

Chapter 9 - HOT WEATHER VENTILATION

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A. Introduction

Heat stress in poultry is a serious problem for the industry. Mortality during extremely hot weather can be significant, especially when combined with high humidity. However, probably even more costly is the ***routine loss of weight and feed conversion efficiency*** during less severe periods of heat stress. Under normal conditions, chickens do a good job of cooling themselves with physiological and behavioral mechanisms but these mechanisms fail at high temperatures. One of the keys to minimizing production losses during hot weather is proper ventilation system design.

Air temperatures that cause heat stress and mortality are considerably below broiler body temperature. Broiler surface temperatures typically range from 95 – 100°F, with skin temperatures warmer than feathers. Air temperatures in this range can virtually stop heat loss from the broiler and accelerate heat prostration. For this reason, an important goal for hot weather ventilation systems is to ***keep air temperatures below 95°F***.

During most of the year when cold or warm conditions prevail, a conventional natural or mechanical ventilation system is employed to ventilate the poultry house. For hot weather a specialized ventilation system is often required in order to achieve high air velocities and evaporative cooling. Hot weather systems are designed to assist broilers in dissipating heat during extreme hot weather.

Hot weather ventilation systems should be designed to:

1. Keep heat buildup within the house to a minimum through proper air exchange.
2. Provide air movement over the broilers to increase convective cooling or windchill effect.
3. Keep house temperature below 95°F through the use of evaporative cooling, if necessary.

Without **evaporative cooling** the air inside the broiler house will always be warmer than the air outside. The temperature difference between the inside and outside of the broiler house is determined by the solar and broiler heat added and the rate at which air in the house is exchanged by the ventilation system. The greater the amount of heat added to

the air, the higher the temperature of the air within the house. The faster the air in the house is exchanged, the closer the house temperature will be to the outside temperature. **Evaporative cooling** is used to maintain temperatures within the **comfort zone** when outside temperatures approach or exceed the upper limit of the comfort zone (see Chapter 7 for more information on the comfort zone of chickens). Evaporative cooling in mechanically-ventilated houses is provided by **fogging, misting, or cooling pads** while in naturally-ventilated houses it can only be provided by fogging or misting.

To design a hot weather ventilation system, calculation of the **heat gain through the building and heat production by the broilers** is needed. Heat flows into the house through the walls and roof and, to a lesser extent, through the floor, due to conduction and to heating by the sun. Heat also enters the house through the ventilation air and is added from the broilers themselves. Heat flows out of the house through the exiting ventilation air.

There is potential for cool night air to increase economic returns. By setting thermostats 10°F below the design rate, fans remain on longer into the cooler night. This strategy was shown to improve production efficiency during hot weather. The strategy did not provide any savings for late summer to early fall flocks because the increased electricity use by fans was about equal to the increased returns due to animal performance. Also, excessive windchill from cooler, high-speed air can result in additional feed energy consumption. ***It is extremely important that a strategy of integrated daily temperature be carefully planned and controlled so as to provide beneficial cooling without chilling the birds.***

B. Building heat gain

Heat gain from walls

The total heat gain through the building wall includes heating from solar radiation as well as conduction heating from the outside air. The **wall heat transmission coefficient** is used to calculate heat gain through a wall based on the temperature difference across the wall. In order to calculate the total building heat gain, the appropriate heat transmission coefficient for each wall and roof surface must be estimated.

Floor contribution to summer heat gain or loss is usually ignored. With a litter floor the floor heat gain (or heat loss if the floor is cooler than the indoor air) is so small that it can be neglected. With a concrete floor there is likely to be some cooling effect by the floor in the hottest part of the day and some warming effect during the cooler evening and night periods, since the mass of the floor takes time to heat up and then cool down.

A practical method of accounting for solar heat gain uses the **sol-air temperature concept**. The sol-air temperature is the equivalent air temperature that causes the same heat gain through a wall as the conduction plus solar radiation heat gains. Thus it is a measure of the solar heating effect added to the effect of the outside air temperature.

The **solar heat gain** through a particular roof or wall surface is affected by that wall's orientation; the outside solar heating for the location and time of year; cloudiness; wind;

and the reflectiveness of the surface. Walls and roof surfaces facing the sun will obviously collect more solar heating than those facing away. **Solar radiation** is affected by the latitude of the location (with the North Pole receiving less radiation than the equator). Also, light-colored, shiny (metallic) surfaces reflect more and absorb less solar radiation than dull, dark surfaces. For example, at 40° north latitude, the difference between sol-air temperature and ambient temperature is 36°F for a light roof but 79°F for a dark roof. Note that the difference in the solar radiation loads between 32 and 40 degrees latitude is only 1%. So it is reasonable to use the above temperature differences for a wide range of locations.

