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BUILDING TECHNOLOGIES OFFICE

Measure Guideline: Supplemental Dehumidification in Warm-Humid Climates

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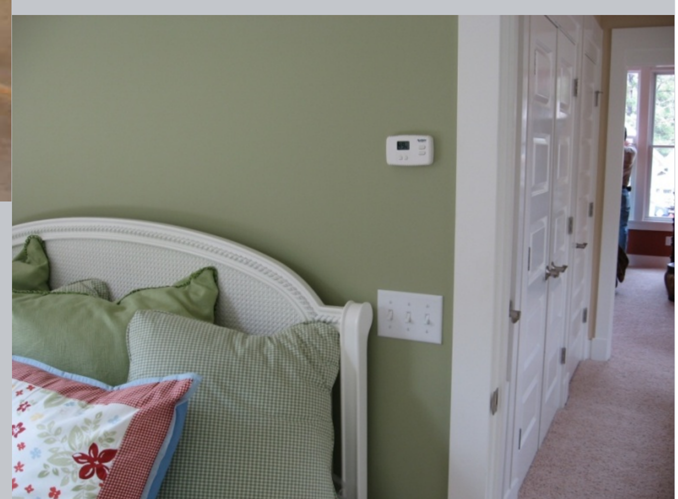
Building Science Corporation

October 2014



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Measure Guideline:
Supplemental Dehumidification in Warm-Humid Climates

Prepared for:

The National Renewable Energy Laboratory

On behalf of the U.S. Department of Energy's Building America Program

Office of Energy Efficiency and Renewable Energy

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The work presented in this report does not represent performance of any product relative to regulated minimum efficiency requirements.

The laboratory and/or field sites used for this work are not certified rating test facilities. The conditions and methods under which products were characterized for this work differ from standard rating conditions, as described.

Because the methods and conditions differ, the reported results are not comparable to rated product performance and should only be used to estimate performance under the measured conditions.

Contents

List of Figures

Unless otherwise noted, all figures were created by BSC.

List of Tables

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Definitions

ACH	Air changes per hour
AHAM	Association of Home Appliance Manufacturers
BSC	Building Science Corporation.
CFIS	Central-Fan-Integrated Supply
cfm	Cubic Feet per Minute
DX	Direct Expansion
HERS	Home Energy Rating System
HVAC	Heating, Ventilation, and Air Conditioning
IECC	International Energy Conservation Code.
RH	Relative Humidity

Abstract

This document covers a description of the need and applied solutions for supplemental dehumidification in warm-humid climates, especially for energy-efficient homes where the sensible cooling load has been dramatically reduced.

Building designers, builders, heating, ventilation, and air conditioning (HVAC) designers, HVAC system contractors, above-code building program managers, utility energy efficiency program managers, and building researchers will be able to use this information to plan and deliver better residential buildings in warm-humid climates.

In older homes in warm-humid climates, cooling loads are typically high and cooling equipment runs a lot to cool the air. The typical cooling process also removes indoor moisture, reducing indoor relative humidity (RH). However, at current residential code levels, and especially for above-code programs, sensible cooling loads have been so dramatically reduced that the cooling system does not run a lot to cool the air, resulting in much less moisture removed. In these new homes, cooling equipment is off for much longer periods of time, especially during spring/fall seasons, summer shoulder months, rainy periods, some summer nights, and some winter days. In warm-humid climates, those long off periods allow indoor humidity to become elevated due to internally generated moisture and ventilation air change. Elevated indoor RH impacts comfort, indoor air quality (including allergen production and chemical off-gassing/interactions), and building material durability. The HVAC and homebuilding industries are responding with supplemental dehumidification equipment, either standalone or integrated with central space conditioning systems, but that effort is really in its infancy compared to what will be needed to respond to the growing need to control indoor RH in homes throughout the year in warm-humid climates.

Available supplemental humidity control options are described and discussed, with application guidance. Some options are less expensive but may not control indoor humidity as well as more expensive and comprehensive options. The best performing option is one that avoids overcooling (cooling below the requested set point) and avoids adding unnecessary heat to the space by using waste heat from the cooling system to reheat the cooled and dehumidified air to room-neutral temperature.

Acknowledgments

The participation of manufacturing partners, Research Products Corporation/Aprilaire, and AAON, Inc., is gratefully acknowledged.

Progression Summary

HUMID CLIMATE HUMIDITY CONTROL

Year-round control of indoor RH to improve comfort, reduce allergen production, reduce chemical off-gassing and chemical interactions, and reduce risk of compromised material durability.

HOME EFFICIENCY LEVEL

1 **U.S. Department of Energy Challenge Home, or ENERGY STAR® version 3 or better, or HERS Index less than 70**

COOLING SYSTEM ENHANCEMENT 1 (not suppl. deh.)

2 Lower airflow with variable-speed blower: Controls to drop airflow to as low as 200 cfm/ton when indoor humidity is high. Initiate at 50% RH set point to be effective. Do not use constant fan mode or fan delay after compressor stops.

COOLING SYSTEM ENHANCEMENT 2 (not suppl. deh.)

3 Overcooling: Controls to overcool (cool below the requested set point) by as much as 2°F when indoor humidity is high. Some occupants may have comfort concerns.

2-STAGE + VAR. SPD. COMPRESSOR (not suppl. deh.)

4 To be effective in improving humidity control, 2-stage and variable speed compressor systems must be combined with at least "COOLING SYSTEM ENHANCEMENT 1" above.

STANDALONE DEHUMIDIFIER

5 For a typical home, a 40–50 pint/day capacity standalone dehumidifier works well with whole-house mixing via the central system fan. The dehumidistat should be in the conditioned space.

INTEGRATED DEHUMIDIFIER

6 A dehumidifier designed to be integrated with the central system ducting works well. The dehumidistat control should be located in a representative area in the conditioned space.

DEDICATED DEHUM MODE WITH CENTRAL SYSTEM

7 Subcooling Reheat: Works well much of the time, but limited. Full condensing reheat: Works best overall. Can continuously supply dry, room-neutral temperature air.

DX + DESICCANT DEHUMIDIFIER

8 Uses direct expansion (DX) dehumidifier condenser heat to regenerate desiccant. Where needed, this system can dry the air to much lower relative humidity than a DX dehumidifier alone.

1 Introduction

This document is focused on indoor humidity control in warm-humid climates. In the last decade, building codes and market demands have been quickly pushing up the energy efficiency requirements of residential buildings. Overall, this is good, and produces a significant net energy and cost savings. However, this situation has forced us to rethink the way we have traditionally thought about conventional residential space conditioning system design in warm-humid climates. Most building efficiency improvements brought about by code requirements and above code incentive programs, such as more insulation, better windows, low-power lighting, and more efficient appliances, are directed at lowering sensible gains while latent (moisture) gains remain mostly unchanged. Latent gains are mostly related to internal moisture generation by occupants and their activities, and ventilation requirements. Because conventional cooling systems are directed to control to a temperature set point, cooling systems in these more efficient, low sensible gain houses, have longer off-times. During those longer off-times, indoor moisture can build up and cause elevated levels of indoor relative humidity (RH). Elevated RH impacts comfort, indoor air quality, and sometimes material durability if mold or fungi growth occurs. Therefore, at some times when there is no need to lower the space air temperature, supplemental dehumidification will still be needed to maintain the RH below acceptable levels. Maximum indoor RH thresholds vary depending on the criteria. For example, to control for dust mite allergen, a maximum of 50% RH is recommended. To control for comfort, at typical indoor cooling season temperatures, a maximum of 60% RH is recommended. To avoid wintertime condensation on metal window frames and single-glazed windows, often resulting in mold on sills, the threshold would be 50% RH or lower.

The information provided in this Measure Guideline applies whether the home was constructed new or retrofitted to be high performance/low sensible heat gain.

Extensive field testing was done with BSC builder partners in Texas and Florida in 2001 to 2007 (Rudd et al. 2003, Rudd 2004, Rudd et al. 2005, Rudd 2006, Rudd 2007). In part, that testing revealed that supplemental dehumidification was needed in high performance, low sensible heat gain homes in order to maintain indoor RH below 60% year-round. Detailed simulations later confirmed that and expanded on those findings (Rudd et al. 2013).

Off-the-shelf standalone supplemental dehumidification systems and central system integrated supplemental dehumidification solutions that allow year-round indoor RH control between 50% and 60% were employed to address this problem. Supplemental dehumidification provides an opportunity to market year-round comfort in warm-humid climates, and is intended to enable further reduction in sensible cooling loads, through further efficiency improvements, without the risk of elevated indoor humidity.

While these advancements have been important and needed in the residential space conditioning industry, supplemental dehumidification technology continues to improve and evolve, and the market for these products is still in its infancy. Design capacity prediction is subject to many unknowns, the most important being sensitivity to internal moisture generation by occupants.

2 Decision-Making Criteria

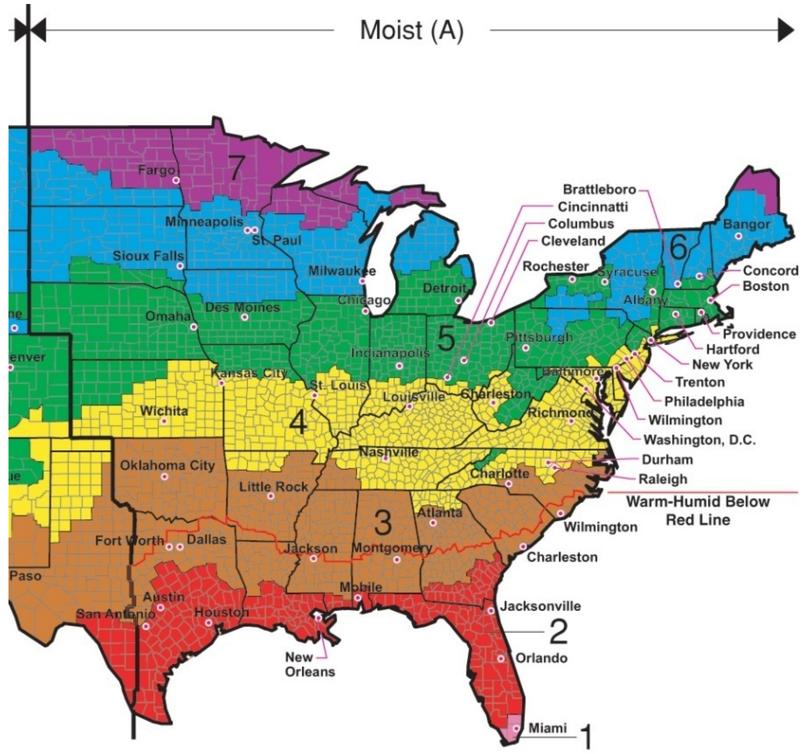

Figure 1. IECC climate zone map showing warm-humid line generally extending from Wilmington, North Carolina to Dallas, Texas

Generally, the decision to employ supplemental dehumidification is coupled with efficiency improvements resulting in low sensible cooling loads in warm-humid climates (Figure 1 below the red line). However, there are some situations where supplemental dehumidification is needed that are not related to efficiency improvements. Those situations are generally found in multifamily buildings, especially first-floor units with little outside wall or roof exposure, or where homes are very shaded by trees or buildings. High outdoor humidity in coastal areas can make supplemental dehumidification important further north than the International Energy Conservation Code (IECC) warm-humid line extending generally from Wilmington, North Carolina to Dallas, Texas (Figure 1).

