# Conditioning Air in the Humid South—Creating Comfort and Controlling Cost

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Building Science Corporation

Abstract:

*An examination of five different systems that show how to cool and dehumidify inside air while maintaining sufficient introduction of outside air for ventilation efficiently and cost-effectively.*

# Building America

## Systems Engineering Approach to Development of Advanced Residential Buildings

# 10. Case Study Material

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Energy Efficient Building Association, Inc.
The Dow Chemical Company

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# Conditioning Air in the Humid South: Creating Comfort and Controlling Cost*

## Background

Houston, Texas. It's quite likely humid…or hot…or both. You are a builder/buyer of **high performance homes** (**http://www.buildingscience.com/buildingamerica/targets.htm**), and naturally want to deliver/buy a comfortable healthy home. So, just how do you most efficiently and cost-effectively cool and dehumidify inside air while maintaining sufficient introduction of outside air for ventilation? And perhaps most importantly, how do you condition for humidity when the season calls for neither heating nor cooling? These are two knotty, nasty questions with a bunch of potential answers, none of which have ever been systematically explored or compared….until now.

One of the great things about the Building America program is hooking up with builders who, while they may not be as tickled with knotty nasty questions as building researchers, are willing and able to work with building scientists and see if a reasonable answer can create more value for them and their customers. Such a builder is **Pulte Homes of Houston, Texas** (**http://www.pulte.com/market.asp?pro=0&ck=58|106**). Pulte Homes arranged for twenty of their sold and occupied new homes in the greater Houston area to be in a year-long study of six different HVAC-integrated dehumidification systems.

The homes were monitored hourly for indoor temperature and relative humidity (five locations), outdoor temperature and relative humidity, and energy consumption broken down by source (cooling, air handler unit, fan cycler, dehumidifier, ventilating fan). In this way, both the comfort conditions provided and energy consumed by each approach over time could be quantified and compared. Here is how each home was set up:

- **Control Homes** Three of the Pulte homes monitored are pre-Building America—they are not high performance homes in terms of their building envelopes, their air tightness, and ventilation (they lacked mechanical central ventilation). These homes represent standard construction practice and performance in the Houston area.
- **Building America High Performance Homes** Three homes were built to the BSC Building America performance targets (**see: http://www.buildingscience.com/buildingamerica/targets.htm**). These homes had no special dehumidification capability, just what the standard cooling system can provide (see the HVAC glossary and discussion of sensible heat ratio that follows). The results from these high performance homes provide a baseline in terms of comfort conditions and energy consumption.
- **Stand-alone conventional dehumidifiers** Two homes have a conventional dehumidifier installed in a louvered closet within the living space and two have the units installed in the conditioned attic. The "dry" air supplied by these units is distributed throughout each home by the **central-fan-integrated supply ventilation system** (**http://www.buildingscience.com/resources/presentations/practical_approaches_residential_ventilation.pdf**), a system that is standard in BSC Building America homes.
- **Continuous filtration/ventilation** Three homes have the **DEC Filter Vent** (**http://www.thermastor.com/**

* This resource is based on the technical report of the study written by Armin Rudd – "Building America final Technical Paper: Advanced System Performance Dehumidification Project, October 31, 2002."

**ventilation/ventilationcentral.html**) and ducted dehumidifier located in the conditioned attic. These two units combine to provide air filtration, fresh air ventilation, and dehumidification.

- **Continuous filtration/ventilation/ dehumidification** Three homes have the **DEC Ultra-Aire APD** (Air Purification Dehumidifier) (**http://www.thermastor.com/dehumid/dehumidresid.html**), a single unit that provides air filtration, fresh air ventilation, and dehumidification.
- **Ventilation with energy recovery** Three homes have **Venmar ERVs** (**http://www.efi.org/products/ventilat/venterv.html**) (Energy Recovery Ventilator) located in the attic. ERVs recover energy associated with both the heat and the moisture content of the exhausted indoor and supplied outdoor air. The Venmar system uses a dessicant wheel to accomplish the transfer and recovery.
- **High-efficiency, two-stage compressor and ECM AHU** One home has a high efficiency **Carrier cooling system with two-stage compressor** ( **http://www.carrier.com/residential/en/us/products/air-conditioners/**) and an ECM (electronically-commutated motor) air handler. The two-stage compressor provides a lower capacity run setting for more sustained operation and hence greater dehumidification. And the variable speed capability of the ECM air handler permits lower fan speed settings that increase the contact time of indoor air at the coils, also increasing dehumidification.

All of the test systems provide some level of ventilation, cooling, and dehumidification. They differ in:

- the **way** in which they dehumidify (as part of cooling, as part of ventilation, or as a part of an individual conditioning activity);
- **what** air they dehumidify (circulating interior air, incoming fresh air, or both);
- **when** they dehumidify (at what stage in the conditioning sequence);
- under **what range of conditions** they can dehumidify (only during cooling, only during ventilation, any time humid conditions exist), and finally;
- the **level of air filtration** they provide.

As much as possible, there was more than one home with each system to reduce the effect of occupants (their number, their thermostat setpoints, and their activities that generate moisture such as cooking, cleaning, bathing). And the homes are concentrated in just a few Pulte developments to reduce the impact of micro-environmental differences.

This study set out to answer the following questions:

- Which system(s) was the least expensive? We report the builder's installed cost.
- Which system(s) was the least expensive to run (operating cost)? We report both the total HVAC system daily energy cost as well as the cost of just the dehumidifying component, if available or applicable.
- Which system(s) did the best overall job in providing humidity control? We report the % of hours each system kept the house average relative humidity below 60%.
- What are other specific advantages/ disadvantages of each system? We report builder and homeowner comments made to researchers over the course of the project, in a written short questionnaire, and in a face-to-face exit interview with the homeowner.

