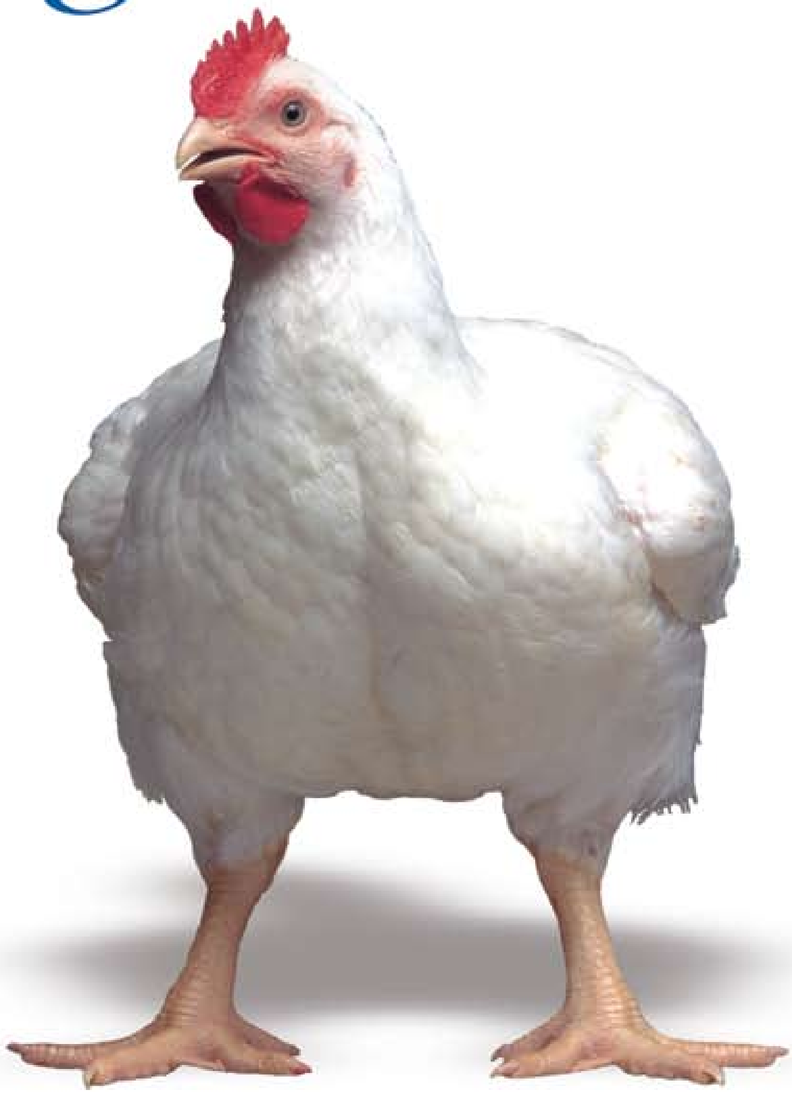

Environmental Management

In The Broiler House

Environmental Management

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Acknowledgments

The main content of this publication was authored by Professor James O. Donald, of Auburn University. Professor Donald is an agricultural engineer widely recognized as an authority on poultry housing and environmental management, and appreciation is expressed to him for permission to use these materials.

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Introduction: Economic Value of Proper Environmental Management

Whether producing meat, eggs, milk or other animal products, it is well established that effectively managing environmental conditions reduces the total cost of production. In the broiler meat production business, all components of the production process – from parent stock broiler breeders to broiler progeny – benefit from effective environmental control. Given the economic benefits of effective environmental control it is imperative for managers and technicians to understand the basic concepts of this topic. This publication has a three fold purpose:

1. To clarify what environmental criteria and conditions are necessary to achieve the genetic potential of the modern broiler.
2. To outline the most important factors in design of modern broiler housing to be able to provide optimum environmental conditions.
3. To provide basic operational guidelines for this housing.

It is well established that effectively managing environmental conditions reduces the cost of production.

Overview: Environmental Management Objective and Methods

The objective is to provide an environment to maximize flock performance, achieving optimum and uniform growth rate and feed efficiency in meat yield while ensuring that bird health and welfare are not compromised.

Supplemental heating systems play an important role in environmental management, especially during the brooding phase. However, in many locations for a portion of the growout supplemental heating may not be needed. On the other hand, proper ventilation is needed throughout a growout, even during times when supplemental heat is being provided, for control of air quality if not for cooling. Ventilation is therefore the most important tool in managing the in-house environment for best bird performance.

Ventilation is the most important tool in managing the in-house environment for best bird performance.

Ways of providing supplemental heat in poultry houses around the world vary far more than do ventilation methods, relying on a wide variety of fuels and heat-delivery methods, including radiant and hot-air systems, direct in-house combustion and indirect heat-exchange, etc. Examination of the details of particular heating systems is beyond the scope of this publication, which focuses primarily on the most widely applicable principles of in-house environmental management.

Except with very young birds and/or in very cold weather, temperature control is the primary goal of ventilation. At each stage of a bird's development, there will be a certain temperature zone in which a surplus of feed energy above the requirements of body maintenance allows the bird to gain weight, as shown in Figure 1 on the next page. Within this broad "thermal comfort zone" there will be a narrow temperature range (within 2 or 3 °F) in which the bird makes best use of feed energy for growth. This is the optimum performance zone. Providing this optimum temperature – along with adequate feed and water – assures that the bird's welfare and economic performance are maximized.

At each stage of a bird's development, there is one optimum performance temperature zone in which the bird makes best use of feed energy for growth.

Note: Although there is a broader temperature range in which the birds will be more or less comfortable (the "thermal comfort zone"), this publication as is common in the industry uses "comfort zone" to mean that narrower range of maximum comfort, the temperature that is the bull's-eye of the performance target.

If the temperature is too low, birds increase their feed intake but have to use more of that feed energy to keep their bodies warm. If temperature is too high, they reduce feed intake to limit heat production. Adequate ventilation prevents heat build-up and keeps birds in their optimum performance zone, first by exhausting warm air from the house and replacing it with cooler outside air, and in most well-equipped modern housing by effective (wind-chill) cooling through tunnel ventilation, and by lowering the actual air temperature through evaporative cooling.

The target temperature for best broiler performance changes daily during a growout – ventilation must be adjusted accordingly.

The target temperature for best broiler performance changes during a growout, typically from around 86°F on day one to near 68°F or lower at harvest time (assuming the ideal humidity of between 60 and 70%), depending on bird size and other factors. The temperature experienced by the bird is dependant upon dry bulb temperature and humidity. If RH is outside the ideal range of 60-70%, the temperature of the house at bird level should be adjusted. For example, if RH is closer to 50%, the dry bulb temperature on day one may need to be increased to 92°F. Ventilation therefore must be adjusted accordingly to maintain optimum temperature. At all stages, monitor bird behavior to ensure that the bird is experiencing adequate temperatures.

Ventilation is the only practical way to lower too-high humidity, which is most often a winter problem and can affect bird health. Even when ventilation is not needed for heat removal, we must maintain at least a minimum rate of ventilation to prevent wet, caked litter and ammonia problems.

By breathing, birds take oxygen out of the air and breathe out carbon dioxide, so fresh air must be brought into the house to replace that oxygen and exhaust the excess carbon dioxide. Ventilation to provide fresh air is needed in all seasons and in hot and cold weather.

The most common air quality problem, however, is ammonia coming from too-wet litter, which leads to health problems and lowered performance. Proper ventilation heads off buildup of ammonia by controlling relative humidity.

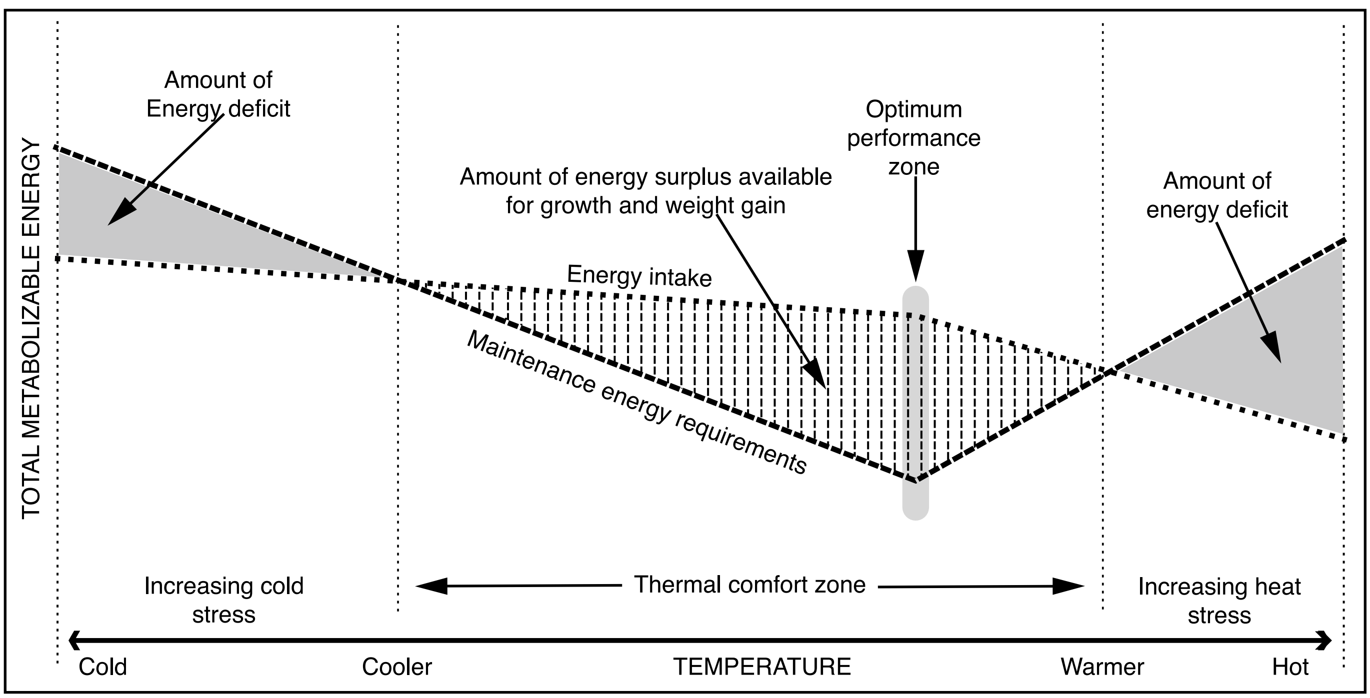


Figure 1. Optimum Performance Temperature Zone – At each stage of a bird's development, there is one narrow temperature range where maintenance energy requirements are lowest and the bird can make maximum use of feed energy for growth. If temperature goes just a few degrees outside the optimum performance zone, cooler or warmer, birds will be using a higher proportion of their feed energy for body maintenance and less for growth.

All of the above factors are important. Fortunately, in most situations bringing in fresh air and exhausting toxic fumes are accomplished by ventilation aimed primarily at controlling temperature and moisture. Important: proper in-house environment must be distributed evenly throughout the house. Pockets of dead air, drafts, cold spots, or hot spots can lower flock performance and even cause mortalities.

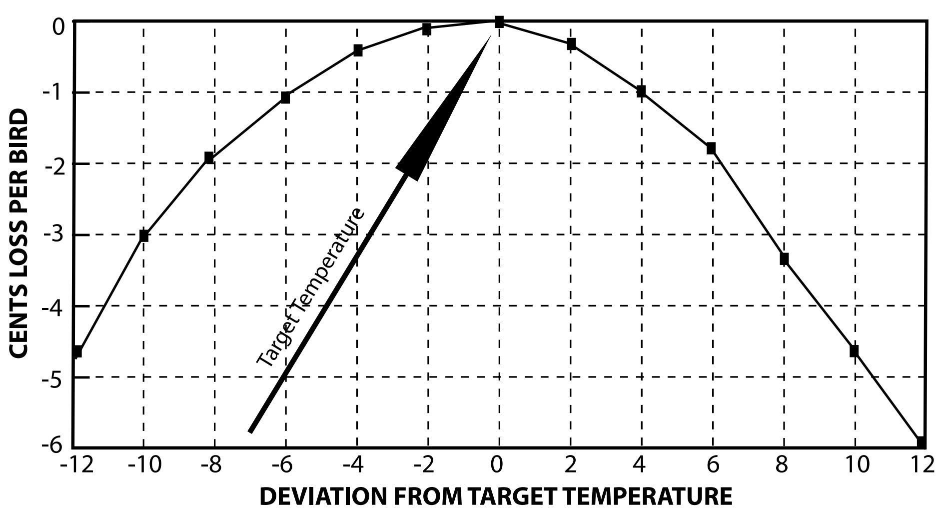
In-house environment must be uniform: pockets of dead air, drafts, cold spots, or hot spots can lower flock performance.

Economic Benefits of Environmental Control

Birds most efficiently convert feed to meat when they are given consistently optimum environmental conditions, with temperature being the most critical factor. Small temperature differences can have a significant effect on returns to the owner. This has been well confirmed by research and by experience worldwide. Figure 2 below shows differences in total cents per bird value resulting from on-target vs off-target temperatures, based on a computer study of temperature effects on bird performance. The study is based on, and figures given solely for, the growing stage after brooding, when the target temperature has leveled off at about 72°F. Under these conditions, consistently missing target temperature on the high side by only four degrees F would mean a one-cent loss in value per bird.

During the brooding phase, even brief chilling can seriously hurt flock performance. For example, university research in the United States showed that exposing day-old chicks to an air temperature of 55°F for only 45 minutes reduced 35-day weights by about one-fourth pound. After the brooding phase, bird performance is more quickly hurt by high than by low temperature. For example, the graph shows the cost of being consistently too high by 8°F is about half again as much as the cost of being consistently too low by the same number of degrees. Since maintaining optimum temperature is even more critical during the brooding phase, the reward for being consistently on target would be even higher for an entire growout.

During the brooding phase, even brief chilling can seriously hurt flock performance.



Consistently maintaining target temperature yields significant returns.

Figure 2. The "Cost of Being Wrong" – Being just a few degrees off target temperature in the growing phase can hurt grower income significantly. Graph shows cents-per-bird differences in total returns for consistent on-target vs off-target temperature control for non-brooding phase birds. Conditions: Broilers grown to 49 days, meat sold for $0.40 per pound, no dockage for nonuniformity; feed costs $278/ton starter, $270/ton grower, $258/ton finisher. ***Source: Veng, Hot climate ventilation.***

Since costs and selling prices vary, the exact reward for on-target temperature control (or, the "cost of being wrong") will also vary. What research and on-farm experience demonstrates is the principle that consistently maintaining target temperature yields significant returns.

Climatic Factors In Housing And Ventilation Decisions

The major factor influencing type or style of housing is climate. Different climatic conditions call for different ventilation and heating strategies, and affect the possible or desirable bird stocking density. Generally, extreme conditions require more and more sophisticated inside environmental control equipment and management. Where seasonal variations in weather are pronounced, a house may require ventilation systems for hot and cold weather.