The type of construction, and time of year of construction and occupancy, can also have an important impact on indoor humidity control. For example, a slab-on-grade, concrete or masonry unit wall home constructed in late summer and occupied in the fall, or constructed in winter and occupied in spring, has a lot of interior moisture to remove due to construction materials drying but little chance of consistent moisture removal until the main cooling season begins. While in some cases, this may require only temporary supplemental dehumidification, builders of high performance homes in warm-humid climates will likely find it more efficient and acceptable to their overall customer base to treat all homes (at least in a given community) alike by employing the more robust permanent supplemental dehumidification solution.

2.1 Cost and Performance

Supplemental dehumidification, in and of itself, does not save energy; rather, it is justified by enabling the energy savings from dramatically reduced sensible cooling loads in warm-humid climates. The supplemental dehumidification solution is intended to enable further reduction in sensible cooling load, through further efficiency improvements, without the risk of elevated indoor humidity.

The estimated equipment cost of supplemental dehumidification, including labor, can range from $400 to $2,000 depending on the system solution chosen. A stand-alone dehumidifier will cost the least and a desiccant dehumidifier integrated with the central space conditioning system will cost the most. The PROGRESSION SUMMARY chart at the beginning of the document follows this order and Table 1 provides more cost estimate detail.

Table 1. First-Cost Estimates for Supplemental Dehumidification Systems

Supplemental Dehumidification System	First-Cost Estimate
Standalone Dehumidifier With Remote Dehumidistat	$400
Integrated Ducted Dehumidifier	$1,000
Subcooling Reheat	$1,600
Full-Condensing Reheat	$1,750
Desiccant Dehumidifier	$2,000

The most effective solutions, having relatively low operating cost and essentially eliminating indoor humidity above 60% RH, are:

- Full condensing and subcooling reheat integrated with the central cooling system
- Ducted dehumidifier
- Standalone dehumidifier with central system mixing
- Direct expansion (DX) condenser-regenerated desiccant dehumidifier.

Supplemental dehumidification operating energy of about 170 kWh/yr can be expected for a Home Energy Rating System (HERS) Index 50 house (having ducts inside conditioned space) with a 60% RH set point. About five times that can be expected with a 50% RH set point.

A second tier performer is the subcooling reheat system but that system allows more elevated RH hours. A third tier (not considered as supplemental dehumidification) is the enhanced cooling option which uses controls for 2°F of overcooling and lower airflow (200 cfm/ton) activated at 50% RH. Two-speed and variable-speed systems do little to reduce hours of elevated RH in warm-humid climates unless coupled with the enhanced cooling option listed above.

2.2 Risk Identification

Elevated RH impacts comfort, indoor air quality, and sometimes material durability if mold or fungi growth occurs. Counting hours above a given RH threshold is a reasonable metric to determine a system’s effectiveness in reducing or eliminating elevated indoor RH. 60% RH is a reasonable and commonly used threshold.

3 Technical Description

Table 2 gives a listing of recommended minimum supplemental dehumidification capacities for several different conditions.[1] Those conditions depend on the desired RH set point, and on house size and occupancy, resulting in expected internal moisture generation. The capacities listed reasonably well match the capacities of available dehumidification equipment, and are given at the Association of Home Appliance Manufacturers (AHAM) rating condition of 80°F and 60% RH. Moisture removal capacity in typical homes at lower temperatures, or lower RH, or both, will be lower than the AHAM rated capacity, but that was considered in making Table 2.

Table 2. Minimum Supplemental Dehumidification Capacity Guideline

	Minimum Supplemental Dehumidification Capacity*			
	Small to Medium House Size (~ <2500 ft^2)		Larger House Size (~ > 2500 ft^2)	
	60% RH Set Point	50% RH Set Point	60% RH Set Point	50% RH Set Point
Average Internal Moisture Generation for 4 People (12 lb/day)	40 pint/day (1.7 lb/h)	60 pint/day (2.5 lb/h)	60 pint/day (2.5 lb/h)	80 pint/day (3.3 lb/h)
Higher Internal Moisture Generation for 4 People (24 lb/day)	50 pint/day (2.1 lb/h)	70 pint/day (2.9 lb/h)	70 pint/day (2.9 lb/h)	90 pint/day (3.8 lb/h)

* Capacities listed are based on AHAM rating at 80°F and 60% RH.

3.1 System Interaction

Designers or builders sometimes want to know if the cooling system capacity can be reduced because of installed supplemental dehumidification capacity. The answer is, no. The reason for that is that operation of supplemental dehumidification is not coincident with the peak design conditions of a cooling system. A cooling system is designed to meet the summer peak sensible cooling load, while understanding that at that condition it will also have some latent (moisture removal) capacity (generally being 20%–25% of total capacity). At summer cooling design conditions, supplemental dehumidification is not needed. Supplemental dehumidification is needed during spring/fall seasons, summer shoulder months, rainy periods, some summer nights, and even some winter days in warm-humid climates.

[1] These recommendations are based on the author's best estimates accumulated over a decade of experience with applying and analyzing supplemental dehumidification systems. Also see references Rudd 2013 and CMHC 2009 for additional information.

4 Measure Implementation

Scope of Work

A. Determine the minimum supplemental dehumidification capacity needed. See Table 2.
B. Determine whether a less expensive standalone dehumidifier approach or a more expensive and comprehensive central system integrated approach will be used. See Figure 2 to Figure 17.
C. Determine how whole-house distribution of dehumidified air will be accomplished (i.e., timed periodic operation of the central system blower or make sure interior doors stay open).
D. Determine a good representative location for installing the dehumidifier controller (dehumidistat) with RH display.
E. Install the system.
F. For dehumidifiers integrated with the central system, install a backflow preventer damper in the dehumidifier outlet duct. Use a "Wye" fitting to connect to the dehumidifier supply duct to the central system supply duct/plenum to help move the dehumidified air downstream for better distribution. See Figure 6 and Figure 7.
G. Verify proper operation of the dehumidifier and control system.

4.1 Install Procedure

4.1.1 Enhanced Cooling Option (Lower Evaporator Airflow and Overcooling)

For comparison, the conventional system for the HERS Index 50 house referred to in this guideline was a seasonal energy efficiency ratio 17.7, 2-speed compressor system with a brushless permanent magnet motor variable speed indoor fan (Rudd et al. 2013; Rudd 2013). The enhanced cooling humidity control option is the same as the conventional system except with controls to provide lower airflow and space overcooling when space humidity is high. These are usually programmable settings on higher end cooling equipment and thermostat/dehumidistat products. Heating, ventilation, and air conditioning (HVAC) contractors are typically familiar with this and would implement it for the builder. Operation in enhanced cooling mode is limited to 50% runtime (10 minutes on, 10 minutes off) and the operating fan power for the brushless permanent magnet motor drops from 0.35 to 0.1 W/cfm at low airflow.

Conventional direct expansion (DX) cooling systems are typically Air Conditioning Heating and Refrigeration Institute rated with airflow of 350–400 cfm/ton of total cooling capacity. Lowering the cfm/ton improves latent cooling performance (moisture removal) but increases energy consumption because of the work it takes to condense additional water vapor. For the results shown in this guideline, the airflow was lowered to 200 cfm/ton. There is a practical limit to lowering the cfm/ton because if parts of the evaporator coil drop to 32°F, frosting and eventual icing of the coil will occur. Ice further blocks airflow, creating more ice, and eventually makes it impossible to deliver the conditioned air. As a protection against icing, the low airflow operation is typically limited in time, and for further protection, temperature switches or sensors can be strategically placed on coil to stop the compressor if the coil temperature drops too low.

Overcooling means, when space humidity increases above the RH set point, the cooling temperature set point is reduced 2°F below the requested temperature set point to continue the cooling operation in hopes of meeting the RH set point. This operation also carries with it a risk of occupant discomfort complaints due to the wide range of temperature control.

This humidity control option is "enhanced cooling" rather than "supplemental dehumidification" because when the minimum cooling set point is satisfied (2°F below the requested set point in this case) then there will no longer be any call for cooling or the moisture removal that typically occurs with that cooling. In other words, moisture removal is locked out at that point.

The information in all of the humidity control performance tables in this document come from two much more detailed references: Rudd et al. 2013 and Rudd 2013. Table 3 shows the humidity control performance of the Enhanced Cooling option with lower airflow and overcooling, compared to conventional cooling, for three cities in the IECC warm-humid climate region (Miami, Orlando, Houston). As shown in Table 3, this humidity control option is not effective at controlling the indoor humidity near 50% RH, but it can be effective in Miami and Houston at controlling the indoor RH near 60% as long as the cooling enhancements are activated whenever the indoor RH is greater than 50% RH. For a HERS Index 50 house, the cost of doing that is low (less than $10/yr).

Table 3. Humidity Control Performance of the Enhanced Cooling Option, With the Lower Airflow and 2°F Overcooling, Compared to the Conventional System

	Hours Above 62% RH	Hours Above 52% RH	Total HVAC Electric Without Furnace (kWh)	Total HVAC Costs With Furnace ($)	Comparison to Conventional System
Miami, HERS 50, Central Fan Integrated Supply (CFIS)					
Conventional System	627	3,280	2,821	288	100%
Low Airflow + Overcooling	–	–	–	–	–
60% Set Point	529	3,275	2,832	289	100%
50% Set Point	40	1,975	2,912	298	104%
Orlando, HERS 50, CFIS					
Conventional System	609	4,087	2,140	261	100%
Low Airflow + Overcooling	–	–	–	–	–
60% Set Point	611	4,087	2,144	261	100%
50% Set Point	324	2,797	2,218	270	104%
Houston, HERS 50, CFIS					
Conventional System	234	2,281	2,261	267	100%
Low Airflow + Overcooling	–	–	–	–	–
60% Set Point	228	2,263	2,264	267	100%
50% Set Point	48	1,600	2,308	273	102%

4.1.2 Standalone Dehumidifier Option

This supplemental dehumidification option includes two versions: a portable, Stand-alone Dehumidifier (nonducted), and a standalone ducted dehumidifier, both of which independently supplement the moisture removal of the conventional cooling system. The smaller portable version is typically a 40–50 pint/day dehumidifier. The larger version is typically a dehumidifier having 65–90 pint/day moisture removal capacity. The dehumidifier operates to maintain the dehumidification set point independently of the conventional air conditioner. To ensure distribution of dehumidified air, and for room air feedback to the centrally located dehumidistat, a fan control ensures that the central system fan runs a minimum of about 10 minutes each hour to provide mixing in the space, based on a recirculation turnover rate of 0.5 air changes per hour (ACH).

