Photos by Thomas Dugan

Practical Ventilation for a Warm, Humid Climate

Lessons learned from building in a coastal region

BY THOMAS DUGAN

Soon after building my first hurricane- and disaster-resistant home in coastal North Carolina in 2010, I realized that making the house structurally able to withstand storm conditions had also improved its building performance. Tightening up the house to prevent water intrusion, using better windows to seal out wind-driven water, and using closed-cell spray foam under the roof deck to seal it and increase resistance to uplift forces from high winds had all contributed to the house being more energy efficient. This made me eager to learn more about building science and provide my homes with better HVAC installations.

I became particularly interested in air infiltration/exfiltration issues and how tightening up the exterior envelope may affect indoor air quality (IAQ). For the homes that I built over the following years, I explored various techniques and technologies as they became available.

This article is a summary of what I've learned, along with a case study detailing specific practices and equipment I've used to improve energy efficiency and IAQ in the homes I've built in my humid coastal environment. My hope is to help both the general contractor and the client make better decisions about the efficiency, comfort, and costs that factor into the structural design as well as the design of the HVAC system.

REQUIRED VENTILATION RATES

For a stand-alone, continuous whole-house ventilation system, the 2012/2015/2018/2021 International Residential Code offers two methods to determine the required airflow in cubic feet per minute (cfm):

Prescriptive table. The simplest way to determine the baseline airflow rate is to use the prescriptive table (below).

Calculation. Another method is to calculate the required airflow using the following equation:

Ventilation rate in cfm = [floor area / 100] + [(number of bedrooms + 1) x 7.5]

MINIMUM CONTINUOUS WHOLE-HOUSE VENTILATION (CFM)

Floor Area (sq ft)	Number of Bedrooms				
	0 to 1	2 to 3	4 to 5	6 to 7	> 7
< 1,500	30	45	60	75	90
1,501 to 3,000	45	60	75	90	105
3,001 to 4,500	60	75	90	105	120
4,501 to 6,000	75	90	105	120	135
6,001 to 7,500	90	105	120	135	150
> 7,500	105	120	135	150	165

Table M1507.3.3(1) of the International Mechanical Code.

The ventilation rates derived using either the equation or the table are specific to continuously running ventilation systems. The IRC does allow whole-house ventilation systems to operate intermittently, provided the ventilation rates from either the equation or the table are increased by a "rate factor" defined in Table M1507.3.3(2). However, continuous ventilation will offer the best performance for both the building and the health of the occupants.

Keep in mind that these are minimum rates. You can provide more, although this is a topic of great debate: The more conditioned air you exhaust from the building, the more energy you use to condition that air. The latest ASHRAE 62.2 (2013 and later) provides guidance for a higher ventilation rate. It has yet to be widely adopted but may make sense for homes equipped with energy recovery ventilation, which reduces the energy penalty associated with exhausting conditioned air.

EXAMPLE VENTILATION RATES

Method	cfm	cfm/person	ACH
IRC	60	15	0.13
ASHRAE 62.2	120	30	0.27

This table compares the IRC requirements—based on ASHRAE-2010—and ASHRAE 62.2-2013 for a 3,000-square-foot, three-bedroom house with a 9-foot ceiling height.

WHOLE-HOUSE VENTILATION

Prior to the introduction of air conditioning in the early 1950s, fresh, outside air entered coastal homes through double-hung windows that created some airflow when the top sash was dropped down and the bottom sash raised up. Many homes also had operable transom windows above exterior doors to move hot air that had risen into their 12-foot ceilings, which were designed for that purpose. Moisture control was not a consideration as there was little that could be done about it.

The widespread adoption of air conditioning and the building boom for WWII veterans needing homes changed all that. Transom windows went away as 12-foot ceilings became 8-foot ceilings, and whole-house air conditioning allowed homes to be completely closed up yet still be comfortable. But the perception that houses needed to "breathe"—either through open windows or through inadvertent openings in the building envelope—in order to provide fresh air to its occupants and allow stale, moist air to escape into the outside atmosphere persisted in building practices for several decades, primarily to encourage drying.

A typical home built during this period relied on air pressure differentials from a simple breeze to push air in (infiltration) and negative pressure on the opposite side of the house to pull air out (exfiltration). Air was simply passing through. As it turns out, this kind of uncontrolled ventilation is not good practice, especially in a hot, humid climate. Fresh air can introduce not only humidity but also pollen, carbon monoxide from a garage, and other contaminants. And as energy costs rise and energy efficiency becomes more important, losing conditioned air becomes more and more costly.