Extreme climates require more sophisticated inside environmental control equipment and management.

In a given situation, housing and ventilation choices must be based on calculating the benefits of providing technology to cope with:

1. Prevailing weather, or prevailing seasonal weather – that is, conditions which generally persist over at least several months; and again,
2. Weather extremes likely to be encountered.

Following is an outline of typical climatic and/or weather conditions and their effects on ventilation decisions. It is impossible to give specific regional advice in the limited space available here, so these are very general recommendations. Elements of more than one climate may have to be applied to a given production facility

Extremely Cold Climate

In locations that produce broilers where extremely cold situations may exist for periods of time during the production cycle, some particular cautions in regard to the design and operation of poultry houses should be noted.

In extremely cold climates, dry conditions may cause birds to lose more heat; temperature setpoints may need to be higher, but minimum ventilation must be maintained.

In regard to direct effects on bird health and performance, extremely cold air is also extremely low in moisture content, so that when this air is heated and mixed with air in the house it is often possible to have conditions that are extremely dry and can affect bird health. Extremely low relative humidity in wintertime production means that birds will respire more heat than those grown in higher relative humidity conditions, thus their heat loss is greater. To compensate for this greater bird heat loss, often we must increase the temperature set points. At the same time, managers are often tempted to reduce ventilation time to reduce fuel costs. This can be a serious mistake, since performance losses caused by inadequate cold-weather ventilation can outweigh additional fuel costs.

Extremely cold conditions may require use of a pre-warming plenum to condition outside air before it enters the house.

In extremely cold conditions we must also take into account issues with the structure that are not common in more temperate climates. When the outside air temperature is well below freezing it becomes more important and more difficult to avoid putting cold outside air directly on the birds, so that a pre-warming plenum or heating room to condition air before entry to the house may be needed. Also, extremely cold outside air, despite its relatively low moisture level, can cause serious condensation problems and even cause air inlet doors to freeze up. Preventing such problems requires special attention to insulation and to sealing to prevent outside air leakage into the house, as well as possibly installing pre-warming plenums for incoming air.

Cold Climate

In high altitude locations and in high northern or southern latitudes with prolonged winter temperatures consistently below 50°F and with moderate summer temperatures, tunnel ventilation and evaporative cooling are not usually needed to cope with bird heat.

In cold climates ventilation is needed to help prevent excessive moisture build-up in the poultry house.

Negative pressure powered ventilation is needed to keep birds comfortable and maintain optimum flock performance, especially by preventing excessive moisture from building up inside the house. Houses typically will need a "minimum ventilation" setup augmented with additional fan (and air inlet) capacity to exhaust bird heat during warm weather. Additional supplemental heating systems and improved insulation may also be needed to handle the effects of extreme cold.

Moderate Climate

Where temperatures consistently rise above the 75°F range, power ventilation will be required for all but the lowest bird stocking densities in small, naturally ventilated houses. Where temperatures consistently rise into or above 75-86°F range, tunnel ventilation is usually recommended. Tunnel ventilation provides high–volume, rapid house air exchange and a high velocity "wind chill" air flow which gives a somewhat lower effective temperature experienced by the birds (see Figure 16, page 15). As temperatures rise into the 95°F range, the wind chill effect begins to disappear, and evaporative cooling must be added to provide actual air temperature reduction.

Even in moderate climates, tunnel ventilation is usually recommended if temperatures consistently rise into or above 75-86°F range.

Hot Climate

Generally, hotter weather makes it more difficult to increase house size and bird density. Air exchange alone can only keep inside air temperature from rising more than a few degrees above outside air temperature. However, if relative humidity is not too high, higher bird densities can usually be maintained reliably even in very hot weather by tunnel ventilation with evaporative cooling.

Higher bird densities can usually be maintained reliably even in very hot climates by tunnel ventilation with evaporative cooling.

In tropical or subtropical areas where temperatures are consistently in the 95-100°F range, high density housing and open sided, naturally ventilated housing are generally not feasible. In hot climates with low humidity (such as high altitude desert facilities) the low humidity contributes to ascites and lowers growth rate.

The combination of high humidity and high temperature is particularly difficult for birds because a major way they expel excess body heat is through breathing (or panting) which evaporates moisture from their lungs and airways. The higher the air humidity, the less self-cooling they are able to achieve. However, in properly designed tunnel ventilated houses the effects of humidity are minimized over naturally ventilated housing.

How Birds Work And What They Need

Very young chicks have little ability to regulate their internal temperatures, and they need warmth – an air temperature around 86°F (assuming a RH of between 60-70%). As the birds grow, their "comfort zone" temperature range widens a bit and drops so that at catch time they're most comfortable at near 68°F (assuming a RH between 60-70%). This means that early in a growout, our main concern usually is making sure the birds are warm enough. As the birds grow, too much warmth, which can happen even in winter, is a more common problem. Our goal in ventilation is to maintain in-house temperatures within the birds' comfort zone–not too warm, not too cold–at all times during the growout. To do this, we need to understand how birds, heat, and humidity interact.

Early in a growout, the main concern usually is keeping birds warm enough. As the birds grow, too much warmth is a more common problem.

Birds Produce Heat and Moisture

Birds convert feed and water into energy they use for body maintenance (operating their organs and muscles and keeping themselves warm) and for growth to produce weight gain. However, they aren't 100% efficient, so they generate quite a bit of excess heat along with quite a bit of moisture (in fecal matter and by breathing).

Typically birds will produce about 5 Btu's of heat per pound. This means that the larger the birds grow, the more heat they put out. If we have 20,000 four-pound birds, for example, they will add around 400,000 Btu's per hour to the house, or as much heat as two or three forced-air furnaces running continuously. If we have 20,000 eight-pound birds, they will produce 800,000 Btu's per hour. World wide the trend is toward bigger bird production. The amount of moisture produced also varies with age. The same flock of four-pound birds may produce 1,000 gallons of water per day, depending on the temperature. Other things being equal, in-house air temperature and humidity both tend to rise as the growout progresses.

20,000 four-pound birds will add around 400,000 Btu's per hour of heat to the house.

20,000 four-pound birds will add around 1,000 gallons of water to the house per day.

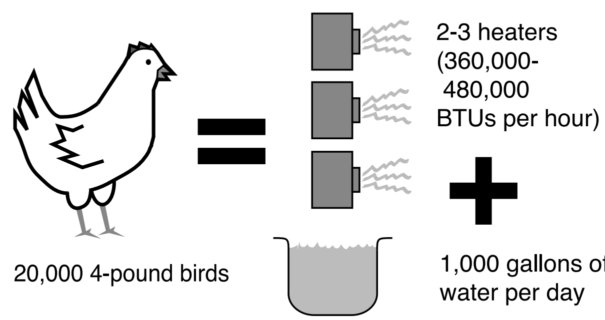


Figure 3. Large numbers of birds contribute large amounts of heat and moisture to a poultry house. In-house air temperature and humidity both rise as a growout progresses.

During the brooding phase, young chicks will need supplemental heat. However, as a growout progresses, especially in cooler weather, the birds increasingly help keep themselves and the house warm with the heat they generate. As birds grow larger, and especially in warm weather, ventilation is essential for heat removal, to keep the in-house temperature from rising to a point where birds cannot continue getting rid of their excess heat and their internal temperature goes too high.

Effects of Temperature and Relative Humidity on Birds

Birds do not sweat; they shed excess body heat primarily to air circulating around their bodies.

Temperature and humidity work together to determine bird comfort, but for simplicity in the following paragraphs we'll look at temperature first, then humidity, and then explain how their interaction affects birds.

Birds are basically air-cooled. That is, air moving over the birds picks up their body heat and transfers it to the environment. Birds do not sweat, and so do not enjoy this kind of built-in evaporative cooling system. They do get some evapora-

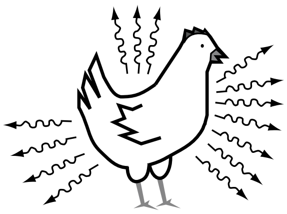


Figure 4. Birds do not sweat and so cannot cool themselves in this way. They shed almost all excess body heat by direct body-to-air heat transfer. In times of heat stress, they begin panting in order to rid their bodies of more heat.

tive cooling effect through breathing and panting (explained below). However, they rely mainly on direct body-to-air heat transfer for cooling. If you see birds lifting their wings, they're feeling hot and exposing more of their bodies to the air to get rid of the excess heat.

If you see birds lifting their wings, they're trying to expose more of their bodies to the air to get rid of excess heat.

For fully-feathered birds to stay comfortable, there has to be a substantial difference between house air temperature and their own internal temperature, which normally is above 100°F. As the in-house air temperature rises higher and higher, the birds' heat-shedding mechanisms become less and less effective. The birds' internal temperatures then begin to rise, and they slow down or stop eating and growing. If the situation isn't controlled, they eventually will die.

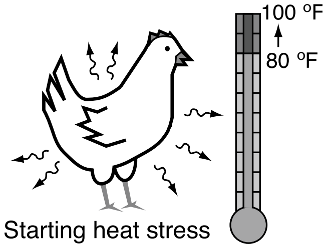


Figure 5. For fully-feathered birds, as the air temperature rises above around 80°F, birds' heat-shedding ability becomes less effective. As they begin to experience heat stress they slow down or stop eating. If heat accumulation in their bodies isn't stopped, they eventually will die.

For air temperatures up to the low 80°F range, ventilation usually can remove warmed-up in-house air at the proper rate to keep birds within their comfort range.

Under most conditions as birds give off heat, the house temperature can be kept from rising too high by exhausting warm air and replacing it with cooler outside air. Since birds get rid of excess heat mainly by warming the air around them, the more rapidly that air is replaced the more excess heat they can lose. In most poultry houses, for outside air temperatures up to the low 80°F range, the ventilation system can be operated so that the warmed-up in-house air is removed at the proper rate to maintain overall house temperature within the birds' comfort range.

In addition to simply changing house air, getting wind on the birds can help them cope with high temperatures. The wind-chill effect of moving air creates a lower effective temperature for them. For example, if you have air in the house at 90°F (and average humidity) moving at 500 feet per minute (about 5.7 mph), it will feel to fully-feathered birds like about 80°F air. The effect is even greater for younger birds, which may be chill-stressed. Tunnel ventilation creates the most effective wind-chill cooling. In non-tunnel houses, stirring or circulation fans can help.

The wind-chill effect of moving air can keep birds comfortable in hot conditions; evaporating water into the air provides additional cooling.

In very hot weather, evaporating water into the air can provide additional cooling. Very fine droplets are sprayed into the air, or water is evaporated by airflow through a wetted pad. As the water evaporates, the air temperature is reduced. Evaporative cooling depends on fans providing proper airflow in the house, and works best when relative humidity is not too high.

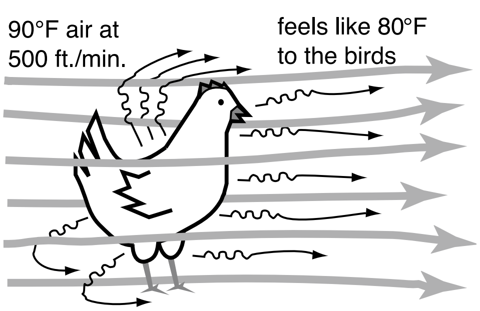


Figure 6. Fast-moving air over birds creates a wind-chill effect that can be very beneficial, especially for larger birds. However, younger birds are more sensitive to wind-chill effects and may be chill-stressed.

Birds can tolerate higher temperatures during the day if nighttime temperatures drop 25 degrees F or more below daytime highs. During the cool nighttime birds can get rid of excess body heat built up during the day. Running fans to get air moving over the birds during the night can help by reducing the "effective" night-time temperature. The birds then can start the next day fresh, which helps keep performance up and lessens the risk of possible mortalities if daytime temperatures are very high.

Keeping birds cool at night helps them stand high daytime heat.

Birds also lose some body heat through breathing. This is why you'll see birds begin to pant when they feel over-heated. It's like a back-up cooling system, that usually starts working when temperatures rise around 7-10 degrees F above their current "comfort zone" temperature. What's happening is the birds are trying to maximize the evaporative cooling effect they get from the air passing over the moist linings of their airways and lungs. This cooling method works best when the air is relatively dry. If the air is already holding a great deal of moisture, it can't readily evaporate the birds' moisture, and the evaporative cooling effect doesn't work as well.

Figure 7. Birds can tolerate higher daytime temperatures if they are able to cool off during the night. The effect is most pronounced when nighttime temperatures drop 25 degrees F below daytime highs. Running fans at night to move air over the birds can help by reducing the nighttime "effective" temperature.

Panting indicates birds are over-heated and are trying to shed additional body heat.

An old rule of thumb used by many poultry producers and managers says that in non-tunnel conventional houses if the in-house air temperature is in the 80's F or above and the temperature and relative humidity numbers add up to 160 or more, birds begin to have trouble shedding their excess body heat. That is, temperature plus humidity gives you a heat stress index. For example, if air temperature is 85°F at 70% humidity (85 + 70 = 155) the birds will be reasonably comfortable. But if the relative humidity goes to 80% (85 + 80 = 165), you're likely to be losing feed efficiency because of overheating. Note that this rule works only in conventional open-sidewall ventilation or in cold-weather power ventilation when air is not moving over the birds. It does not apply to tunnel ventilation because of the wind-chill effect.

Temperature and relative humidity work together; high relative humidity can cause problems even at relatively low air temperatures.

In cold weather when direct-combustion heaters are being used, not only the birds but the house heaters add moisture to house air, since water vapor is one of the combustion products from burning most fuels. This is a small amount compared with the moisture coming from the birds, but the combination can produce high house humidity if the ventilation rate is too low. This means you can have a heat stress problem with the birds when you would least expect it, if

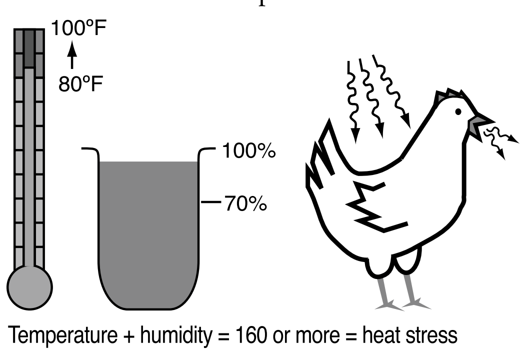


Figure 8. A rough guide to whether the combination of temperature and relative humidity will stress birds is to add the numbers. If the temperature is above 80 °F and the temperature and relative humidity add up to 160 or more, birds are likely to be stressed.

the temperature/humidity index goes above 160. Too much moisture contributes to litter caking and ammonia problems. (Note: If a heat-exchange system is used so that combustion products are not released into the house, heating will not add moisture to house air.)

Too much moisture in a house contributes to litter caking and ammonia problems.

In warm weather, humidity is not often a problem, except in connection with rainstorms on hot days. For example, after an afternoon thunderstorm on a hot summer day the air temperature may reach 90°F, with relative humidity above 90%. You must have maximum air exchange and air movement under these conditions.