Broiler heat production

Broiler sensible heat production is affected by air temperature and humidity; air speed; and the type, age and stocking density of the broilers. For summer design purposes, broilers are generally assumed to be market weight. Broiler sensible heat loss contributes to building air temperature rise and must be estimated to determine required ventilation rates in hot weather. The **latent heat loss** is affected by humidity, and it contributes to the indoor humidity level, which is more of a problem for winter environment control.

C. Desired air exchange rates

The ventilation system has to exhaust the heat entering the building through the walls and roof, and the heat produced by the birds. There are separate calculation methods for conventional and tunnel ventilation. The **conventional approach** bases the calculation on heat removal. For **tunnel ventilation**, the calculation is based on the desired air velocity through the building.

When designing a hot weather ventilation system, the acceptable difference between inside and outside temperature must be defined. At first thought, the choice might be to maintain inside house temperature within a degree or two of the outside temperature. Although this would be 'ideal,' it is not practical or necessary in many situations. For example, if a producer wants to ensure that it would never be more than a degree warmer inside than it is outside, it would require that 771,000 cubic feet of fresh air be brought into the house each minute. This would be roughly equivalent to the air-moving capacity of nearly forty, 48-inch exhaust fans (20,000 CFM each).

Over the years, designers of ventilation systems have found that under most conditions a ventilation rate based on a house temperature 5°F degrees warmer than the outside temperature is sufficient to minimize heat stress in poultry housing. For example, to make sure that the house temperature would not exceed 95°F on a 90°F day, approximately 154,000 cubic feet of air would have to be brought into the house each minute (approximately eight, 48-inch fans). When evaporative cooling is used, the allowable temperature difference might be 6°F; the larger temperature rise minus the cooling effect will still be comfortable for the broilers.

Tunnel ventilation air exchange rates

The goal of tunnel ventilation is to provide a high air velocity or **windchill cooling effect** on the broilers by pulling air through the poultry house, like a wind tunnel. Tunnel ventilation is used only during hot weather and requires its own fans, inlets, and controls in addition to those provided for the conventional ventilation system. It is an additional ventilation system.

Tunnel ventilation often results in higher ventilation rates than required for heat removal, especially with well-insulated, relatively-short buildings (< 300 feet). However, for longer buildings or those housing large numbers of broilers, the tunnel ventilation air exchange rate may be very close to or even less than the rate required for heat removal.

D. Evaporative cooling systems

When used in conjunction with air movement, evaporative cooling can be effective at alleviating or preventing poultry heat stress during hot weather. **Evaporative cooling** uses **heat from the air to vaporize water**. It results in a reduced air temperature and increased humidity. During the hottest part of the day, outdoor relative humidity drops and the potential for evaporative water increases. Thus evaporative cooling can be useful even in very humid climates.

To evaporate water, heat (energy) is required. In fact, to evaporate a gallon of water requires almost 8,500 BTUs of heat. The heat comes from whatever the water is in contact with as it evaporates. This could be a hot sidewalk, your body, a tree, or the air itself. As the heat is removed from the object, the temperature of that object is decreased. If you put your hand in a bucket of warm water and pull it out, your hand feels a slight chill as the water evaporates.

It is important to realize that the temperature of the water itself does not have a great effect on the cooling produced through its evaporation. If you were to place a gallon of 50°F water on a warm sidewalk (90°F) it would produce 9,000 BTUs of cooling. A gallon of 90°F water would produce 8,700 BTUs of cooling, only a 3% difference. ***Energy and equipment should not be used to either increase or decrease the water temperature prior to cooling.***

A significant amount of cooling can take place by simply getting an animal wet and providing air flow over the animal. The water comes in contact with an animal's skin, and as the water evaporates, heat is removed directly from the animal. This is not typically done with chickens for two reasons. First, the feathers insulate chickens from much of the cooling effect of the evaporative of water. Second, in order to get the chickens wet, you also have to wet the house, including litter and feed.

The goal in most poultry houses is to evaporate water directly into the air. This removes heat from the air, decreasing air temperature. Two types of evaporative cooling systems are commonly used in poultry housing:

- Pad and fan, also known as evaporative cooling pad
- Fogging or misting system

The difference between these two systems lies in the ways water and air interact. Pad and fan systems use exhaust fans to draw air through a wetted porous material at the air inlet. As air moves over the wet pad, water is evaporated off the pad, removing heat from the air.

Fogging or misting systems spray fine droplets of water directly into the indoor air. With a fogging system, water is sprayed through nozzles into the air so that very small water droplets float around the house, removing heat from the air as they evaporate. 'Fogging-pad' systems are evaporative cooling pads that are kept wet by fogging or misting nozzles, rather than by the more common water recirculation systems. Pad and fan systems are used in mechanically ventilated houses, while fogging or misting systems may be used in either naturally or mechanically ventilated facilities.

