

Getting the most from evaporative cooling systems in tunnel ventilated broiler houses

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High temperatures have a negative effect on bird performance. During some weather conditions the in-house temperature can be kept from rising excessively by providing a high air exchange rate; also, the effective temperature can be lowered by increasing the wind speed in the house. When these methods are not sufficient, additional measures have to be taken. Evaporative cooling proves to be a useful tool, but one has to go by certain rules to get the maximum out of the system.

Today's broiler industry is placing more and more demands on housing and equipment systems to provide good environmental conditions within the house to achieve maximum performance and production levels. Over the last ten years, more and more poultry houses have been either built or retrofitted to tunnel ventilation. And almost all of these houses have some form of evaporative cooling. The reason for this is that today broiler producers want to maintain and maximize bird performance in hot weather. The wind-chill cooling effect of tunnel ventilation begins to drop off as air temperature gets into the mid to upper 90s °F (30s °C), and above the high 90s increased air flow around the birds produces almost no wind-chill. Under such conditions, reducing the actual temperature of the air going through the house is the only way to keep birds performing without reducing bird density. And the only practical way to achieve the real cooling needed is by evaporative cooling.

A refined tool to manage the environment

Evaporative cooling technology - let's call it EC for short - has evolved to become a refined tool for managing the environment in hot weather. EC is being applied by broiler growers across the U.S. and in other countries. Effective use of EC, however, requires a properly designed installation for the situation, and proper management. The following survey of EC fundamentals provides some basic guidelines for growers and flock supervisors who want to get the most out of evaporative cooling.

The first thing to understand is that all modern types of EC systems work as an add-on to tunnel ventilation. Airflow is more important than any other item in having a good hot weather house. If you don't have enough fans, or fans are not operating properly, you will have heat build-up that cannot be overcome by a cooling system. If you do not have the air velocity to provide good wind-chill cooling, an EC system will not be able to bring temperatures down far enough to keep birds comfortable. This means that the most basic requirement for successful EC is that the house be designed, maintained and operated for effective tunnel ventilation. It is much better if a house is designed and built from the start to include tunnel ventilation and EC, since add-ons can be difficult. In either case, however, an EC system can be successful only if the house and ventilation system are adequate. In terms of the house itself, the structure must be tight, with no air leakage.

The basics have to be perfect

In tunnel ventilation all vent boxes and curtains must be closed and sealed tightly for the whole length of the house. We absolutely want all air coming into the house to come into the tunnel inlets only. Any air leakage prevents attaining the air velocity needed for wind-chill. For pad systems, leakage pulls in hot, uncooled air, bypassing the pads. We also need at least R-11 under-roof insulation, preferably R-19, and preferably with a drop ceiling instead of air deflector baffles. A poorly insulated roof can allow solar heat transfer into the house that no ventilation or EC system can cope with. Under Southeast U.S. conditions, and assuming that the house structure and insulation are adequate, a rule of thumb often used for a broiler house fan system is that it should be capable of completely exchanging house air at least once every minute. This is, however, only a rule of thumb, not a fixed design criteria.

A once per minute air exchange, for example, may not be enough for a house growing heavier birds. To achieve adequate wind-chill cooling, a tunnel system must be designed to produce an air velocity through the house of 500 feet per minute. A properly designed EC system is built on the foundation of an adequate tunnel ventilation system, and takes into consideration the house configuration (size, ceiling height, baffles or no baffles, type and amount of insulation, etc), number of birds, market weight of birds, and the climate where the house will be built. That is, we need to know what the system has to work with and what has to be accomplished in terms of heat removal and cooling. A cooling system for a house that is growing 4 pound birds is a very different design situation from a house that is growing 7 or 8 pound roasters.

A heat balance should be calculated for a house before it is built, to make sure the ventilation and EC systems can do the job we want. Most of the major ventilation companies and state Extension engineers can help you do the heat balance. Unfortunately, most times the calculations are done after the fact, when it can be very difficult to bring an inadequate system up to the level of performance needed.