How Relative Humidity Works

When water evaporates, it passes into the air as water vapor. You can't see it, but gallons and gallons of water are floating around in the air all the time. In the poultry house, what matters most isn't simply how many gallons of water are in the air, but how close the air is to holding all it possibly can – that is, to being saturated with water vapor. The idea of "how close to saturation," stated as a percentage, is what we mean by the term relative humidity.

If the air is holding half its maximum water vapor capacity, that's 50% relative humidity. If the air is holding three-fourths of its capacity, that's 75% relative humidity. When the air is saturated with water vapor, holding all it can, that's 100% relative humidity.

Relative humidity indicates how close the air is to holding all the moisture it can before condensation occurs.

The key thing to realize is the saturation amount (in quarts or gallons per so many cubic feet of air) changes depending on the air temperature. This is why we use the term *relative* humidity. Warm air can hold a lot more moisture than cold air. This means that warmer air can absorb a lot more moisture from the birds and the litter without approaching saturation than would be possible with colder air. Also, if you have cold air at high relative humidity, warming that air automatically lowers its relative humidity. This is what makes winter ventilation possible. When your ventilation system brings cold winter air into the house, this air gets warmed up once it's in the house. That means its relative humidity drops, which in turn means its water-holding capacity goes up, so it is able to pick up moisture from the litter and carry it on out of the house.

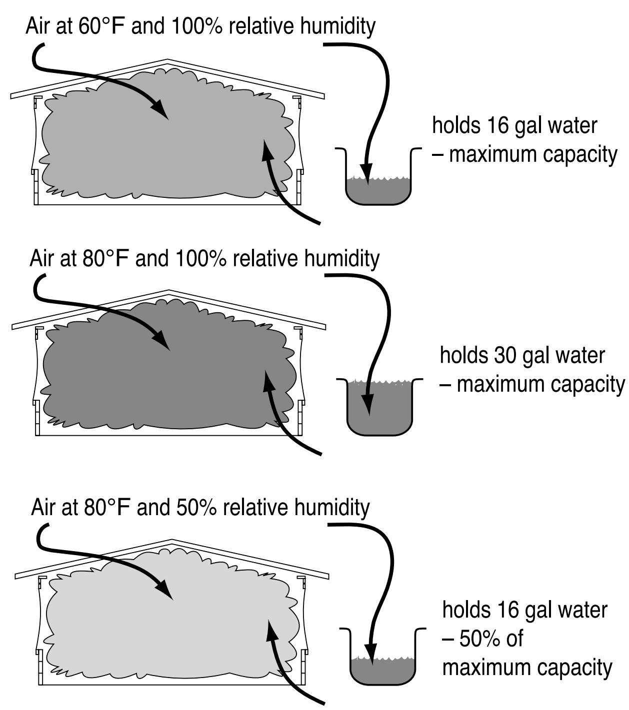


Figure 9. As air temperature rises, the amount of water a given amount of air can hold increases. An approximate rule of thumb is that a 20 degree F rise in air temperature cuts relatively humidity in half. That is, raising the air temperature increases the absorbency of the air. At 80°F the air is more absorbent and can hold almost twice as much water vapor as the same air at 60°F.

Warmer air holds much more moisture. A 20 degree F change in temperature can double (or cut in half) the relative humidity of air.

Ventilation Basics

Because ventilation is so important in providing an optimum in-house environment for broiler rearing, understanding basic ventilation principles is essential for proper house design and management. There are two basic ventilation types: natural ventilation and fan-powered ventilation.

Natural Ventilation

Natural ventilation relies on opening up the house to the right extent to allow outside breezes and inside convection currents to flow air into and through the house. This is often done by lowering (or raising) sidewall curtains, flaps or doors. Sidewall curtains are most common, and natural ventilation is often referred to as "curtain ventilation."

Natural (curtain) ventilation works well only when outside conditions are near desired in-house conditions.

In curtain ventilation, the curtains are opened to let in outside air when it gets warm; when it gets cold, they are closed to restrict the flow of air. Opening house curtains allows a large volume of outside air through the house, equalizing inside and outside conditions. Curtain ventilation is ideal only when outside temperature is close to the target house temperature. The air exchange rate depends on outside winds. On warm to hot days with little wind, circulation fans may be used to provide some wind chill cooling effect. Foggers or misters can be used with circulation fans to add a second level of cooling.

Curtain ventilation requires constant, 24-hour management.

If curtain ventilation is used in cooler weather, it is essential to have curtain machines operated on frequent on-off timers and with bird-level safety thermostats and curtain drops (or fail-safes) in case of high temperatures or power outages. Circulation fans can help mix incoming cold and in-house warm air. In the absence of stirring or circulation fans, small curtain openings cause heavy outside air to enter at low speed and drop immediately to the floor, which chills the birds and creates wet litter. At the same time, warmer air escapes from the house, resulting in large temperature swings. Even in moderate weather, however, normal fluctuations in air temperature and winds during the day (or night) can call for frequent adjustments in curtain settings. *Curtain (natural) ventilation requires constant, 24-hour management.*

The curtain ventilation house air exchange rate depends on outside winds; in cold weather, cold outside air is likely to drop directly onto the birds.

Natural ventilation as a system does not allow a great deal of control over in-house conditions. In the early days of the industry it was commonly used, especially in mild climates, and houses were specifically designed to facilitate natural air convection currents for ventilation purposes. In more recent times, managers of more modern curtain-sided houses equipped with fan-powered ventilation systems have used natural ventilation as an "in-be-

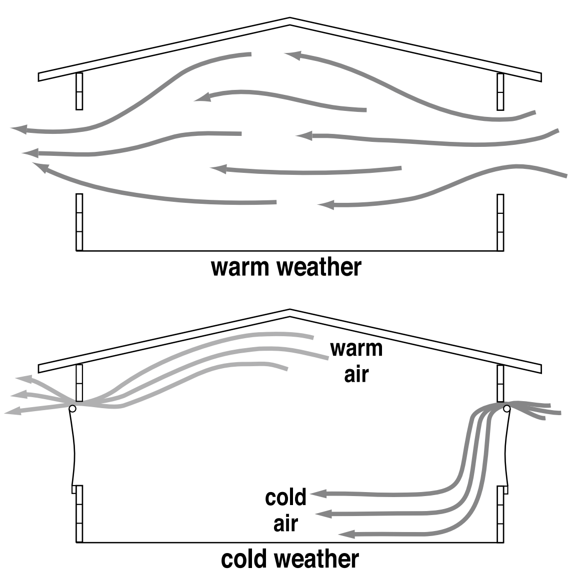


Figure 10. Natural (curtain) ventilation works well only when outside conditions are near what is needed inside the poultry house. In hot weather, strong winds are needed to achieve an acceptable air exchange rate; in cool weather, cold outside air is likely to drop directly onto the birds.

tween" option, when outside air temperature is close to desired in-house temperature and neither heating (and minimum ventilation) nor cooling is needed.

However, full-time fan-powered ventilation has proven worldwide to provide better flock performance and returns in most cases, even in houses still equipped with curtain sidewalls. Natural ventilation therefore will not be further discussed in this publication.

Stirring fans can help improve conditions in a curtain-ventilated house.

NOTE: Inside circulation or stirring fans are often used in curtain-ventilation setups and can help with mixing of outside and inside air, preventing temperature stratification in cool weather, and to some extent cooling birds with direct breezes. This type of fan setup, however, does not move outside air into the house, so a curtain-ventilated house with stirring fans is not considered a power-ventilated house.

Fan-Powered Ventilation

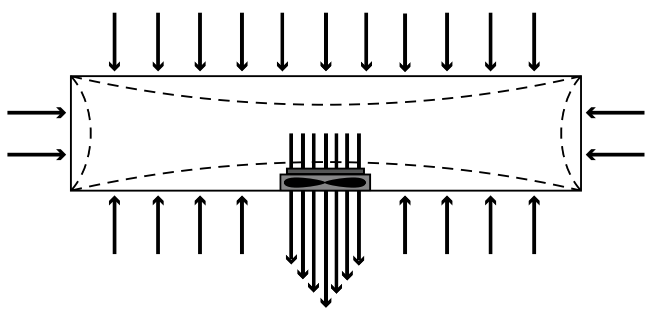
Fan-powered ventilation uses fans to bring air into and through the house. Powered ventilation generally allows much more control over both the air exchange rate and the air flow-through pattern, depending on the configuration of fans and air inlets and the type of control used.

Fan-powered ventilation systems can use either positive or negative pressure. Positive-pressure wall-mounted fan systems, which push outside air into the house, are most often seen in setups used for cooler weather. However, most poultry house fan-powered systems now use negative-pressure ventilation. This means that the fans are exhaust fans, pulling air out of the house. This creates a partial vacuum (negative pressure) inside the house, so that outside air is drawn into the house through inlets in the house walls or under the eaves.

Negative-pressure fan-powered ventilation creates a partial vacuum in the house, allowing control of the ventilation airflow pattern.

Achieving a partial vacuum inside the house during ventilation allows for much better control of the air flow-through pattern in the house and for more uniform conditions throughout the house. That is, both dead air areas and hot or cold spots are minimized.

Figure 11. Negative-pressure ventilation creates a partial vacuum that pulls air into the house evenly through all inlets, creating more uniform conditions in the house.



Need for Tightly Sealed House

Having a tightly sealed house is critical for successful control of in-house conditions in negative-pressure ventilation.

Modern negative pressure ventilated houses must be tightly sealed. In naturally ventilated houses, tightness is not at all critical. But in using negative pressure ventilation, the key is to take total control of how and where air enters the house, so house tightness has paramount importance. During cool weather operation, air coming under foundations, around doors, or through cracks only serves to chill or discomfort birds, create moisture problems, and detract from optimum rearing temperature environments. Air leaks during tunnel ventilation destroy the needed single air path from one end of the house to the other, causing reduced wind velocity and wind-chill cooling.

A house tightness test used in the poultry industry for many years for 40 ft x 400 ft or 40 ft x 500 ft houses is to turn on two high-quality 36-inch fans or one high-quality 48-inch fan with all inlets and doors completely sealed. The differential static pressure reading from the house interior to the outside will give an indication of the level of negative pressure achieved by the fans. The higher the negative pressure achieved, the tighter the house. The goal for a house should be a minimum of 0.15 inches of water column negative pressure; for newer houses, static pressure should far exceed 0.20 inches of water column.

Types of Negative-Pressure Ventilation Operation

Fan-powered, negative-pressure poultry house ventilation can be operated, with different fan and air inlet setups, in three different modes, according to the ventilation needs to be addressed:

Different fan and air inlet setups are used in negative-pressure ventilation to achieve different purposes, according to prevailing conditions.

1. Minimum ventilation (also called just "power ventilation" or even "power vent") – operated on a timer and used for cooler weather and/or smaller birds.
2. Transitional ventilation – operated on thermostat or temperature sensor and used for heat removal when wind-chill (tunnel) cooling is not needed or desirable.
3. Tunnel ventilation – used for warmer weather and/or larger birds; operated on thermostat or temperature sensor.

The different negative-pressure ventilation modes work in certain static pressure ranges.

All three of these ventilation modes of operation use the negative pressure principal, but operate at different static pressures. Static pressure, in areas using imperial units measured in inches of water column, indicates the difference between in-house and outside air pressure, or the degree of partial vacuum achieved in the house. Minimum-ventilation setups operate at higher static pressure (greater vacuum), usually between 0.07 and 0.12 inches. Tunnel ventilation may produce static pressures ranging from 0.04 to 0.10 inches, depending on whether pad-type evaporative cooling is installed, and the type of evaporative cooling system used.

The changing needs of birds and changing weather requires managers to be ready to switch ventilation modes as needed.

Important distinctions sometimes get overlooked in the way we talk about houses. We'll talk about a "tunnel house," for example, as though there was only one kind or mode of ventilation used. The tunnel setup is used only in warm to hot weather, and the "tunnel house" for cool weather or small birds is probably equipped for and switched either to minimum or transitional ventilation as weather and the size of the birds dictates. The changing needs of birds as they grow and the variability of weather, especially in autumn and spring, requires managers to be ready to switch their ventilation system from one mode or setup to another when needed.

Following are brief descriptions of how these basic fan-powered ventilation setups work. For more detailed information on systems and management considerations, see sections starting on page 26.

How Minimum Ventilation Works

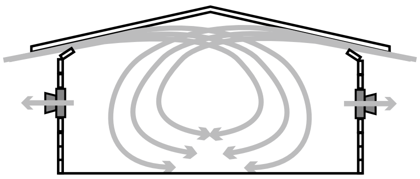
The purpose of minimum ventilation is to bring in just enough fresh air to exhaust excess moisture and ammonia in cold weather or during brooding.

The purpose of the minimum ventilation setup is to bring in just enough fresh air to exhaust excess moisture and ammonia fumes during cold-weather conditions and/or when birds are very small. And, to do this without chilling the birds. Typically, from two to six 36-inch exhaust fans are used, with the location of fans and air inlets varying as described below.

The key to successful minimum ventilation is creating the proper partial vacuum so that air comes in with sufficient speed and at the same speed through all inlets. With air inlets distributed evenly along the whole length of the house, air flow is then uniform throughout the house. Just as important, cool outside air comes into the house at high enough velocity to mix with warm in-house air above the flock, rather than dropping directly onto and chilling the birds.

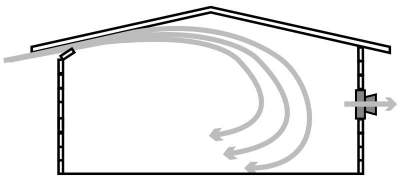
Note: Several variations of negative pressure ventilation set ups are used for minimum ventilation in different regions (and for non-tunnel heat removal in transitional ventilation, as described later). The most commonly seen are illustrated in Figure 12 below.

Figure 12. Four common variations on fan/inlet setups for minimum ventilation:

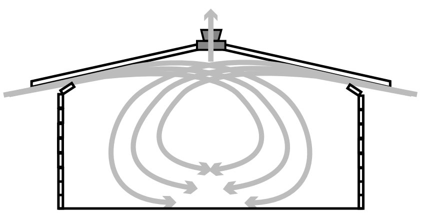


1. Exhaust fans on sidewalls and air inlets around the perimeter (high on sidewalls or in ceiling). This setup works well in cool weather and for use in tunnel ventilated houses operating in transitional mode.

Negative-pressure fan and air inlet configurations around the world vary widely, but the same basic principles apply to all.

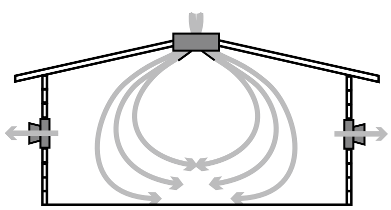


2. Exhaust fans on one side of building and air inlets on the other. Commonly called "cross ventilation," this setup is most popular in areas where tunnel ventilation is not needed.



3. Exhaust fans in the roof and air inlets in the sidewalls. Often called "ridge extraction," this type of setup is also most used in cooler climates.