The one-story and two-story configurations shown in Figure 2 and Figure 3 are representative of a standalone dehumidifier installed in a mechanical closet or a hall linen closet with a louvered door. It is best if the closet location is near the main central system return air grille. That will help distribute the dehumidified air throughout the conditioned space. It is also best if the dehumidistat to activate and deactivate the dehumidifier is installed near the central system return air grille, even though it can work to use the dehumidistat control that comes standard on the unit. Installing the dehumidistat remotely requires an electrician to install a line voltage dehumidistat that controls the dehumidifier power receptacle, or installing a low-voltage to line-voltage relay in the receptacle box. Referring to the different dehumidistat location shown in Figure 4 versus Figure 5, in two-story homes where the first floor is very open to the second floor, due to moisture buoyancy, it can be better to install the dehumidistat on the second floor even when the dehumidifier outlet supplies only to the first floor. This is a matter of gaining experience with specific installations.

Table 4 shows the current (Version 3.0, October 2011) performance criteria for ENERGY STAR®-qualified dehumidifiers.

Table 4. Performance Criteria for ENERGY STAR-Qualified Dehumidifiers

(EPA 2011)

Product Capacity (Pints/day)	Energy Factor Under Test Conditions (L/kWh)
< 75	≥ 1.85
≥ 75 to 185	≥ 2.80

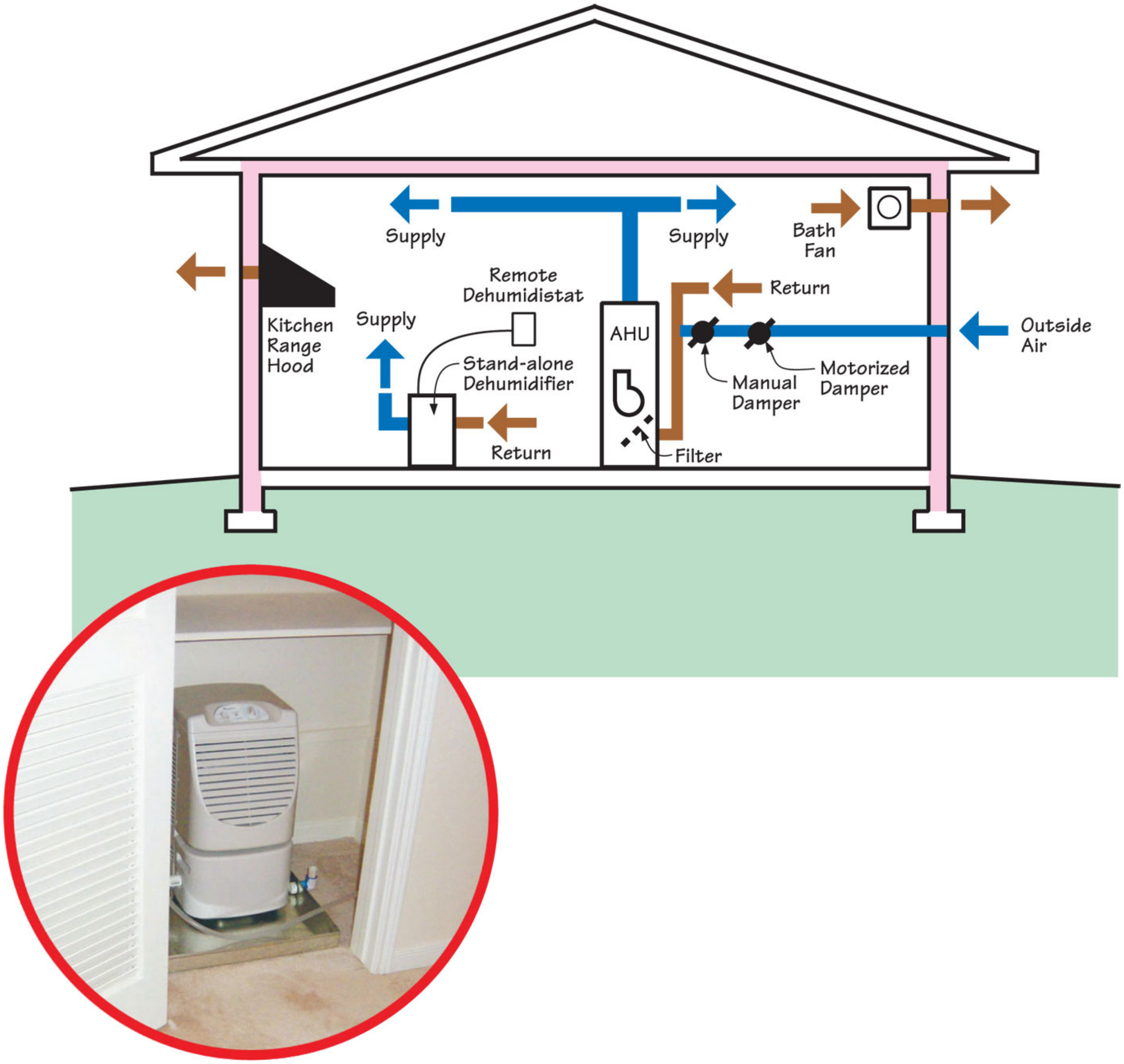

Figure 2. Standalone dehumidifier option, in one-story home closet application, with louvered closet door, near central system return air grille

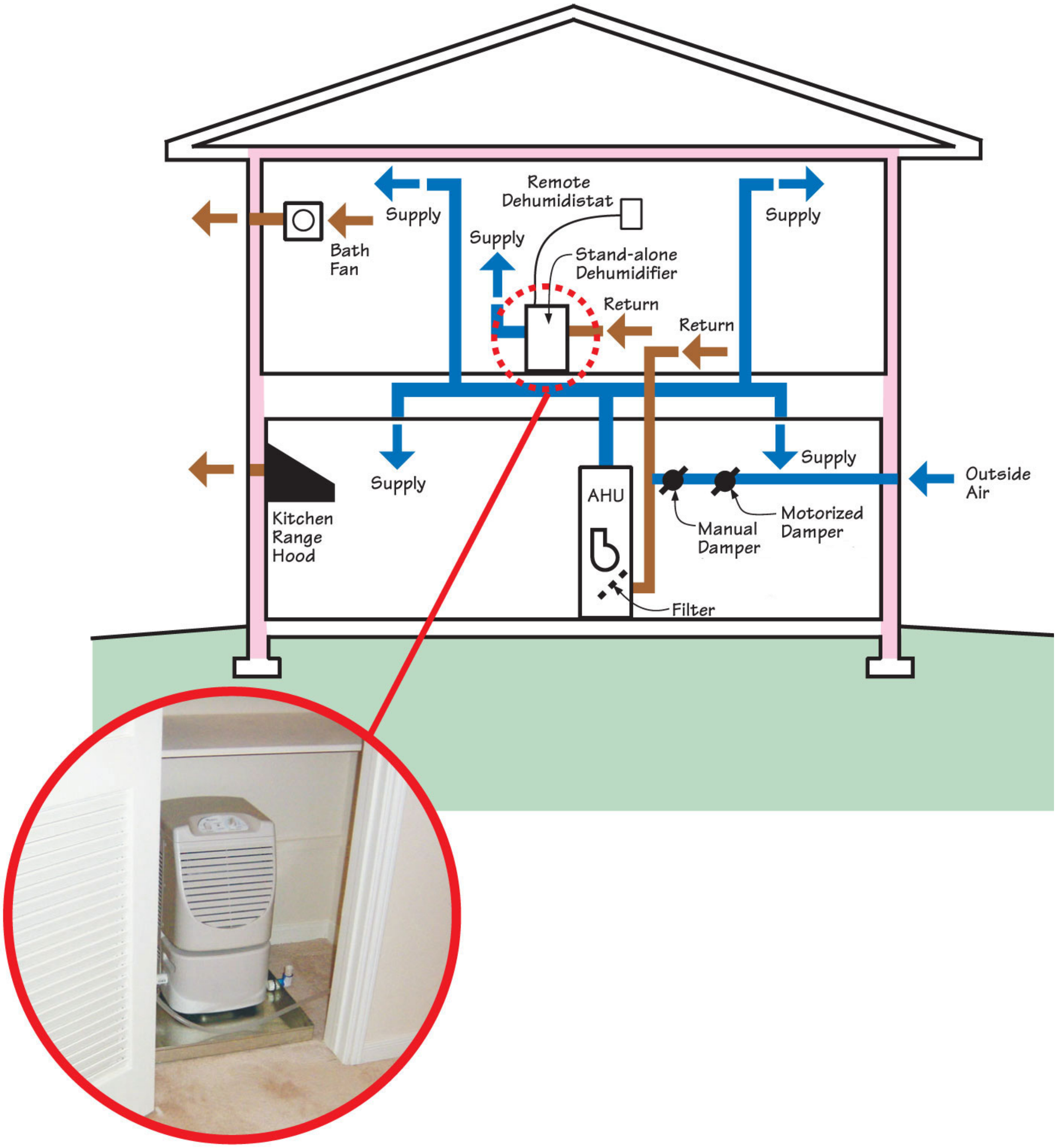

Figure 3. Standalone dehumidifier option, in two-story home closet application, with louvered closet door, near central system return air grille