The key to getting the most out of any evaporative cooling system is **to maximize the amount of air which comes into contact with the moisture added** to the house. Evaporative cooling efficiency is the percentage of the wet-bulb depression (or evaporative cooling potential) by which an evaporative cooling system lowers the dry bulb temperature.

In general, the choice of system type should be based on:

- Benefits of cooling broilers
- Capital expense
- Operating costs
- Quality of dealer service and support
- Ability to maintain the system

Fan and Pad system

Evaporative cooling pads are currently the most effective and efficient systems for cooling broiler houses. These systems drip water downward through a porous pad while air flows across the pad into the broiler house. New pads, or those in good condition, generally have high efficiencies (70 – 90%); and when sized, installed, and maintained properly, can provide more cooling effect than fogging without the risk of wetting the broiler house interior. **Recirculating-type pads** use a plumbing system including a sump and pump to recirculate the water through the pads. **Fogging pads** are a variation in which the pad is wetted by fogging nozzle spray instead of a Recirculating water delivery system.

Pads are made of corrugated cellulose, shredded fibers (e.g., 'hog-hair' or 'horse-hair'), and other materials. They provide cooling by having moisture in the pad evaporate as air flows through the pad into the house. Pad systems typically produce the most evaporative cooling because they are designed to provide a maximum interaction possible between air and the water. A typical 100' x 6' x 4" pad has more than 20,000 square feet of surface area. This allows the air entering the house to become totally saturated with water, resulting in the maximum cooling effect.

With pad systems, **it is especially important that the house be airtight** without cracks, holes, or other 'unplanned' openings. All ventilation air should pass through the pads to

achieve the cooling effect. If the house has 'unplanned' openings, only limited cooling is achieved. Pad systems typically cause a rather large static pressure drop of 0.05 – 0.10 inches of water. With such resistance to airflow, hot outside air will preferentially flow into the house through any other less restrictive openings such as cracks or inlets.

Pad and fan evaporative cooling systems can be very effective and are widely used in houses with more valuable chickens, such as breeders and layers. Since a static pressure drop across the pads is required, pad and fan systems cannot be used with natural wind (open curtain) ventilation and are mostly used in tunnel-ventilated poultry houses. Since pad and fan systems tend to be more expensive than fogging systems, meat bird producers have been slower to adopt them. Fogging-pad systems represent an intermediate option.

Pad selection, sizing and placement

Selection of evaporative cooling pads should involve consideration of product effectiveness, useful life, maintenance requirements, and dealer support and service, in addition to initial cost. ***The least expensive pad materials may not be very cost-effective***, since they are generally less effective at cooling. The evaporative cooling efficiency is a good indicator of pad performance, since it represents the fraction of the potential cooling effect which the pad will provide. Evaporative cooling efficiencies of 80-90% are typical of well-designed cellulose pad systems in good condition.

Sizing of pad systems is based on preventing excessively high air velocities through the pad. High velocities can cause high static pressure drops and blow water off the pads both of which reduce system effectiveness.

Placement of the pads depends on the ventilation system design, since the pads serve as the hot weather air inlets. The tunnel ventilation inlet area should ideally be placed in the end wall farthest from the exhaust fans to avoid a dead-air space near this end wall. However, the large amount of pad area required and the large endwall access doors typically necessitates placing most, if not all pad material on the sidewalls. Place one-half the pad area in each sidewall and directly across from each other.

Pad system costs are affected by the length of pad since distribution pipe, header, and gutter increase in size and installation cost with pad length. However, the height of each pad section should be no more than 6-ft to allow uniform wetting. Since the framing and enclosure to hold the pads will obstruct a small amount of pad at the top and bottom, subtracting that area allows for a more precise calculation.

Pump and sump sizing

In order to size the pump, **the pumping head** (or pressure against which the pump 'pushes') and the **water flow rate**, must be known. Pump manufacturers typically specify the water flow in gal/min (gpm) for several values of total head in feet (for example, one particular ½ hp centrifugal pump delivers 47, 37, and 25 gal/min at total heads of 10, 20, and 30 feet, respectively). The pump head includes the change in elevation of the water plus the loss of head that occurs at elbows, couplings, tees, valves, and filters, as well as losses due to friction along lengths of pipe. In addition, there must be some pressure

head at the top of the distribution pipe to squirt water out of the holes properly and to overcome friction down the distribution pipe. Typically, 1-2 pounds per square inch (psi), or about 4 feet of head is provided at the pad header. Dirty filters in the pipes can cause severe head losses, so good maintenance is necessary.

