Whole-House Dehumidification

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Scope

In warm-humid climates, install equipment as needed to maintain indoor relative humidity (RH) at or below 60%.

- Install an HVAC system that includes cooling equipment with controls to operate in dehumidification mode.
- or, Install additional dehumidification equipment that is either stand-alone or integrated into the supply or return of a central forced air system.
- Properly size all heating and cooling equipment to accommodate the design loads for each room as determined using ACCA Manual J, ASHRAE Handbooks, or equivalent software, as well as the pressure drop from all specified filters.

See the Compliance Tab for related codes and standards requirements, and criteria to meet national programs such as DOE’s Zero Energy Ready Home program, ENERGY STAR Certified Homes, and Indoor airPLUS.
**Description**

High humidity levels inside the home are uncomfortable for occupants and can lead to mold, mildew, and rotting of building materials. Humidity in the homes is measured in terms of relative humidity (RH), which is the ratio between the actual amount of water vapor in the air and the maximum amount of water vapor the air can hold at a given temperature. Excessive humidity will condense on cold surfaces, encouraging the growth of mold and mildew and creating an environment conducive to dust mites and other pests.

Refrigerant-based air conditioning will dehumidify as well as cool the air. It cools by reducing sensible heat (lowering the temperature) and dehumidifies by reducing latent heat (removing humidity) from the air. If the HVAC system's coil temperature is below the dew point of the air (the temperature at which water vapor will condense into liquid water), the air conditioning system will remove moisture while also lowering the air temperature. Together, sensible heat and latent heat constitute the cooling load on an HVAC system.

Air conditioning equipment is sized based on peak-load outdoor design temperature, determined by the home's location. A home's total cooling load consists of a sensible load (temperature component) and a latent load (humidity component). Conventional systems generally dehumidify well during peak-load temperatures when the system operates for extended periods. At lower temperatures, the system cools the house relatively quickly and cycles off, but provides proportionally less dehumidification. As a result, indoor humidity levels tend to rise. This effect is exacerbated during cloudy or more humid days and also for newer, energy-efficient homes, which tend to have lower sensible loads but latent loads that can be the same or higher due to ventilation requirements [Home Innovation Research Labs 2017](#).

For maximum effectiveness, a well-designed HVAC system depends on an accurate room-by-room calculation of the heating and cooling loads. The system cooling load is calculated by summing the amount of sensible heat and latent heat that needs to be removed from the air. Important factors that contribute to sensible and latent heat calculations include outdoor climate, building orientation, building design, and other factors.

The optimal cooling system will be sized to meet its projected loads, resulting in better temperature and humidity control. Oversizing the cooling system can cause short-cycling of the equipment (i.e., short periods of “on” time when cooling is provided followed by long periods of “off” time when no cooling is provided). In homes with over-sized air conditioners, the thermostat quickly reaches the desired set point before moisture can condense on the coil and be removed from the home. In this situation, the temperature in the home drops but the relative humidity climbs.

In order to ensure proper sizing of heating and cooling systems, the HVAC industry uses the “[Manual J](#)” calculation worksheet developed by the Air Conditioning Contractors of America (ACCA). (See description below.) The Manual J worksheet accounts for factors such as the local climate, the orientation of the home, and the thermal performance of the building enclosure including windows, roofs, walls, and floors. After completing a Manual J load calculation, the HVAC designer then uses a procedure described in ACCA Manual S to properly select equipment capable of meeting both the sensible and latent heat loads in the home.

In hot-humid climates, the air conditioner alone may not be able to remove enough latent heat to keep relative humidity below 60%. In such cases, the HVAC designer should consider adding dehumidification by adding dehumidification controls or a separate dehumidifier. For more on solutions specific to Hot-Humid Climates, see the Home Innovation Research Labs TechNotes, [Humidity Control: Supplemental Dehumidification in Hot-Humid Climates](#).

**How to Improve Dehumidification in Warm-Humid Climates**

Types of equipment for providing dehumidification to homes include stand-alone dehumidifiers, central fan-integrated dehumidifiers, and additional dehumidification controls for existing HVAC systems.

**Stand-Alone Dehumidifiers**

Stand-alone dehumidifiers separate portable appliances (Figure 1). These self-contained portable units include all necessary components: the fan, controls, and coils. They generally run from an outlet plug and can be stored away during non-humid seasons. Some units have condensation reservoirs that must be emptied on a regular basis – controls will sound an alarm bell or trigger a light when the unit is full and will shut down operation to avoid spillage. Many units have both a reservoir bucket and a drain line, giving the homeowner the option to use either. If a drain line, it must be routed to the outdoors or to a drain inside the home. Portable dehumidifiers use a fan to pass room air over the condenser coils to cool the refrigerant for cycling. The exhaust air will be slightly warmer than the room air.

The major benefit of the stand-alone dehumidifier is the ability to control the indoor relative humidity in the home without having a major effect on temperature; i.e., they do not reduce indoor temperature like an air conditioner would while dehumidifying. This is valuable for climates that have a low sensible load but higher humidity (latent load), such as coastal climates.