All minimum ventilation setups bring outside air in high in the house to avoid putting cold air directly onto the flock.



4. Exhaust fans in the sidewalls and air inlets in the apex of the roof. Often called "reverse flow" ventilation, this setup is similar to setup #1 above except for the location of the air inlets.

For convenience in presentation and because it is commonly used worldwide, setup #1 (fans on sidewalls and perimeter air inlets) is used in this publication. Readers should understand that while negative-pressure configurations around the world vary widely in their details, the same basic principles apply to all of the above fan/inlet setups, and all can and must be capable of running properly in the minimum ventilation mode.

The air flow pattern created in a minimum ventilation setup is illustrated in Figure 13, below. To get this needed air flow pattern, the air inlet area must be matched to the fan capacity being used. If the air inlet area is too small (for the number of fans running), fans will have to work against too-high static pressure and will

To get the airflow pattern needed in minimum ventilation, the air inlet area must be matched to the fan capacity being used.

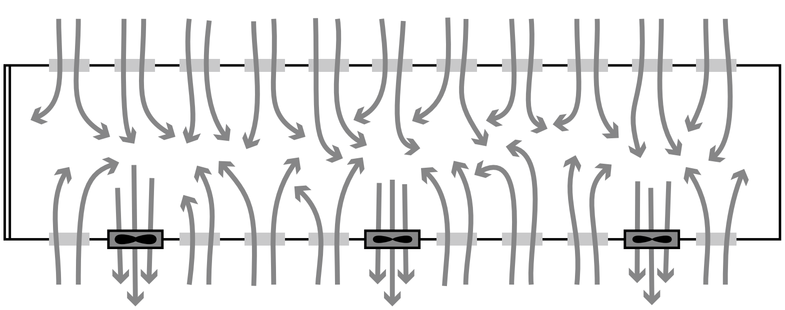


Figure 13. The goal of minimum ventilation is to bring air in evenly and at high velocity through inlets spaced around the house above bird level, so that cold outside air mixes with in-house air, as shown in this plan view diagram. This air flow pattern prevents cold outside air from dropping onto the birds.

Using cool-weather adjustable perimeter air inlets actuated by a static pressure controller gives best minimum ventilation airflow.

not deliver the air exchange rate needed. If air inlets are opened too wide, static pressure drops too low, and air will come in mostly or only through inlets closest to the fans, creating non-uniform air flow and poor conditions for birds. Using cool-weather adjustable perimeter inlets actuated by a static pressure controller makes the inlet area adjustment automatic. Curtain cracks and fixed board inlets are more likely to allow too-wide openings and dump cool incoming air onto the birds. Minimum ventilation also requires a tight house: air leaks will tend to spoil the desired air flow-through.

Minimum ventilation is timer-controlled, not temperature controlled.

Minimum ventilation is timer-driven, and may be set to operate as little as one-half minute in five early in a growout or in very cold weather. As birds grow larger and/or weather warms, thermostats override the timer to provide an adequate ventilation rate. Important: In cold weather the need to remove moisture from the house means that some minimum ventilation rate must be maintained even when the thermostat doesn't call for ventilation and even if a small amount of house heat must be removed in the process.

How Transitional Ventilation Works

Transitional ventilation is temperature driven, when heat removal is needed but without putting cold air onto birds.

The change from minimum to transitional ventilation is basically a switch from timer-driven to temperature-driven ventilation. This is true no matter what the particular fan/inlet setup is. That is, whenever temperature sensors or thermostats override the minimum ventilation timer to keep fans running, the minimum ventilation setup will be running in the transitional ventilation mode. Additional sidewall or other fans (and air inlets) may be added as outside temperature increases.

An additional stage in transitional ventilation is a "hybrid" setup, illustrated in Figure 14, using some of the large tunnel fans to bring air into the house through perimeter air inlets instead of through the tunnel inlets, which are kept closed. Outside air enters and mixes with in-house air in much the same way as in a minimum-ventilation negative pressure system using sidewall fans. The big difference over the minimum ventilation setup is that the increased fan capacity gives a larger volume of air exchange. Running four tunnel fans in the transitional setup, for example, gives the same ventilation rate as running four-fan tunnel ventilation,

When the need for heat removal requires a higher air exchange rate than the minimum ventilation setup can handle, tunnel fans can be used to bring large amounts of air in through perimeter inlets.

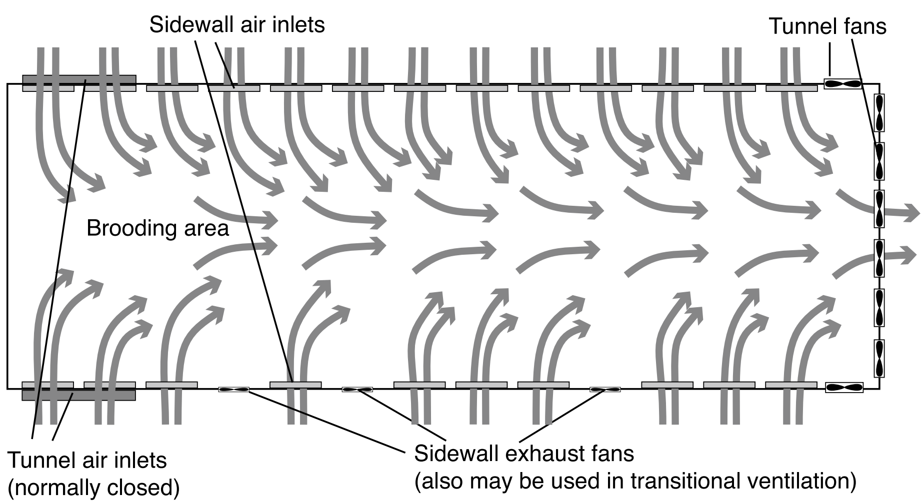


Figure 14. The transitional ventilation mode begins whenever temperature sensors override the minimum ventilation timer. When the need for heat removal requires a higher air exchange rate than the minimum ventilation fans/inlets setup can handle, some of the tunnel fans can be used to bring large amounts of air in through perimeter inlets, as shown in this diagram of the "hybrid" transitional mode, without putting air directly on the birds.

but without putting any wind directly on the birds. In some locations, tunnel fans are not used for transitional ventilation because of concern for uniformity. Use of tunnel fans for transitional ventilation is based on climate and the ability to mix and stir the incoming air.

As with minimum ventilation, transitional ventilation inlet area should be matched to fan capacity and inlet opening adjustments made by an automatic static pressure-operated controller.

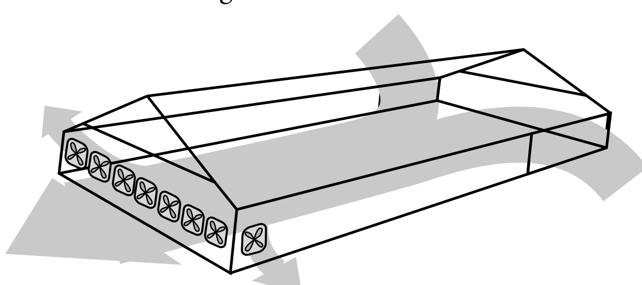
As with minimum ventilation, the air inlet area during transitional ventilation must be matched to the fan capacity used. Enough sidewall inlet area should be provided to operate at least half of the installed tunnel fans in the hybrid transitional mode without creating excessive static pressure. For most efficient operation, air inlets are controlled by static pressure-operated machines, as in minimum ventilation.

How Tunnel Ventilation Works

The goal of tunnel ventilation is to keep birds comfortable in warm to hot weather by using the cooling effect of high-velocity airflow. The tunnel setup is especially suited to warmer areas and where larger birds (4-8 pounds) are being grown. Tunnel systems are designed first to handle the expected need for heat removal, providing the air exchange rate needed to exhaust excess house heat in hot weather. Full tunnel mode operation, with all fans running may produce a complete house air exchange in under one minute.

The tunnel setup also provides wind-chill cooling, moving air as in a wind-tunnel through the length of the house. A velocity of at least 500 feet per minute is needed for most effective wind-chill cooling.

Figure 15. Tunnel ventilation is designed to move large amounts of high-velocity air over the birds, achieving maximum heat removal plus a wind-chill cooling effect.



The purpose of tunnel ventilation is to achieve maximum cooling by the wind-chill effect of high-velocity airflow.

The wind-chill effect created by high-velocity air can reduce the effective temperature felt by fully-feathered birds by as much as 10-12 degrees F. The graph below (Figure 16) shows estimated effective temperatures that result with different air velocities, for 4-week and 7-week birds.

As the illustration shows, caution must be used in tunnel ventilating with younger birds, since they experience greater wind-chill effect for a given air velocity. Note that the "effective" temperature can only be estimated, not read from a thermometer or calculated. Bird behavior must be the guide to judging the right number

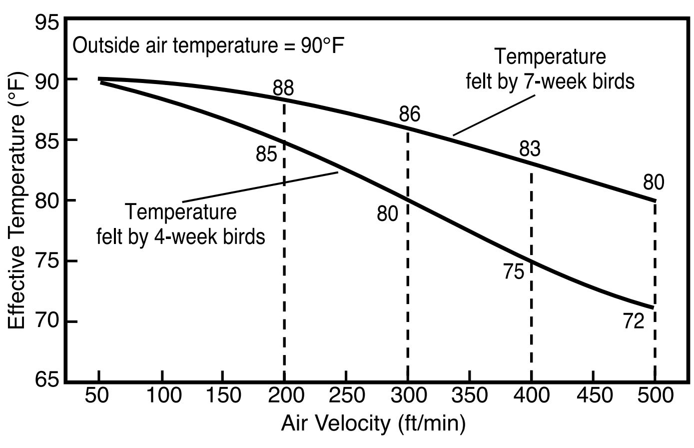


Figure 16. The wind-chill effect created by high-velocity air flow is much greater for younger birds.

The "effective" temperature created by the wind-chill effect must be estimated, and varies according to bird age/size and actual air temperature.

of fans to turn on to create the air velocity and air exchange rate that is needed to keep birds comfortable.

The high-velocity airflow of the tunnel setup makes it well suited to adding evaporative cooling. This can be done either with in-house foggers or with evaporative cooling pads placed outside the air inlets. This real cooling of incoming air, on top of the "effective" cooling produced by wind-chill, can keep birds performing well even in very hot weather. Used alone, the wind-chill effect of tunnel ventilation becomes less pronounced as air temperatures rise much above 90°F, and above 100°F the air begins to warm instead of cool the birds.

The wind-chill effect becomes less pronounced as air temperatures rise above 90°F; above 100°F the air begins to warm instead of cool.

Adequate tunnel inlet area is essential. More area is needed for pad cooling (as explained below). Tunnel houses also must be tight, since any air leaks will spoil the desired airflow pattern.

How Evaporative Cooling Works

When water evaporates, whatever it is in contact with gets cooled. Evaporating just one gallon of water into the air takes 8,700 Btu's of heat out of that air. Evaporative cooling (EC) is therefore an effective tool for poultry production in hot weather.

Evaporating just one gallon of water into the air takes 8,700 Btu's of heat out of that air.

The simplest application of EC for broilers is the use of fogging nozzles mounted overhead in curtain-ventilated houses. The most efficient and effective modern systems, however, are designed to complement and work in conjunction with tunnel ventilation. By adding some actual temperature reduction on top of the wind-chill cooling effect of tunnel, properly designed and operated tunnel-house EC systems can keep birds performing well in very hot weather.

The two major setup choices for tunnel-house EC are in-house foggers and wetted pads (spray-on or recirculating) mounted over the tunnel air inlets. Either setup can do a good job, but recirculating pad systems are becoming predominant. These high-efficiency systems demand less management attention and do not risk wetting birds or litter.

How well EC works –that is, how much cooling it produces – depends on three factors:

How well evaporative cooling works depends on air temperature, relative humidity, and efficiency of the cooling system.

1. The starting outside air temperature – the higher this is, the more degrees of cooling are possible, other things being equal.
2. The relative humidity (RH) of the outside air – the lower the better.
3. How efficient the system is in evaporating water – typical systems range from 50% to 75% efficient.

The table below [(Figure 17) shows the in-house air temperatures that result given higher or lower starting air temperature, system efficiencies, and relative humidity. For example, if it is 95°F outside at 50% relative humidity, a 75% efficient

Figure 17. Evaporative cooling possible under different conditions.

Starting air temperature (°F)	System efficiency	Resulting air temperature (°F) for given relative humidity		
		40%RH	50% RH	60%RH
100	50%	90	92	94
	75%	84	87	90
95	50%	85	87	89
	75%	80	83	85
90	50%	81	83	84
	75%	76	79	81

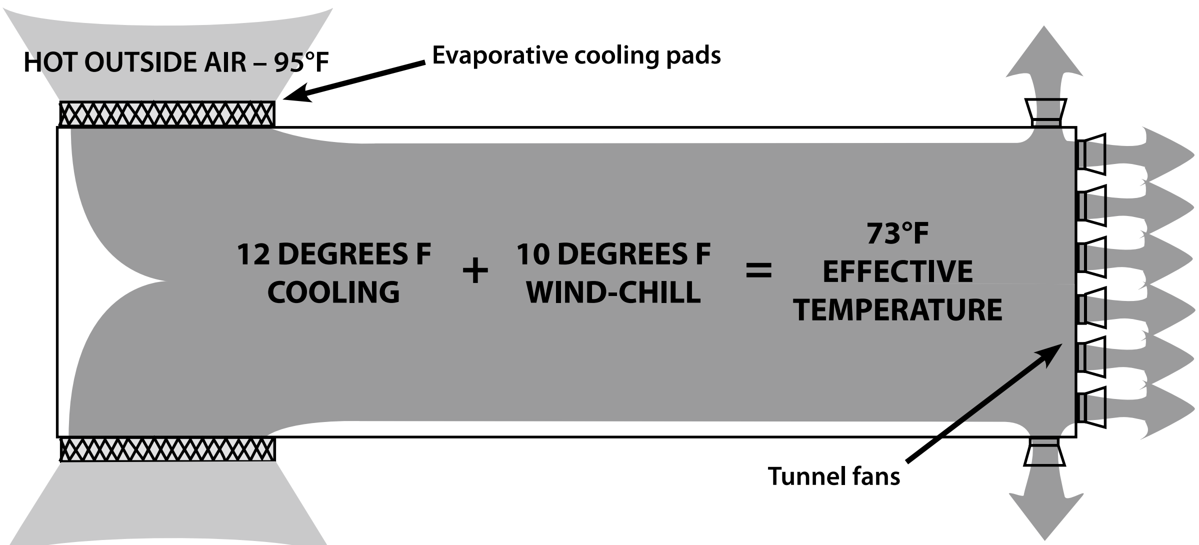
EC system will give 12 degrees of cooling, to 83°F. If the tunnel wind-chill gives another 10-12 degrees of effective cooling, fully-feathered birds will feel like they are in 71°-73°F air.