How much cooling can be achieved

First, we must realize that the goal of EC is not to get 95- or 100°F air down to 70°F degrees. Often, that would be impossible - but it is not necessary anyway. Because the EC system is working with tunnel ventilation, we only need to bring the air temperature down to the range where the tunnel wind-chill effect can help the birds feel as though it was near 70 or so degrees.

For example, if the air temperature is 95°F and our EC system can bring that temperature down by 12 degrees, and we get another 10°F “effective temperature” reduction from wind-chill, the birds will feel like they are in 73-degree air. And this is the kind of cooling we can expect from properly designed EC systems on most hot summer days.

Of course, there will be days when temperatures soar to 100°F and above, and we will not be able to keep birds perfectly comfortable. The birds will, however, experience far less stress and we will see far fewer mortalities than would otherwise occur on these unusually hot days.

All EC systems work by arranging to get water in contact with warm incoming air, so the water evaporates into the air. This cools the air, since it's the heat energy in the air that powers the change from liquid water to water vapor. Every gallon of water evaporated will take 8,700 Btu's of heat out of the air. That sounds like a lot of heat, and it is. But what we really want to know is

how much of a temperature drop we can expect EC to produce in the air going through a chicken house. The actual amount of cooling depends mostly on just two factors:

1. How much moisture is already present in the air. This determines the theoretical maximum cooling potential. The lower the relative humidity (RH), and the higher the temperature, the greater the theoretical cooling potential. Under Southeast U.S. conditions, this maximum theoretical cooling potential typically ranges around 15 to 17 degrees when air temperatures are in the 90° - 100°F range. This corresponds to a relative humidity of about 50%.

2. How efficient the EC system is. This determines the practical achievable cooling -- how much of the theoretical cooling potential we will actually achieve. Efficiencies of current systems range in practice from around 50% to about 76% or so. A 50%-efficient system, for example, will give half (50%) of the maximum potential cooling. This means the actually achievable temperature drop may range from as little as 7°F to as much as 13°F or so in the 90°-100°F range, with 50% RH (76% of 17 = 13; 50% of 15 = 7.5).

Key role of relative humidity

Relative humidity is critical because the less moisture air is holding at the start point, the more evaporating water it can accept, thus the more cooling will occur. As shown in *Figure 1*, early in the morning on a typical summer day, relative humidity may be close to 100%, but the temperature will be in the low 70s. As the day goes on, the air heats up and can hold more water vapor. That is, its relative humidity drops. A 20-degree temperature rise comes close to *doubling* the water-holding capacity of the air (cutting its RH in half). So by the time air temperature hits 95°F or so in mid to late morning, the *RH* will have dropped to around 50% or so. This gives an evaporative cooling system room to work, evaporating water into the warm air, raising its RH but lowering its temperature, typically getting it back down into the 80°F-85°F range.

The day-night temperature swing alone gives a basis for estimating the approximate theoretical cooling potential: that is, the theoretical maximum possible cooling. The rule of thumb is that every three degrees of day-night temperature difference results in a two-degree theoretical cooling potential. Stated another way: The maximum theoretical cooling potential is about two-thirds of the difference between the nighttime low and the daytime high temperatures. For example, if the day-night temperatures are 72°F vs 96°F, a difference of 24 degrees, then there will be about 16 degrees of cooling theoretically possible. That would mean we could expect to get about 8 degrees actual cooling - to 88°F - with a 50% efficient EC system, or about 12 degrees of actual cooling for a 75% efficient system, to about 84°F.

Relatively inexpensive hand-held electronic instruments are available for directly measuring relative humidity, and thus knowing more precisely what can be expected from an EC system. The older method uses a *sling psychrometer*, twirling a thermometer wrapped in a wet cloth to get the *wet-bulb temperature*. The lower the wet-bulb temperature, the lower the RH. The difference between the dry-bulb and wet-bulb thermometer readings equals the maximum theoretical cooling potential.