Water flow rate through the pads should be sufficient to flush away dirt, salts, and minerals that could otherwise foul the pads. This flow rate will be several times the actual water evaporation rate from the pads. Specific recommendations of water flow rate and sump capacities provided by pad manufacturers should be followed. When pads are installed on sidewalls, a separate sump and pump should be used for each pad to avoid excessive pumping distances.

Larger pipes and fittings are needed as the required flow rate (gpm) increases. For riser and feeder lines longer than 50 feet, pipe and fitting sizes should be increased to avoid excessive head loss or a larger pump will be needed. The same size pipe should be used from the outlet of the pump to the inlet of the distribution pipe.

Distribution pipe

For PVC distribution pipe, holes should be approximately 1/8 inch in diameter and free of burrs. The holes should be spaced evenly, 3-4 inches apart along the distribution pipe, and should face upward. **Holes** in the bottom of the distribution pipe will plug with dirt. The water should squirt out the holes onto the header pipe and drip down into the pad. The pad cover should have a **deflector** which spreads the jets of water out and back down over the top of the pad. With some older systems, water squirting upward to rectangular covers may leak out through the joints and screw holes and off the pad face. This may require caulking the joints or installing an improved deflector cover over the pads.

To ensure **uniformity in pad wetting** along its length, the water should squirt out uniformly along the distribution pipe. Remove the pipe cover to observe the distance that the water will squirt above the distribution pipe. Removing the cover to measure this distance can help troubleshoot water distribution problems. Holes less than 1/8 inch in diameter require more pumping head, are more likely to clog, and will deliver less water. On the other hand, holes larger than 1/8 inch in diameter are not recommended, since they can flood the pads and cause uneven water distribution.

To assure uniformity of pad wetting along the pipe for long pads, it is often desirable to split the water distribution with a tee at the center of the pad and pump water in both directions.

Since inadequate water distribution can result in ineffective cooling and shorten pad life, and excessive pumping head increases pump cost, methods of reducing pumping head, such as the following, should be considered:

- Avoid using unnecessary fittings, elbows, valves, etc., since they waste pumping head.
- Consider removing any in-line filter. If it will not be cleaned weekly it will greatly reduce flow.

- Filters with clear covers may clog with algae. Exclude light by covering with black paint or dark plastic bags.
- Make sure the distribution pipe is clean, because sediment and debris in the pipe will clog the holes. Clean by removing the end cap and flushing the pipe while the pump is running.

Maintenance of pad systems

In order to get efficient performance from a pad system, provide proper maintenance and operation. Maintaining a uniformly wet pad, cleaning scale and dirt from the pad and plumping systems, controlling algae, allowing the pads to dry out overnight, and fixing leaks will greatly extend the life of a system.

In order to avoid salt and dirt buildup in the water, it is important to **bleed-off** about 5-10% of the water flow continuously, or to flush the entire system periodically (e.g., weekly). Bleed-off methods include draining from the water supply line, return line, or sump tank or using a dump system to drain the entire system. Bleeding from the gutter, rather than the pump, reduces waste of clean water. Since the purpose of bleeding is to prevent salt and dirt buildup, the bleed-off drain line should not be routed to the pad gutter.

Proper water distribution is the most important factor in prolonged pad life. Necessary steps for providing efficient water distribution include ensuring adequate pressure in the distribution pipe, adjusting water flow to eliminate dry streaks, keeping the distributor pipe level, cleaning the filter, and using an adequate pump. Hard water may need to be adjusted to a pH of 6 – 8.

The following procedure is recommended for **cleaning and flushing the pads** on a **quarterly** basis:

- Completely empty the sump of water and silt
- Refill the sump with clean water
- Turn off the ventilation fans, if possible
- Manually turn pumps on to run fresh water over the pads for thirty minutes, using as much water as possible
- Open the ends of the water distribution pipes to flush out debris; replace the covers
- Remove the plug and drain the system for silt collection
- Gently hose deposits from the face of the pads (do not use a power washer)
- Completely empty the sump to remove the algae and dirt rinsed off the pads
- Disinfect the system with the proper amount of approved chemical
- Check to make sure the bleed-off is working properly
- Refill with clean water

Algae growth within the pads can clog pad pores reducing cooling efficiency. Algae require light, moisture, and nutrients to survive, and all of these can be plentiful in pad systems. In order to control algae, the following are recommended:

- Shade the pads and the pump
- Dry the pads daily (usually overnight)
- Avoid nutrient contamination (either from nutrients blowing into an uncovered sump or algaecides which degrade into nutrients)
- Drain and disinfect the sump regularly

In some tests of **algaecides**, those using quaternary ammonia (such as ammonium chloride) have been more effective than oxidizing-type biocides such as sodium hypochloride and calcium hypochlorite. Use the recommended concentration specified by the chemical manufacturer. Since different algaecides can have vastly different recommended concentrations, it is extremely important that manufacturers' specifications be followed. Overdosing is easy to do and can damage the pads, pumps, and gutters.