Evaporative cooling can provide useful cooling even in areas usually considered quite humid. In many ares of the world, for example, RH may reach 90% during a summer night, but typically drops to 50% or even lower by midday. The reason is that nighttime air temperature is usually in the low 70°F range, so that a 20-degree rise to the low 90°F range cuts the RH in half (see p. 9). A rule of thumb is that EC is very practical if there is at least an average 20-degree F difference between nighttime low temperatures and daytime highs.

Evaporative cooling is very practical if there is at least an average 20-degree F difference between night-time low temperatures and daytime highs.

Figure 18 illustrates the basic principles of tunnel-house cooling through lowered effective temperature by high wind speed plus lowered actual temperature by evaporative cooling.

Figure 18. Basic principles of tunnel plus evaporative cooling are shown here, representing typical results possible with a well-designed high-efficiency evaporative cooling and tunnel ventilation system with wind speed at 500 feet per minute or more.



Making Good Ventilation Decisions

In making decisions as to how to design and equip a broiler production house, it is important to understand the capabilities of and the kind of benefits that can be expected from modern environmental control technology.

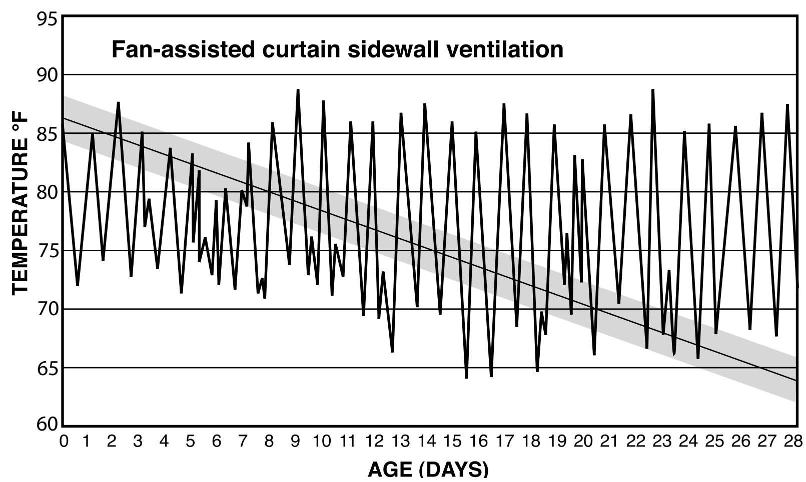
Research studies and industry experience show modern environmental control technologies can provide a significant performance advantage.

The charts below (Figure 19) show actually monitored temperature variations recorded by data-logging monitors in curtain-ventilated vs environmentally controlled broiler houses in the U.S. Southeast in autumn. While the conventional curtain-ventilated house allows very little if any temperature control, the environmentally controlled house tracks the target temperature line fairly closely. That these results were recorded for the first 28 days of a growout is particularly significant.

For later stages of a growout and for warmer weather, especially when birds are grown to larger sizes (4-8 pounds), tunnel ventilation with evaporative cooling has been shown to give a definite performance advantage. The table on the opposite page (Figure 20) shows actual in-field data recorded by a commercial broiler operation during summer growouts in the Southeast U.S., comparing conventional curtain and tunnel ventilated houses with evaporative cooling.

Another study showing the potential of the modern tunnel house to deliver better bird performance was done by U.S. Dept. of Agriculture researchers, comparing the effects on bird weight and feed conversion efficiency of different tunnel wind speeds in hot conditions (Figure 21).

Figure 19. Temperature monitoring shows the environmentally-controlled house maintains close-to-target temperature; curtain-ventilated house allows wide temperature swings. Shaded lines show target temperature zone.



Data-logging monitors in commercial poultry houses document the ability of environmental control equipment to maintain close to target temperature.

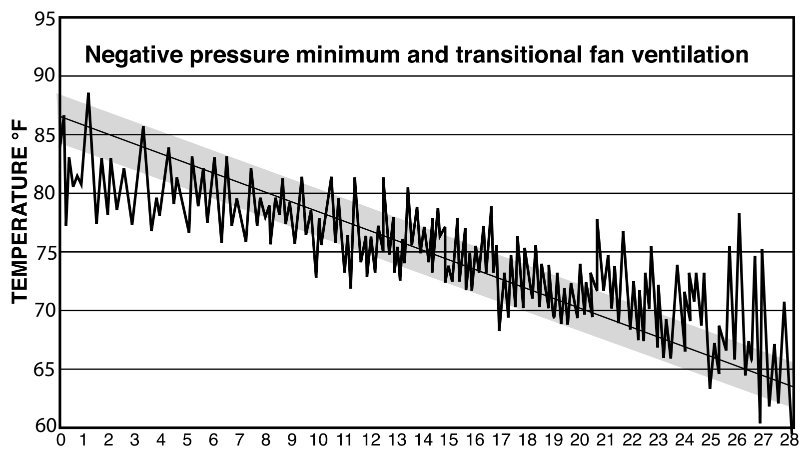


Figure 20. Performance factors recorded for tunnel +EC vs conventional curtain-ventilation houses in U.S. Southeast in summer.

58-day broilers	Broiler weight (lbs)	Feed conversion	% Livabiity	% Condemnations	Live cost (cents/lb)
Tunnel + EC	7.2	2.18	92.4	1.71	21.8
Conventional	6.85	2.24	88.1	1.90	22.5

In the U.S. Southeast in summer, tunnel ventilation with evaporative cooling improved performance by every measure that matters.

Figure 21. U.S. Department of Agriculture research study – effects of different wind speeds on bird weight and feed conversion in hot conditions.

Air velocity	Bird weight (lbs)	Gain in preceding week (lbs)	Feed conversion for that week
After 4th week:			
600 fpm	2.826	1.276	1.495
400 fpm	2.803	1.252	1.482
still air	2.720	1.167	1.521
After 5th week:			
600 fpm	4.284	1.458	1.712
400 fpm	4.235	1.432	1.698
still air	3.936	1.216	1.804
After 6th week:			
600 fpm	5.737	1.453	1.966
400 fpm	5.559	1.324	2.080
still air	4.847	0.911	2.469
After 7th week:			
600 fpm	7.065	1.328	2.277
400 fpm	6.654	1.096	2.610
still air	5.588	0.721	3.026

Research under controlled conditions has shown that high wind speed is especially beneficial for performance of larger birds.

It must be stressed that the potential payoff from investment in ventilation technology is only realized where systems are properly designed for the purpose and setting, with careful attention given to choosing component parts, and – equally important – are managed properly.

The following sections outline key decision factors for the most important ventilation system components.

Choosing Fans

Having good fans is essential for a successful ventilation program. The key consideration is airflow capacity–that is, the cfm's (cubic feet per minute) a fan delivers. Fans are the air-moving muscle of a ventilation system, and you want to be sure the fans you install deliver the cfm's that are needed.

The key fan performance factor is airflow capacity under static pressure load.

Fan Performance Factors

Fan capacity (cfm's) varies according to the static pressure the fan is working against. In free air (as with a stirring fan), with zero static pressure, a fan will move the greatest amount of air. In negative-pressure ventilation fans have to pull air from the inlets through the house and exhaust it to the outside, and so have to work against a certain amount of resistance, which we call static pressure. As static pressure goes up, fan airflow capacity goes down. A fan's airflow ratio (cfm at 0.20 inches ÷ cfm at 0.05 inches) indicates how well it maintains airflow capacity at higher static pressure. Airflow ratios range from around 0.65 to 0.90. Higher is better.

"Airflow ratio" indicates how well a fan maintains airflow capacity at higher static pressure – higher is better.

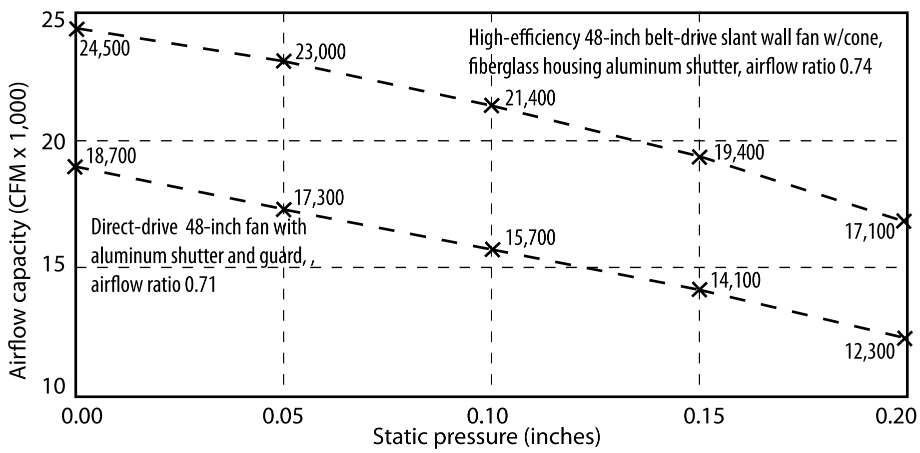
Fan efficiency (cfm's per watt), matched with the utility cost per kilowatt-hour, tells us how much it costs to run a fan to get a given airflow in cfm's. Fan efficiency also usually goes down as static pressure goes up.

Fan performance curves are very useful in comparing fans and judging which fan would be best for a given situation. Fan curves show either fan capacity or fan efficiency. That is, they plot or graph how a fan's cfm capacity changes as static pressure increases, or tell us what a fan's cfm/watt efficiency will be at different static pressures. The example fan curves shown in Figures 22 and 23 show the performance differences between typical direct drive low-efficiency and high-efficiency belt-drive 48-inch fans.

Fans are usually advertised or rated for cfm output at a static pressure of 0.05 inches. This is the standard customarily used for ventilation design purposes, and is a typical operating static pressure. If static pressure in a house rises too far beyond the design operating range – which is likely to happen if shutters or cooling pads are allowed to get dirty or there is insufficient tunnel inlet area – fans will not deliver the desired airflow. The high-efficiency fan shown in Figure 22, for example, delivers 23,000 cfm at 0.05 inches static pressure. But if through improper design, management, or maintenance of the poultry house we allow static pressure to rise to 0.15 inches, the airflow drops to only 19,400 cfm, a 16% decrease.

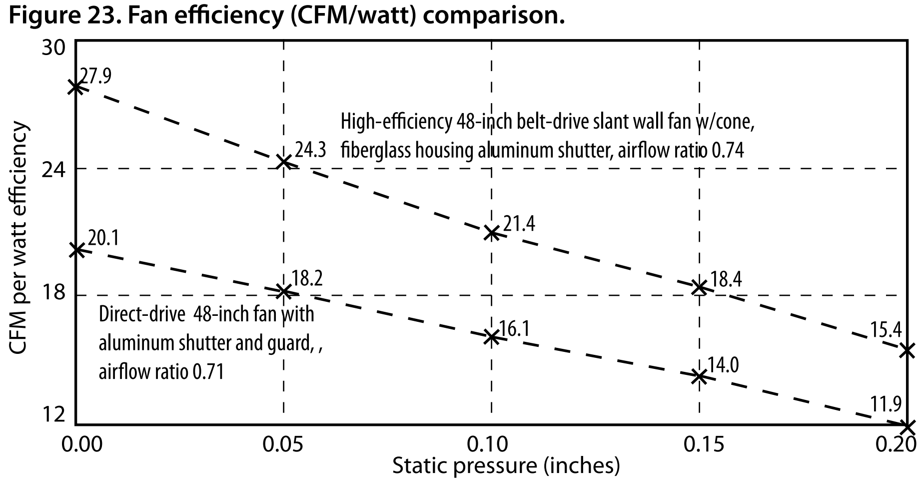
Fan efficiency is measured in cfm/watt. A more efficient fan with a high airflow ratio costs more but performs better and saves on long-term electricity costs.

Figure 22. Fan airflow capacity (CFM) comparison.



Fan airflow capacity and efficiency curves should be consulted to judge performance over the range of static pressure it will be used in – and to estimate operating costs.

Figure 23. Fan efficiency (CFM/watt) comparison.



Fan Shutter Factors

Shutters should give little or no airflow resistance when open, but should completely block air flow when closed. Recent testing has shown even high-quality, new and clean louver-type shutters on 48-inch tunnel fans not to be closing tightly. The supposedly closed shutters allowed enough air leakage to cause several hundred dollars in heat losses per house during cool-weather minimum ventilation. Even more important, the air leakage also disrupts the needed airflow pattern, which can hurt bird performance.

Fan shutters must close tightly to avoid air leakage; and must be kept clean to maintain rated fan capacity.

If louver-type shutters are used, a commitment must be made to keep them clean. Enough dirt can accumulate on these shutters in a week to reduce airflow by 25%. One reason for considering cone or slant wall fans is that shutters are mounted inside the house where they are much easier to clean.

Integrated Control System Decision Factors

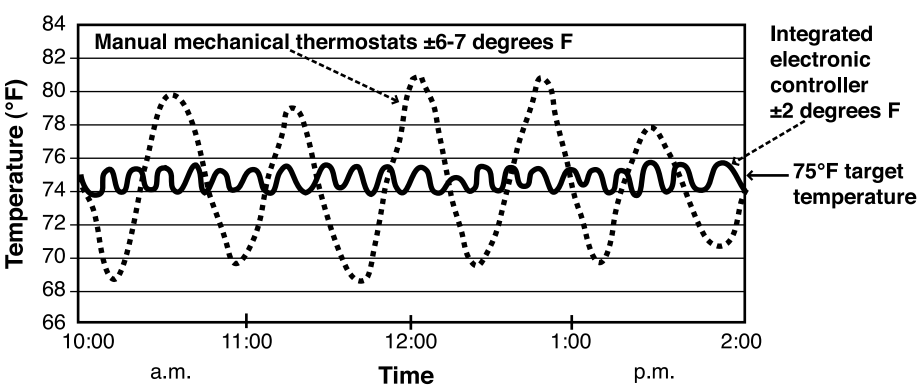
Modern electronic controllers can save a great deal of management time, such as in resetting thermostats.

An integrated electronic control system provides consistent control of the in-house environment 24 hours a day, 7 days a week. Such systems add significant cost, but can pay off in improved bird performance by limiting temperature swings above and below the target optimum to a much narrower range. As shown in Figure 24, an electronic controller is capable of plus or minus 2-degree (F) control, where typical mechanical thermostats allow swings of plus or minus 6-7 degrees F. An integrated controller also eliminates the labor of changing individual settings on separate controls such as thermostats. However, a good human manager is still needed to oversee and operate the integrated control system.

A good system will be easy to learn, which usually means having a good display screen and being menu-driven. It should be capable of keeping heating and ventilation systems from fighting each other, and moving the house automatically from heating to minimum ventilation to transitional to tunnel and evaporative cooling (and back). It also should have enough data channels so you don't have to add extra contactors. An important part of a good integrated controller is adequate built-in protection against power line voltage spikes and surges.

A good controller will have a range of capabilities – being operator-friendly is a must.