# Basics

## Humidity 101

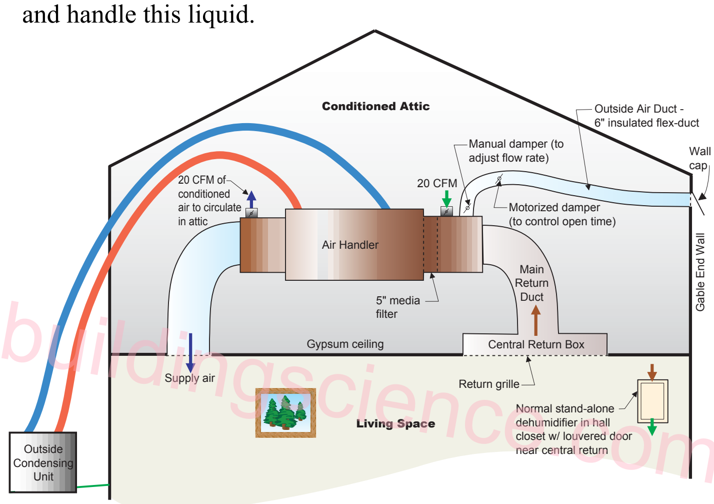
Humidity is the water vapor in the air. There are two expressions of this vapor content—absolute and relative humidity. Absolute humidity refers to the total amount of water vapor in the air. Relative humidity refers to the amount of water vapor in air relative to the total amount of water vapor the air can actually hold. Air can hold different amounts of water vapor at different temperatures—warmer air can hold more than colder air. That's why water can and often does condense on a cold glass—the air just around the glass gets cold enough that it can't hold all of its water vapor and some condenses on the outside surface of the glass.

So, if you raise the temperature of the air, it's relative humidity goes down; cool the air down and the relative humidity goes up. Cool the air down enough so that the relative humidity becomes 100% and you have reached that air's dewpoint, or the point at which that air just can't hold that amount of moisture anymore. Raising or lowering the temperature of a given volume of air changes the relative humidity but it does not change the absolute humidity. The dewpoint temperature of air is often used to describe or quantify absolute huimidity.

Relative humidity is critical to the performance of buildings for two reasons. One, all living things sense and respond to humidity based on the concentration of water in air--relative humidity--more than the absolute amount of water in the air--absolute humidity, within the temperature range of indoor environments. Two, in a surprising twist of science, materials adsorb and desorb water based on relative, not absolute humidity.

# HVAC GLOSSARY

***Air Conditioner*** A mechanical unit that uses a refrigerant (selected for performance attributes including boiling point, chemical stability, heat exchange capacity) under pressure in coiled tubes to pick up interior heat and release that heat to the exterior. An air conditioner consists of a compressor in line with the tubes filled with refrigerant, a fan to move outside air past outside coils (which shed heat), and an air handler to move interior air past the interior coils (which pick up heat). As air cools on the interior coils, water vapor condenses and drips off of these coils—this is why all air conditioners, your refrigerator included, have a condensate line or pan to collect and handle this liquid.




The EPA Energy Star program includes central (and room) air conditioners — **http://yosemite1.epa.gov/estar/consumers.nsf/content/cac.htm**. Qualifying units have a SEER of 12 or greater.

***Dehumidifier*** There are three ways to wring (or condense) water vapor out of air—cool the air (thereby decreasing its ability to hold moisture); increase the pressure ("squeeze the air to reduce its ability to hold moisture); and pass the air over a dessicant (a substance that picks up moisture, like the silica beads that are packed with electronic equipment). A conventional room dehumidifier is like an air conditioner with all the parts of the system **inside** the conditioned space. As air is cooled, moisture in the form of either water droplets (or ice) builds up on the refrigerant coils and is collected in a pan for manual removal or piped to a drain. The key to efficient operation of a dehumidifier is to continually move "new" air past the coils to avoid frosting the coils or the energy penalty associated with defrosting the coils.

The EPA Energy Star program includes dehumidifiers—**http://yosemite.epa.gov/estar/consumers.nsf/content/dehumid.htm**. Qualifying dehumidifiers are evaluated based on their capacity (liters of water removal per day) and energy factor (liters of water removed per kilowatt-hour) under standard test conditions.

***Latent load*** This is the portion of cooling energy necessary to remove water vapor content of indoor air as the ability of the indoor air to hold moisture drops with lower air temperatures.

***Sensible load*** This is the portion of cooling energy necessary strictly to lower the indoor air temperature.

***Sensible Heat Ratio*** SHR is the portion of total cooling capacity that a specific HVAC unit delivers for sensible heat load removal. (Conversely the Latent Heat Ratio is 1 – SHR, or the portion of total cooling capacity that delivers latent heat load removal.) Several factors in the design of air conditioners affect the unit's SHR and performance tables containing this rating are available to HVAC contractors. For hot humid climates, the SHR should be no greater than .75.

***SEER*** The Seasonal Energy Efficiency Rating is a standardized test for air conditioners and heat pumps. In the test, the unit is operated under three different sets of indoor and outdoor conditions. It represents the total seasonal cooling output in Btu divided by the total seasonal electric input in watt-hours. The minimum SEER by federal law is 10, while units are available with a SEER as high as 18. Most units installed today are between 10 and 13.


***Manual S*** The Air Conditioning Contractors of America (ACCA) has standards for correctly sizing HVAC equipment (Manual J), for designing duct systems (Manual D) and for selecting air conditioning equipment to meet the design loads—Manual S. Proper use of Manual S ensures that both the sensible capacity and the latent capacity of your system will be adequate to meet the cooling load.

## Why—believe it or not--you care about humidity

*It affects your comfort* If air "feels" too dry (generally at relative humidity below about 20% for most people), throats and eyes can get scratchy, skin can get cracked or flaky. If air "feels" too moist (generally at relative humidity above about 70% for most people), skin to skin contact can feel clammy and make you feel either "colder" or "warmer" depending on other factors such as the air temperature, the season, and clothing. The scientific understanding of thermal comfort and the contribution relative humidity makes to thermal comfort is laid out in ASHRAE *Standard* 55 and ASHRAE's 2001 Fundamentals, Chapter 8. Perhaps most importantly for this study, Chapter 8 states:

> "…The upper and lower humidity levels of the comfort zones are less precise…."

and:

> "…The upper humidity limits of ASHRAE *Standard* 55 were developed theoretically from limited data…."