Table 1 shows this maximum theoretical cooling potential for a range of dry-bulb temperatures and relative humidities. To illustrate with some examples what these numbers typically can

mean in practice, *Table 2* shows the actual resulting (lowered) air temperatures to be expected for 90°-100°F starting temperatures, given typical relative humidities for incoming air of 50% and 60%, and EC system efficiencies of 50% and 75%.

Figure 2 demonstrates how relative humidity and system efficiency combine to determine the cooling that can be achieved, using 95°F as an example.

If the house contains fully-feathered birds, evaporative cooling systems usually should be turned on (either manually or by controller settings) as soon as the temperature rises into the 80°-84°F range, or at least well before any sign of heat stress. It is easier for the system to cope with heat as it comes into the house than to cope with a large heat build-up already present when it is turned on. On the other hand, care must be taken not to chill younger birds by turning on either tunnel ventilation or evaporative cooling when they do not need the temperature reduction.

Water requirement for effective EC

Since only evaporating water results in actual cooling, it is essential to provide adequate water. To lower air temperature one degree F requires evaporating about 0.125 gallons (0.5 liters) of water per hour for every thousand cubic feet (30 cubic meters) of air going through the house. If a broiler house has a fan capacity of 180,000 cfm, to continuously lower the air temperature 10 degrees requires evaporate 225 gallons into the air every hour: $180,000 \times 0.125 \times 10 = 225$. Calculations can be made on this basis to estimate amounts of water needed per day, per house, etc, depending on the amount of cooling desired (and possible).

It is important to make sure that any EC system will be able to cope with the maximum cooling situation the system is expected to deal with. In the Southeast, for example, this might be a 100°F day at 50% relative humidity, so there is a 17°F spread between dry bulb and wet bulb readings (say, 100°F vs 83°F). With a high-efficiency EC system, we could achieve about a 13-degree temperature reduction in this situation (76% of 17 = 12.92). To accomplish this in a house with nine 22,500 cfm fans, the system must evaporate 329 gallons per hour ($9 \times 22.5 \times 0.125 \times 13 = 329$).

In addition to the system efficiency requirement (76% in this case), we must also make sure items such as the total pad area, number of fogging nozzles, etc are adequate, and check the delivery rates of our nozzles and/or pumps. In a six-inch recirculating pad system, a rule of thumb is that the pump must deliver 1.5 gallons of water per minute for each square foot of top area on the pad, or 0.75 gpm for each lineal foot of pad.

It is also essential to make sure the water supply will be adequate, especially for systems that do not recycle or recirculate, and thus are likely to waste water in run-off. If we are going to do evaporative cooling at all, the last thing we want is to have the amount of cooling we can get to be water-limited, either in terms of supply or delivery capability.

Maintenance requirement

Getting the most out of an EC system requires keeping both water and air passages open. Keeping water lines clear requires various steps, depending on the EC type and the manufacturer's specifications, including cleaning or changing filters, clearing clogs, and taking steps to prevent and to clear any algae build-up. Air channels or flutes through pads are also susceptible to clogging by either algae or mineral scale, and preventive measures are called for here also. Two basic steps that are very helpful for pad systems is to keep on-off cycles as long as possible - that is, keeping the pads wet as consistently as possible during the cooling period; but to allow pads to thoroughly dry out at night, turning the water supply off but keeping the fans running. Both of these steps help prevent scale and algae problems. Also, running at least some tunnel fans through the night has been shown to help birds all by itself, giving them a cooler "head start" on the next day's heat.