Dew point. Of course, as hot, moist outside air is drawn inside and comes into contact with cool, conditioned air, the moisture in the air can condense and change to liquid form, making whatever surfaces are close by wet. The most common dew point temperature (at which condensation occurs) in our area on an 85°F to 90°F day with normal relative humidity is around 74°F. Meanwhile, the most common temperature setting for air conditioning systems is 72°F to 74°F. These conditions can lead to moisture problems and black mold.

To avoid uncontrolled ventilation, building scientists have told us to build tighter building envelopes and use blower door testing to find and fix air leaks. This is what led to my interest in the topics of controlled mechanical ventilation and dehumidification.

Mechanical ventilation. In northern climates where humidity and air conditioning do not typically pose problems, some building codes allow for the use of an exhaust fan, such as in a bathroom, running continuously to slightly depressurize the house. As a result, air infiltration becomes a source of fresh air, diluting the existing air inside the building. But bringing in fresh air this way to dilute the existing air is like adding a couple of drops of food coloring to a bucket of water. You can stir it around, but you will never completely change the color to what was added.

In small, confined spaces, like bathrooms, where the moist or smelly air is exhausted out of the house by a fan and replaced with air from the main house, the fan has to run for a length of time to pull air in from under the door. A range hood is another example. As it exhausts air with cooking contaminants, that air is replaced by air from other parts of the house. In both cases, uncontrolled air infiltration—air leaking through the cracks and openings in the building envelope—is typically the source of that replacement air, which is not a good thing. A better option is to provide an inlet—such as a vent through the wall—near the exhaust so that the exhaust air is replenished with fresh air.

In my area, fresh air is often provided for by simply running a duct from a soffit outside to the return air supply on the HVAC air handler. This approach is certainly better than doing nothing but addresses only part of the problem. It is effective for diluting poor indoor air only when the HVAC air handler is running (so not in spring and fall shoulder months) and does nothing about removing contaminants year-round or addressing concentrations of contaminants.

A well-designed whole-house ventilation system should provide a controlled path for needed fresh air. We want to control where, when, and how that air enters the building envelope. It will need to be filtered and conditioned to match the indoor temperature and humidity level as close as is reasonable.

Ventilation rate. Currently, the IRC requires at least 1 cfm of fresh air for each 100 square feet of conditioned floor area, plus 7.5 cfm per person (see "Required Ventilation Rates," opposite page). For a 3,000-square-foot house with three bedrooms and a 9-foot ceiling height, this would be 0.13 ACH50. This is good general guidance but isn't always effective for all the various conditions found in specific buildings. Without accurate measurements in any given building, this can be both wasteful and insufficient. This is why I recommend including an air-quality measurement device in any HVAC system design.

The simplest way to remove contaminants such as CO_2, VOCs, and particulates from a home is to remove the bad air and replace it with better air. However, there is no practical way to completely remove and replace the conditioned air within a building all at once. Bringing in fresh outdoor air introduces measured amounts of air and mixes it with existing stale air. To what degree we want to dilute the indoor air is based upon how many cubic feet per minute of new air we can bring in and our ability to remove that same volume from the building. The farther the input air opening is from the removal opening, the better the dilution.

Makeup air. It is best to remove pollutants as close to the source as physically possible to prevent them from dispersing into the air in the rest of the house. The most common concentrated source of pollutants is the cooktop or stove, which is typically equipped with a hood that has a blower; the hood captures some portion of the moisture and contaminants, and the blower exhausts them to the exterior before they can disperse into other areas of the home. A range hood's blower can be quite powerful, up to 1,000 cfm or more, which can overpower most general ventilation systems and create a negative pressure differential in the house, something we never want to happen where naturally drafted combustion appliances, such as a furnace or water heater, are present.

The best solution is to provide makeup air as close as possible to source of contaminants to replenish the contaminant-laden air exhausted from the hood with fresh air. In homes with naturally drafted combustion appliances, building codes mandate that a demand-driven makeup air system consisting of a fresh air inlet near the exhaust must be included in the system design for any exhaust fan rated 400 cfm or more.

DEHUMIDIFICATION

While IAQ is important to inhabitants, excess humidity is a structure's enemy. Along with being uncomfortable, it can condense into its liquid state almost anywhere the air is cooled below the dew point. Black mold loves to find moisture in dark, remote places where it can thrive undetected.