We will come back to this later after presenting the results of the study.

*It affects the "comfort" of your building*
Let's face it—if you ever have high relative humidity and temperatures inside your home compared to the outside (or vice versa!), then you have just set up the potential for a little dewpoint experiment somewhere INSIDE your walls and/or roof. You just don't want water vapor cooling down and condensing inside your building assembly—the results are never good. If you live in a cold climate you have this moisture drive from the inside to the outside in your whole house all winter. If you live in a hot climate, you have this moisture drive from the outside to the inside whenever you run your air conditioner.

## What to do about humidity inside your home

Let's start with the easiest season—winter. We tend not to worry about high humidity as much during the winter because the outside air is dryer than the inside air. Localized areas of high humidity—bathrooms, kitchens, and laundry rooms—are easy to control with exhaust fans and occupants know they have a problem that must be addressed when condensation appears on the inside of windows in these rooms. And don't forget—moist interior air that is exhausted is ultimately replaced with dry outside air.

It's a different story in the summer—the outside air often holds a lot of moisture and our air conditioners cool this air when we bring it inside. Remember, inside air comes from outside—always. Cooling this air increases its relative humidity.

But can't an air conditioner remove humidity as well as heat? The answer is yes, to some degree. As interior air moves past the cold coils in your air handler, the air gives up heat (this is called sensible heat removal) and moisture in the air condenses out on the cold coils (this is called latent heat removal). There is even a measure of how much of each type of heat removal any air conditioner accomplishes called the sensible heat ratio or SHR. An SHR of .80 (a pretty typical SHR for residential AC units) means that 80% of the AC unit's heat removal capacity is sensible heat removal and 20% is latent heat removal.

### Why your AC system may not provide enough humidity control

- **Climate and the shoulder seasons** You may live in a climate where you need humidity control when you don't need cooling or when you don't want to pay to run the AC system just to give you a comfort bump (What everyone else calls fall and spring, building science folks demote to "shoulder seasons" because, alas, there may be little to no mechanical equipment operation called for!).

- **Internal moisture generation** While your interior humidity levels are principally dependent on the moisture content of outside air, a significant driver may be moisture generated by occupants. Cooking, house cleaning with water, showering/bathing, and clothes laundering/drying all dump lots of moisture into the air; some homes need humidity control year round just to handle internal moisture generation.

- **Spot ventilation** Externally-vented exhaust fans in bathrooms, kitchens and laundry rooms can go a long way towards controlling for internal moisture generation, but the switch has to go on! Many people will use these spot ventilation fans for odor control, but do not consistently use them for moisture control. Combine lack of exhaust fan use with lots of internal moisture generation, and you are a prime candidate for humidity control that goes way beyond your AC system.

  The switch has to go off too, though. Remember that any air exhausted is replaced with outside air. In hot humid climates, extended or continuous use of exhaust fans just means that unconditioned outside air is being pulled into replace conditioned inside air.

- **High performance homes** It's ironic but it's a fact: high performance homes with thermally efficient envelopes reduce the total sensible heat gain compared to the latent heat gain causing your AC to run less and giving it less of a chance to handle the latent load. High performance homes also reduce how much your AC runs because they extend the shoulder seasons, parts of the spring and fall when the higher performance means less heat gain and less need for AC.

  But can't I just switch to an AC unit with a lower SHR to reflect my high performance home's reduced sensible heat gain? Well, no…

- **AC unit** High performance homes in the hot humid south need an AC unit with an SHR of about .5 to deliver adequate humidity control as part of their operation, and there simply aren't any residential units with SHRs this low on the market. So, we just don't have the equipment to make the AC the answer to controlling relative humidity in many homes.

Unfortunately, this is quite a list and chances are, more than one applies to you and your home. That's the bad news. The good news is that the rest of this paper is about systems that provide interior humidity control.

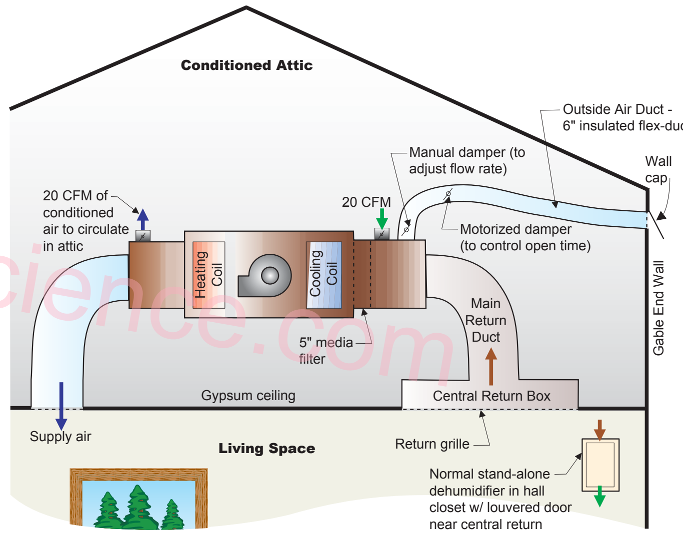
# The Systems and How They Stack Up

## Stand-alone Dehumidifier

(in hall closet with central-fan-integrated supply ventilation)

***Representative House Characteristics***: 2400 sq. ft., 2-story, 5 occupant

| | | | ***Rank[1] (out of 6)*** |
|---|---|---|---|
| ***Builder-reported Installed Cost[2]***: | | $ 250 | 1 |
| ***Annual Operating Cost[3]:*** | ***Total HVAC*** | $ 964 | 5 |
| | ***Dehumidifier portion*** | $ 40 | 1 |
| ***Humidity Control Performance[4]***: | | 93% | 3 |






**System Description** The stand-alone dehumidifier system includes the installation of an off-the-shelf dehumidifier in an interior closet with a louvered door, along with central-fan-integrated supply ventilation. Outside air is intermittently drawn in by normal thermostat-driven operation of the central cooling and heating system or by activation of the central air handler blower via the **AirCycler™** control. The stand-alone dehumidifier has a built-in dehumidistat that will energize the dehumidifier whenever the humidity level rises above the setpoint (nominally 50% relative humidity). Intermittent operation of the central air handler fan moves the dry air throughout the house. In this way, year around humidity control is achieved along with controlled mechanical ventilation for improved indoor air quality.