Local weather determines the economics

Whether evaporative cooling will pay off for a given operation, or which type of evaporative cooling will provide the best return on the investment, is determined by the interplay of market economics and prevailing weather. In the U.S., the market seems to demand ever-higher efficiency of production. Producers more often than not have found that any gains in efficiency are rewarded in the marketplace and more than repay the investment in technology to control the in-house environment, not letting in-house conditions depend on the chances of outside weather. This is a major reason we have seen broiler house EC systems become common in the last few years. That we see the most widespread adoption of EC in the South and Southwest, is a function of weather.

The production factor that is most critical in making EC system decisions is market weight of birds. A producer growing eight-pound birds will have much greater need for cooling than a producer growing four-pound birds. The type of system needed, however, will still depend on the weather.

The most critical weather factor is the prevailing pattern of high temperatures and coincident relative humidity. That is, how hot it is for how long, and what the relative humidity tends to be at these times. In the Southwest of the US, temperatures regularly exceed 100°F, so cooling is definitely needed; but relative humidity is usually low enough at these times that even a modest EC system can produce the cooling needed. In the Southeast, daytime temperatures above 90°F are common, but relative humidity is often in the 50-60% range, with dry-bulb/wet-bulb spreads of not much more than 16 to 17 degrees. This narrower gap between dry-bulb and wet-bulb temperatures means that higher-efficiency EC systems may be needed to keep birds in their comfort range, or at least keep them out of the critical heat-stress range.

Weather data help determine feasibility of evaporative cooling

Weather data are available to help judge the feasibility of cooling, and determine the kind of EC system that will be needed for a particular area. For example, the following selected cooling-need weather data for Montgomery, Alabama, during the warmest six months of the year (more limited than would be used in a complete study) suggest why evaporative cooling has apparently been found to be needed, and both technically and economically feasible in Alabama.

1. Number of hours dry-bulb temperature is at or above 80°F - 1,611 hours
2. Mean (average) daily range of temperature, high-low - 21 degrees
3. Dry-bulb temperature that is exceeded 2.5% of the time - 95°F. Mean (average) coincident wet-bulb temperature - 76°F
4. Dry-bulb temperature that is exceeded only 1% of the time - 96°F. Mean (average) coincident wet-bulb temperature - 76°F

Briefly, the high number of hours in the cooling-need zone (over 80°F) tells us that this location is definitely one where some kind of cooling is needed. The average daily temperature swing, along with the approximately 20-degree spread for dry-bulb/wet-bulb highs at 95°-96°F, suggest that EC will be feasible at this location, but that the dry-bulb/wet-bulb spread is no wider than that indicates that fairly high-efficiency systems may be needed to achieve the desired cooling.

Pros & Cons of various EC systems

Three types of EC systems are most often used: in-house fogging, spray-on pad, and recirculating pad systems. In-house fogging is the oldest system type, and is seen in a number of different configurations with widely ranging efficiency levels.

The trend has been away from in-house fogging, which carries very high management requirements, toward pad cooling, and most recently to high-efficiency recirculating pad systems, which have the lowest operational management requirements. Following is a brief outline of the most important features, advantages and disadvantages, and operational characteristics of these systems.

In-house foggers: Fogging nozzles are usually installed laterally across the house in successive rows, but many variations are seen, including nozzles mounted inside air inlets. Whatever the configuration, the object is to put a fine mist of water into the tunnel air stream to be evaporated and bring about cooling. To achieve the fine misting needed, a booster pump is required to provide high-pressure water (160-200 psi) to one-gallon per hour nozzles. A rule of thumb is that 15 to 20 fogging nozzles are needed for each 48-inch fan installed in a house. The exact number depends on the pressure used and the nozzle ratings, which must be known. Nozzles are typically rated for 85 psi, and a 1-gal/hour nozzle is likely to put out about 1.3 gallons per hour at 160 psi. Fogging lines are staged on as needed, depending on the air temperature and relative humidity (that is, how much moisture the air can accept).

The biggest disadvantage of in-house fogging is its strict management requirement. Fogging systems require close monitoring to make sure the desired cooling effect is achieved that is, enough water is being put into the air stream and, on the other hand, to make sure there isn't so much water being injected that the birds and litter aren't being wet down. Clogging of nozzles is also common, requiring frequent checking. Water quality can be an issue, and the supply for the system must be filtered.