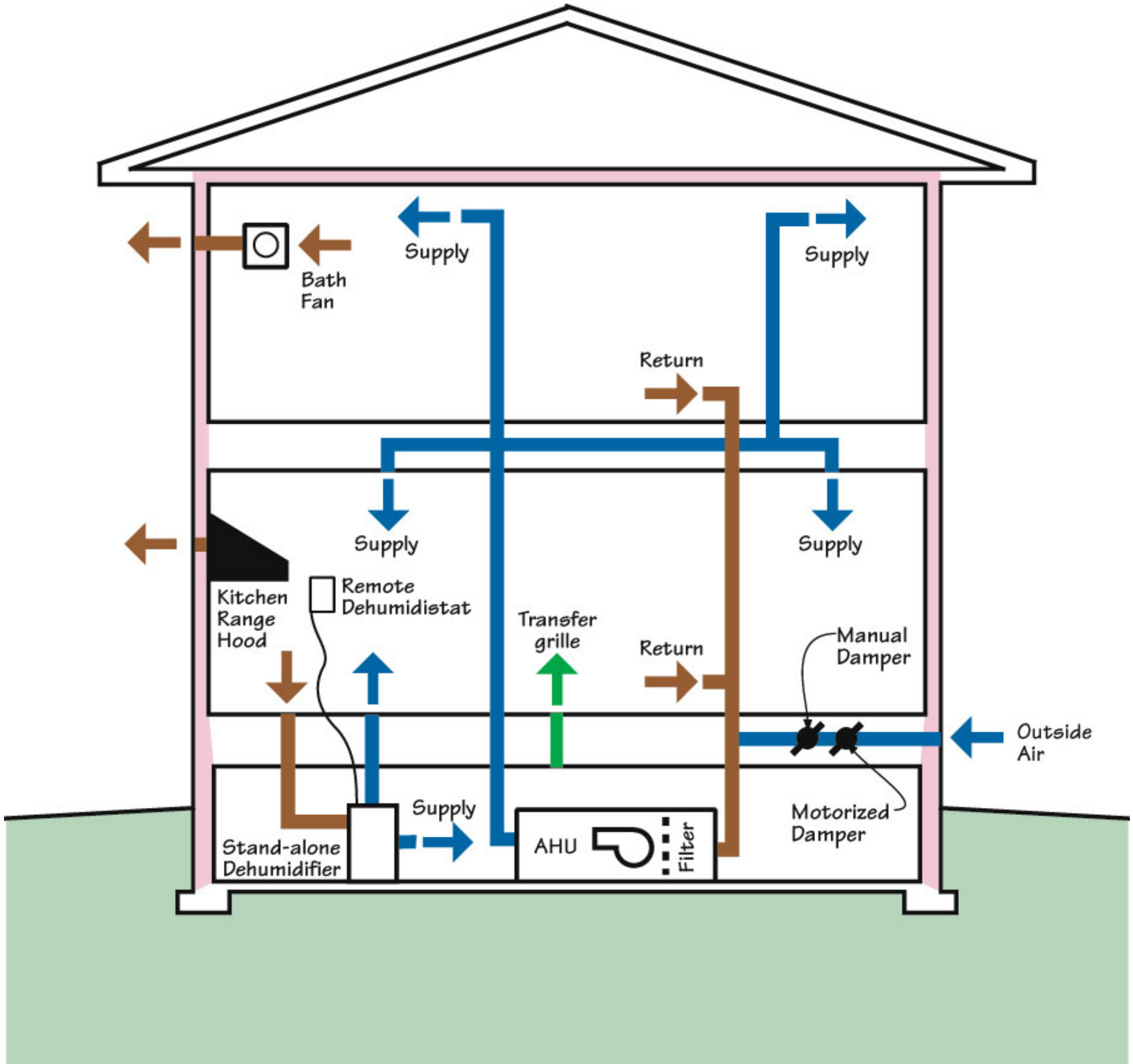

Figure 4. Standalone ducted dehumidifier option, in unvented crawlspace application

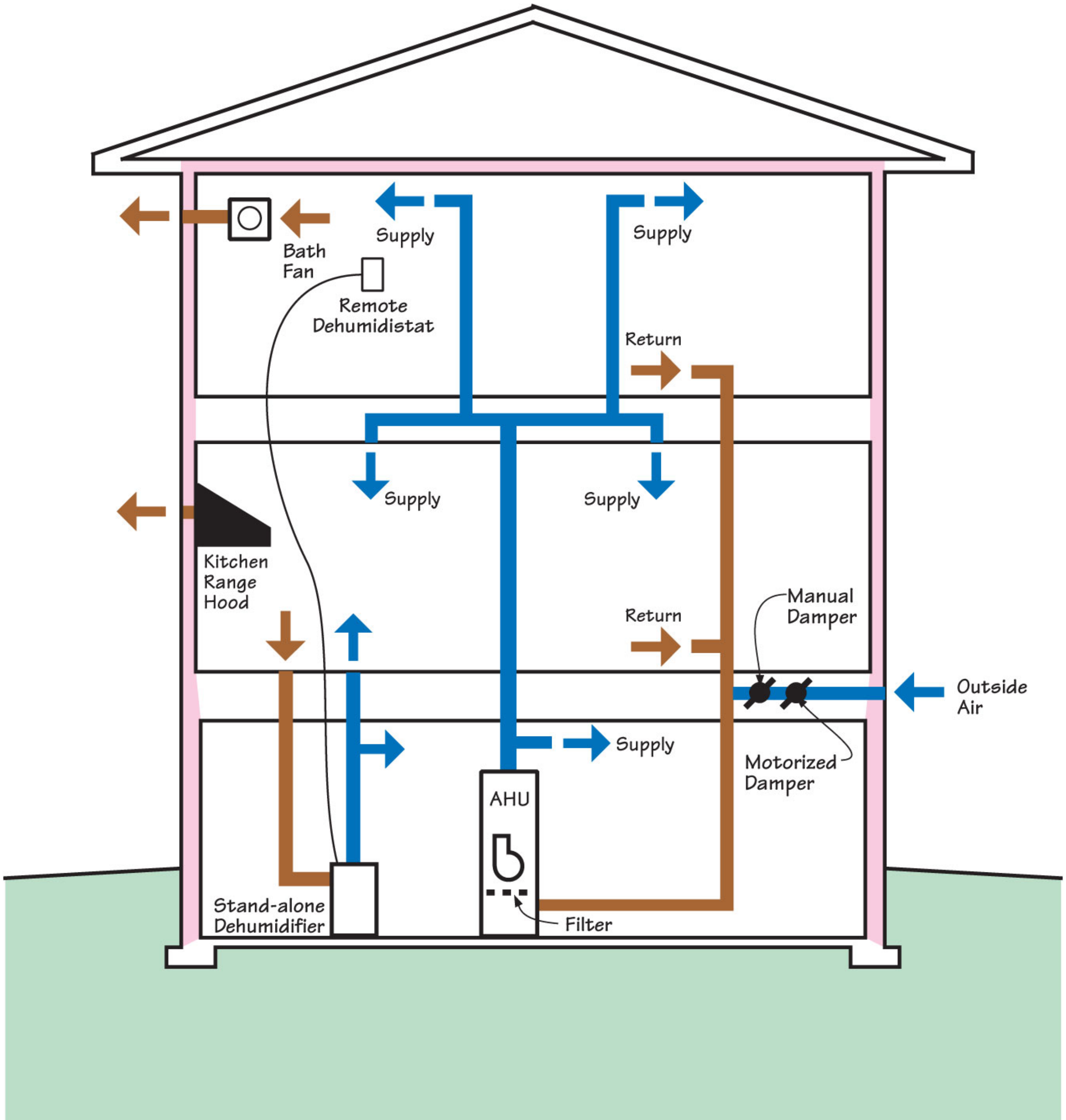

Figure 5. Standalone ducted dehumidifier, in basement application

Table 5 shows the humidity control performance of the standalone dehumidifier option, compared to conventional cooling, for three cities in the IECC warm-humid climate region (Miami, Orlando, Houston). These performance results take into account the heat added to the space by the dehumidifier. Field experience and computer modeling have shown that supplemental dehumidification is mostly needed when the house interior conditions are floating between the cooling and heating set points, which diminishes the cooling energy consumption impact of dehumidifier waste heat. As shown in Table 5, this humidity control option is effective at controlling the indoor humidity near 50%–60% RH. For a HERS Index 50 house, the annual cost of controlling the indoor humidity to 60% RH is low (about $10, or 1%–4% increase in total HVAC operating costs compared to the conventional system). Controlling indoor humidity to 50% RH increases total HVAC cost by up to $75/yr, or 30% more than the conventional system.

Table 5. Humidity Control Performance of the Standalone Dehumidifier Option, Compared to the Conventional System

	Hours Above 62% RH	Hours Above 52% RH	Total HVAC Electric Without Furnace (kWh)	Total HVAC Costs With Furnace ($)	Comparison to Conventional System
Miami, HERS 50, CFIS					
Conventional System	627	3,280	2,821	288	100%
Standalone Dehumidifier	–	–	–	–	–
60% Set Point	–	3,185	2,932	298	104%
50% Set Point	–	–	3,598	365	127%
Orlando, HERS 50, CFIS					
Conventional System	609	4,087	2,140	261	100%
Standalone Dehumidifier	–	–	–	–	–
60% Set Point	–	3,834	2,272	269	103%
50% Set Point	–	16	3,055	337	129%
Houston, HERS 50, CFIS					
Conventional System	234	2,281	2,261	267	100%
Standalone Dehumidifier	–	–	–	–	–
60% Set Point	–	2,035	2,326	270	101%
50% Set Point	–	2	2,724	301	113%

4.1.3 Integrated Ducted Dehumidifier Option (Integrated With the Central System)

This supplemental dehumidification option involves a larger and more efficient ducted dehumidifier having 65–90 pint/day moisture removal capacity. The ducted dehumidifier has a fan that allows it to be integrated with the central cooling unit in a recirculation configuration (pulling air from the main zone and then supplying air into the central system supply duct). This configuration requires that the dehumidifier unit have a backflow damper to ensure that the central system supply fan does not cause air to flow backwards through the unit when the dehumidifier is off. The dehumidifier operates to maintain the humidity set point. To ensure distribution of dehumidified air, and for room air feedback to the centrally located dehumidistat, a fan control ensures that the central system fan runs a minimum of about 10 minutes each hour to provide mixing in the space, based on a recirculation turnover rate of 0.5 ACH.

Integrated ducted dehumidifier configurations are shown in Figure 6 to Figure 10. Note the “Wye fitting” in Figure 6 where the dehumidifier duct connects with the central system duct. That typical fitting recommendation is important to help the dehumidifier outlet air move downstream in the central system duct when the central system fan is off. Without that, especially in supply plenum installations, dehumidifier air can tend to preferentially flow into a single plenum outlet rather than being more distributed. If that happens, the warm dehumidifier air (typically 105°F or higher) may make a specific room uncomfortably warm and the centrally located thermostat will not sense that.