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[1] The ranking is a simple way of comparing the relative performance of each system in the study. Bear in mind that these results are not normalized so the differences in house size, number of stories, number of occupants, thermostat setpoints, etc. have not been accounted for in this ranking. In other words, take each ranking with a grain of salt.
[2] The labor portion of the installed cost for each system was about the same. The difference in installed cost is almost entirely determined by the cost of the equipment.
[3] This assumes an electric utility average rate of $0.11/kWh, a number derived from calculations used in the Environments for Living™ energy guarantee in Houston.
[4] This percentage is the amount of total time that the average interior relative humidity remained below the threshold of 60%. The selection of 60% for the threshold in terms of comfort, health, and impact on building durability is certainly an arguable one and is discussed in detail in a later section of this paper.

**System Advantages** The off-the-shelf Energy Star dehumidifier in the hall closet is a simple, relatively inexpensive system for homes that have central-fan-integrated supply ventilation. It also provided good humidity control for quite reasonable operating cost.

**System Disadvantages** There is the loss of closet space and the noise of operation within the living space. There is the uncertainty of service life for light-duty dehumidifiers when used for conditioning the volume of an entire house.

**Homeowner Comments**: The two homeowners with this system reported high levels of satisfaction with the system.

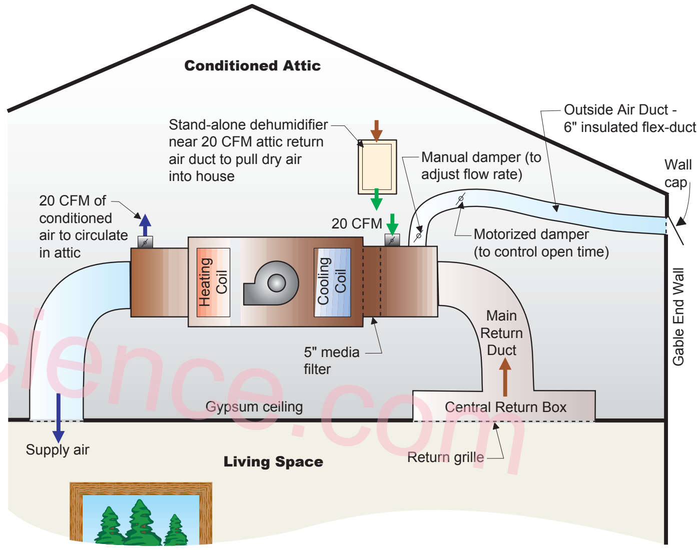
**Researcher Comments/Observations**: This system performed well even in a home with 5 occupants, two of whom were home all day, and with almost no use of spot exhaust ventilation fans in the kitchen, baths, and laundry rooms.

## STAND-ALONE DEHUMDIFIER

(in conditioned attic w/ central-fan-integrated supply ventilation)

***Representative House Characteristics***: 2400 sq. ft., 2-story, 5 occupants

| | | | Rank (out of 6) |
|---|---|---|---|
| ***Builder-reported Installed Cost***: | | $ 275 | 2 |
| ***Annual Operating Cost:*** | ***Total HVAC*** | $1,646 | 6 |
| | ***Dehumidifier portion*** | $ 482 | 6 |
| ***Humidity Control Performance***: | | 99% | 1 |






**System Description** The stand-alone dehumidifier in the conditioned attic system includes the installation of an off-the-shelf dehumidifier in the conditioned attic, along with central-fan-integrated supply ventilation. Outside air is intermittently drawn in by normal thermostat-driven operation of the central cooling and heating system and by activation of the central air handler blower via the **AirCycler™** control. The stand-alone dehumidifier has a built-in dehumidistat that will energize the dehumidifier whenever the humidity level rises above the setpoint (nominally 50% relative humidity). A small return duct near the dehumidifier, and intermittent operation of the central air handler fan, moves the dry air throughout the house. In this way, year around humidity control is achieved along with controlled mechanical ventilation for improved indoor air quality.

**System Advantages** The off-the-shelf Energy Star dehumidifier in the conditioned attic is a simple, relatively inexpensive system for homes that have central-fan-integrated supply ventilation. It also provided good humidity control for quite reasonable operating cost. This system's remote location in the conditioned attic also alleviated the problem of operating noise.

**System Disadvantages** As both the annual operating cost and humidity control performance numbers suggest, off-the-shelf dehumidifiers were over-dehumidifying in the conditioned attic much of the time (see Researcher Comments for more detail). There is also the uncertainty of service life for light-duty dehumidifiers when used for conditioning the volume of an entire house.

**Homeowner Comments**: The two homeowners with this system reported high levels of satisfaction with the system.

**Researcher Comments/Observations**: This system performed well even in a home with 5 occupants (three of whom were home all day), with the homeowner reporting use of the kitchen and bath spot ventilation exhaust fans only about 50% of the time, and no use of the laundry room exhaust fan. But note that since this home and the representative one for the dehumidifier in the hall closet were identical down to the model type, the large difference in dehumidifier operating cost is likely due to over-dehumidification by the system with the dehumidifier in the attic. And the difference in total HVAC system operating cost may in large part be due to occupant behavior, such as thermostat setpoint.