Wetted pad cooling systems: Whether fogger-pad or recirculating, these systems are alike in getting moisture into the air stream by wetting pads placed over the tunnel air inlets. Both can do a good job if designed, installed and managed properly.

The most critical aspect of pad cooling is to match the total pad area to the installed fan capacity so that the desired cooling efficiency is achieved and house static pressure does not exceed 0.10 inches. . The lower the air velocity through the wetted pad, the more moisture the air is able to pick up, which means higher cooling efficiency, and a lower static pressure drop across the pad. Higher air velocity through the pad, for a given total pad area, will mean lower cooling efficiency and increased static pressure. It must be realized in this connection that the static pressure drop across the pad will add to the static pressure in the house proper, which can load fans so as to reduce fan output. Figures 3 and 4 illustrate the typical relationships between static pressure, cooling efficiency, and air velocity for 2-inch and 6-inch cooling pads.

Note that the air velocity through cooling pads is not the same as the velocity through a house. It is the cross-sectional area of the house that determines the air velocity after the air moves into the house. The pad area is almost always larger than the house cross-section, in order to slow down the air as it goes through the cooling pads.

It is most important to realize that a manufacturer's efficiency specification for a given cooling pad can hold only for a stipulated air velocity, and that a certain static pressure drop will follow, depending on the pad area and airflow resistance characteristics. The most common mistake made in EC system installations is not having enough total installed pad area. The result commonly is too high static pressure, so that fan output, air velocity and cooling are not what was desired.

The formula for determining the **total pad area required (sq ft)** is:

$$\text{Installed tunnel fan capacity (cfm)} \div \text{Recommended air velocity through pads (fpm)}$$

The recommended air velocity, then, is based on keeping static pressure in the 0.10-inch range and achieving good cooling efficiency. Installing insufficient pad area forces static pressure too high, which reduces the output of the fans below the rated cfm's we are counting on. With tunnel fan performance reduced in this way, we won't get the cooling we wanted.

Another point to keep in mind is that while we design systems using rated efficiency and static pressure numbers, these represent the best-possible, off-the-shelf or out-of-the-wind tunnel cases. As systems age and collect dust, algae and mineral scale, efficiencies inevitably decline at least slightly, and static pressures go up at least slightly, even under the best maintenance regimen. This is good reason for taking a conservative approach, designing in a "cushion" beyond the bottom-line need and/or adjusting our expectations for system performance.

Table 3 shows an example of such a design approach, with recommended installation specifications for 2-inch spray-on and 6-inch recirculating system alternatives for a typical modern broiler house to be built in Alabama. Note that the pad areas stipulated are larger than might be seen in manufacturer literature, in order to assure that house static pressure is kept low and fan performance and cooling are as desired. The reason in this case is a decision not only to provide a cushion against degraded performance over time, but to protect bird performance and at least limit if not completely avoid mortalities during periods when temperatures reach into the high 90s and above. Systems with significantly less pad area would be somewhat cheaper and would have no problem delivering adequate cooling on a 90°F day. However, in many parts of

the U.S. Southeast (and the world), choosing this design approach means accepting a high probability of significant losses in bird performance and in mortalities during extremely hot weather.

Spray-on pads: These systems, using fogging nozzles to wet pads placed over the tunnel air inlets, usually can achieve higher efficiency than in-house foggers, and are cheaper to install than recirculating systems. Moisture is evaporated both by the fogging into the air stream and from the wetted pad. A 2-inch paper spray-on pad is most often chosen, although some systems use 4-inch pads. *Figure 3* shows the efficiency vs static pressure curves for a typical 2-inch pad at different air velocities.