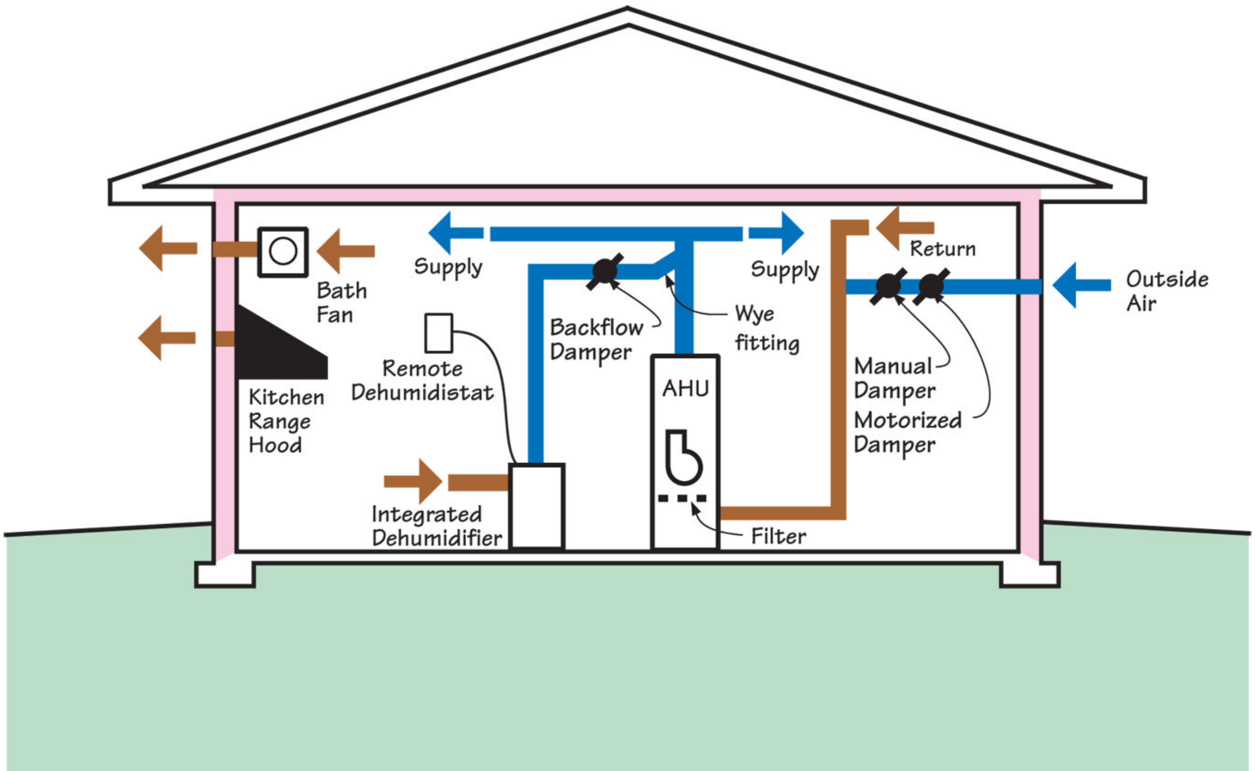

Figure 6. Integrated ducted dehumidifier integrated with central system, in one-story home closet application

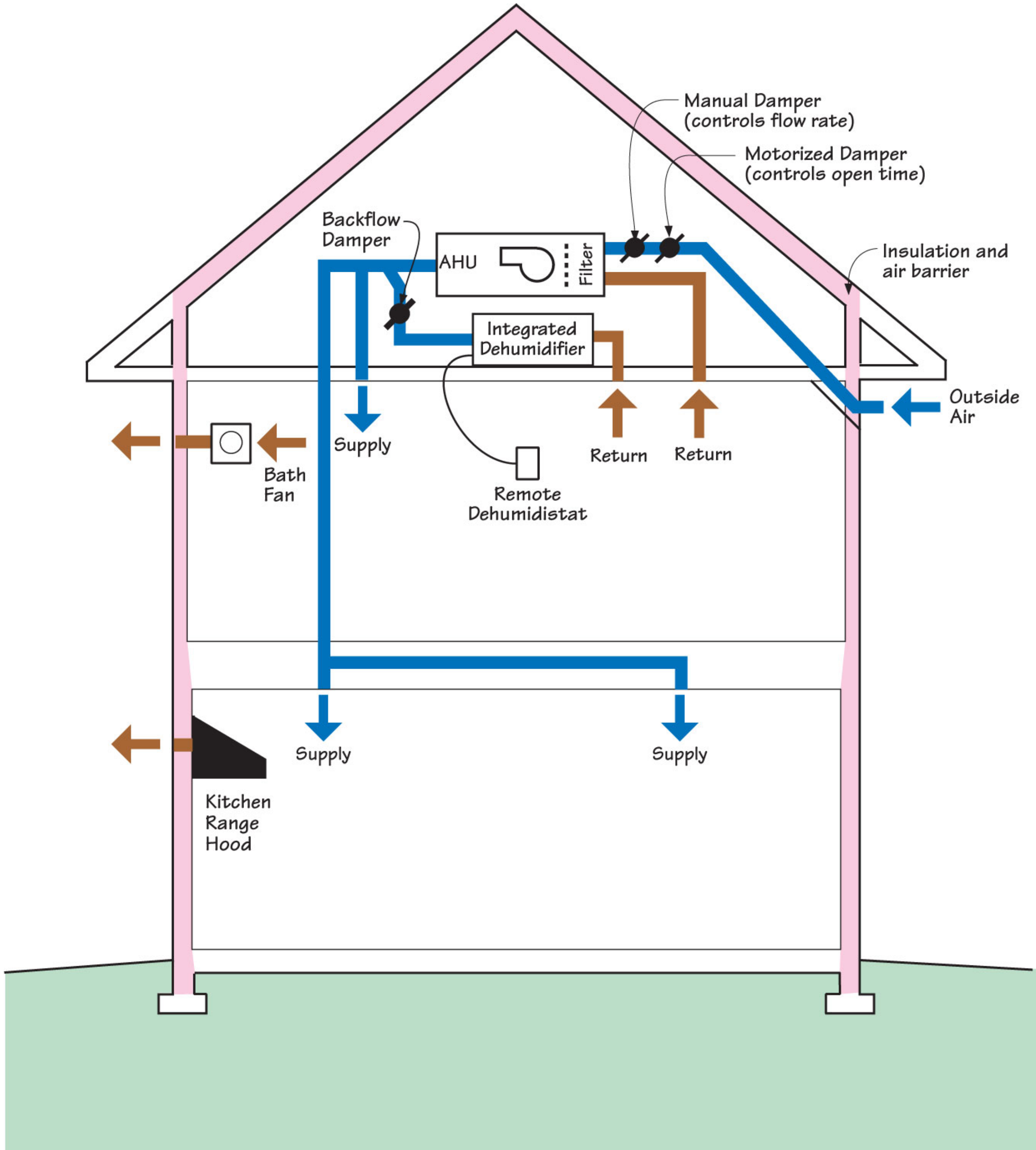

Figure 7. Integrated ducted dehumidifier integrated with central system, in unvented attic application

Figure 8. Integrated ducted dehumidifier installation

Figure 9 and Figure 10 show an Integrated ducted dehumidifier integrated with the central system in an unvented crawlspace and a basement application (for the few basements in the upper reaches of the warm-humid climate). In both cases, a small amount of dehumidifier supply air (10%–15% of total flow) should be directed into the crawlspace or basement. That amount of dehumidifier air will help moderate the air conditions in those spaces without taking too much air for adequate humidity control in the conditioned living space.

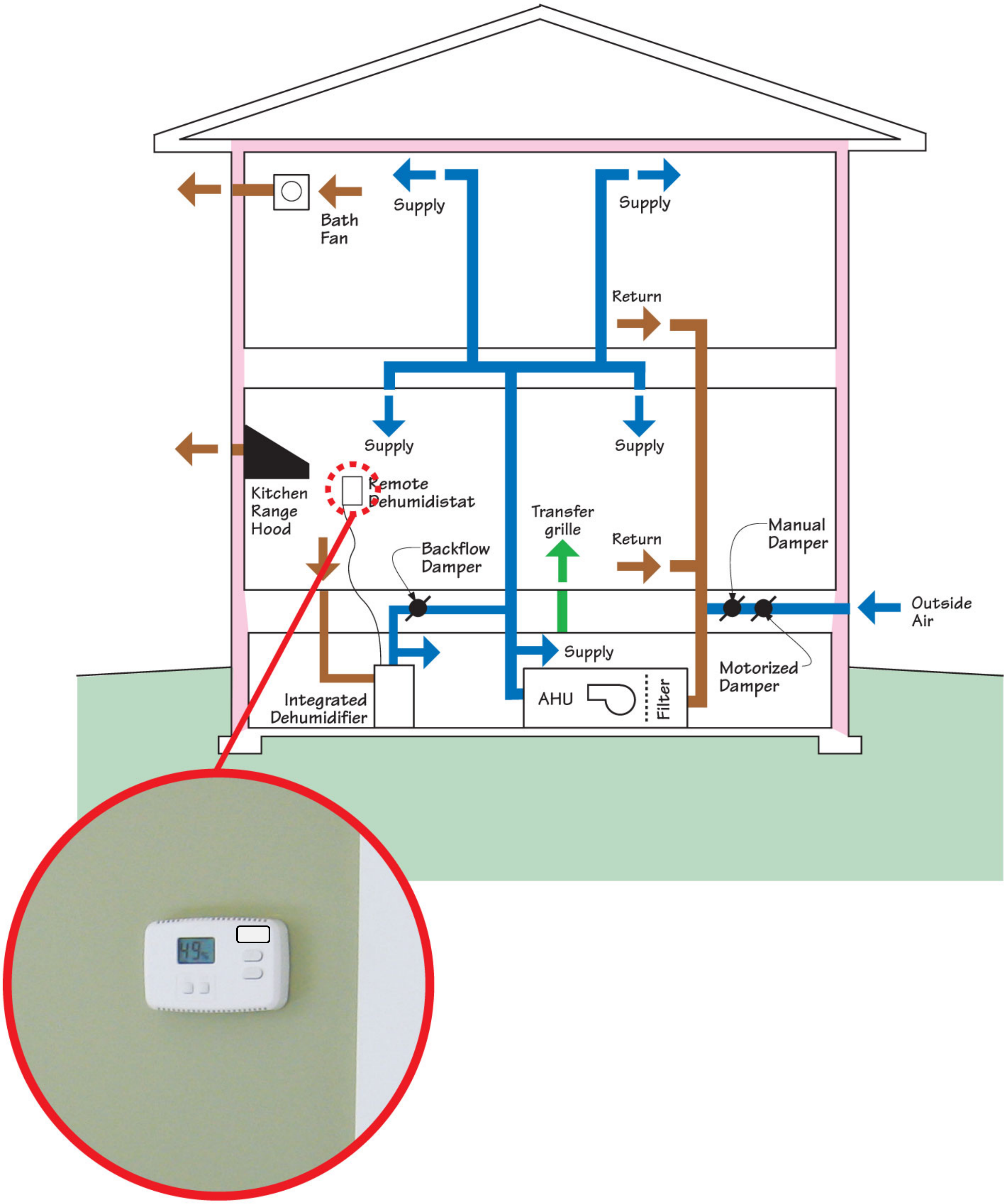

Figure 9. Integrated ducted dehumidifier integrated with the central system, in an unvented crawlspace application

