

replaces OMAFRA Factsheet #13-073, *Tunnel Ventilation for Livestock and Poultry Barns*

Tunnel Ventilation in Livestock Barns — With and Without Evaporative Cooling

D. Ward, P.Eng.

INTRODUCTION

Ontario's hot, humid summer weather makes it difficult for livestock and poultry to perform at their best. It is important to provide cooling in barns so animals do not experience heat stress, resulting in an associated decrease in production. The two most common cooling methods used in Ontario are air-based and water-based. This factsheet discusses the design factors and management of tunnel ventilation — with and without evaporative cooling.

The main method of air-cooling livestock barns in Ontario is tunnel ventilation. The entire air inlet is located on one end wall of the barn (Figure 1) with all of the exhaust fans located on the opposite barn end wall (Figure 2). The idea is to create a high velocity wall of air moving down the long axis of the building like a wind tunnel. This provides a beneficial wind chill effect that cools the animals by convection (the removal of heat from the surface of an object by an airstream moving over it) and exhausts this heat out of the building.



Figure 1. Tunnel ventilation inlet doors across the end wall of a barn without evaporative cooling.



Figure 2. Exhaust fans across the end wall of the barn.



Figure 3. Tunnel ventilation inlet with evaporative cooling pads installed.

In many parts of the world, evaporative cooling pads are added to the air inlets of tunnel-ventilated barns (Figure 3) because there is a critical upper temperature for tunnel ventilation. Excessive air movement above 40°C — a chicken’s core body temperature — will increase the heat stress experienced by the animal. At these high temperatures, some form of evaporative cooling is incorporated into the system to reduce the effects of the incoming air temperature.

With evaporative cooling, the incoming air is pulled through a saturated medium (cooling pad). The process of converting water from a liquid to a vapour removes heat energy from the incoming air, lowering its temperature but increasing its relative humidity.

Until recently, these systems were not commonly used in Ontario. However, following several summers with prolonged periods of temperatures higher than 30°C, these systems are being used in more barns.

AIR-BASED COOLING — TUNNEL VENTILATION DESIGN CONSIDERATIONS

In a cross-flow ventilation system (air flows across the width of the building) with a slot-type air inlet, the air speed at the animal level ranges from 0.25–0.50 m/s (50–100 ft/min). With tunnel ventilation, the goal is to achieve an air speed of 1.0–2.5 m/s (200–500 ft/min) over the animals. The recent trend in Ontario and elsewhere is to design systems to operate at even higher airspeeds, with very good results.

Research conducted by the U.S. Department of Agriculture Poultry Research Laboratory at Mississippi State University on 7-week-old broiler chickens showed that air moving at 1 m/s (200 ft/min) over the birds results in similar growth rates to birds raised in still or slow-moving air that is 1°C cooler. Similarly, air moving at 2 m/s (400 ft/min) creates a wind chill effect of 3.7°C. The birds in this trial, grown under tunnel ventilation at 2 m/s, were 0.5 kg heavier at 7 weeks of age than the birds grown in still air.

Tunnel ventilation is not recommended when ambient air temperature is below 15°C or for sensitive, younger animals (baby chicks prior to feathering), as the wind-chill cooling effect is not necessary and could be stressful to these animals. For this reason, when tunnel ventilation is designed for a building, the normal cross-flow ventilation system is usually sized to supply 40%–50% of the summer ventilation requirements to accommodate the three cooler seasons of the year and for the early growth stages of sensitive animals.

FAN CAPACITY FOR TUNNEL VENTILATION

The size of the tunnel ventilation system is based on the amount of power needed to create a wall of air moving the length of the building at a velocity of 1.0–2.5 m/s (200–500 ft/min or 3.6–9 km/hr) or higher. Therefore, the required fan capacity is the useable barn cross-sectional area multiplied by the desired air speed. Note that floor-reared birds occupy the lower 0.3 m (1 ft) of the barn cross-section, so it is not useable for air movement. Similarly, cattle stalls, swine pen partitioning, etc., will reduce the net cross-sectional area available for airflow.