Up-sizing the HVAC air handler can help by increasing the air volume passing through the coils while dropping the air velocity. Some air handlers have a setting for dehumidification that slows the airflow, allowing more time for condensation to occur on the coils. It will drop the coil temperature a few degrees as well. This water is then collected and drained to the outside. While this helps in most situations, it is usually limited to a 3°F drop in temperature as a greater drop may make the inside air feel moist and clammy.

This is where a dedicated dehumidifier can help. It will kick in to help the air conditioning system when it is needed during peak summer months. Dropping the relative humidity to 45% to 50% often makes it possible for inhabitants to set the thermostat several degrees higher and still feel comfortable.

In addition, in our area, there are several months during the year when the HVAC system seldom runs for either air conditioning or heating. The swing, or shoulder, months in spring and fall are when a dedicated dehumidifier that can maintain 45% to 50% relative humidity is most important. And sometimes, it will kick on during rainy winter weather, even with the heat on.

Balancing return airflow. An air handler can deliver only the amount of air it can pull in from the return trunks. Returns that are restricted or undersized put a load on the blower fan that reduces the amount of air that is put out to the supported spaces. Depending upon the layout of the rooms, more than one return trunk may be required. This is where system design comes into play, and it is

Built with concrete panels, this wind-resistant North Carolina house measured less than 1 air change per hour in blower door testing **(1)**. To bring the attic and HVAC system within the home's conditioned space, the author specced closed-cell foam insulation to be sprayed on the underside of the roof system **(2)**. Here the ductwork has been installed, and the electrical has been roughed in **(3)**.

important that the HVAC designer understands the requirements: Will there be multiple zones? Is controlling humidity an issue? Does the system need to be really quiet?

The preferred solution is to provide return air ducts sized to handle the necessary flow. Additional return ducts can require some changes to the framing of the building along with some additional cost for the system, but the improved performance of the system and comfort to inhabitants will make it worthwhile. The goal is to limit both positive and negative air pressures within the whole house envelope, though being slightly positive—with the help of a mechanical makeup air device, for example—is preferred.

Tightening up a house reduces the number of places air gets in, but wind against a building will always cause some infiltration on one side and exfiltration on the other. We can't guarantee a house will never have negative pressure, but we can recognize what causes it and mitigate what we can with makeup air techniques.

CASE STUDY

Here is an example of a house that I built in 2020 that addresses these issues using some of the techniques and technologies that I have found effective in my hot, humid climate. Located in Southport, N.C., it is a single-story home built with Superior Walls concrete panels, with 2,260 square feet of habitable space, and rated for winds up to a low Category 5 hurricane. In a blower door test, it measured less than 1 ACH50, which included the conditioned attic space along with the habitable space **(1)**.

Before the ductwork was installed or any other trades went in, the spray-foam subs started with a completely empty building shell. All that stood were the exterior walls and the roof system, which resulted in a uniform foam application with no overspray on the ductwork **(2)**. Along the top of the walls, we used a gray mastic to seal the double top plates to the concrete panels. The foam insulation, concrete walls, and mastic are the keys to achieving blower door test results that are less than 1 ACH50.

We always include the crawlspace and attic within the air-sealed building envelope. This allows us to locate various components such as HVAC equipment and ducting in these conditioned spaces for better efficiency **(3)**. Also, when makeup air is introduced into the building, these spaces can be helpful in blending and conditioning outside air prior to it being introduced into the living spaces. Conditioned air is also ducted into these spaces, as shown here.

An additional benefit is that the owner gains a great deal of safe storage space. You may notice the OSB curbing around the perimeter of the walkable areas to prevent stored objects from falling onto the ceiling below **(4)**.

Dehumidifier installation. Shown in the sidebar "Whole-House Dehumidification Study" (see opposite page) are three options for installation of a "DHU" (dedicated dehumidifier), from a research study

WHOLE-HOUSE DEHUMIDIFICATION STUDY

In 2018, the Florida Solar Energy Center (FSEC) set out to answer some basic questions about ducted dehumidification systems, including:

- Does ducting a dehumidifer unit (DHU) though a central cooling system diminish the performance of the cooling system or the dehumidifier?
- Is it better to run a stand-alone dehumidifier that runs independently from the cooling system, so the DHU pulls air from and delivers dehumidified air to the living space?
- Does the location of the DHU and DHU ductwork affect heat loss or heat gain in the conditioned areas of the home?

