

- Tunnel ventilated
- Cross ventilated
- Hybrid systems

Tunnel ventilated

Tunnel-ventilated barns are often designed to function as naturally ventilated barns for most of the year. During hot summer weather, the curtains and ridge openings are closed, and fresh air is drawn in through air inlets at one end of the barn and exhausted by large fans at the opposite end. The air direction is perpendicular to the free stalls. They are designed to provide the air speed and air changes necessary to reduce heat stress in the summer. Tunnel ventilation isn't always effective as air can short circuit down a feed alley without effectively getting into the free stall areas. Tunnel ventilated barns can benefit from having supplemental fans mounted over top of the free stalls to direct the air down into the free stall area.

Cross ventilated

Cross ventilated barns are wide-bodied barns with multiple rows of free stalls and feed alleys. Fresh air enters on one side of the barn and moves across the barn parallel to the free stalls and is exhausted by fans on the wall opposite to the air inlets. Cross ventilated barns require use of fans throughout the year. Baffles are positioned to direct the air down into the free stalls. The other option is to use supplemental fans to direct the air down into the free stalls.

Hybrid system

The hybrid ventilation system operates as a naturally ventilated barn during the cooler months of the year. When the weather becomes warm, the curtains close and a row of fans under the eaves blow air into the barn and down into the free stall area. This design only works well in a head-to-head stall arrangement.

Ventilation assessment

The only way to determine whether the ventilation system is performing as it should to reduce heat stress is to complete a ventilation assessment. This includes:

- Collecting information about the barn and the ventilation system
- Observing the cows for signs of heat stress
- Measuring air speeds in the cow resting areas
- Measuring temperature and humidity levels

The Factsheet: Ventilation Assessment provides a method of evaluating the effectiveness of the ventilation system in your barn.

Assessment targets

The Dairyland Initiative has developed a number of ventilation assessment targets through their work with ventilation assessments on dairy farms (Table 1 & 2). Ventilation assessments on your farm should meet or exceed these targets.

Ventilation Criteria	Target
% Stalls with MCAS air speeds of 1 m/s (200 fpm) at the cow resting height in the summer	>90%
% Stalls with Target air speeds of 2 m/s (400 fpm) at the cow resting height in the summer	>90%
% Cows with Heat Stress: breathing rate >60 breaths per minute (minimum ~ 20 cows)	<25%
% Cows panting: breathing rate >100 breaths per minute (minimum ~ 20 cows)	0%
History of bunching	No

Table 1. Ventilation assessment targets.

Ventilation Criteria	Target
Air changes per hour – summer	40-60
Air changes per hour – winter	4-8
Air exchange per cow	>2,550 m^3/h (>1,500 cfm)
Measured inlet airflow speed	2.5-4 m/s (500-800 fpm)
Temperature increase between inlet and exhaust	< 2°C (<3.6°F)

Table 2. Ventilation assessment targets specific to negative pressure mechanically ventilated barns.

In 2021 a study on “Managing Extreme Heat on Fraser Valley Dairy Farms” (Langlois, Denis & Jesse Wheeler. 2003) was conducted on eight dairy farms. An assessment was performed to determine if the ventilation system met the Minimum Cooling Air Speed (MCAS) in the free stall area. A colour-coded airspeed map was developed to indicate the airspeed in the free stall area where yellow met the minimum standard of 1 to 2 m/s (200 to 400 fpm), green exceeded the minimum standard of 2 m/s (400 fpm) and red was less than 1 m/s (200 fpm).

Although 1 m/s (200 fpm) is considered the minimum cooling air speed, the study showed that there was less of a drop in milk production as the % of free stalls with air speeds exceeding 2 m/s (400 fpm) increased. This may be due to the high humidity levels that are experienced in the Fraser Valley.

Figure 5 shows the air speed map for a naturally ventilated barn that was assessed in the study. There were few areas of concern in this barn except the pack area and another area near a water trough. Note that there was a double row of fans over the head-to-head free stalls resulting in higher air speeds in these areas. It was determined that 89% of the free stalls met the MCAS of 1 m/s (200 fpm) and 86% were greater than 2 m/s (400 fpm). The average fat-corrected production loss was 1.68%. Air speeds in the pack area could be increased by installing fans to direct air down onto the pack.