Since fogging nozzles are used, these systems share some of the drawbacks of in-house fogging, regarding water quality and clogging, and in the high level of management required. If the foggers are not putting out the needed amount of water, the needed cooling will not occur. Personnel must monitor the system and conditions, checking for clogged nozzles, turning the system on and off, etc, to consistently get the right amount of water evaporating into the air stream, depending on temperature and relative humidity of the entering air. On the other hand, the system must not be allowed to deliver too much water. Waste water runoff around the broiler house especially can be a serious problem with spray-on pads if they are not properly managed. In some areas, legal regulations prohibit such discharge altogether.

Recirculating pads: Supply piping to recirculating type pads has much larger holes than fogger nozzles do (on the order of 1/8 inch or more), so that clogging is not as much of an issue as long as routine maintenance is done. Water that is not evaporated from the pad is collected at the bottom of the unit and returned to the pump. Therefore, recirculating systems do not have to be turned on and off to regulate cooling and prevent water runoff the way a spray-on pad system does. They can be tripped on either manually or by controller whenever the air temperature in the house rises to the threshold point. Recirculating systems can also use thicker pads, giving the air more wetted surface area to flow across, and therefore, more opportunity to evaporate cooling water. *Figure 4* shows the efficiency vs static pressure curves for a typical 6-inch pad at different air velocities (compare with *Figure 3*, for a 2-inch pad).

Key points for effective tunnel-house evaporative cooling

1. Airflow is more important for a good hot weather house than any other item. Evaporative cooling extends the capabilities of tunnel ventilation.
2. The goal of evaporative cooling in a tunnel house is to get inside air temperature down to the range (80°-84°F) where wind-chill cooling can keep birds comfortable. We do not have to reduce air temperature all the way to 70°F.
3. The relative humidity of air (spread between dry-bulb and wet-bulb temperatures) determines the *theoretical cooling potential* available.
4. The *practical achievable cooling* depends on the efficiency of the EC system. Since EC system efficiencies typically range from 50% to less than 80%, achievable cooling in the U.S. Southeast may be from 7 to 12+ degrees, depending on the system.
5. If the house contains fully-feathered birds, evaporative cooling systems usually should be turned on in the 80°-84°F range, or at least well before any sign of heat stress.
6. Both the water supply and the system itself must be capable of putting out the full amount of water needed for the cooling we want - at least several hundred gallons per hour - so the effectiveness of the EC system isn't water-limited.
7. In-house fogging systems and spray-on-pad systems are cheaper but require much closer management than do recirculating pad systems.
8. The most critical aspect of pad cooling is to match the total pad area to the installed fan capacity so that the desired cooling efficiency is achieved and house static pressure does not exceed 0.10 inches..
9. The most common mistake made in EC system installations is not having enough total installed pad area. The result commonly is too high static pressure, so that fan output, air velocity and cooling are not what is needed
10. As systems age and collect dust, algae and mineral scale, efficiencies tend to decline and static pressures go up. This should be taken into account in system design decisions - and is a reason for faithful maintenance of installed systems.
11. The most critical production factor in making EC system decisions is market weight of birds. Growing birds to greater weights means much greater need for and demand on EC systems.
12. The most critical weather factor in making EC system decisions is how hot it gets for how long, and what the relative humidity tends to be at these times. The higher the temperature and the lower the relative humidity, the more need for cooling and the more effective EC can be.

Table 1. Theoretical cooling potential (°F reduction) at different outside air temperatures and relative humidities.

Air temperature (°F)	Temperature reduction (°F) for given relative humidity					
	80%	70%	60%	50%	40%	30%
105	7	10	14	18	22	27
100	6	9	13	17	21	25
95	6	9	12	16	20	24
90	5	9	11	15	18	23
85	5	8	11	14	17	21
80	4	7	10	13	16	20

Table 2. Resulting lowered air temperatures at different outside temperatures, for given EC system efficiencies and relative humidities.