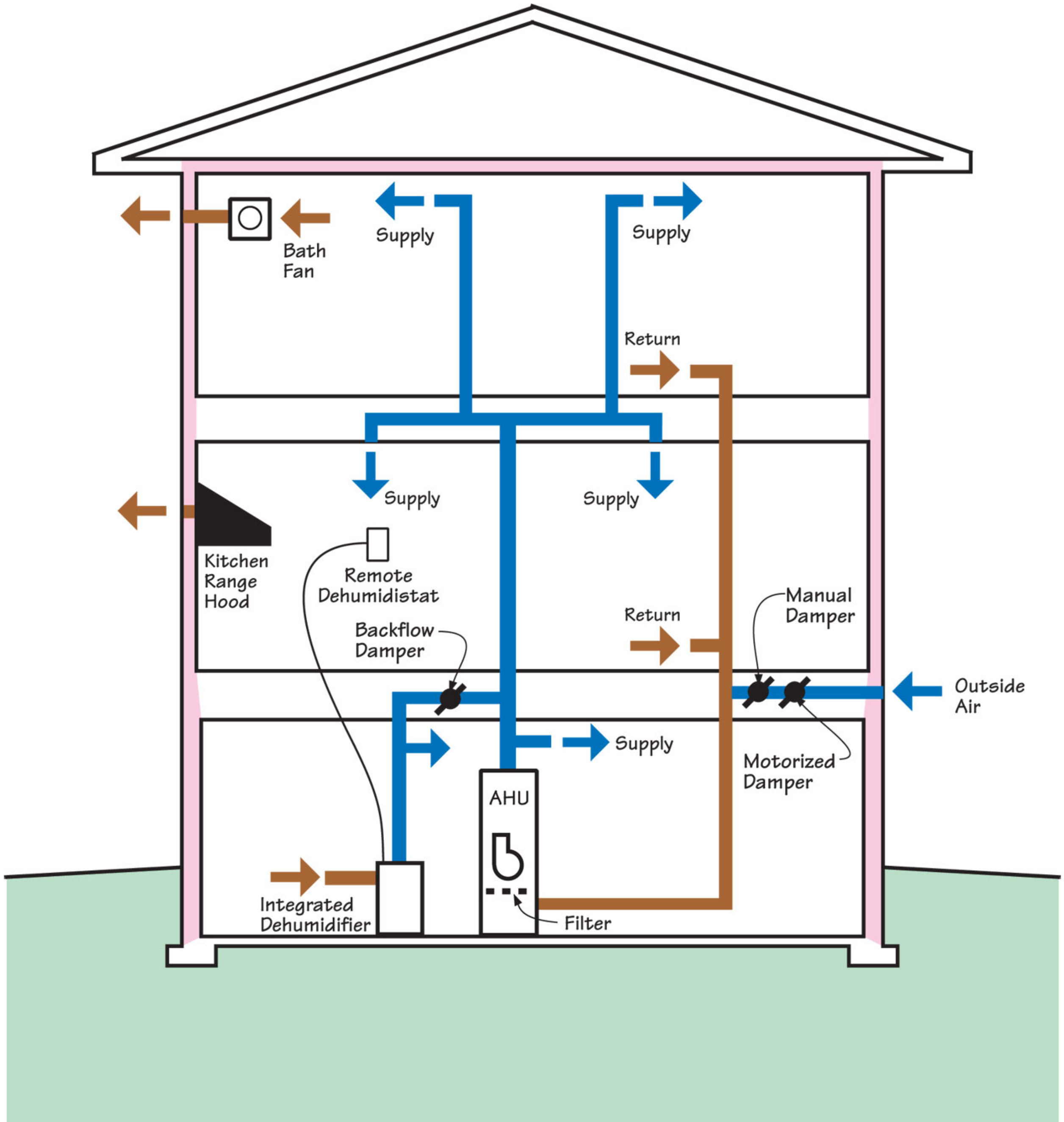

Figure 10. Integrated ducted dehumidifier integrated with central system, in basement application

Table 6 shows the humidity control performance of the integrated ducted dehumidifier option, compared to conventional cooling. The performance is very similar to that of the standalone dehumidifier option, except with more moisture removal capacity and higher efficiency. As shown in Table 6, this humidity control option is effective at controlling the indoor humidity near 50%–60% RH. For a HERS Index 50 house, the annual cost of controlling the indoor humidity to 60% RH is low (about $10, or 1%–4% increase in total HVAC operating costs compared to the conventional system). Controlling indoor humidity to 50% RH increases total HVAC cost by up to $70/yr, or 25% more than the conventional system.

Table 6. Humidity Control Performance of the Integrated Ducted Dehumidifier Option, Compared to the Conventional System

	Hours Above 62% RH	Hours Above 52% RH	Total HVAC Electric Without Furnace (kWh)	Total HVAC Costs With Furnace ($)	Comparison to Conventional System
Miami, HERS 50, CFIS					
Conventional System	627	3,280	2,821	288	100%
Integrated Ducted Dehumidifier	–	–	–	–	–
60% Set Point	–	3,178	2,921	298	104%
50% Set Point	–	–	3,528	358	125%
Orlando, HERS 50, CFIS					
Conventional System	609	4,087	2,140	261	100%
Integrated Ducted Dehumidifier	–	–	–	–	–
60% Set Point	–	3,838	2,254	267	102%
50% Set Point	–	8	2,976	330	127%
Houston, HERS 50, CFIS					
Conventional System	234	2,281	2,261	267	100%
Integrated Ducted Dehumidifier	–	–	–	–	–
60% Set Point	–	2,012	2,320	270	101%
50% Set Point	–	–	2,691	299	112%

4.1.4 Subcooling Reheat Option (With Enhanced Cooling Option)

Once again, this humidity control option is not a full supplemental dehumidification option because it cannot continue to operate indefinitely to control indoor humidity without unacceptably overcooling the conditioned space. This system involves a central DX cooling system with an indoor refrigerant subcooling reheat coil installed after the evaporator coil. Typically this is a two-speed, high-efficiency cooling unit. It uses the lower airflow and overcooling enhancements discussed above and also activates a subcooling reheat mode after the unmodified cooling set point is reached but indoor RH is still high. In that mode, the supply air is reheated to a maximum of about 65°F, so moisture removal can continue for a time with less overcooling of the space, however, that process is still limited by the maximum 2°F overcooling allowed. Because of that, the system is less effective in controlling the indoor to 50% RH than it is in controlling to 60% RH.

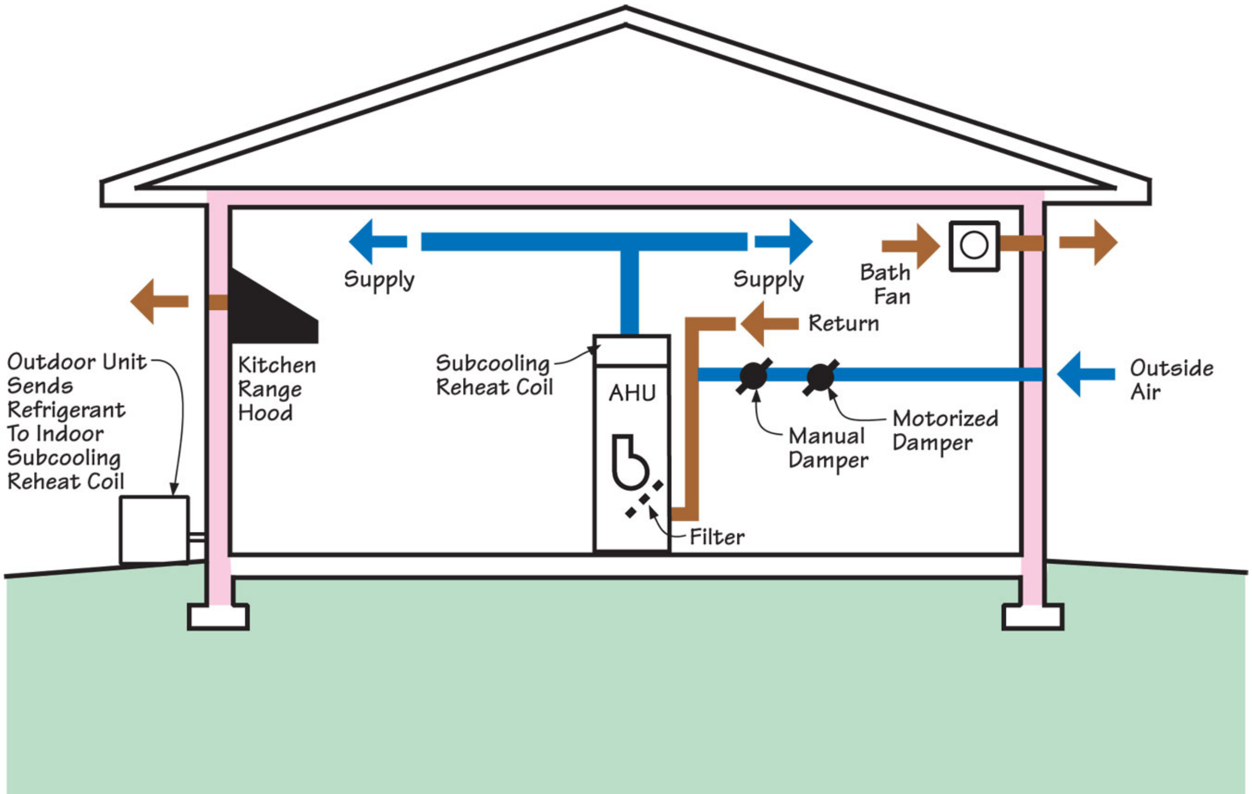

Figure 11. Enhanced cooling with subcooling reheat option

Figure 12. Photo of subcooling reheat coil

Table 7 shows the humidity control performance of the subcooling reheat option, compared to conventional cooling. The performance is better than the enhanced cooling option but not as good as the standalone dehumidifier option. As shown in Table 7, this humidity control option is effective at controlling the indoor humidity near 60% RH in Miami and Houston, but less so in Orlando. It is not very effective in controlling indoor humidity near 50% RH. For a HERS Index 50 house, the annual cost of controlling the indoor humidity to 60% RH is low (< $10, or 1%–3% increase in total HVAC operating costs compared to the conventional system). Attempting to control indoor humidity near 50% RH increases total HVAC cost by up to $60/yr, or 20% more than the conventional system.

Table 7. Humidity Control Performance of the Subcooling Reheat Option, Compared To the Conventional System

	Hours Above 62% RH	Hours Above 52% RH	Total HVAC Electric Without Furnace (kWh)	Total HVAC Costs With Furnace ($)	Comparison to Conventional System
Miami, HERS 50, CFIS					
Conventional System	627	3,280	2,821	288	100%
Subcooling Reheat	–	–	–	–	–
60% Set Point	64	3,203	2,916	297	103%
50% Set Point	–	256	3,412	348	121%
Orlando, HERS 50, CFIS					
Conventional System	609	4,087	2,140	261	100%
Subcooling Reheat	–	–	–	–	–
60% Set Point	287	3,976	2,216	268	103%
50% Set Point	45	1,035	2,736	322	123%
Houston, HERS 50, CFIS					
Conventional System	234	2,281	2,261	267	100%
Subcooling Reheat	–	–	–	–	–
60% Set Point	75	2,134	2,298	270	101%
50% Set Point	–	350	2,615	298	112%

4.1.5 Full Condensing and Subcooling Reheat Option

Central DX cooling system with modulating hot gas reheat providing full condensing and subcooling at an indoor reheat coil. Overall, this is the best performing supplemental dehumidification option. The refrigeration cycle operates more efficiently than the subcooling reheat system, it avoids overcooling (cooling below the requested set point), and avoids adding unnecessary heat to the space by using just the right amount of waste heat from the cooling system to reheat the cooled and dehumidified supply air to room-neutral temperature. Operation of this option can continue indefinitely until the RH set point is met without overcooling.