Fan Sizing Example

What is the fan capacity required for an 18-m x 91-m (60-ft x 300-ft) broiler chicken barn with a 2.7-m (9-ft) ceiling height and a desired tunnel air speed of 2.5 m/s (500 ft/min)?

Metric Airflow Q
 = (Velocity x Area) x 1,000
 = 2.5 m/s x 18 m x (2.7 – 0.3 m) x 1,000
 = 108,000 L/s

Imperial Airflow Q
 = Velocity x Area
 = 500 ft/min x 60 ft x (9 ft – 1 ft)
 = 240,000 CFM

Historically, the most common fans used for tunnel ventilation were belt-driven, single-speed 1,200-mm (48-in.) diameter or larger fans equipped with exhaust cones. These fans have a high-energy efficiency rating (normally >7.5 L/s/W (16 CFM/W)).

Recent advances in electric motor and fan design have resulted in increased use of direct drive, variable frequency drive (VFD) fans 1,200 mm (48 in.) diameter or larger, equipped with exhaust cones. These fans are more energy efficient than the belt drive fans, and the variable frequency drive changes how the system is operated. These VFD fans are more expensive to purchase than the older belt drive units but the reduced energy use during operation will compensate for this difference in price. On average, a 1,200-mm (48-in.) fan will move approximately 9,400 L/s (20,000 CFM) of air. Therefore, the number of fans required for the broiler chicken barn in the previous example (18-m x 91-m (60-ft x 300-ft) with a 2.7-m (9-ft) ceiling height) is:

Metric: $108,000/9,400 = 12$ fans

Imperial: $240,000/20,000 = 12$ fans

Other fan sizes, or a combination of fan sizes, are used and may be desired for a particular situation. A common problem encountered when designing a tunnel ventilation system is insufficient room on the end wall to install all the tunnel fans required to meet the target airflow. It is acceptable to install some fans around the corner onto the sidewall as shown in Figure 2.

AIR INTAKE FOR TUNNEL VENTILATION

Tunnel ventilation inlets contain motorized louvers, curtains, panels or large doors. These openings are usually sized on the basis of 2 m² per 5,000 L/s (2 ft²/1,000 CFM) of fan capacity. Since air does not easily turn corners, this type of inlet works best when located across an end wall so that the incoming fresh air travels straight into the barn in the correct airflow direction. As shown in Figure 1, a large panel door across the end wall provides the necessary cross-sectional area for the air intake. Some barns are equipped with a combination of panels and a roll-up door to achieve the required inlet opening.

Air Intake Sizing Example

What is the required air intake size for the broiler chicken barn in the previous example?

Metric Area

$$= (2 \text{ m}^2/5,000 \text{ L/s}) \times \text{Airflow } Q \text{ L/s}$$

$$= (2 \text{ m}^2/5,000 \text{ L/s}) \times 108,000 \text{ L/s}$$

$$= 43.2 \text{ m}^2$$

$$= 2.59 \text{ m} \times 16.7 \text{ m}$$

Imperial Area

$$= (2 \text{ ft}^2/1,000 \text{ CFM}) \times \text{Airflow } Q \text{ CFM}$$

$$= (2 \text{ ft}^2/1,000 \text{ CFM}) \times 240,000 \text{ CFM}$$

$$= 480 \text{ ft}^2$$

$$= 8.5 \text{ ft} \times 56.5 \text{ ft}$$

TUNNEL VENTILATION CONTROL

Tunnel ventilation is strictly a warm-weather system and should only be used in temperatures above 21°C for animals that are not overly sensitive to drafts, such as birds older than 3 weeks of age. As with normal cross-flow ventilation, stage the tunnel ventilation system to automatically turn on when the barn temperature increases. Typically when using single-speed, belt-drive fans, two or three tunnel stages are used to manage the barn conditions. For example, Stage 1 operates the first group of two or three tunnel fans, Stage 2 operates another group of fans and Stage 3 operates the remaining fans. This control strategy allows a staggered wind chill effect to match the ambient air conditions experienced by the animals. As the temperature increases through the day, the corresponding stages are activated to create more air flow and as the cooler night temperatures arrive, the stages are deactivated in reverse order to decrease air flow.