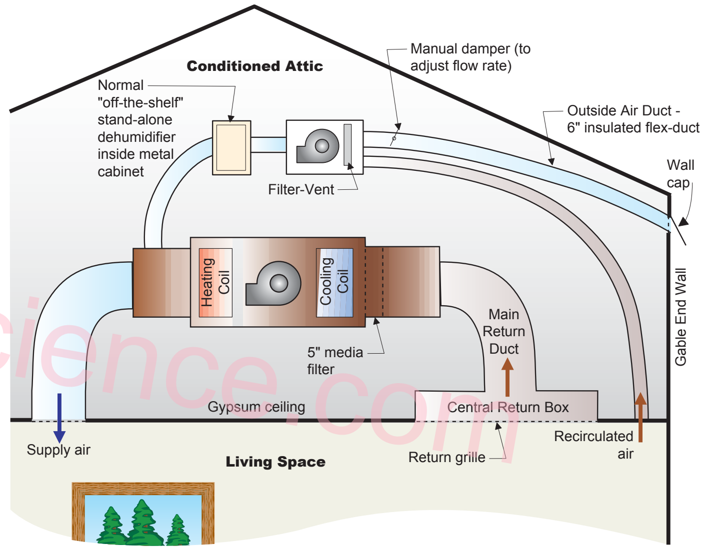
Off-the-shelf dehumidifiers have a rather primitive humidity-sensing device that is apparently sensitive to both air moisture content **and** air temperature. This can result in the dehumidifier running more than it should at a given setting when the dehumidifier is operating in a space such as the conditioned attic where air temperatures ranged 10 or more degrees higher than the main house. A solution to this performance problem was developed near the end of this study: “hardwire” the humidifier to a run-position but wire the unit to a remote humidistat/control located in the conditioned space. This would add an estimated $40 to $50 to the system, but make its performance comparable to that of the off-the-shelf dehumidifier located in the hall closet.

## FILTER-VENT (FV) WITH DUCTED DEHUMIDIFIER

***Representative House Characteristics***: 1830 sq. ft., 1-story, 2 occupants

| | | | Rank (out of 6) |
|---|---|---|---|
| ***Builder-reported Installed Cost***: | | $ 750 | 3 |
| ***Annual Operating Cost:*** | ***Total HVAC*** | $ 903 | 4 |
| | ***Dehumidifier portion*** | $ 381 | 5 |
| | ***Filter Vent portion*** | $ 120 | |
| ***Humidity Control Performance***: | | 95% | 4 |






**System Description** The Filter-Vent ventilation/dehumidification system includes the installation of a blower and filter system that is ducted to a stand-alone dehumidifier located inside a sheetmetal cabinet. The sheetmetal cabinet is ducted to the main supply duct of the central air distribution system. These components are located in the conditioned attic. The Filter-Vent blower will operate continuously, drawing in about 40 cfm of outside air, and mixing it with about 120 cfm of recirculated inside air. The mixed air is filtered and pushed through the dehumidifier cabinet where moisture is removed as necessary according to the dehumidistat setting on the dehumidifier. The resultant air is delivered to the main supply duct of the central air distribution system. In this way, year around humidity control is achieved along with controlled mechanical ventilation for improved indoor air quality.

**System Advantages** The Filter-Vent with ducted dehumidifier demonstrated excellent performance in terms of humidity control and uniformity of conditions throughout the house, including the conditioned attic. It also has the added benefit of superior whole-house air filtration—the standard filter for the FV is a MERV-8, 2-inch pleated, but the unit accepts up to a total of 6 inches of filters, including activated carbon.

**System Disadvantages** This system has an installed cost more than double that of the stand-alone dehumidifiers. It also exhibited relatively high operating costs, in part because of the additional fan motor for the filtration/ventilation component and in part because the system is continuously drawing in outside air and the associated added latent heat load.

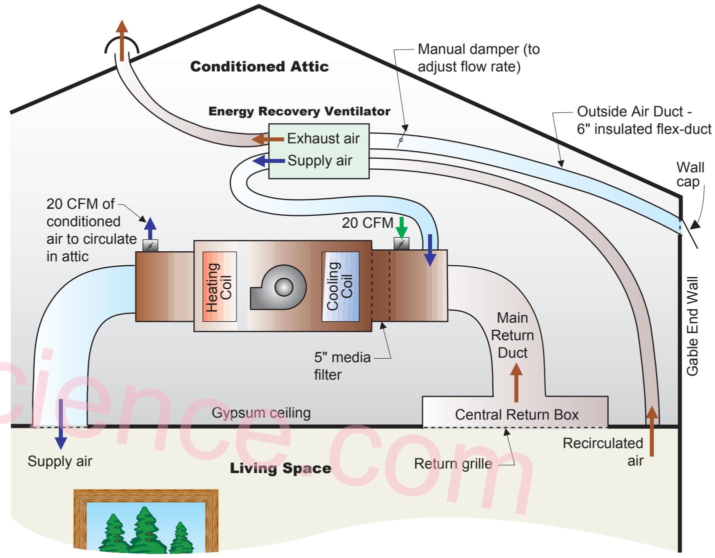
**Homeowner Comments:** The one homeowner with this system who completed the written questionnaire gave the system a moderate satisfaction rating but noted that, as an asthmatic, she thought the system was far more effective in dealing with her symptomsa than the HVAC system in their previous residence. During the homeowner interviews, none of the homeowners expressed performance concerns with their systems, but one did express concern about the operating cost.

**Researcher Comments/Observations**: As with the stand-alone dehumidifiers located in the conditioned attic, the ducted dehumidifiers in the Filter-Vent system had long run times, high operating costs, and tended to over-dehumidify. Since this situation can most likely be attributed to the dehumidifier's sensing device and its sensitivity to both relative humidity and air temperature, the performance of this system would likely improve significantly if the ducted dehumidifier were controlled by a remote humidistat located in the living space.