System control

Evaporative cooling is part of the **overall environmental control strategy** and should be integrated into other ventilation components by using a thermostat or computer-control system. Evaporative cooling is not used when air temperatures are cool. Cooling is not normally needed between the hours of 10 PM, and 9 AM. Note that a high thermostat/controller setting of about 85°F can achieve this, as nighttime temperatures are rarely above 80-82°F. If the cooling system is to turn on at a lower temperature, a timer will be needed so that they cycle off at night. Timers should not be used to turn the evaporative cooling system on and off during the day, however.

Any practice that results in dry areas on the pads during operation will reduce the cooling effect. ***The pads must remain wet over their entire area when cooling is desired.*** In addition to reducing cooling, cycling water flow through pads during the day, with timers or other devices, will reduce pad life. Daytime cycling of water flow through pads causes increased dirt and mineral buildup because it disrupts the continuous flushing of dirt and minerals out of the pads.

Variations – Pad and plenum arrangement

Although most pad and fan systems for poultry housing are used in tunnel ventilation, a 'pad and plenum' arrangement may be useful for houses using **conventional ventilation**. The evaporative pad is placed along one or both sidewalls and the cooled air first enters a '**plenum, or duct**', and then enters the room through a slotted inlet. A pad and plenum system might be desirable **when the building is too short for tunnel ventilation**, (or too wide as is the case in some experimental facilities). Since evaporative cooling system costs are greatly affected by the length of the pads, this type of system is not generally economical for long buildings.

E. Fogging and misting systems

There are a few things to keep in mind when designing a fogging system for a poultry house to ensure maximum evaporation of water. These include **droplet size**, **nozzle placement**, and fogging **system flexibility**.

It is important that the **water droplets** produced by the fogging system be kept aloft as long as possible to ensure maximum air temperature reduction in a poultry house. The longer a droplet floats around a house the greater the amount of water that evaporates off the droplet. If the droplet stays suspended long enough, it will totally evaporate before coming in contact with the floor. Once a droplet hits the floor, very little additional reduction in house temperature will occur.

One of the keys in **keeping droplets aloft** is to make them as small as possible. The smaller the water droplet, the more it is suspended by air movement. Generally speaking, at a constant pressure, the lower the nozzle flow rate, the finer the mist produced. The magnitude of the differences varies with manufacturer. The 2 gal/hr nozzles of some manufacturers put out droplets nearly 30% larger than their 1 gal/hr nozzles.

Another factor that affects droplet size is **water pressure**. With most nozzles the greater the water pressure the finer the mist produced. At 40 psi the typical misting nozzle produces a 72 micron droplet. To give you an idea of how small a droplet we're talking about, the period at the end of this sentence is 500 microns in diameter. At 200 psi the droplet size is decreased to 32 microns. At either pressure, we're talking about a very small droplet; however, there is a substantial difference between the two. The smaller droplet stays aloft much longer than the larger droplet and completely evaporates more than twice as fast as the larger droplet. Theoretically there are advantages to increasing water pressure above 200 psi, but the cost of specialized fittings, pipe, and pumps usually limits most fogging systems to 200 psi and below.

The other factor that determines how long a droplet will stay aloft is **air movement**. Without air movement a droplet emitted from a nozzle will stay suspended only a few seconds before hitting the ground. This suspension time can be increased dramatically by air currents by **circulating fans**. In addition, the circulation fans help mix the droplets with all the air in the house, not just the air in the immediate vicinity of the misting nozzles. It is important to note that the larger the water droplet the more crucial it is to have good air movement to keep the droplets suspended.

To get maximum suspension time it is best to deposit the droplets into the top of an air stream. This would mean that the droplets would have to pass through the air stream before they could reach the floor. For instance, let's say a naturally-ventilated house had a row of 36" circulation fans 50 feet apart blowing down the center line of the house; the fans would produce a significant amount of air movement within seven feet of either side of the fans. To get maximum suspension time, nozzles should be installed near the ceiling no further than seven feet from the center line of the house. Nozzles placed outside this area would be more likely to cause floor wetting. If two rows of paired fans were used, the nozzles could be placed in a wider area.

Care must be taken not to place nozzles directly in front of or behind a circulation fan. **Nozzles should be placed at least 15' away from any circulation** fan because the air velocity leaving a fan can disturb the cone of water droplets emitted from a nozzle, leading to the formation of large water drops that quickly fall to the floor. Nozzles placed too close to the intake side of the fan can also lead to the wetting of the fan, increasing the collection of dust and feathers on screens and fan blades and increasing the chance of an electrical short.