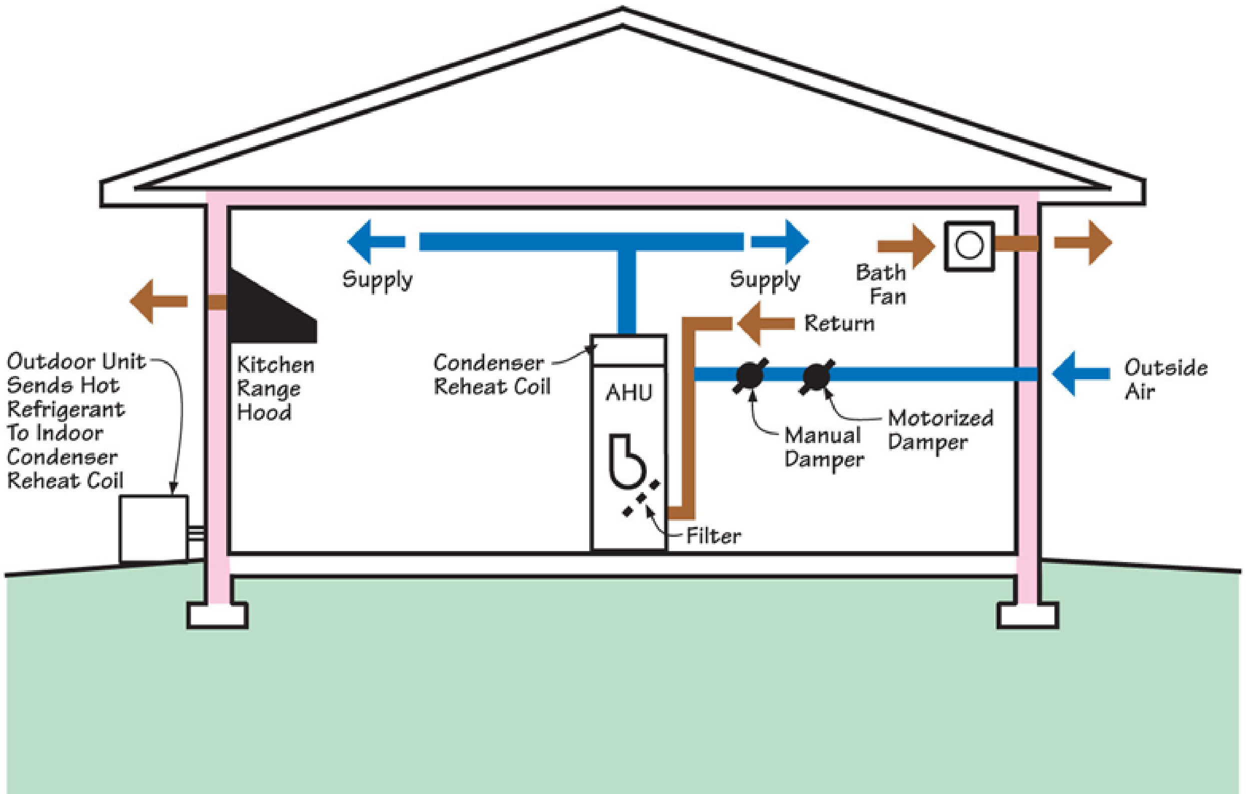

Figure 13. Full Condensing and subcooling reheat option, with modulating hot gas reheat, supplying dry air at room neutral temperature

Figure 14. Outdoor (left) and indoor (right) units of the full condensing and subcooling reheat option; the outdoor unit shows the three refrigerant connections to the indoor unit; the indoor unit shows the condenser reheat coil at the top

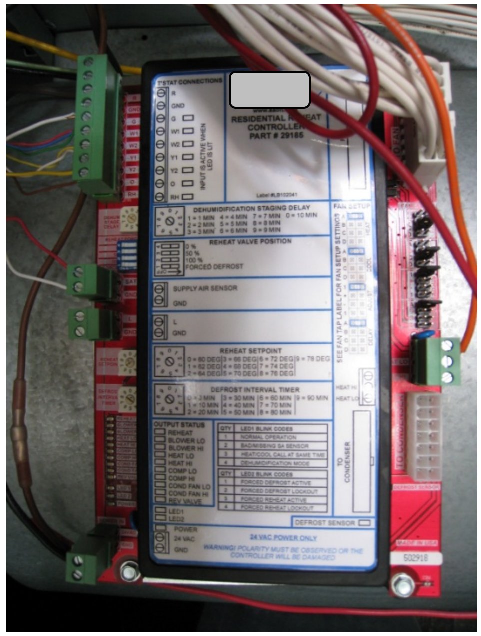

Figure 15. Controller with detailed settings and on-board diagnostics for the full condensing and subcooling reheat option with modulating hot gas reheat

Table 8 shows the humidity control performance of the full condensing and subcooling reheat option, compared to conventional cooling. This is the most energy-efficient option for effectively controlling indoor humidity near 50% RH. As shown in Table 8, this supplemental dehumidification control option is effective at controlling the indoor humidity near 50%–60% RH in all three warm-humid climate locations. There are a relatively small number of hours that remain slightly above the desired RH set point compared to the standalone dehumidifier or integrated ducted dehumidifier options. That is because those systems can provide supplemental dehumidification in parallel operation with the central cooling system whereas this system provides supplemental dehumidification in series (i.e., the priority of this system is to meet the temperature set point first, then the RH set point). For a HERS Index 50 house, the annual cost of controlling the indoor humidity to 60% RH is modest (< $15, or 4%–6% increase in total HVAC operating costs compared to the conventional system). Controlling indoor humidity near 50% RH increases total HVAC cost up to $35/yr, or 8%–13% more than the conventional system.

Table 8. Humidity Control Performance of the Full Condensing and Subcooling Reheat Option, Compared to the Conventional System

	Hours Above 62% RH	Hours Above 52% RH	Total HVAC Electric Without Furnace (kWh)	Total HVAC Costs With Furnace ($)	Comparison to Conventional System
Miami, HERS 50, CFIS					
Conventional System	627	3,280	2,821	288	100%
Full Condensing Reheat	–	–	–	–	–
60% Set Point	14	3,102	2,989	305	106%
50% Set Point	–	30	3,141	320	111%
Orlando, HERS 50, CFIS					
Conventional System	609	4,087	2,140	261	100%
Full Condensing Reheat	–	–	–	–	–
60% Set Point	13	3,716	2,300	276	106%
50% Set Point	–	50	2,465	294	113%
Houston, HERS 50, CFIS					
Conventional System	234	2,281	2,261	267	100%
Full Condensing Reheat	–	–	–	–	–
60% Set Point	12	1,977	2,402	279	104%
50% Set Point	–	60	2,498	288	108%

4.1.6 Direct Expansion Condenser-Regenerated Desiccant Dehumidifier Option

This supplemental dehumidification option involves a combination of DX refrigeration and desiccant drying in a ducted dehumidifier. The desiccant system is regenerated by condenser waste heat from the internal DX compressor. The advantage of this system is the ability to dry air to levels below 50% RH whenever that is desired, for example, for better dust mite control. This ducted unit has a fan that allows it to be integrated with the central cooling unit in a recirculation configuration (pulling air from the main zone and then supplying air into the central system supply duct). This configuration requires that the dehumidifier unit have a backflow damper to ensure the central system supply fan does not cause air to flow backward through the unit when the dehumidifier is off. The dehumidifier operates to maintain the humidity set point. To ensure distribution of dehumidified air, and for room air feedback to the centrally located dehumidistat, a fan control ensures that the central system fan runs a minimum of about 10 minutes each hour to provide mixing in the space, based on a recirculation turnover rate of 0.5 ACH.

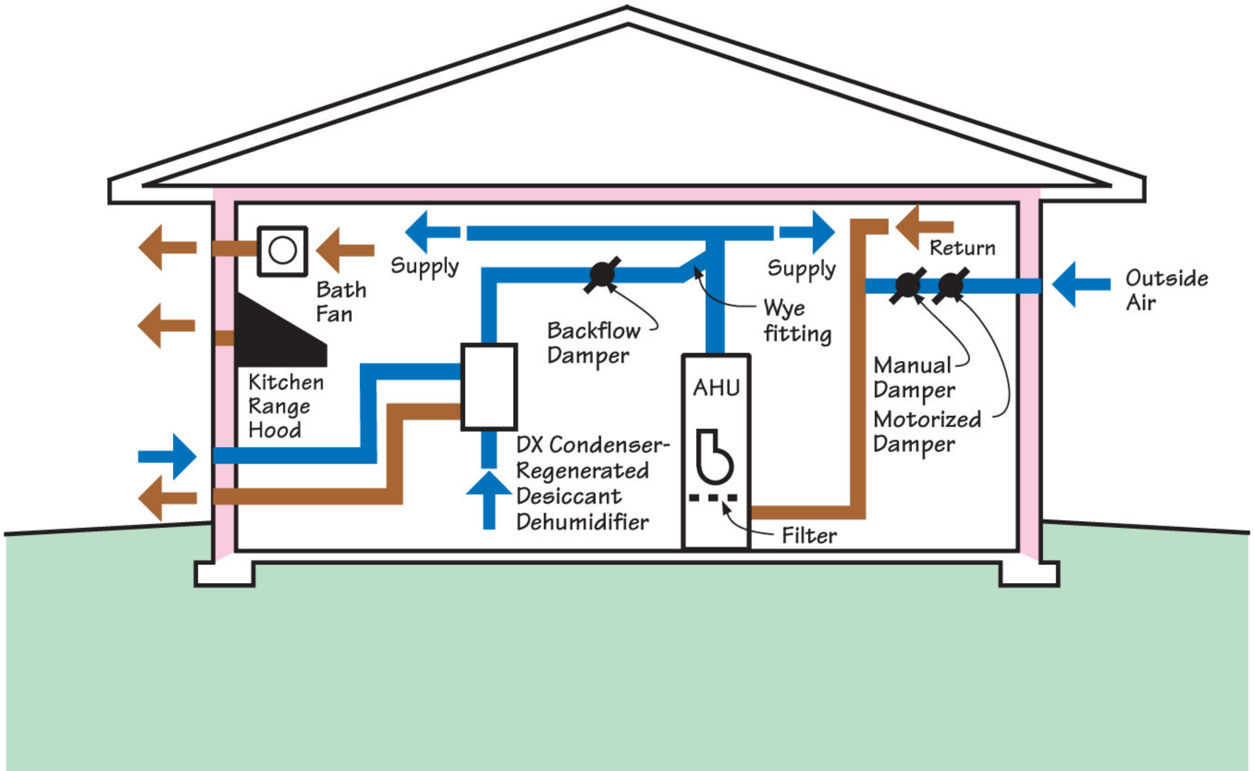

Figure 16. DX condenser-regenerated desiccant dehumidifier option

Table 9 shows the humidity control performance of the DX condenser-regenerated desiccant dehumidifier option, compared to conventional cooling. This supplemental dehumidification option works very much like the integrated ducted dehumidifier option except for having more moisture removal capacity at lower RH. This commercial-building-type system will effectively control indoor humidity below 50% RH in all three warm-humid climate locations. As shown in Table 9, for a HERS Index 50 house, the annual cost of controlling the indoor humidity to 60% RH is low (< $10, or 1%–4% increase in total HVAC operating costs compared to the conventional system). Controlling indoor humidity near 50% RH increases total HVAC cost up to $75/yr, or 11%–28% more than the conventional system.