# Energy Recovery Ventilation

***Representative House Characteristics***: 2200 sq. ft., 1-story, 2 occupants

| | | | Rank (out of 6) |
|---|---|---|---|
| ***Builder-reported Installed Cost***: | | $1,450 | 5 |
| ***Annual Operating Cost:*** | ***Total HVAC*** | $ 642 | 2 |
| | ***Ventilation portion*** | $ 120 | n/a |
| ***Humidity Control Performance***: | | 80% | 6 |





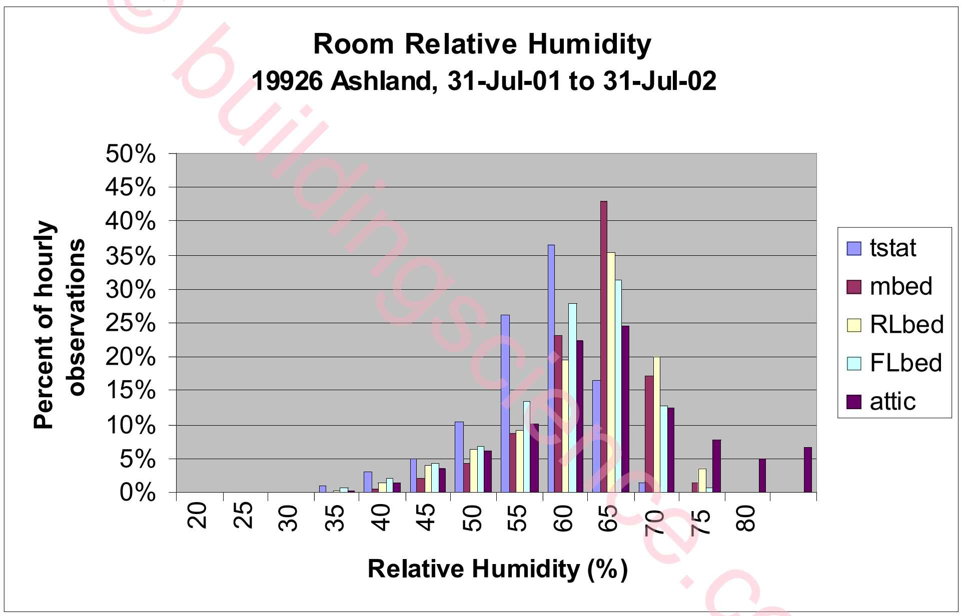

**System description** The Energy Recovery Ventilation (ERV) system includes a desiccant wheel energy exchanger installed in the conditioned attic. The ERV blower operates continuously, drawing in about 40 cfm of outside air, and exhausting about 40 cfm of inside air. Heat and moisture are exchanged between the incoming outside air and the outgoing inside air, such that much of the heat and moisture stays on the side that it came from. In this way, during the cooling season, the introduction of heat and moisture from ventilation air is lessened. This system will not dehumidify house air, but will lessen the need for dehumidification. During the heating season, the introduction of cold and dryness from ventilation air is lessened. The house exhaust air stream exits through the roof, and the tempered ventilation air is supplied to the main supply air duct of the central air distribution system.

**System Advantages** The ERV system has one primary advantage—operating cost. Its energy recovery reduces the load on the air conditioning system (and furnace, for that matter) and reduces latent load that incoming ventilation air could introduce to the conditioned space. In homes with low internal moisture generation, it's lack of dehumidification capacity for re-circulated air may not be critical to overall home performance.

**System Disadvantages** This system has an installed cost almost six times greater than that of the stand-alone dehumidifiers. Its humidity control performance is entirely dependent on occupant numbers and behavior in terms of internal moisture generation and use of spot ventilation.

**Homeowner Comments**: Two out of the three homeowners gave their overall HVAC/dehumidification system the highest satisfaction rating possible, while admitting that they could not separately assess the value of their ventilation/dehumidification components.

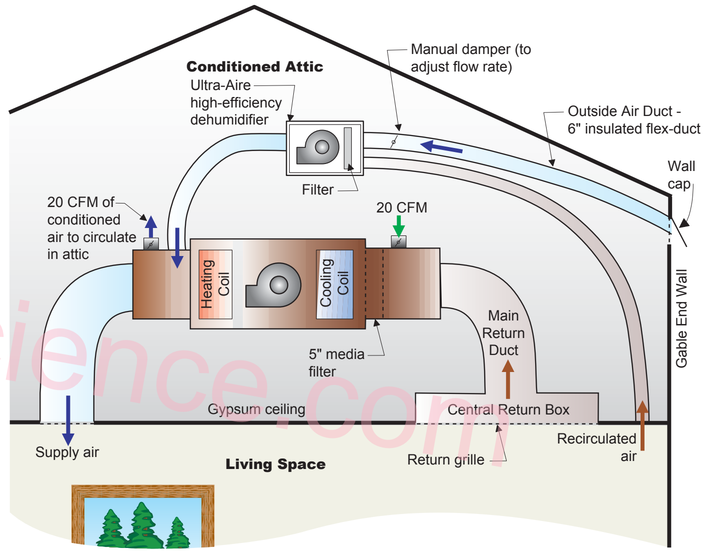
**Researcher Comments/Observations**: It's really interesting to look at a relative humidity distribution for one of the homes with the ERV system and try and reconcile that with the lack of comfort complaints from homeowners. Perhaps this is due to variation in individual tolerances for humidity comfort conditions and/or personal schedules that mean a home is unoccupied during the periods of highest interior relative humidity (For comparison sake, take a look at the RH distribution bar graph for one of the Ultra-Aire systems on page 17).



## ULTRA-AIRE DEHUMIDIFICATION AND VENTILATION SYSTEM

***Representative House Characteristics***: 2100 sq. ft., 1-story, 1 occupant

| | | | Rank (out of 6) |
|---|---|---|---|
| ***Builder-reported Installed Cost*:** | | $1,250 | 4 |
| ***Annual Operating Cost:*** | ***Total HVAC*** | $ 723 | 3 |
| | ***Dehumidification portion*** | $ 80 | 2 |
| | ***Ventilation portion*** | $ 120 | |
| ***Humidity Control Performance*:** | | 97% | 2 |