In mechanically-ventilated houses using **exhaust fans** and **eave air inlets**, fogging nozzles should be placed near the wall inlets so that the air is cooled as soon as it enters the building. Furthermore, placement of the nozzles near the sidewall will ensure that the fog is introduced into an area of high air movement, aiding evaporation and minimizing house wetting.

In order to maximize cooling and minimizing floor wetting, **the amount of moisture added to the air should be matched with the relative humidity** in the house. The lower the relative humidity, the greater the amount of water that can be added and the more cooling that can be produced. On very humid days, only a limited amount of water can be added. Ideally, a system would monitor house temperature as well as relative humidity and then turn on enough fogging nozzles to cool the air, but not so many as to wet the house. Though this is not practical in many instances, it is possible to design a system that has some flexibility.

A two- or three-**staging fogging system** can offer a wide degree of flexibility at minimal cost. For instance, two lines of 1 gal/hr nozzles on 20' centers could produce the initial cooling at 83°F. On humid days, the grower could have the flexibility to turn on just this set of nozzles to avoid floor wetting. On warmer days, above 85°F, if the humidity allows for more cooling, two additional lines of 1 gal/hr nozzles, situated near the other two lines, could also be turned on. It is even possible to employ a third system to be used during the hottest days of a summertime grow-out.

Though fogging lines can run lengthwise in a naturally ventilated house, they are easier to manage if they are installed in multiple lines running from sidewall to sidewall. For instance, if the circulation fans are located 40 feet apart down the center line of a house, a row of fogging nozzles could be placed 15 feet downwind of each fan. The first row of nozzles would be viewed as stage one. A second row of nozzles would be placed 10 feet from the first and used as stage two.

Fogging pads

Fogging-pad cooling systems have become popular for tunnel-ventilated broiler houses, since they keep the house interior drier than traditional fogging systems; are easy to manage; and are relative relatively inexpensive. Fogging nozzles are used instead of water recirculating system to wet the pads. Some **disadvantages** of fogging-pad systems are that fogging is subject to wind, which can reduce the wetting effect, and that water dripping out of the pads is not re-used. **Advantages** include their lower cost and cooling effects of up to 10-13°F. A **gutter** should convey water dripping out of the pads away from the building wall and causing structural damage. Fogging pad system

development is continuing. System manufacturers and dealers will have the latest information on pad specifications, nozzle types, and placement, etc.

One successful method of installing fogging pad systems is to place the pad 8-10 inches away from the sidewall. The sidewall curtain is positioned between the pad and sidewall. Advantages of installing fogging pads 8-10 inches off the sidewall include the following:

- Pad life is increased since the curtain is not dragged across the pad surface as it is opened or closed.
- Rodents are discouraged from nesting in the pads in winter since the pads are outside and cold.
- The gap between the pads and sidewall reduces the amount of water entering the house.
- The sidewall curtain can protect the pad from dust and mechanical damage from debris originating from inside the house.
- The gap enables placement of a 5-foot pad on a 4-foot curtain opening or 6-foot pad on a 5-foot curtain opening. This increases the air speed through the smaller curtain opening, which reduces dead-air space at the inlet end of the house.
- When the pad and curtain openings are the same size, the gap allows the curtain opening to be closed 8-12 inches, which increases air speed and reduces dead-air zones.

F. Mechanical ventilation systems

Mechanical ventilation systems use fans to bring air into a building and are especially appropriate when a narrow control of temperature is desired, such as with young broilers, or in special applications, such as light-controlled pullet and layers houses. Well-designed systems provide for adequate air exchange capacity and uniform air distribution.

The major types of **mechanical ventilation** are positive-pressure systems and negative-pressure systems. The two differ in whether the house interior is at a higher (positive-pressure) or lower (negative-pressure) static pressure than outside static pressure. Air movement is in response to pressure differences with air moving from regions of higher pressure to lower pressure. Resistance to airflow causes a static pressure drop, measured in inches of water gauge (iwg). Air enters the building at a speed dependent on the static pressure difference between the inside and outside of the inlet, which is affected by the dimensions of the inlet.

In **positive-pressure ventilation systems** fans push air into a building which creates a higher static pressure within the structure. This forces air to leave the building through any opening including doors, windows, exhaust outlets, and building cracks. Positive-pressure ventilation systems tend to have less uniform air distribution. Ducts with carefully sized and positioned holes are often used to create proper air patterns. However, duct systems are costly to design and maintain and require additional fan power to overcome resistance to airflow through the duct.

Sometimes **positive-pressure ducts** are used as a supplement to negative-pressure systems to distribute fresh or tempered air specifically to where it is needed. Ducts are more commonly employed during cold and mild weather when air exchange capacity through the duct is significantly lower than summer's high air exchange rates.