Shifting to variable-frequency drive fans changes how the controller is set to operate the system and allows a more gradual fan transition as the barn temperature increases or decreases through the day. As ambient temperatures begin to rise, a large number of these VFD fans may be activated but only operate at 30%–50% speed, which uses less energy than the same size fan operating at 100%. As the temperature continues to rise, the controller will either add additional fans at low speed OR increase the speed of previously operating fan(s) proportionally until all fans are operating at 100% when the maximum temperature setting is reached. Conversely when the ambient temperature begins to cool as night

approaches, the controller will begin to slow the fan speeds and eventually shut down some of the excess capacity.

Normally the cross-flow ventilation system is turned off completely once the tunnel fans/inlets are activated. The sidewall fans are turned off, and the baffle board air inlet is closed to get the full wind-tunnel effect down the length of the barn. Remember, the main objective is to remove the hot air in the barn, as quickly as possible.

POTENTIAL TUNNEL AIRFLOW CHALLENGES

Air Inlet Location

Locate air inlets on the end wall if at all possible. Air will not turn 90° corners unless forced. Any air entering from the sidewall creates airflow across the barn rather than along the length. Airflow from the sidewall inlet will eventually turn and move endwise to the exhaust fans but will leave a dead air zone (Figure 4) along the sidewall containing the inlet panel.

Service or Entrance Room Location

Locate the service or entrance room outside the main building, as shown in Figure 1, to provide full end wall exposure for the tunnel air inlet. Besides reducing the available end wall opening, it creates a major wind shadow down that side of the room. An unconfined air stream will fan out at about a 10° angle, and a 2.4-m (8-ft) wide service room will prevent tunnel air movement along that wall for at least 14 m (46 ft) (Figure 5). Smoke testing shows the actual affected distance is even greater due to a slow, backward eddy-type flow in the wind shadow area. If an interior room is necessary, locate it near the tunnel exhaust fans and opposite the winter air inlet to minimize the amount of airflow blocked.

Outside Wind Effect

Significant summer winds, blowing at an angle into the tunnel air inlet, can direct the airflow inside to one side of the barn (Figure 6). This situation drastically reduces the airflow along the other side of the room. Compare an outside wind speed of 20 km/hr (12.5 mph) to a typical tunnel air speed of 6 km/hr (3.8 mph) to understand the potential for the wind to overpower the airflow pattern. Opening the side air inlet baffle board to introduce more air to the side with less airflow can help even out the airflow. Air-deflecting baffles located at the tunnel inlet have also reduced this problem.

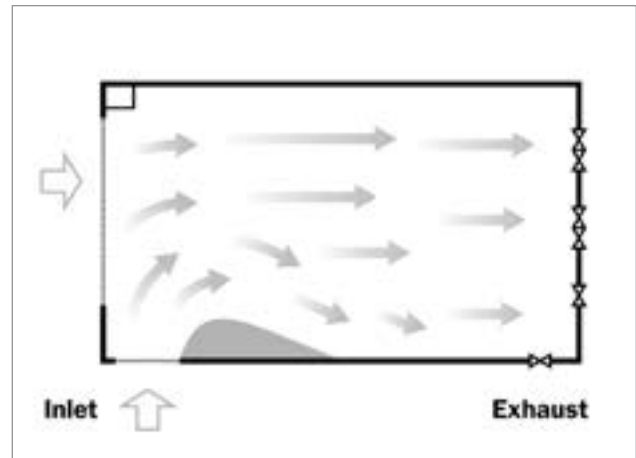


Figure 4. Floor plan showing dead air zone (shaded area) due to placement of sidewall tunnel ventilation air inlets.