A good control system also will include zoning capability, allowing the manager to place temperature sensors in various parts of the house and set up the controller to use different sets of sensors for different conditions. For example, if half-house brooding is used, the controller would work only off sensors in the brood area for early growout minimum ventilation, but work only off sensors at the fan end of the house for hot weather tunnel ventilation.



A good controller will be able to keep in-house temperature on target plus or minus 2 degrees F.

Figure 24. As this graphic of recorded temperatures shows, integrated electronic controllers achieve far better in-house temperature control than thermostat-operated systems. Controller costs are usually fully justified by the improvement in flock performance

A controller with data collection and display can be very helpful in trouble-shooting and improving management practices.

The better controllers incorporate data collection and display, so that a manager can, for example, look at house temperatures at different intervals for the past 24 hours, or for the entire growout. This capability is extremely useful for trouble-shooting. Remote monitoring and control, usually through networking through a personal computer, is a desirable option in controllers, allowing a manager or owner to check on house conditions from his separate office or residence and take care of troubles as they arise.

Air Inlet Design Considerations

Adjustable hinged-door perimeter air inlets have been found superior in producing the airflow pattern needed for minimum and transitional ventilation.

Design of air inlets used during minimum and transitional ventilation is very important for achieving good mixing of cool incoming and warm in-house air, without allowing cold outside air to flow directly onto birds. As mentioned earlier, there are several variations in placement of fans and inlets that can accomplish these goals; the fundamental principle is to bring air in high and at high velocity. Adjustable hinged-door inlets mounted high around the perimeter of the house (on sidewalls or in ceiling openings) have been found superior in producing the airflow pattern needed. Figure 25 shows the desired airflow pattern achieved by adjustable perimeter inlets, as contrasted with curtain ventilation inlet arrangements.

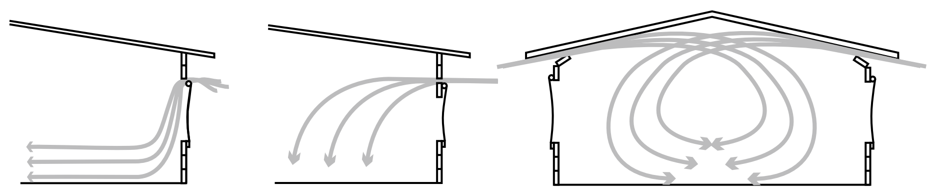


Figure 25. During minimum or transitional ventilation, it is important to avoid putting cold outside air directly on the flock. Adjustable inlets located high around the perimeter of the house accomplish this goal, directing air into the house above bird level so it mixes with warm in-house air before contacting birds.

The size of the opening is critical, and this varies with the number of fans running and changes in static pressure. Manually adjusting these inlets to consistently maintain proper airflow, however, is next to impossible. Cool-weather inlets actuated by static pressure sensors accomplish proper adjustments automatically, providing much better conditions for birds than would otherwise be possible. For more information on inlet management, see Page 30.

Benefits of Using Stir Fans

In-house circulation or stirring fans can help reduce temperature stratification and save on heating fuel bills during minimum ventilation.

Even with the best management of adjustable air inlets to provide good air mixing during minimum ventilation, minimum ventilation fans run only a fraction of the time. When the fans are turned off, mixing of warmer air in the upper part of the house with cooler air toward the floor stops. Stirring (or, circulating) fans mounted inside the house can help prevent this temperature stratification, keeping young chicks warmer and helping remove more moisture from the litter.

Another increasingly important effect of using stirring fans is to reduce heating fuel costs. Well insulated, well managed houses with adjustable air inlets have been found to experience somewhere between 15% and 20% fuel savings. Older houses often achieve higher fuel savings, although the total fuel cost will probably stay higher than for a well-managed and insulated modern house. A house with convective heating and/or a high-ceiling house would experience the greatest fuel savings, sometimes as high as 40%.

Both paddle (Casablanca-type) and axial vane fans have been found useful. Paddle fans usually work best in the up-draft mode. Axial fans are mounted along the center-line of the house and blow air horizontally. The air circulation patterns achieved and installation details (typical for Southeast U.S.) are shown in Figures 26 and 27.

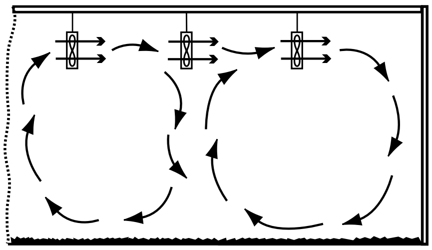
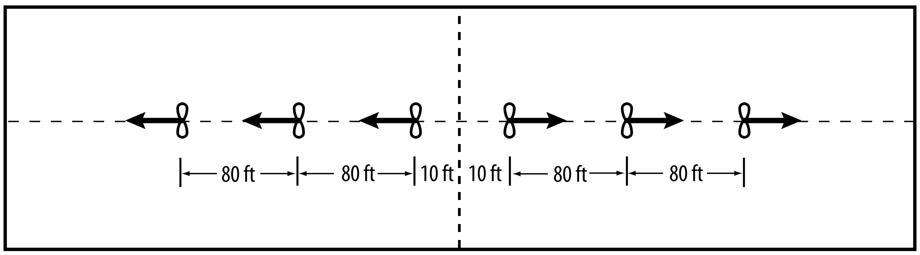


Figure 26. Typical installation details (below) and air circulation pattern achieved (left) by axial vane stirring fans in a 40 ft x 500 ft poultry house.



Both axial vane and paddle (Casablanca) type stirring fans have proven useful for mixing in-house air layers. Paddle fans work best in the up-draft mode.

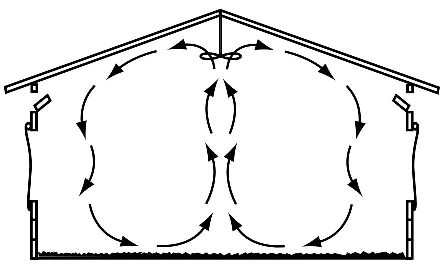
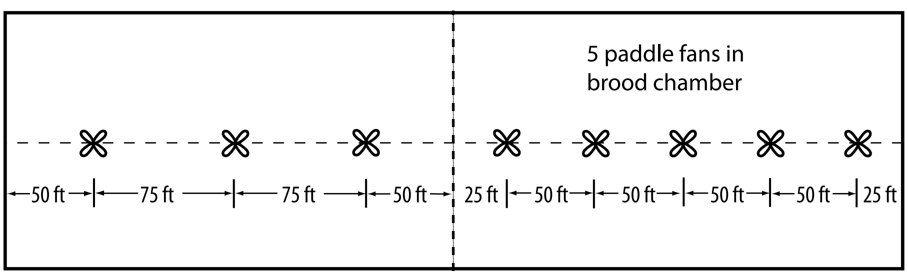


Figure 27. Typical installation details (below) and air circulation pattern achieved by paddle stirring fans (left) in a 40 ft x 500 ft poultry house.



Evaporative Cooling: Foggers or Pads?

Pad cooling has become much more common than in-house fogging, primarily because pad systems are easier to manage and do not risk wetting the house down. Evaporative pad systems also provide more cooling capability. However, a properly designed in-house fogging system with or without tunnel ventilation can be very efficient and effective in suitable climates if operated properly.

Recirculating pad evaporative cooling systems provide more cooling than fogging systems, are easier to manage, and do not risk wetting the house down.

The difficulty with in-house fogging is that if more water is put into the air than it can absorb, water drops on the birds and litter. A fogging system must be managed so that just the right amount of water is fogged into the air to get maximum cooling, but staying just this side of wetting the house. This can be very difficult, and requires a vigilant and active manager. Clogging of nozzles is also common, requiring frequent checking. Water quality can be an issue, and the supply for the system must be filtered.

Evaporative Pad Cooling: How Much Pad Is Needed?

A reasonable goal is to achieve the desired cooling efficiency with the least pad area required, and at the same time keep house static pressure from rising above 0.10 inches. The most common mistake made in pad EC systems is not having enough total installed pad area. This forces static pressure too high, which reduces the output of the fans below the rated cfm's we are counting on. Not having enough pad area also means lower cooling efficiency because air velocity through the pad will be too high. The lower the air velocity through a wetted pad, the higher the cooling efficiency.

A critical factor in achieving effective evaporative pad cooling without excessive loading of fans is to have adequate installed pad area.

Note that the air velocity through cooling pads is not the same as the velocity through a house, or the velocity through the tunnel inlets. It is the cross-sectional area of the house that determines the air velocity after the air moves into the house. The pad area almost always must be larger than the house cross-section, because a lower air velocity is needed through the pads in order to achieve adequate cooling efficiency. The formula for determining the pad area, assuming we know the installed fan capacity and the design air velocity needed through the pads is:

$$\text{Installed tunnel fan capacity (cfm)} \div \text{Recommended air velocity through pads (ft/min)} = \text{Total pad area required (sq ft)}$$

Manufacturers recommend that optimum air velocity through the pads be obtained from test data.

Need for Backup and Fail-Safe Systems

The more environmental control a house has, the more it needs backups and fail-safes to prevent catastrophic losses from failure of the controls.

The more environmental control a house has, the more need it has for backups or fail-safes to prevent catastrophic losses from failure of the controls. In a curtain-ventilated house, there should be a thermostat wired to a curtain drop device which will drop the curtain if temperature goes too high. In a fan-ventilated house, curtain drops also must operate in case of power failure. A backup generator is essential in modern poultry houses. It can not only prevent catastrophe but keep the system going and the birds performing during an outage. Integrated control systems also must be backed up with an independent controller that allows the main system to operate only within a "window" of acceptable conditions, usually plus or minus ten degrees F. The controls backup must have its own independent sensor, usually placed mid-house.

All backup or fail-safe systems should be as independent as possible; that is, not subject to failure because another system failed.

Alarms are needed to signal problems with various functions, such as temperature, power, water pump activation, etc. In addition to a local alarm, remote signaling capability is valuable, including connection through phone dialers and beepers. One very useful alarm is built into static pressure actuated air inlet controllers. It senses and signals static pressure variations, and since it is independent of the main controller it can act as a sentry on the primary system. All backup or fail-safe systems should be as independent as possible; that is, not subject to failure because another system failed.

House Orientation

The best house orientation for optimum in-house conditions is with the roof ridge running at least approximately east-west.

How a poultry house is placed on the land in respect to sun angle is important. The best house orientation for optimum in-house conditions is with the roof ridge (long axis of the house) running at least approximately east-west. In winter this allows the low winter sun to hit the sun-facing sidewall in the middle of the day and contribute to house heating. In summer, when you want to minimize heat build-up, the midday sun is much higher in the sky, so the eave overhang keeps sun from hitting the sun-facing sidewall for most of the day. The midday sun hits only the roof, which is typically the best insulated part of the house. Houses lined up more than 10 to 15 degrees off east-west are likely to use more fuel in winter and need a higher summer ventilation rate and closer ventilation management.

Insulation Requirements

The value of insulation in saving heating fuel costs is widely recognized in moderate and cold climates. Houses with attic space above a ceiling should have at least R-19 insulation above the ceiling. Open-truss houses without an attic should have at least R-8 insulation under the roof, which can be accomplished with 1.5-inch polyurethane foam board or 2-inch polystyrene bead-board. Neither foil-type reflective insulation nor reflective roof coatings have proven adequate when used alone in poultry houses, without batt, board or loose-fill insulation. Any exposed insulation material must be robust enough to withstand regular cleaning and bird damage. Special attention must be paid to preventing absorption of water into insulating materials.

Insulation to save heating fuel is essential; batt, board, and loose-fill insulation are superior.

In warmer areas, managers sometimes feel insulation to be unnecessary and uneconomical. What must be realized is that regardless of the location, birds must be protected during the warm season from solar heat radiating down from an uninsulated roof. This is confirmed by studies in the U.S. Southeast in fan-ventilated open-truss broiler houses, identical except for having or not having under-roof insulation. With outside temperature at 91°F, temperature in the insulated house ran around 92°F, with negligible mortalities. In the uninsulated house, inside temperature ran to 99°F with 14% mortality.

Insulation under the roof or above the ceiling is essential in warm weather to keep solar heat from radiating down onto the flock.

Heat radiated from an uninsulated roof or ceiling can add more heat than is produced by an entire flock of 6-week-old birds. Ventilation systems, even with evaporative cooling, cannot be expected to handle such an additional heat load. Radiant heat is especially dangerous because it goes directly to the birds without directly warming the inside air. It is only after the birds have already absorbed this extra heat load that house air temperature starts to rise and the problem becomes evident. If no other insulation alternative is possible, foil-type reflective insulation or reflective roof coatings may provide some relief from radiant heat.

Keys To Managing A Modern Tunnel House

Tunnel ventilation was invented to provide growers with a tool to keep birds eating and gaining weight in warm to hot weather. The method has become so popular and the setup is so distinctive that houses with this setup are usually called "tunnel ventilated houses," although they are operated in the tunnel mode for only part of the year. Tunnel ventilation is not needed in all climates, but is widely used in many poultry-producing regions.

For basics on how ventilation modes work, see pages 12-16.

There are actually three basic ventilation modes used in most "tunnel" houses. Terminology used to describe these ventilation modes varies; for convenience in this publication we describe them as: **minimum mode for cold weather and small birds (brooding), transitional mode for moderate weather and medium-size birds when heat removal is needed, and tunnel mode for additional cooling in hot weather.**

Modern controls reduce management labor time but do not eliminate the need for a good manager.

Managing a modern tunnel house year-round for top bird performance (and a good return on the investment) first of all requires being able to judge which ventilation mode is best for the birds at any given moment; and then making the fine-tuning adjustments to keep temperature and other air quality factors as close to optimum as possible. Integrated electronic control systems now make the management job easier, since they can automatically switch modes and adjust ventilation rates as conditions change. However, even the smartest controller is not infallible, and must be monitored. Even more important, the controller settings themselves must be determined by a knowledgeable human. **There is just no substitute for a good poultry husbandman who is in the house frequently, watching the birds and making the control adjustments they need for best performance and welfare.**

Which Ventilation Mode Is Needed?

The key to making the right ventilation mode decision is knowing how much, if any, heat needs to be removed from the house, and whether outside air should be allowed to flow directly over the birds. The basics:

MINIMUM VENTILATION

Maintain minimum ventilation until there is need to exhaust heat from the house.

- We do not need to remove heat from the house, and do not want outside air to contact the birds directly. Either the birds are too small and/or outside air is too cold.
- Fans are on a timer, not a thermostat, and the ventilation goal is to prevent moisture build-up and provide fresh air.
- We want to stay in minimum ventilation as long as it is possible to keep birds comfortable this way.

TRANSITIONAL VENTILATION

Transitional mode removes excess heat but keeps cold air off birds.

Starts when birds grow larger and/or outside air gets warmer so that in-house air temperature rises and we begin to need to exhaust excess heat from the house. We need a higher air exchange rate. But we still do not want outside air to contact the birds directly.

- The first stage of transitional ventilation is often simply by a temperature sensor overriding the timer to run the minimum ventilation fans, and in some systems by bringing additional (non-tunnel) fans and air inlets on.
- Even more heat removal can be accomplished by using some number of tunnel fans to bring air in through sidewall air inlets (hybrid transitional mode).