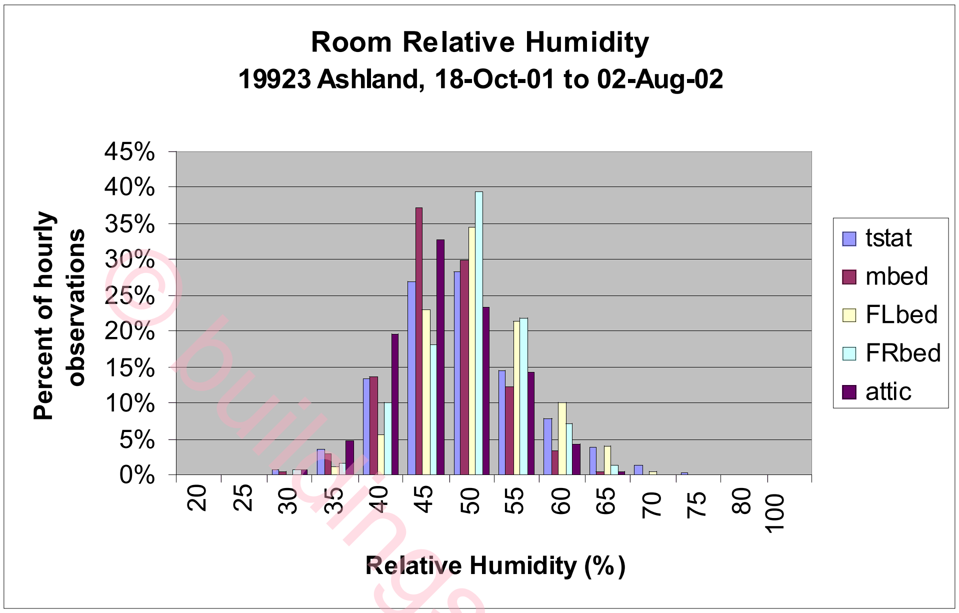

**System Description** The Ultra-Aire system includes a high-efficiency dehumidifier installed in the conditioned attic. The Ultra-Aire blower operates continuously on low speed, drawing in about 40 cfm of outside air, mixing it with about 120 cfm of recirculated house air, filtering that air, and supplying it to the main supply air duct of the central air distribution system. A dehumidistat located in the conditioned space will activate the dehumidifier compressor if the humidity level rises above the setpoint (nominally 50% relative humidity). In this way, year around humidity control is achieved at high-efficiency along with controlled mechanical ventilation for improved indoor air quality.

**System Advantages** The Ultra-Aire system delivers near-perfect humidity control and among-the-best total HVAC operating cost. The Ultra-Aire high efficiency filtration system also delivers well above average overall air quality as well.

**System Disadvantages** This system has an installed cost nearly five times greater than that of the stand-alone dehumidifiers.

**Homeowner Comments**: All three homeowners with this system gave high marks for overall satisfaction. The sole occupant of the representative house spoke highly of this system's performance in light of her allergies, asthma, and sensitivity to some chemicals.

**Researcher Comments/Observations**: The only two homes reporting 100% use of both bath and laundry spot ventilation exhaust fans and 80% use of kitchen fans were Ultra-Aire homes. This certainly contributed to the overall humidity control of the systems, although other systems probably needed this sort of diligence a lot more than the Ultra-Aire! The bar graph below certainly attests to the stellar moisture control of this system.



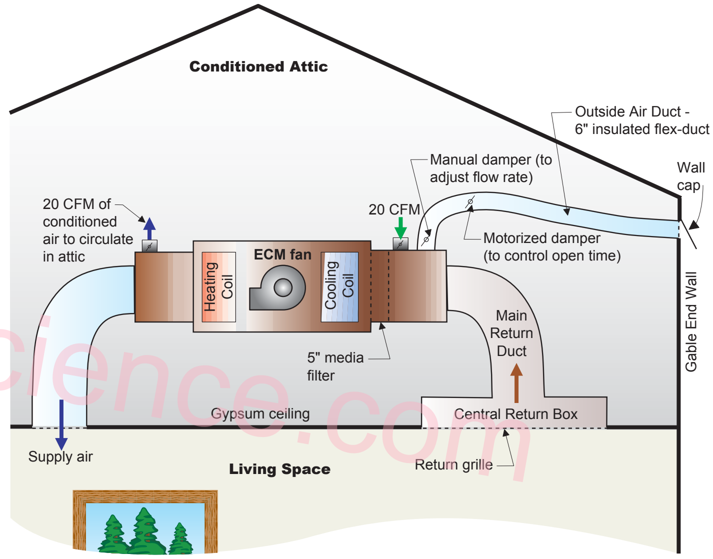

Per manufacturer recommendations, both the Ultra-Aire and the Filter-Vent systems were ducted to the supply plenum (see diagrams). This configuration could result in reverse air flow across the air handler when the air handlers were **not** running but the 160 cfm, continuously-operating Filter-Vent and Ultra-Aire systems were. This could mean the re-evaporation of condensed water off of wet cooling coils, defeating at least a part of the latent heat removal of the AC system. We did not observe this phenomenon in this study's Filter-Vent and Ultra-Aire systems most likely because of the resistance imposed by the 5-inch pleated air filters in the systems. An alternative duct configuration that alleviates the potential for this problem, however, is described in the summary section at the end of this paper.

# ENHANCED COOLING SYSTEM DEHUMIDIFICATION

(with central-fan-integrated supply ventilation)

***Representative House Characteristics***: 2100 sq. ft., 1-story, 2 occupants

| | | | Rank (out of 6) |
|---|---|---|---|
| ***Builder-reported Installed Cost***: | | $1,750 | 6 |
| ***Annual Operating Cost:*** | ***Total HVAC*** | $ 502 | 1 |
| | ***Dehumidification portion*** | $ 120 | 3 |
| ***Humidity Control Performance***: | | 80% | 5 |






**System description** The enhanced dehumidification with cooling and central-fan-integrated supply ventilation system includes the installation of a Carrier cooling system with a 2-stage compressor, an ECM indoor fan motor, and a Thermidistat controller. The 2-stage compressor allows better matching of the load to the cooling system capacity to avoid poor humidity control inherent with short-cycling of over-sized systems. The electronically commutated motor (ECM) allows lowering the flow rate of air over the cooling coil for enhanced moisture removal. The Thermidistat control is the smart thermostat that coordinates the 2-stage compressor and ECM fan features to achieve enhanced humidity control, especially at partial-load conditions.

**System advantages** The overall HVAC system is state-of-the-art ultra high efficiency. The total HVAC operating costs reflect the energy-saving capacity of the two-stage compressor and ECM fan unit.

**System disadvantages** This system provided relatively poor dehumidification and comes with among the heftiest cost premiums of all the systems.