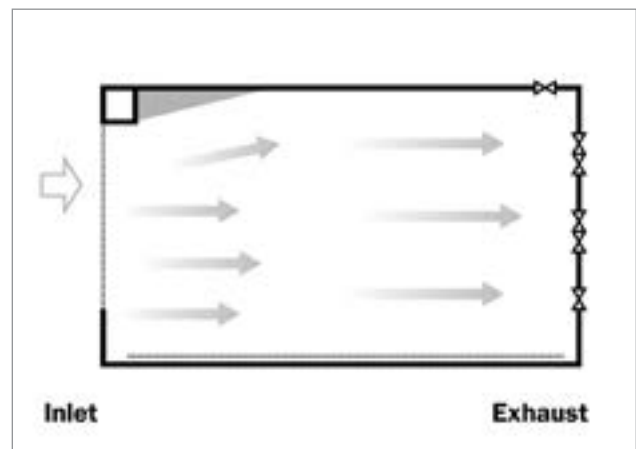


Figure 5. Floor plan showing dead air zone (shaded area) due to obstruction by a service room entrance.

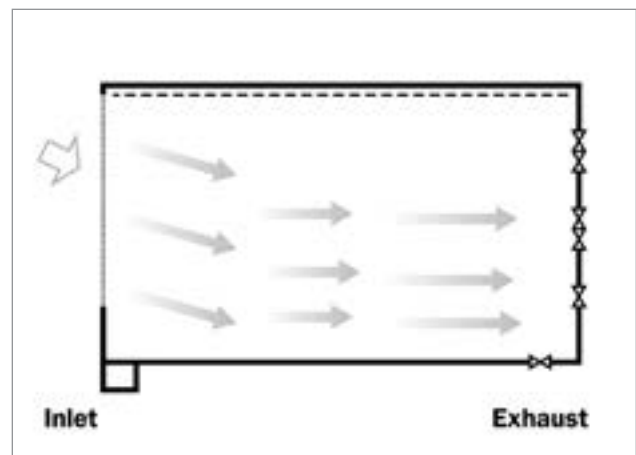


Figure 6. Floor plan showing a skewed air flow pattern due to wind effect.

CEILING AIR DEFLECTORS

A method of increasing the air speed at animal level, without installing extra tunnel fans, is to install drop curtains or other air deflectors from the ceiling every 12–25 m (40–80 ft) along the length of the barn to reduce the barn cross-sectional area. Limit the increased air speed to a maximum of 2.5 or 3.0 m/s (500 or 600 ft/min) to prevent a reduction in fan performance. Too much reduction in the building cross-sectional area will increase the static pressure the fan(s) has to work against.

EVAPORATIVE COOLING EQUIPMENT Design

The evaporative cooling pad is made of fibrous material woven together, similar to corrugated cardboard, with large gaps in the grooves. The pad is mounted vertically over the tunnel air intake with the bottom sitting in a drain trough. A water delivery pipe, with evenly spaced holes, runs across the top of the pad.

A circulating pump pumps the water from the trough at the bottom of the pad to the distribution pipe at the top of the pad. When evaporative cooling is needed, the controller activates the pump, which delivers water to the distribution pipe that trickles water down the face of the pad to wet it.

Fresh water is added into the system via a float mechanism to replenish the water that is evaporated into the air stream during the ventilation process (Figures 7–10).



Figure 7. Evaporative cooling pad, showing circulating pump, cooling pad, fresh water feed pipe (blue pipe) and filter.



Figure 8. Close-up of water trickling down the outside of the pad surface.



Figure 9. Inside surface of the evaporative cooling pad with the insulated door open.



Figure 10. Insulated door closed to cover the evaporative cooling pad.

The cooling capability or efficiency of the pad system is directly related to pad type, size of pad and the air velocity allowed to pass through the pad. The cooling efficiency ranges from 55%–75% for most evaporative cooling pads. Air velocity and size of the pad are directly related to the fan's capacity. A smaller pad area means a higher air velocity through the pads. Most pad manufacturers recommend a design air velocity of 1.27–1.78 m/s (250–350 fpm) through their pads to ensure a long enough contact time between the air and the wet surface to achieve the best cooling efficiency.

The most common design problem seen with evaporative cooling systems is not enough pad area. Since the wet cooling pad presents a greater barrier to air flow than a typical tunnel inlet, designers usually increase the size of the inlet opening for the evaporative cooling pad to ensure the static pressure drop across the pad is "limited to" a 7.47–22.4 Pa (0.03–0.09 in.) water column. The recommended inlet opening size is 2.5 m² of opening/5,000 L/s (2.5 ft² of opening/1,000 CFM).