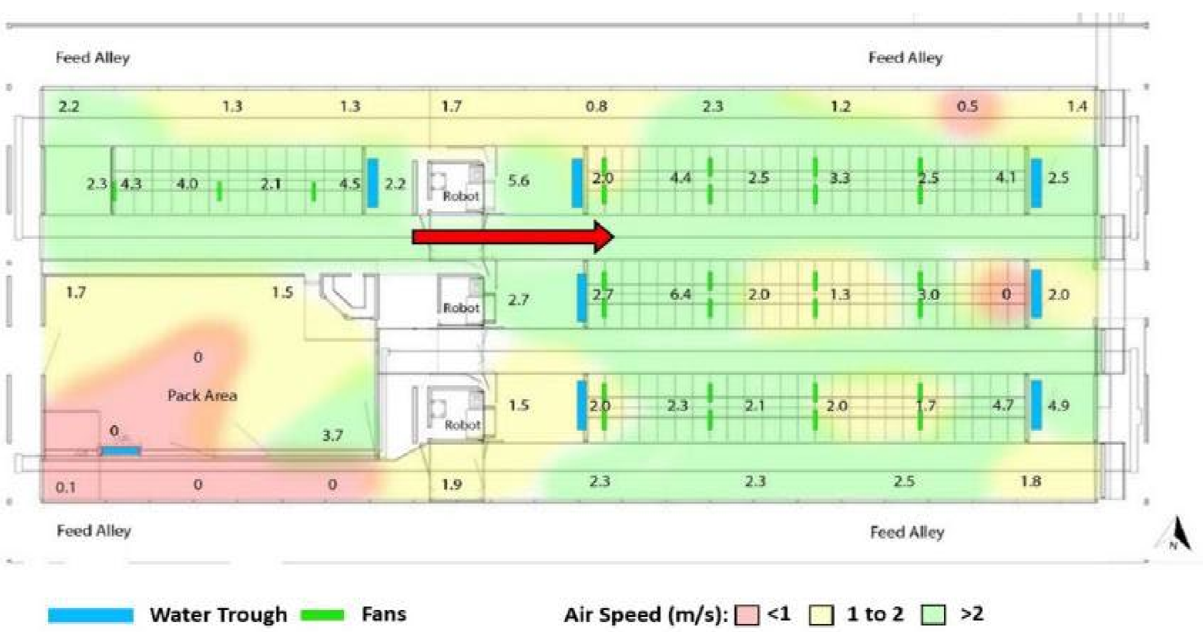

Figure 5. Airspeed map for a six row naturally ventilated free stall barn with perimeter feed alleys.

Figure 6 shows the airspeed map for a tunnel ventilated barn that was assessed in the Fraser Valley study. There were no fans over the free stall rows resulting in lower air speeds. The map showed that the robotic milkers blocked air flow and there was no air flow in parts of the pack area. The air speed map also showed that there were higher air speeds down the scrape alley next to the feed manger. This is common in tunnel ventilated barns as there is less resistance to air flow in the scrape alley unless all the cows are eating at the feed manger. It was determined that 73% of the free stalls met the MCAS of 1 m/s (200 fpm) and only 8% met the 2 m/s (400 fpm) target. The average fat corrected production loss was 4.54%.

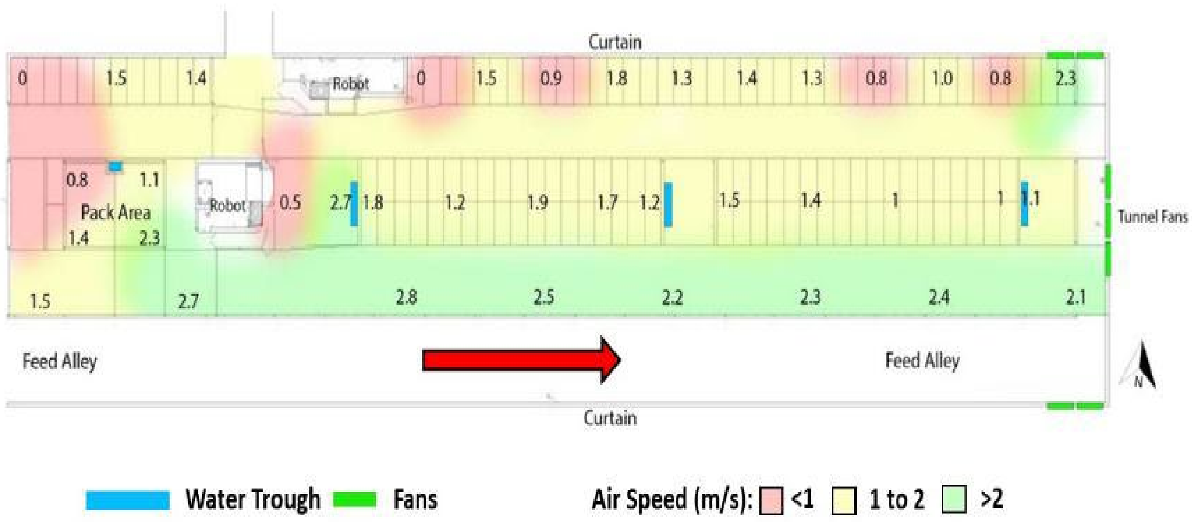

Figure 6. Airspeed map for a tunnel ventilated barn.

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