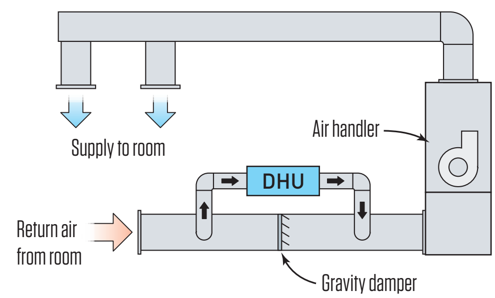
Three systems tested. To answer those questions, the FSEC studied three configurations:

1. A DHU ducted from and to the central cooling system's air return.
2. A DHU ducted from and to the central cooling system's air supply.
3. A stand-alone DHU ducted directly from and to the living space.

Results. Findings and recommendations of FSEC include:

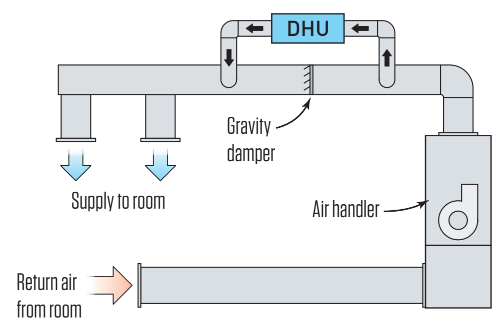
- Pulling air from the return side of the cooling system and dumping dehumidified air back into the return upstream of the cooling coil is the worst-performing scenario. In fact, FSEC advised it should not be permitted by code. Even if you use a gravity damper to prevent short-circuiting the DHU, there is an enormous energy penalty to the central cooling system. In essence, if the dehumidifier runs after the air conditioning turns off, you'll have to run the air-handler fan to move the dry air into your home. As the fan moves that air across the wet cooling coil, moisture evaporates back into the airstream, degrading the performance of the system.
- Pulling air for the DHU from the supply side of the cooling system and dumping it back into the supply resulted in the most efficient dehumidification, since you're pulling cooler air, which is already drier than house air, into the DHU. The conditioned (cooled) air also tempers the dehumidified air. However, this configuration is more complex because you need to wire the system so the air handler runs when the DHU runs, and dampers need to be installed to prevent backflow into the DHU.
- The independently ducted system provides optimal performance, and FSEC proposed this as the "base case" for the performance path of the energy code.

DHU Ducted From/To Return Side



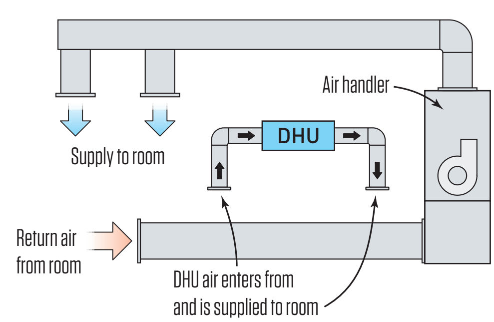
A DHU that pulls air from and delivers drier air back to a central cooling system's return is the least effective, according to the FSEC study.

DHU Ducted From/To Supply Side



Pulling air from and delivering it back to the supply side is marginally better, but you still have higher static pressures from the two different blowers.

Stand-Alone: DHU Air Ducted Directly From/To Living Space



An independently ducted DHU proves the simplest and most effective since you have only one blower influencing the air pressure in the ductwork.

illustrations by Tim Healey

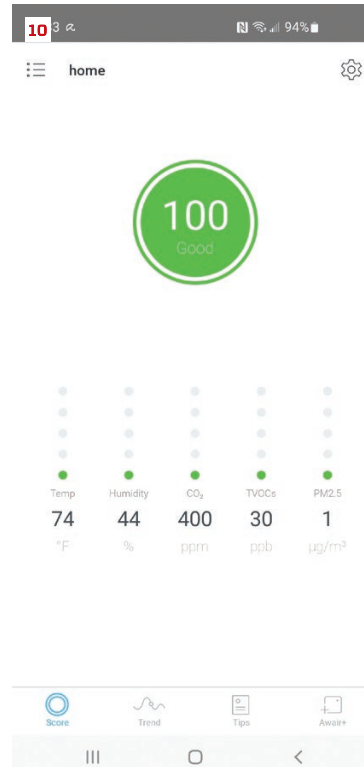
The supply duct in the attic allows new air to be mixed with conditioned attic air before being drawn into the living space. The OSB around the perimeter of the walkable attic area prevents stored items from falling onto the ceiling below **(4)**. The Air King QFAMD makeup air unit brings outside air directly into the attic buffer space via a 6-inch-diameter flex line from a grille in the front porch ceiling. There is a replaceable filter in the unit, but it seldom gets dirty. Power usage is only 26 watts **(5)**. Also installed in the attic is an Aprilaire E070 dehumidifier, shown here with an open duct that draws in attic air for dehumidification. The unit's condensation line is connected to the home's DWV plumbing **(6)**. Here, the author is shown adjusting the relative humidity setting to his preferred setting of 45% **(7)**.