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

Table 3. Example recommended conservative-design EC system options for a 40 x 500 ft broiler house in Alabama with total fan capacity of 190,000 cfm

System option	Total pad area	Air velocity through pad	Static pressure drop across pad	Total static pressure on fans	System efficiency
6-inch (small-flute) recirculating system	567-542 sq ft	335-350 f/m	0.04-0.07"	0.06"- 0.09"	72-74%
2-inch spray pad system	679-612 sq ft	280-310 f/m	0.03-0.05"	0.05"- 0.07"	55-66%

Figure 1. Typical summertime temperature vs relative humidity pattern in the U.S. Southeast

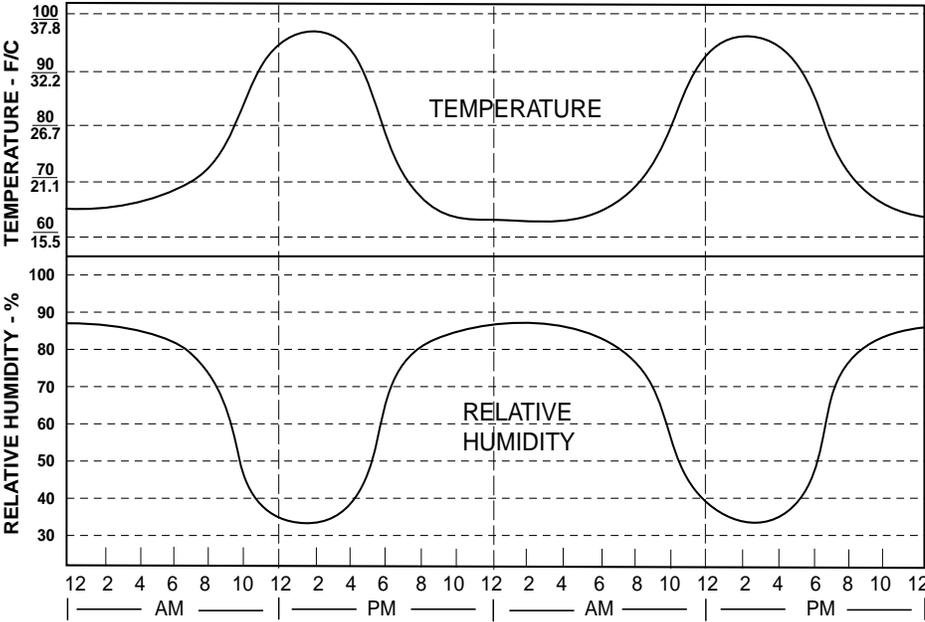


Figure 2. Evaporative cooling temperature reduction from 95°F outside air temperature for different relative humidities and system efficiencies