Evaporative cooling, like all water-based cooling systems, increases the relative humidity of the air in the barn space. Ensure the relative humidity in the barn never exceeds 80% when using an evaporative cooling pad during warm weather, as this may cause the animals more distress. For example, poultry pant to shed heat at higher temperatures (25°C+). This method of controlling body temperature relies on evaporative cooling within the bird's own lungs to get rid of excess heat from its body. However, when the bird is placed in a barn with a relative humidity greater than 80%, it cannot release heat. The ability of the room air to absorb any additional moisture above 80% is slowed or lessened. Since the bird is unable to lose this excess heat, its core body temperature begins to rise.

WATER SUPPLY (QUALITY AND QUANTITY)

Water used for cooling needs to be very clean to prevent blockage or fouling of the system. A filter is added to the water feedline to remove sediment. Treat hard water through a softener to avoid issues of scaling on the pads and to remove high levels of minerals (e.g., iron).

When considering the addition of evaporative cooling to your barn, ensuring an adequate water supply is important. The cooling system requires this water at the same time that the animals are usually drinking more due to the high temperatures, so having an adequate well/storage tank is a must.

To lower air temperature 1°F (0.55°C) requires evaporating 0.125 gallons (0.5 L) of water per hour for every 1,000 CFM of airflow pulled through the pads.

To lower the barn temperature by 9°F (5°C) for the example broiler chicken barn (60 ft x 300 ft x 9 ft), with a target air speed of 350 ft/min, the required flow rate for this one cooling system would be:

$$\begin{aligned} & (350 \times 60 \times 9) / 1,000 \times 9 \times 0.125 \\ & = 213 \text{ gal/hr (805 L/hr)} \\ & = 3.55 \text{ gal/min (13.4 L/min)} \end{aligned}$$

OPERATION

With a recirculating pump system, the most important factor to monitor is the small holes in the distribution pipe along the top of the evaporative cooling pad. Ensure these holes are not plugged and allow water to continually flow evenly across the pad, as this is essential for good cooling performance. If the pad is always streaking or there are dry spots on the pad, the distribution system likely needs cleaning and/or flushing.

Common reasons for a pad becoming plugged:

- **High mineral content of feed water.** This can result in mineral deposits or scale forming on the pad. To avoid this problem, treat the water used for the evaporative cooling pad through a water softener to remove the minerals.
- **Algae growth.** Since the pad is made of organic material and kept in a warm moist state, algae have a chance to grow on the pad and in the water collection sump. It is highly recommended to allow the pad to dry out at least once daily. Add approved algaecides to the collection sump to discourage algae growth: check with the manufacturer for a list of approved products.

The pad materials decay over time due to the repeated wet/dry cycles and should be replaced every couple of years. Some corrugated plastic pad materials have been tested to determine if they would provide a longer-lasting alternative to current cardboard pads. These pads would not promote algae growth since the plastic is non-organic. However, the performance of the plastic pads, in terms of water evaporation, was not as good as the cardboard pads.

WINTER MAINTENANCE

Completely drain the evaporative cooling systems before freezing temperatures arrive to prevent damage to the piping and pump.

To protect the pad materials from damage caused by ultraviolet light, snow, ice, etc., during the winter months when the system is not in use, place a watertight protective structure over the outside of the pad (Figure 11).



Figure 11. Evaporative cooling pads with protective covers (white tarp material) partially closed.

To prevent moisture migration and heat loss through the pad from inside the barn during colder temperatures, install air-tight, insulated panels on the inside of the tunnel inlets opening (Figure 10).

SUMMARY

Tunnel ventilation and evaporative cooling systems are effective methods for relieving heat stress and enhancing animal performance in hot weather. Both systems require careful design, operation and regular maintenance in order to make them work effectively.

This factsheet was written by Daniel Ward, P.Eng., Poultry & Other Livestock Housing & Equipment, OMAFRA, and reviewed by Steve Beadle, P.Eng., Swine & Sheep Housing and Equipment, OMAFRA; Al Dam, Poultry Specialist, OMAFRA; and Arlene Robertson, Education Coordinator, OMAFRA.