• Transitional mode should be maintained as long as we can adequately remove the excess heat from the house in this way.

Note: One common alternative description lumps minimum ventilation and transitional ventilation under the term "power ventilation." **The distinctions between timer-driven and temperature-driven ventilation on the one hand, and between non-wind-chill heat removal and wind-chill cooling on the other, are very important and are maintained by the terminology used here.**

TUNNEL VENTILATION

• We switch to tunnel mode only when it is no longer possible to keep birds comfortable using the transitional setup. That is, we need to be cooling the birds by the wind-chill effect of tunnel ventilation.

• We have to be very careful in switching from transitional to tunnel mode when birds are under four weeks old, because they experience a greater wind-chill and may be stressed by the sudden drop in the effective temperature.

• We want to be in (and stay in) tunnel only when birds need wind-chill to stay in their comfort range.

Start tunnel ventilation when birds need cooling; air exchange will no longer keep in-house temperature from rising above birds' comfort zone.

Importance of Staying On Target Temperature

Each given day during a growout, the operator needs to know what the target temperature should be for that day, and manage the ventilation system to maintain that temperature. Maintaining optimum temperature is most critical early in a growout. Performance losses in young birds cannot be made up later. It's a good idea to post the target temperature on the wall by the controller every day. For broilers, the optimum temperature typically starts near 90 degrees on day one and drops gradually to near 70 degrees by the sixth week (see Figure 28 below). Someone should be comparing actual and target temperatures at regular intervals throughout each day of the growout, and making adjustments as needed.

A good manager knows the target optimum temperature for every day of a broiler growout.

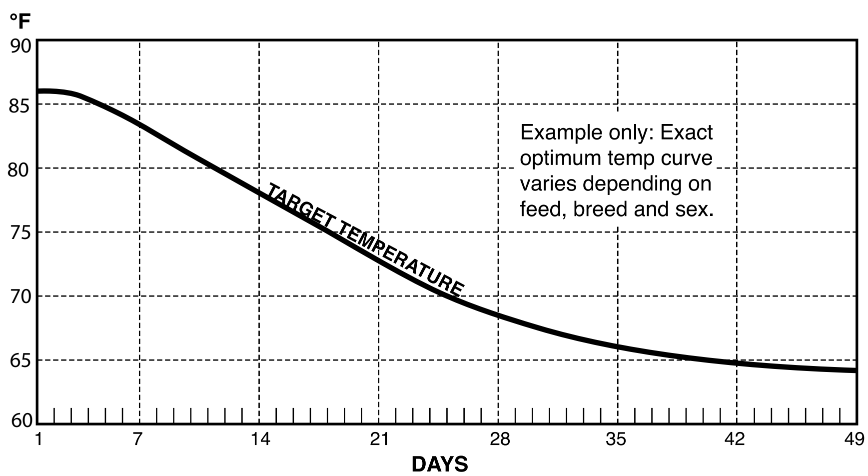


Figure 28. The temperature at which birds make best use of feed to gain weight begins at near 90°F on day one and declines to around 70°F toward the end of a seven-week growout. Staying close to target temperature is most important in the early part of a growout, but for best flock performance managers should strive to keep actual in-house temperatures within one or two degrees F of the target until tunnel ventilation is started, when the *effective* wind-chill temperature is what matters.

During tunnel ventilation the goal is to keep the *effective temperature* on target – what the birds feel, not what the thermometer says.

What matters is what is being experienced by the birds, not by the manager or even by a thermometer, especially one mounted four feet above bird level. All thermometers, thermal sensors or thermostats need to track temperature at bird

We do not want to lower the thermometer temperature to target if the birds are experiencing wind-chill.

level. Further, when a house is switched into the tunnel ventilation mode, the temperature the birds will experience is NOT the same as the thermometer reading. In the tunnel mode, the management goal is to keep the equivalent temperature on target. We do not need to and do not want to lower the thermometer temperature to target if the birds are experiencing wind-chill. This is especially important to remember early in a growout. It can be disastrous to wind-chill stress young birds who need to feel higher temperatures than do fully-feathered birds.

Keys to Managing Minimum Ventilation

The goal of minimum ventilation is to maintain air quality during any time when it is not necessary to exhaust heat from the house. This means bringing in just enough fresh air to provide adequate oxygen and to prevent moisture build-up and ammonia problems.

Even when heat removal is not needed, ventilation is essential to maintain air quality.

KEY #1 – It is imperative as long as birds are present to ventilate at least some minimum amount of time, no matter what the outside weather is, and even when there is no need to remove heat from the house.

House heat lost during minimum ventilation is insignificant compared to the benefits gained.

The amount of house heat lost during proper minimum ventilation is insignificant compared with the benefits gained in bird performance. Even when ammonia is not an issue (as with new litter), failure to provide adequate fresh air and to break up in-house air stratification can be very costly in terms of bird health and performance. One research study in the U.S., for example, found that just twelve hours of mild to moderate oxygen deficiency on day one caused a significant increase in ascites ("water bellies") and reduced weight gain at the end of the growout.

It's also important to realize there is no need to worry about moisture coming into the house during minimum ventilation. Cold air can't hold that much moisture to start with, and as it is warmed by mixing with house air its relative humidity drops drastically. This enables the ventilation air flow through the house to absorb and exhaust excess moisture. We can – and must – operate minimum ventilation even when an all-day cold rain is falling outside.

KEY #2 – While air quality must not be sacrificed to save heating fuel, it is extremely important to keep young birds from being chilled.

Young birds especially must be kept warm; pre-heat house and litter before chick placement, and monitor temperature at bird level.

Even mild chilling during brooding results in decreased weights and increased feed conversion, vaccine reactions, and mortalities. Monitoring thermometers and thermostats must be set at bird level and outside cold air must not be allowed to flow directly onto birds.

KEY #3 – It is critical to pre-heat the house and litter before chick placement.

Placing chicks on cold litter will hurt performance. A good rule of thumb is that litter should ideally be at 85°F at the time of placement. This can only be achieved if brooders are lit 24 hours ahead of placement. If convective heaters are the sole source of brooding heat, they should be turned on 48 hours before placement. The costs of not pre-heating are illustrated by one poultry company study which found that the best ten flocks for lowest early (seven-day) mortality, at 0.7%, placed chicks on litter at recommended temperatures. The worst ten, which placed chicks on litter averaging 72.5°F, experienced 4.0% seven-day mortalities.

KEY #4 – Minimum ventilation should be operated on a five-minute timer. As birds grow larger and put out more moisture and heat, system on-time and/or number of fans on needs to be increased.

Using a five-minute timer provides short (frequent) on-off cycles, which result in much better uniformity and consistency of house conditions. Using a ten-minute or longer timing cycle allows house temperature and air quality conditions to swing widely between extremes. Although average conditions may be the same as for the five-minute cycle, the birds will not be experiencing consistently optimum conditions. A rule of thumb for determining timer settings is that the minimum ventilation rate needed for starting chicks is about 0.10-0.20 cfm per bird, depending on outside air temperature. In-house relative humidity and litter moisture, along with bird behavior, serve as guides in setting the minimum ventilation rate.

Operating minimum ventilation on a 5-minute timer minimizes temperature and RH extremes and provides a better rearing environment.

KEY #5 – A critical factor for successful minimum ventilation is making sure that incoming cold air mixes uniformly with and is warmed by in-house air before coming in contact with the birds.

Adjustable perimeter air inlets operated by static pressure-sensing controllers are by far the best way to accomplish this on a consistent and continuing basis. If the inlet area is not adjusted properly according to the fan cfm's being used, either the ventilation rate will be choked down below what is needed, or incoming cool air is likely to fall directly to and chill-stress the birds. (See Figure 29, p. 31.)

KEY #6 – The switch to transitional ventilation mode comes when birds are producing too much heat for the minimum ventilation fans to cope with.

Switch to transitional mode only when heat removal is needed and minimum ventilation cannot keep birds comfortable.

The cooler the outside air and the younger the birds, the longer it takes to get to the point where ventilation must be switched from minimum to transitional mode. The warmer the outside air and the larger the birds, the sooner we will need to switch.

Keys to Managing Transitional Ventilation

The goal of transitional ventilation is to exhaust enough heat to keep the house temperature within the birds' comfort range, while at the same time not allowing outside air to flow directly onto the birds.

KEY #1 – To be successful with transitional ventilation, it is essential to have the sidewall inlets on a static pressure controller.

It is very difficult or impossible to manually adjust the size of the inlet openings to keep the proper static pressure as the number of fans running changes.

KEY #2 – We never want to switch to tunnel ventilation while it is still possible to maintain bird comfort in transitional ventilation mode.

As birds get older and give off more heat per pound of body weight, or as outside weather gets hotter, we must get rid of more and more heat from the house. For large birds in a well-designed house, if the outside temperature is more than ten degrees F cooler than the inside target, then we should be able to maintain target temperature with transitional ventilation. We should not be using tunnel ventilation. If birds are smaller, we should be able to maintain target temperature with transitional when there is even less than ten degrees F spread between inside and outside temperature. Switching into tunnel mode too soon is also likely to produce a large temperature difference from one end of the house to the other, which will hurt flock performance.

Switching from transitional to tunnel ventilation too soon can hurt bird performance severely.

KEY #3 – There is no problem with switching from one ventilation mode to another – minimum, transitional or tunnel – as conditions change.

A flock may need transitional ventilation during the night and in the early morning, but some form of tunnel during the heat of the day. The question is, What will keep the birds performing best?

KEY #4 – In judging the time and need to switch to tunnel, we must keep the wind-chill effect in mind.

If we are using maximum transitional ventilation capacity – running, say, four tunnel fans – and switch into tunnel mode, the birds will experience a drop in the "equivalent" or "effective" temperature, which may be quite a bit lower than the thermometer reading. When birds are younger and more sensitive to wind-chill, the effective temperature drop may be difficult for them to cope with.

Keys to Perimeter Inlet Management

In cold weather, perimeter air inlets are the tool to help blend cold outside air with warm inside air.

In both minimum and transitional ventilation, achieving proper airflow through the perimeter air inlets is essential. Inlets control direction of air movement and affect the velocity of air entering the house, and thus air mixing. In cold weather, inlets are the tool to help blend cold outside air with warm inside air to save fuel and maintain precise temperatures. Good inlet management prevents all the hot air from being in the top of the house. In houses with poor inlet management, as much as 15 to 20 degrees difference in floor and ceiling temperature are observed. Good inlet management can keep this temperature difference to 5 degrees.

Proper perimeter inlet management can cut heating fuel bills as much as 20%.

Good inlet management also saves fuel costs. Houses with poor air mixing will use 20-25% more fuel. In addition, the combination of temperature and air quality from day one is probably the most significant factor in broiler flock performance. Extreme temperatures can be devastating during the brooding period especially. Too cold conditions dramatically impact the ability of young birds to get adequate feed and water, and if early growth is slowed the performance losses cannot be made up during the life of the flock. Proper management of air inlets to provide birds the temperature and air quality they need is absolutely essential.

KEY #1 – Inlet management starts with making sure the house is tight, with no air leaks around doors, curtains, torn insulation, etc to rob from the inlet air stream.

KEY #2 – The next step is to make sure inlets are opening properly. The size of the inlet openings must be set so as to achieve both the static pressure desired and the airflow "throw" needed. See Figure 29 on facing page.

Sidewall air inlets should open at least 2-3 inches and ceiling inlets 1 to 1.5 inches to provide good airflow.

For perimeter inlets to flow air properly they must open a minimum of 2-3 inches for a sidewall inlet or 1-1.5 inches for a ceiling inlet. Inlets opened beyond the "fully open" position (opening at tip of board equal to inlet throat opening) don't increase air flow. Too wide board openings tend to direct air downward toward the birds. The right airflow happens only with the right amount of inlet opening.

KEY #3 – Use a static pressure-operated controller to operate air inlets.

Managing inlets manually is a well-nigh impossible job. Each time a fan came on and went off an inlet opening adjustment would need to be made. The static pressure control senses the static pressure in the house and then opens or closes the inlets to achieve the proper opening that will produce the static pressure desired — and thus produce the airflow pattern desired. These machines work very well and have greatly benefited our industry.

KEY #4 – The number of air inlets allowed to operate must be matched to the total fan capacity being used.

Deciding how many of the installed inlets will actually be used is one aspect of inlet management does need to be taken care of manually. A typical broiler house will have enough inlets installed to handle half the total installed fan capacity, but when only one or two fans are being used, as in brooding, we also need to cut back on the number of inlets that will open. The reason for this is that if too many inlets are operating for the number of fans running, the static pressure machine will have to choke the inlet openings down too far in order to maintain static pressure, and the airflow "throw" needed will not be achieved.

The number of air inlets allowed to operate must match the total fan capacity being used.

With all inlets in use, running only one 48-inch fan results in the static pressure machine opening the inlets only about one-quarter to a half-inch, and the air barely leaks into the house at the inlets and then falls to the floor. In this situation, proper air mixing cannot happen because there is no real air stream with any air velocity. This leads to wet litter, high humidity, ammonia, high fuel usage and poor air quality. The key is to match the number of inlets in use to the fan capacity that will be used during a given day or period of the growout.

To get good airflow during the early days of a growout when using only one 48-inch fan (or two 36-inch fans) in half-house brooding, we usually need to latch closed every other inlet in the brood chambers (and all the inlets in the growout end). This allows 15 evenly distributed inlets in the brood chamber to respond to the inlet machine. We would unlatch more inlets in the brood chamber only if there was need to run additional fans. After turnout, more inlets in the growout end are unlatched as more fans are used.