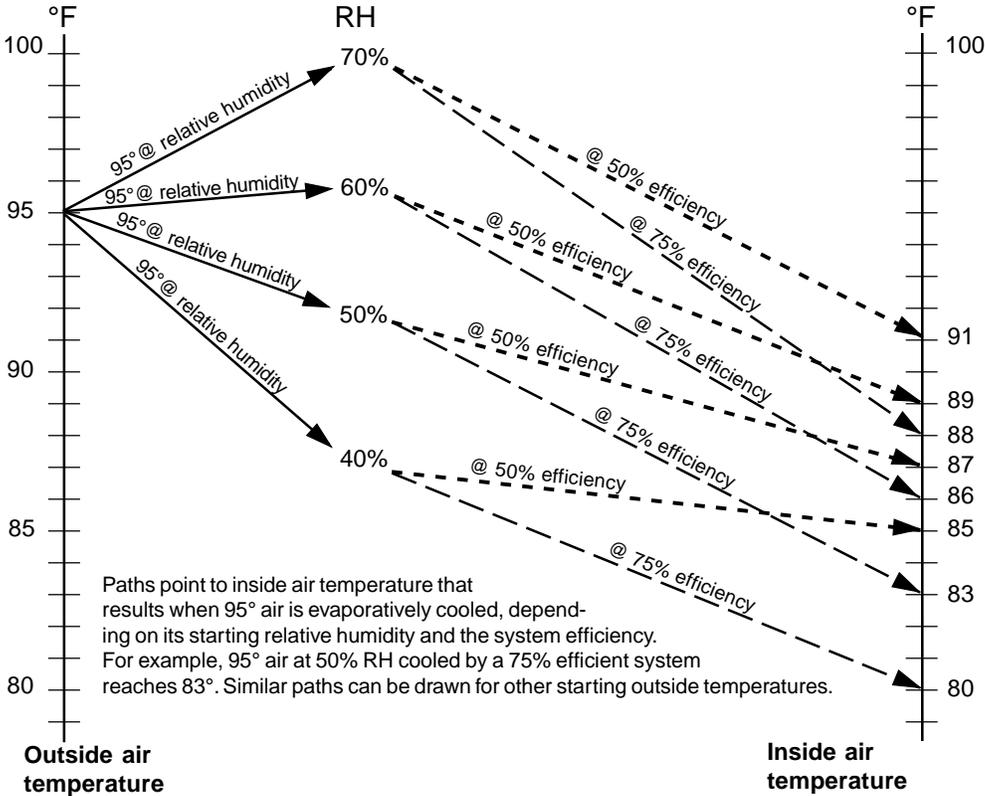


Figure 3. Efficiency and static pressure curves for typical 2-inch spray-on EC pad, as air velocity through pad is increased

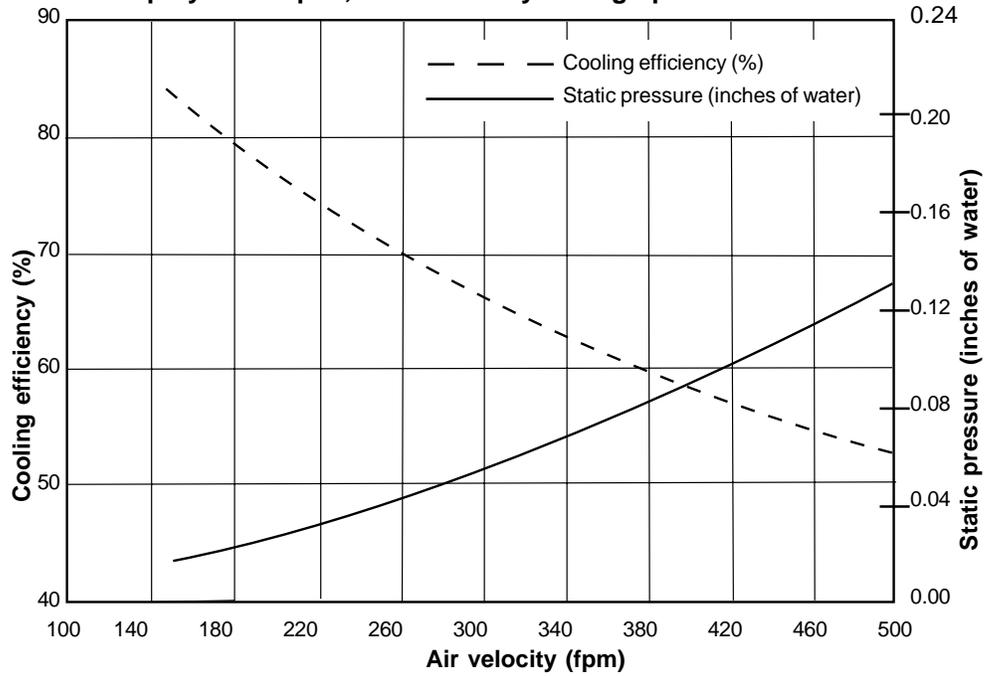


Figure 4. Efficiency and static pressure curves for typical 6-inch recirculating EC pad, as air velocity through pad is increased