**Homeowner Comments:** The single homeowner with this system gave it relatively low value, stating that they could not really tell much of a change in comfort levels after the change-out of the compressor and AHU fan motor.

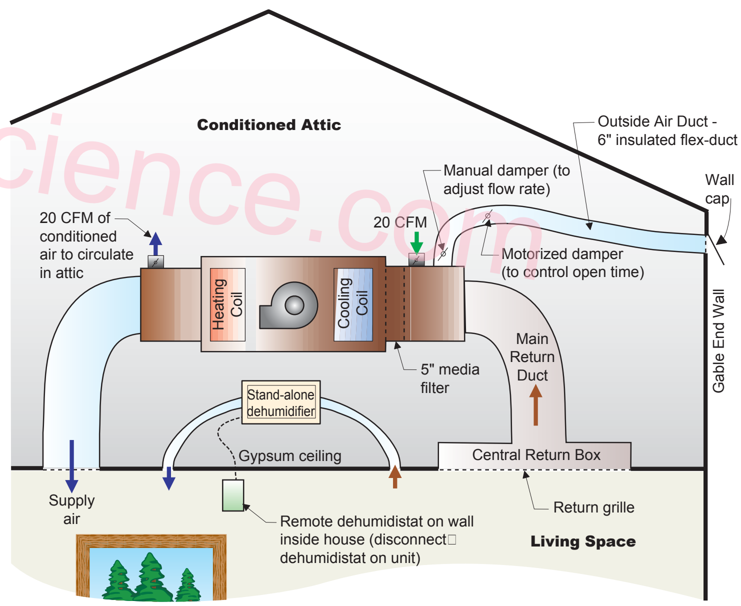
**Researcher Comments/Observations**: This system did not provide the level of dehumidification that was expected. It is possible that the humidity control performance could be improved by:

- lowering the fan speed during first-stage cooling (to keep the evaporator coil colder) and
- having the fan shut off immediately at the end of cooling calls (preventing re-evaporation of condensed water on the evaporator coil).

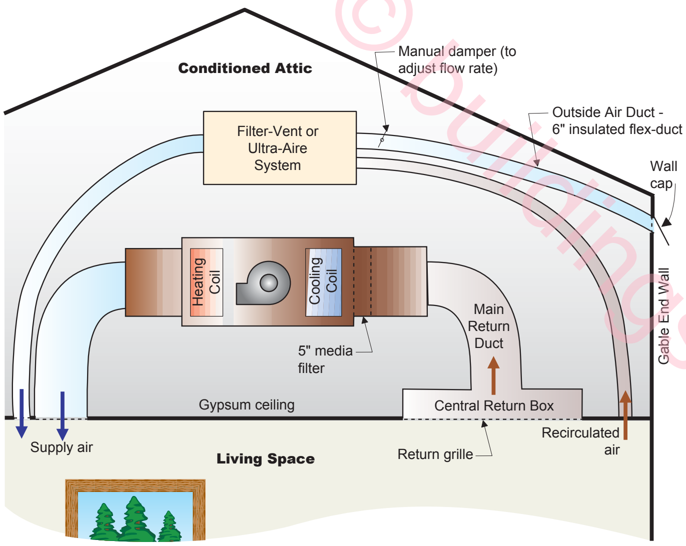
## Summing Up

We field-tested six different systems that provide supplemental dehumidification beyond what standard air conditioners provide. The systems varied widely in terms of their installed cost, operating cost, and moisture control performance. As in all studies, we got some answers to the questions we asked as well as some new questions.

- The reduced sensible heat gain resulting from the superior thermal envelope of Building America high performance homes also reduces the opportunity for standard, even properly-sized AC systems to remove latent heat gain; that is, to dehumidify.
- Of the six humidity control systems tested in this field study, the systems that dehumidified recirculated air as a function independent of the cooling system performed significantly better than the others.
- The stand-alone dehumidifier systems delivered good moisture control performance at a reasonable installed cost and reasonable operating cost. The stand-alone dehumidifier system represents the best overall strategy for production builders who choose to offer supplemental dehumidification in their new homes. But note the following:
  - ➢ The moisture control performance of the stand-alone dehumidifier system is dependent on effective and regular mixing of all of the indoor air. A fan cycler that also includes central-fan-integrated supply ventilation handles both the introduction of fresh outside air as well as this necessary mixing.
  - ➢ If the preferred location of the stand-alone dehumidifier is the conditioned attic, then its performance in terms of moisture control and operating cost is dependent on remote location of an independent humidistat.
  - ➢ Further, its performance can be improved by using the duct configuration shown below. This essentially ties its function to the living space while maintaining its location in the attic for sound attenuation and space saving.



- The Ultra-Aire system provided excellent moisture control at a reasonable operating cost with the added benefit of high performance air filtration. Hence, its relatively high installed cost may be acceptable to individuals with particular indoor air quality sensitivities.
- The ducting configuration shown below eliminates the potential for reverse air flow in both the Filter-Vent and Ultra-Aire systems.




- Because spot ventilation fans were used so infrequently in most of the test homes, the impact of their consistent use in kitchens, bathrooms, and laundry rooms on overall humidity control is uncertain.

- The following factors affect the need for supplemental dehumidification in Building America homes in hot humid climates:
  - the relative humidity at which an individual experiences and/or expresses thermal discomfort
  - the number of occupants in a home
  - the use of spot ventilation fans in kitchens, baths, and laundry rooms
  - the local outdoor dewpoint temperatures throughout the year.

The bad news is that there is only one of these—dewpoint temperatures—that builders can get hard-and-fast information on. And there is only one other—use of spot ventilation fans—over which builders can exert any degree of control (by hard-wiring exhaust fans to light switches or educating homeowners about the importance of using exhaust fans for moisture control).

The good news is that this study identified a good supplemental dehumidification system that has both a reasonable first and reasonable operating cost, and that can be readily installed either during construction or after occupancy. The prudent thing to do? Install the supplemental dehumidification in hot humid climates and sell the greater comfort and improved indoor environmental quality as part of a high performance home package.

## About this Report

This report was prepared for the US Department of Energy's Building America Program.

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