Positive-pressure systems can force moist air into walls and attic spaces, causing condensation and water damage and, potentially, frozen-closed doors and windows in cold weather. Positive-pressure systems are uncommon in poultry houses because of the disadvantages mentioned.

Circulation fans are installed within a building to overcome stagnant air problems or to increase air velocity at bird level. These fans do not contribute to the air exchange. A well designed mechanical ventilation system does not need circulation fans. Circulation fans in a poorly-insulated, leaky house help prevent temperature and moisture stratification through improved air distribution. They are usually used in naturally ventilated buildings and discussed later in the natural ventilation section.

There are two approaches to **negative pressure mechanical ventilation** – conventional and tunnel. In each case, fans exhaust air from the building creating a lower static pressure inside the building compared to outside conditions. This draws air into the building. **Conventional systems** are designed based on removing bird heat in the summer and on removing moisture and contaminants in the winter. **Tunnel systems** are a hot weather strategy designed to create the desired air velocity at broiler level and to remove broiler heat. In each case, fans are selected to provide the desired air exchange rate and inlets are designed to provide good air distribution.

Large broiler houses generally use 36-inch and 48-inch diameter, single-speed fans. In a conventionally ventilated house fans are either uniformly spaced or banked in groups of two or three along one or both sidewalls while inlets are located along one or both sidewalls at the eaves. Tunnel-ventilation systems, often combined with evaporative cooling, may be used during hot weather. In tunnel ventilation, exhaust fans are located on one end of the building and inlets are grouped at the other end.

Fans

The air exchange capacity of a mechanical ventilation system is provided by fans. Fans discharge a volume of air per minute from the building and, in concert with inlets and a static pressure difference, cause fresh air to enter the building to replace the exhausted air.

An **exhaust fan** creates a slight vacuum within the structure compared to outside static pressure. The static pressure difference required to ventilate a building is very small – on the order of 0.05-inch water (pressure is often measured as a depth of water in a column). This can be visualized as the amount of suction needed to draw water 5/100 of an inch up a straw. This may not seem like a lot of suction, but it is enough to create sufficient airflow to properly ventilate a building. Static pressure should be maintained within a reasonably constant range. Creating a static pressure difference requires relatively tight building construction, however, and not all poultry buildings meet this criterion. Mechanical ventilation buildings need a static pressure gauge (manometer) so

the operator can verify that desired static pressure (0.05 – 0.08-inch water) is being maintained.

Fans for the poultry house ventilation are **belt- or direct-drive propeller fans** and are designed for providing large volumes of air against low airflow resistance. Poultry house fans require **totally enclosed motors** for protection from dust and gas damage. In a conventional system, fans are often banked, or installed side by side, in sets of two to four fans approximately every 50 – 100 ft along one or both sidewalls of long broiler houses. Some producers locate summer fans on or near one end wall for tunnel ventilation applications.

The **resistance to airflow** that must be overcome by fans is affected by **ventilation inlets** and **fan shutters** and **guards**. Additional pieces of equipment, such as **wind protection devices**, **evaporative pads**, or **light traps**, further restrict airflow. Fan airflow capacity is influenced in turn by static pressure, which is most effective when kept at 0.05 to 0.08 inches water gauge (iwg) across the broiler house inlets. This is monitored as part of the ventilation system control, but it only represents one component of the static pressure difference against which the fan must operate. Total resistance along the airflow path from outside to building interior and back outside, can be as high as 0.20 iwg if the fan is moving air through evaporative pads or exhausting air into strong winds. Obstructions within twenty fan-diameters' distance downstream of the fan should be minimized. For example, a 36-inch fan should have no obstructions within 60 ft of its exhaust side. **Light trap hoods** violate this rule, but they are often necessary for light-controlled poultry houses.

G. Tunnel ventilation for hot weather

Tunnel ventilation is an extremely effective method of cooling broilers during hot weather. Using a 40' x 400' example house, six 48-inch fans each providing 18,000 CFM at 0.10 inch static pressure mounted in one end wall are required to tunnel ventilate the house. Increased air velocity produces a **windchill** effect on birds. The benefits arise from the increased convective heat loss with increasing air velocity. When evaluating the windchill effect in commercial production conditions, it should be kept in mind that air velocities around the birds are approximately 50% lower than the air stream velocity in the open area of the house.

A tunnel-ventilated house requires two ventilation systems and therefore two sets of inlets – winter and summer. The summer tunnel inlets consist of a bank of light trap inlet units. If 56" x 56" units are used, then provide two of these light-trap inlets per 48-inch fan. This is equivalent to 1 ft² of inlet per 450 CFM.