Table 9. Humidity Control Performance of the DX Condenser-Regenerated Desiccant Dehumidifier Option, Compared to the Conventional System

	Hours Above 62% RH	Hours Above 52% RH	Total HVAC Electric Without Furnace (kWh)	Total HVAC Costs With Furnace ($)	Comparison to Conventional System
Miami, HERS 50, CFIS					
Conventional System	627	3,280	2,821	288	100%
DX Condenser-Regenerator Desiccant	–	–	–	–	–
60% Set Point	–	3,144	2,915	297	103%
50% Set Point	–	–	3,512	357	124%
Orlando, HERS 50, CFIS					
Conventional System	609	4,087	2,140	261	100%
DX Condenser-Regenerator Desiccant	–	–	–	–	–
60% Set Point	–	3,790	2,239	269	103%
50% Set Point	–	–	2,926	335	128%
Houston, HERS 50, CFIS					
Conventional System	234	2,281	2,261	267	100%
DX Condenser-Regenerator Desiccant	–	–	–	–	–
60% Set Point	–	2,006	2,304	270	101%
50% Set Point	–	–	2,639	297	111%

4.1.7 Gas-Regenerated Desiccant Dehumidifier Option

This supplemental dehumidification option is a gas-regenerated desiccant dehumidifier. The unit uses desiccant to further dehumidify high RH supply air coming off the conventional cooling system evaporator. It regenerates the desiccant by pulling in regeneration air from outdoors and then heating it via a gas burner and exhausting it back to outdoors. The 400 cfm unit has a dehumidification capacity of 145 pint/day (6.3 lb/h) at AHAM rating conditions. Gas consumption is 10,000 Btu/h. The advantage of this system is the ability to dry to levels below 50% RH whenever that is desired, for example, for better dust mite control. The dehumidifier and the central system must operate together to maintain the humidity set point.

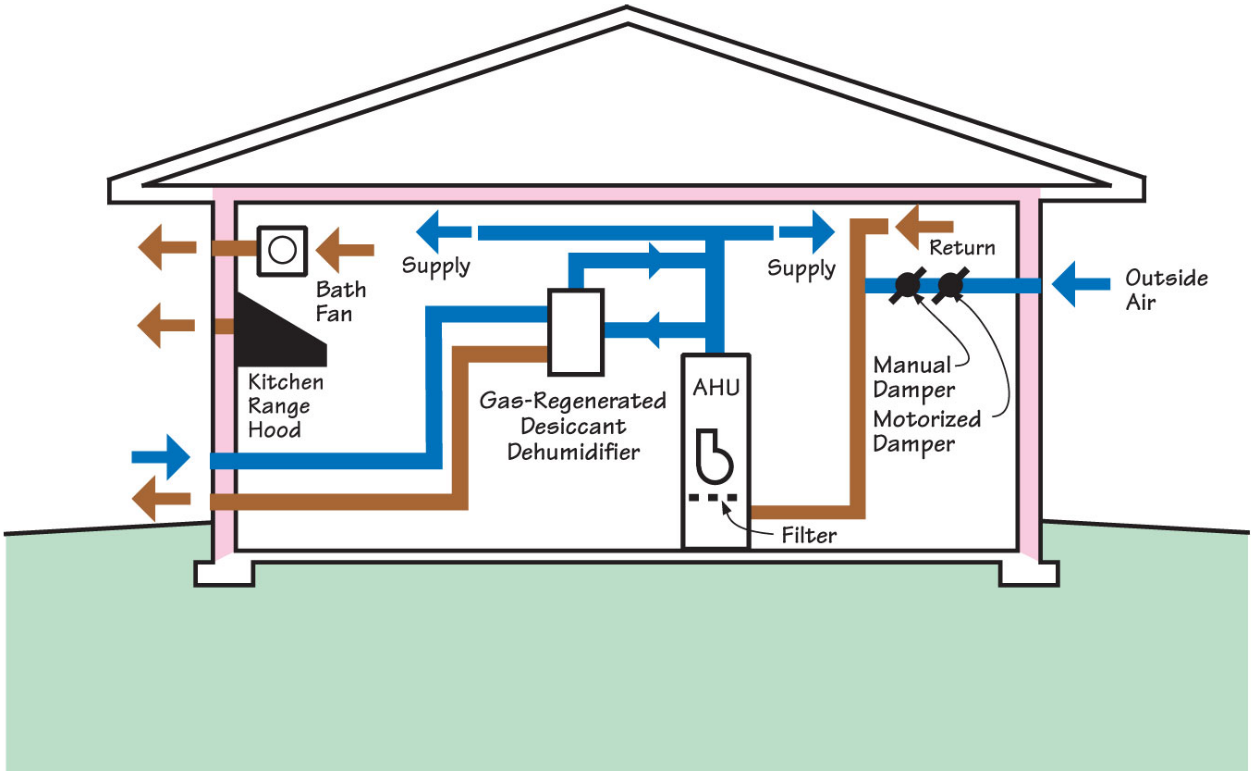

Figure 17. Gas-regenerated desiccant dehumidifier option

Table 10 shows the humidity control performance of the gas-regenerated desiccant dehumidifier option, compared to conventional cooling. This supplemental dehumidification option has high moisture removal capacity at lower RH. This commercial-building-type system will effectively control indoor humidity below 50% RH in all three warm-humid climate locations, but it has the highest operating cost. As shown in Table 10, for a HERS Index 50 house, the annual cost of controlling the indoor humidity to 60% RH is modest (up to $25, or 1%–9% increase in total HVAC operating costs compared to the conventional system). Controlling indoor humidity near 50% RH increases total HVAC cost up to $190/yr, or 23%–67% more than the conventional system.

Table 10. Humidity Control Performance of the Gas-Regenerated Desiccant Dehumidifier Option, Compared to the Conventional System

	Hours Above 62% RH	Hours Above 52% RH	Total HVAC Electric Without Furnace (kWh)	Total HVAC Costs With Furnace ($)	Comparison to Conventional System
Miami, HERS 50, CFIS					
Conventional System	627	3,280	2,821	288	100%
Gas-Regenerated Desiccant	–	–	–	–	–
60% Set Point	–	6,982	2,806	314	109%
50% Set Point	–	–	3,198	480	167%
Orlando, HERS 50, CFIS					
Conventional System	609	4,087	2,140	261	100%
Gas-Regenerated Desiccant	–	–	–	–	–
60% Set Point	–	7,207	2,119	279	107%
50% Set Point	–	–	2,482	434	167%
Houston, HERS 50, CFIS					
Conventional System	234	2,281	2,261	267	100%
Gas-Regenerated Desiccan	–	–	–	–	–
60% Set Point	–	4,010	2,234	270	101%
50% Set Point	–	–	2,443	329	123%

5 Verification Procedures and Tests

Ensuring Success

Enhanced Cooling Option:
1) Activate the lower airflow (cfm/ton) and overcooling at 50% RH set point or lower to be as effective as possible.

Standalone Dehumidifier Option:
1) The dehumidifier closet must have a louvered door for air transfer, and the closet should be close to the central system return air intake grille.
2) A remote dehumidistat in a representative living space location works better than a dehumidistat on the unit.

Stand-alone Ducted Dehumidifier Option:
1) Keep a good distance between the dehumidifier inlet and outlet grilles to avoid air short-circuiting.
2) Supply the warm, dehumidified air in a location that will not cause occupant discomfort or adversely affect temperature near the thermostat or dehumidistat.
3) A remote dehumidistat in a representative living space location works better than a dehumidistat on the unit.

Integrated Ducted Dehumidifier Option:
1) Use a Wye fitting where the dehumidifier supply duct connects to the central system supply duct/plenum. This will help move the air more uniformly through the duct system.
2) Use a backflow damper in the dehumidifier outlet duct.
3) A remote dehumidistat in a representative living space location works better than a dehumidistat on the unit.

Subcooling Reheat Option:
1) Activate at 50% RH setpoint for best possible humidity control.
2) Inform the occupants of the operation, as overcooling may elicit occupant comfort complaints.

Full Condensing Reheat Option:
1) Set the supply air temperature control set point for the expected room neutral temperature.

DX Condenser-Regenerated Desiccant Option:
1) Use a Wye fitting where the dehumidifier supply duct connects to the central system supply duct/plenum.
2) Use a backflow damper in the dehumidifier outlet duct.
3) Do a good job of air sealing the two duct penetrations through the building enclosure and locate them so as to avoid air short-circuiting.

Space conditioning equipment is only as good as its installation. For example, as obvious as it may seem, where a standalone dehumidifier is installed in a closet with a louvered door, make sure the discharge air faces the louvered door. Standalone dehumidifiers come with different air discharge configurations and if the warm-dry air is directed toward a side or back wall, the unit will cycle frequently and operate inefficiently.

All of the equipment discussed in this guideline condenses water from air. That water needs to be properly drained or pumped away. Verification to ensure that the drain pans slopes slightly toward the drain outlet ensures that little water will be stored in the system. Regular maintenance to make sure the drain pans and condensate lines are clean and draining properly is important. A secondary drain pan and associated piping should be installed in case of a primary drain failure, especially when the equipment is installed over any water sensitive material. Air filtration not only protects the equipment coils from getting dirty or clogged, but can improve indoor air quality by removing particle contaminants. Verify that the manufacturer's equipment maintenance literature is available to the occupants and that expected maintenance procedures have been explained to them.

Finally test and verify that the controls that operate the dehumidifier, and the central system where applicable, have been properly wired and are functioning in all modes as intended. Verify the proper RH set point and explain the reason for that setting to the occupant. In general, the RH set point should be set high enough (about

60% RH) in summer so that the dehumidifier does not need to operate when the cooling system is regularly operating. Outside of the regular cooling season, the dehumidifier RH set point can be set lower (50%–55% RH) to provide additional comfort control.

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