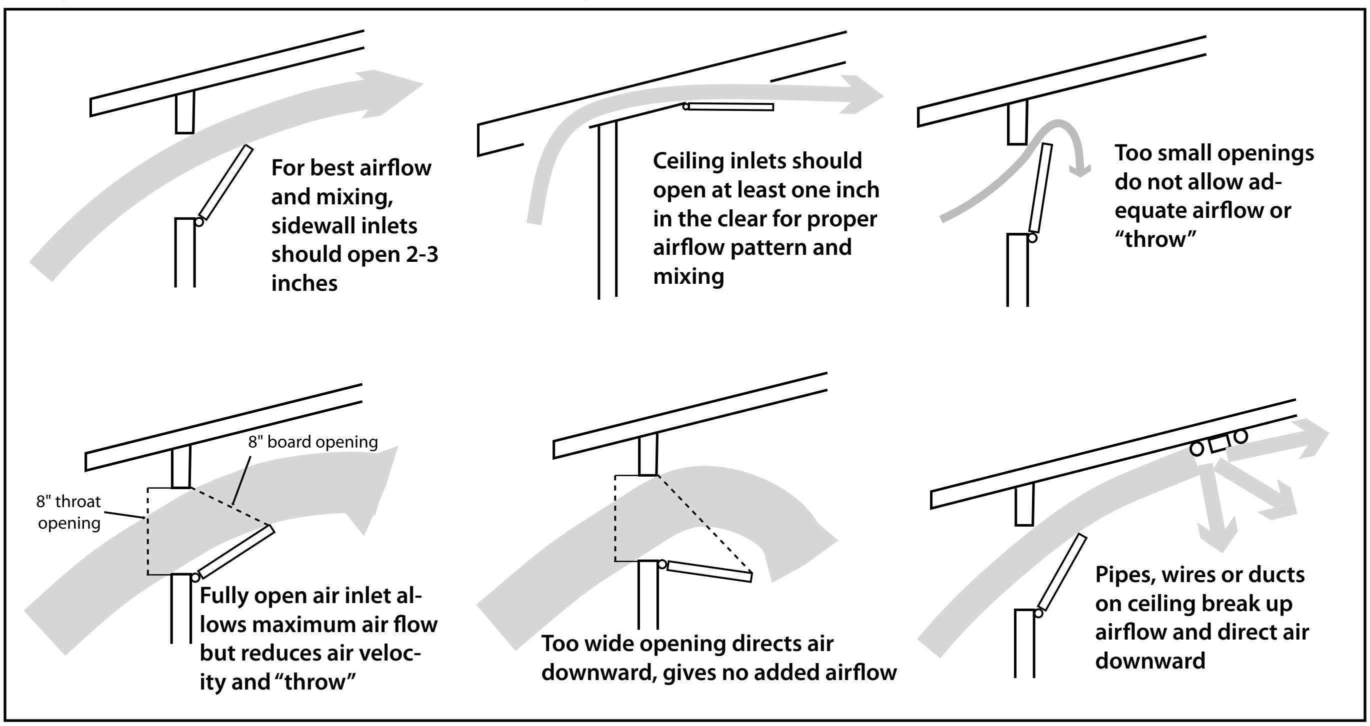
A good rule of thumb in a tunnel house is to have about 15 operating inlets for each 48-inch fan that will be brought on during that phase of the growout or that prevailing weather.

A rule of thumb is to have about 15 operating perimeter air inlets for each 48-inch fan being used.

<u>KEY #5</u> – Avoid having any obstructions to airflow being placed directly in the airstream from the inlet.

Water lines and electrical conduit are often strapped to the ceiling right in the path of airflow from the inlets. When the airflow stream hits such an obstruction it breaks up and drifts downward. This defeats the goal of having a high-velocity air stream flowing smoothly along the ceiling to the center of the house.

Figure 29. Correct and incorrect air inlet openings.



Keys to Managing Tunnel Ventilation

The goal of tunnel ventilation is cooling. We are in the tunnel mode only when it is no longer possible to keep birds comfortable by removing heat from the house. They need the wind-chill effect; and in hotter weather, the real temperature reduction of evaporative cooling.

<u>KEY #1</u> – Success in managing tunnel ventilation depends on understanding effective or equivalent temperature produced by the wind-chill effect.

Wind-chill effect depends most of all on bird age and air velocity.

To determine effective bird temperature, you must take the in-house thermometer reading and subtract the number of degrees of wind-chill cooling you estimate the birds are experiencing. Determining equivalent temperature is not an exact science. The felt temperature is very much affected by bird age (that is, feathering and body size) and the speed of the air. Other things being equal, the effective temperature drop will be:

– Greater for younger birds, less for older birds;

– Greater for lower temperatures, less for higher temperatures.

The wind chill effect decreases as we approach 95°F and completely goes away as we approach 100°F.

<u>KEY #2</u> – Extreme caution should be exercised when tunnel ventilating young birds.

Wind-chill on 4-week birds may be double that for 7-week birds.

The effect of wind-chill on 4-week birds may be double that for 7-week birds. Growers often get into trouble when trying to tunnel ventilate young birds when the weather is too cold. But under extremely hot conditions it may be necessary to ventilate day-old birds using two or three tunnel fans.

<u>KEY #3</u> – To determine the wind-chill effect in a given situation, you must observe the birds' behavior to pick up any signs of their being too warm or too cool.

There is no way to predict or calculate exactly what the wind-chill effect will be. The key signs of bird discomfort to look for are:

– When birds are too warm they migrate to cooler or higher airflow areas, hold feathers closer to the body, droop or lift their wings to get more air cooling, drink more and eat less. If they stop eating and begin panting, and especially if normally pink skin areas turn dark red, they are definitely getting over-heated.

– When birds are too cold, they tend to go to the floor to try to avoid the cool airstream, move away from the direction of air movement and huddle together, and "fluff" feathers to increase their insulating value.

<u>KEY #4</u> – It can be very helpful to develop guidelines for using tunnel ventilation based on your situation and experience.

If it is to cool outside, tunnel can hurt more than it helps; bird age is the critical factor.

Following are some example guidelines for judging whether you should be in tunnel or transitional mode. Caution: these are general guidelines only, and must be checked against bird behavior.

– If the outside temperature is less than 70°F and birds are four weeks old, stay in transitional mode.

– If the outside temperature is 65°F and the birds are between 5 and 8 weeks old, stay in transitional mode.

– If the outside temperature is 60°F or lower and the birds are 8 weeks old, stay in transitional mode ventilation. The fact is, if it's too cold outside, tunnel ventilation hurts rather than helps.

– Under normal conditions with fully-feathered birds, don't consider running in tunnel mode with fewer than half of your tunnel fans. This has more drawbacks than benefits, especially regarding temperature uniformity. If you can do the job with fewer than half of the fans, stay in transitional ventilation mode.

<u>KEY #5</u> – Monitor the temperature difference in the house from inlet end to fan end. This can indicate two different things, depending on the situation:

– During tunnel in hot weather, a temperature difference much greater than 5 degrees F (normal) can indicate insufficient airflow or air leaks letting hot air into the house. In this situation, check air velocity and look for dirty fans, shutters and/or pads, and for open doors or other leaks.

– In cooler weather with smaller birds, a more than 5 degree rise in temperature from one end of the house to the other during tunnel ventilation may indicate you should be in transitional ventilation, not tunnel. Under these conditions, the temperature rise from one end of the house to the other may be telling you that the incoming air is too cold, and as it passes through the house is picking up more heat than is desirable. You don't experience this with transitional ventilation because the air is coming in uniformly through the perimeter vents all around the house.

End to end temperature difference can indicate poor airflow, or need to be in transitional, not tunnel ventilation.

<u>KEY #6</u> – Migration fences should be installed as soon as we move from the brooding phase to full house ventilation.

When using tunnel ventilation for cooling, birds will tend to move toward and crowd into the cooler, inlet end of the house. Migration fences will keep them spread out. Keeping birds uniformly spread out ensures conditions for growth are the same throughout the house. Properly installed fences are vital for the proper operation of tunnel houses. Fences must be constructed 18-inches to 24-inches high and allow air to pass through the fence to allow good air circulation around birds.

Using migration fences keeps birds spread out, ensures conditions for growth are uniform throughout the house.

<u>KEY #7</u> – If you see any sign of birds being too warm during full tunnel ventilation (and the system is operating properly), it's time to turn on evaporative cooling. However, on any day when the temperature is expected to go at least into the 90°F range, it may be best to turn on evaporative cooling before getting to the point where all tunnel fans are running.

Turn on evaporative cooling before birds begin to feel heat stress, and before reaching full tunnel (all fans).

See more explanation of this issue in the next section.

Keys to Managing Tunnel + Evaporative Cooling

The goal of evaporative cooling in a modern tunnel broiler house is to work in combination with wind-chill cooling to keep birds in or near their comfort temperature zone. Evaporative cooling extends the range of conditions under which we can get top performance from birds. An evaporative cooling system does not have to lower the air temperature to the actual target thermometer reading – it only has to get it into the range where the added effective temperature drop produced by the tunnel airflow will do the job.

Evaporative cooling only needs to lower thermometer reading to range where wind-chill can keep birds comfortable.

For example, if it is 95°F outside and we can get 12 degrees of evaporative cooling from our system, the real air temperature coming into the house is 83°F. If the wind chill effect from the 500 feet-per-minute air velocity is another 10 degrees F, the effective temperature felt by the birds will be 73°F – very close to optimum for fully-feathered birds.

KEY #1 – Evaporative cooling should be turned on or programmed to come on before birds begin to feel heat discomfort.

For fully-feathered birds, this may be in the 80°-85°F air temperature range. It is easier and better to keep heat build-up from happening in a house than it is to reduce the heat load after it has progressed too far.

KEY #2 – Evaporative cooling does not have to be delayed until we are in full tunnel and running all fans.

Turning on evaporative cooling with less than all fans running is economical and can help younger birds.

Running, say six of eight fans with evaporative cooling on can be especially beneficial to younger birds, which are more sensitive to wind-chill. Using fewer fans reduces the wind speed, and evaporative cooling is more efficient when run with slower air speed, so that you can get the same effective cooling at lower cost.

KEY #3 – A good rule of thumb is that evaporative cooling systems should not be used when the relative humidity is above 80%, which in many locations includes after dark or before 9 a.m.

Rule of thumb: Do not run evaporative cooling after dark or before 9 a.m.

Nighttime temperatures usually drop significantly, and in many areas humidity during nighttime hours may be so high in summer that almost no cooling will be experienced. On the other hand, there is rarely high enough relative humidity during a hot summer day in most regions to necessitate turning off properly-staged foggers or pads. Evaporative cooling does little good if the relative humidity is much over 80 percent. However, as a warm day progresses and air temperatures increase, the cooling we can get from evaporative cooling also increases.

Good maintenance is especially important for successful evaporative cooling.

KEY #4 – Pad cooling systems work well only when all incoming air goes through a completely wetted (and clean) pad – which means it is especially important to properly maintain and monitor the system and the house. No doors can be open or any air leaks permitted. Side curtains must fit tight against the house. Water pumping rates must be right, and pads must not be allowed to clog. Reducing the number of on-off cycles helps, as does allowing pads to dry out completely during the night, turning the water off but keeping fans on.

Management Includes Monitoring

Monitoring job #1: watch bird behavior.

Probably the hardest part of doing ventilation right is that you can't usually see air movement. Bird behavior is the first and most important item to monitor. If birds are eating and drinking normally and distributed evenly through the house, they're OK. If they aren't, you have a problem to investigate. It's also important to keep watch on other key indicators. Monitoring temperature, air movement, relative humidity, and static pressure can show you expensive problems you weren't aware of, and help you head off problems before they occur. Here are some ways to keep watch:

Temperature

Temperature is extremely important: invest in good thermometers and put them in the right places.

- The large dial thermometers seen in most houses are convenient but inaccurate. High/low recording mercury thermometers are more accurate and allow you to see and keep a log of temperature ups and downs. Recording ("data logging") thermometers and humidistats print out a record of temperature or humidity swings in the house, which can be extremely valuable.
- Mount thermometers high and low in the house to see how much air/temperature stratification you have. The critical reading is the temperature where the birds are. You need at least three thermometers at bird level: at the front, at the middle, and at the rear of the house.

- Handheld digital thermometer/humidistat combinations are not too expensive, are fast reacting and can be used to calibrate mercuries.
- An infrared thermometer shows you the temperature of any surface you point it at, not the air temperature. These are more expensive but can show up expensive problems you might otherwise miss, such as ceiling insulation breaks, cold floors, overheating motors or circuit breakers, etc.

An infrared thermometer helps spot a number of different kinds of problems.

Air Movement

- Simple to use, accurate, and affordable airspeed meters are now available. These electronic gadgets are not too expensive and are accurate enough to be useful. A handheld model that includes a thermometer is especially useful and convenient for surveying house conditions.
- Strategically placed lengths of light ribbon, like surveyor's flags, are useful airflow indicators. Generally you want them along the ceiling and at bird level. A fluttering streamer does not tell you that air movement at that place is perfectly OK, just that there is some air moving. A streamer hanging still when it should be fluttering definitely signals a problem.

Airspeed meters and streamers take a lot of the guesswork out of ventilation management.

Relative Humidity

- Monitoring relative humidity also requires some instrumentation. There is no way you can "feel" relative humidity differences that can spell loss of bird performance if they continue. To easily check relative humidity trends up or down, use an inexpensive digital relative humidity meter (humidistat), accurate to about ±5%. A high-accuracy digital costs more but is accurate to about ±2%. Again, you want to know what's going on at bird level, so get down with the birds to make your checks.

Static Pressure

- Monitoring static pressure over time and in given conditions is especially useful to spot problems such as air leaks, shutters not opening fully, declining fan performance, etc. Easy to use and inexpensive hand-held or wall-mounted manometers are available. Magnehelic type meters are slightly more expensive but also more accurate.

A static pressure meter helps spot air leaks, shutter problems, poor fan performance, and more.

NOTE: Get expert help wherever you can. Company service personnel, consultants, and University specialists (where available) will have or have access to good monitoring equipment. They can give advice, help you check your house periodically, and show you how to do it all yourself.

HELPFUL CONVERSION FACTORS

Following are approximate Imperial (English) to metric and metric to Imperial (English) conversion factors for measurements and units commonly encountered in discussions of commercial poultry house environmental management.

Air velocity	in feet per minute ÷ 197 = meters per second in meters per second x 197 = feet per minute
Area	in square feet ÷ 10.76 = square meters in square meters x 10.76 = square feet
Airflow	in cubic feet per minute ÷ 2119 = cubic meters per second in cubic meters per second x 2119 = cubic feet per minute
Static pressure	in inches of water x 249 = Pascals in Pascals ÷ 249 = inches of water
Volume	in gallons x 3.785 = liters in liters ÷ 3.785 = gallons
Heat	in Btu's x 1.055 = kilojoules in kilojoules ÷ 1.055 = Btu's
Heat loss	in Btu's per hour per pound x 2.323 = kilojoules per hour per kilogram in kilojoules per hour per kilogram ÷ 2.323 = Btu's per hour per pound
Length	in inches x 2.54 = centimeters in centimeters ÷ 2.54 = inches in feet x 0.305 = meters in meters ÷ 0.305 = feet
Weight	in pounds ÷ 2.2 = kilograms in kilograms x 2.2 = pounds
Light intensity	in lux ÷ 0.093 = foot-candles in foot-candles x 10.764 = lux

Temperature Conversion Chart

Fahrenheit to Celsius (°F-32) ÷ 1.8		Celsius to Fahrenheit 1.8°C + 32	
°F	**°C**	**°C**	**°F**
105	40.56	40	104
100	37.78	35	95
95	35.00	30	86
90	32.22	25	77
85	29.44	20	68
80	26.67	15	59
75	23.89	10	50
70	21.11	5	41
65	18.33	0	32
60	15.56	-5	23
55	12.78	-10	14
50	10.00		
45	7.22		
40	4.44		
35	1.67		
30	-1.12		
25	-3.90		
20	-6.68		

Note: In converting temperature differences or intervals, the ±32° constant is not used. For example, a 15-degree Fahrenheit interval equals an 8.3-degree Celsius interval: 15 (F) ÷ 1.8 = 8.333 (C)

NOTES

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