by the Florida Solar Energy Center. One option is to duct the DHU from and to the central cooling system's air return. The second is to duct the DHU to the main central supply duct, and the third is to provide a stand-alone DHU ducted directly from and to the living space.

Running dehumidified air through the air handler works fine but has some downsides due to possible additional static load on the handler and recycling moisture back into the living space from coils in the handler. The key is that the dehumidifier should be able to run without running the air handler. If you have the space for a separate supply and return, I prefer the third option.

To provide a metered supply of fresh outside air for overall air quality in the house, I installed a QFAMD makeup air unit, made by Air King, which brings outside air directly into the attic buffer space through a 6-inch-diameter flex line from a grille in the front porch ceiling. The unit has a replaceable filter, but it seldom gets dirty. The new air is mixed with attic-space air so it can be conditioned before entering the living space. Power usage is only 26 watts **(5)**.

This unit allows me to select how many cfm I want, up to



To fine-tune the operation of the home's ventilation system, the author uses an Awair Element indoor air quality monitor **(8)**. Sensor data can be viewed on the device and shared wirelessly through the free Awair app, which allows the user to track the metrics over time **(9)**. The unit can track temperature, humidity, CO_2 levels, total VOCs, and particulates **(10)**.

130 cfm. It also allows me to select temperature range and humidity range. We want to avoid bringing in 95°F, heavily saturated air.

This new air is mixed with the already conditioned air before being brought into the living spaces. Reducing the cfm to 60 to 100 puts it well within a range that a 1 ACH50 house can handle using moderate exfiltration. Also if possible, I prefer to have the house slightly positive to reduce air infiltration from other sources. At this low level of air being brought in, I feel that an ERV is unnecessary for this environment.

The Aprilaire 70-pint dedicated dehumidifier that we installed can handle homes of up to 2,800 square feet **(6)**. It has its own filter, but with the return duct being placed high in a 14-foot wall in the common area space, it can go a long time before cleaning. The panel on the front is for setting the desired relative humidity **(7)**. I always select 45%, as that is supposed to be best for limiting viruses. The unit has a condensation line that goes into the plumbing waste pipe using its own trap. The open duct pipe shown in front of the unit is for drawing in attic air to be dehumidified along with the return air from the living space below.

Note that the makeup air introduced by the QFAMD unit is part of the air being dehumidified. The Aprilaire and the QFAMD are spaced as far apart as reasonable to provide air volume for the makeup air to be mixed in with the air from the living space. Like the QFAMD, this unit uses only 26 watts maximum, which is the equivalent of two LED light bulbs.

There are many recommendations as to how much fresh air should be brought into a house to provide a healthy environment. Rather than picking makeup air numbers from various sources, I combine mechanical makeup air with a measurement device that monitors the IAQ. The Awair Element air quality monitor **(8)** maintains a continuous readout that is displayed on the monitor, as well as a Wi-Fi connection to an app on a cellphone. The app gives you a total quality score and specific numbers for each category, along with graphs, historical data, and export capability **(9, 10)**. Using these scores, we can "tune" the house as needed by raising the cfm setting on the QFAMD makeup air unit. We can also make changes to the dehumidifier setting to maintain the RH percentage. As a builder who is using closed-cell spray foam under all roof decks, I am sensitive to owners' concerns regarding chemical off-gassing. As such, I include an Awair unit in every home.

The ability to collect and track this data and manually adjust the volume of air being brought in by the QFAMD allows the home to be fine-tuned to fit the air quality needs of its occupants. One or two people living in the home may not need a lot of makeup air, so the cfm setting could be quite low for daily living. If visiting family members increase the number of occupants, the cfm setting can be increased to accommodate them.

Thomas Dugan is a retired general contractor in coastal North Carolina who specialized in building hurricane-resistant homes.