The light-traps would be located in the end of the house opposite the fans. During the winter, sidewall inlets would be used as previously described. Since only about one-third of the fans would be required to cool the house, sidewall inlets would be closed and the large, tunnel ventilation summer inlets would be opened.

Tunnel ventilation is only a hot weather ventilation system. Exhaust fans and air inlets installed in the sidewall are absolutely necessary for ventilation needs during cold

and cool weather. Therefore, construction costs of tunnel ventilated poultry housing is more expensive than conventional ventilation. However, considering the effect of good environment on growth rate and feed consumption, tunnel ventilation should be strongly considered in regions subject to hot summer temperatures.

Caution is advised at air temperatures greater than 100°F. At these temperatures, increased wind speed actually causes a heat gain to the birds and any heat loss from the birds is almost entirely evaporative. When interior air temperatures are over 100°F, catastrophic broilers losses could result from operating 'cooling' fans without implementation of evaporative cooling.

H. Natural ventilation in hot weather

In warm or hot weather, naturally ventilated buildings rely almost completely on wind-induced ventilation. Ridge openings allow heated air near the interior roof line to escape. Ridge openings are also high enough to capture wind effect pressures, which drive ventilation airflow. During calm, hot weather, circulation fans may be needed to provide air flow (wind chill) over the birds. Some naturally-ventilated houses will have a mechanical or tunnel ventilation system installed to assure there is sufficient air exchange and air movement during hot weather.

Circulation fans

The primary purpose of circulation fans is to provide **air movement over the birds** in order to **remove body heat**. The faster the air moves, the more heat is removed from the broilers. Circulation fans should produce an air speed of at least 400 ft/min at broiler level. It is essential that every bird be exposed to adequate air movement. Broilers in dead-air spots, such as the corners of the building, are often the first to die during extreme hot conditions.

The **shape and size of a fan's coverage area** are partially determined by the type of fan. Generally, a belt-driven axial fan will produce 400 ft/min or better air speed over an area fifteen times the fan diameter in length by five times the fan diameter in width. For instance, air emanating from a standard 36-inch circulation fan with a ½-hp motor travels in an egg-shaped pattern. The dimension of this area is approximately 45' x 15'. On the other hand, a direct drive fan will produce the 400 ft/min over an area approximately twenty times the fan diameter in length by three to four times the fan diameter in width.

In some coastal areas and mountain ridge locations, breezes are prevalent enough that additional air movement is only needed in the center of the house. A single row of fans can be installed down the middle and/or near the ends of the house to minimize dead air zones.

There are **two principles** which should be considered when sizing and placing mixing fans for cooling:

1. Maximize coverage of broilers with air speeds sufficient to give a cooling effect. For floor-raised broilers, this is expressed as the floor area covered by air speeds

of 200-500 ft/min. Fan type, placement, and orientation affect air speed distribution.

2. Uniform, fast air speed over the coverage area is desirable. Broilers will crowd into the areas with highest air speeds in hot weather, which causes additional heat stress and mortality from piling. Some fan arrangement provides better coverage of the floor with uniformly high air speeds.

The type and placement of mixing fans greatly affect the air velocity distribution. For floor-raised birds, the velocities within a foot of the floor are of interest.

- **Titling mixing fans** toward the floor about 10° increases the total area covered with air velocities from the fan, but it also increases the maximum air velocity near the floor. If the highest velocities are not above 600 ft/min, this trade-off may be beneficial.
- **Increasing the height of the fan** above the floor from 40 inches to 60 inches reduces both maximum velocity and the total area to be covered by desirable air velocities. Place the fans on winches so their height can be adjusted.
- **Turning propeller fans** to blow downward results in more floor area covered with desirable velocities, but a large area is covered with air velocities above 600 ft/min, which may cause excessive bird crowding in hot weather.
- **Ceiling paddle fans** blowing downward can cover large areas with desirable velocities without the excessive air velocities associated with propeller fans blowing downward. This is the result of spreading the airflow over a larger fan blade area. Use higher-powered paddle fans since low-power (150 W or less) ceiling fans cover much less floor area with desirable air velocities.

Other **placement strategies** for mixing fans including the following:

1. Keep fans away from the sidewall. Otherwise birds tend to move toward the fans and pile against the sidewall.
2. Fans should blow with the direction of any strong prevailing wind at the site to increase the area covered by each fan.
3. To minimize dead air spots, provide air movement in the ends and corners of the house with smaller fans, if necessary.

These examples demonstrate that providing complete coverage of indoor floor area with high air speeds using mixing fans can require many fans. For buildings where wind environment is not favorable, mixing-fan costs should be compared to the cost of fans and energy use for tunnel ventilation, which provides fresh air exchange in addition to uniform high air speeds at bird level.