Portable dehumidifiers have no installation costs so they are lower in cost than stand-alone ducted systems and systems integrated into a central air handler and they have about the same life expectancy as ducted and integrated systems. They may have less capacity depending on the size purchased and they may not dehumidify large, multilevel homes as consistently as centrally integrated systems; however, they can provide zoned dehumidification and provide good humidity control for problem areas like basements, kitchens, laundry rooms, or bathrooms.
Figure 1. A stand-alone dehumidifier can be installed in a closet with louvered doors; a dehumidistat can trigger the dehumidifier to turn on when relative indoor humidity reaches a set point. (Image Source: Supplemental Dehumidification in Warm Humid Climates, Building Science Corporation 2013)

Independent Ducted Dehumidifiers

An independent ducted dehumidifier is ducted separately from the home’s heating and cooling equipment (Figure 2). The dehumidifier can be installed in an attic, basement, crawl space, mechanical room, or closet and ducted to draw air from and supply air to the conditioned space. It could have one or more supply and return registers. Because it does not rely on the central HVAC system for distribution, it is ideal for homes with ductless HVAC systems. The inlet and outlet grilles should be separated as far as is practical within the home to improve air distribution. Locate the outlet grille so warm outlet air does not affect occupant comfort or a thermostat control. A wall-mounted humidistat control is recommended to measure room RH and reduce dehumidifier short-cycling.

Figure 2. An independent ducted dehumidifier draws air from and supplies air to the living space using its own ducts, not ducts that are connected to the HVAC system (Source: Home Innovation Research Labs).

Integrated Ducted Dehumidifiers

A ducted dehumidifier can be integrated with the central air conditioning distribution system as shown in Figure 3. The fan inside the dehumidifier unit draws air from the living space and provides the dehumified air to either the supply side or return side of the central air handler (as shown in Figures 4, 5, and 6). Figure 7 shows a dehumidifier that draws in air from both a return air grille located inside the home and an outdoor air intake so the system provides fresh air ventilation as well as dehumidification. The air is pulled through the dehumidifier and pushed into the supply air stream with the aid of the blower fan in the dehumidifier. Because this system warms the supply air slightly, during cooling periods this will force the air conditioner to run a little bit longer, which will dehumidify the air even more. Most dehumidifier include a high-efficiency filter.
Figure 3. A supplemental dehumidifier is integrated with the home’s HVAC air handler to provide extra dehumidification when needed. (Image courtesy of BSC)

Figure 4. A supplemental dehumidifier can be integrated with the central air handler to use the HVAC ducts for air distribution, with controls including a dehumidistat located in living space to switch on the dehumidifier and the central fan when extra dehumidification is needed. (Image Source: Supplemental Humidity Control, Building Science Corporation 2009)

Figure 5. The dehumidifier draws air from a common area in the house, dehumidifies it, and adds it to the supply side of the central air handler for mixing and distribution. (Source: Home Innovation Research Labs).
Figure 6. The dehumidifier draws air from a common area in the house, dehumidifies it, and adds it to the return side of the air handler for conditioning, mixing, and distribution. (Source: Home Innovation Research Labs).

Figure 7. The dehumidifier draws air from both a common area in the house and from outside, dehumidifies it, and adds it to the supply side of the air handler for distribution (image courtesy of Calcs Plus).

Additional Dehumidification Controls

Another option for reducing humidity in the home is to add additional dehumidification controls to the HVAC system that will operate the cooling system at a slower fan speed when in dehumidification mode. This allows the air to spend more time on the cold coil surface, which results in additional dehumidification. Because the system is still operating as an air conditioner, it is also decreasing the temperature in the home, which may result in potential comfort issues.

Adding controls to the HVAC system is generally less expensive than installing a central or stand-alone dehumidifier. However, this option is best suited to climates with shorter shoulder seasons because of the potential for comfort issues while running the air conditioner in cooler weather. The stand-alone dehumidifier may be a more costly upfront investment, but stand-alone dehumidifiers generally use less energy and thus cost less to operate than central air handlers and also operate with less risk of comfort issues in the home.

How to Select Dehumidification Equipment

1. The HVAC contractor is required to conduct a Manual J calculation of HVAC system design loads. See description below.
2. Use ACCA Manual S to right-size the HVAC. Supplemental dehumidification is not intended to be used as a means for compensating for over-sized HVAC equipment or excessive building leakage rates.
3. Calculate the dehumidifier capacity needed, as described below.
4. Select the dehumidifier option desired (stand-alone, independent ducted, integrated ducted) and install per manufacturer’s instructions.
5. Show equipment and installation details on plans, specifications, and scopes of work for subcontractors.
6. Specify recommended control set points, as required, for enhanced dehumidification (e.g., initiates at 55% RH) and supplemental dehumidification (e.g., dehumidifier initiates at 60% RH).
7. Avoid exhaust-only ventilation as it tends to depressurize a house, which, in turn, may increase infiltration of outdoor air and indoor humidity.
8. Provide cautions for homeowners:
   - Aquariums, large numbers of house plants, and hanging clothes to dry indoors all add significant amounts of moisture into the home.
   - Turning off the HVAC system or using a high set point (e.g., 80°F) could allow the relative humidity to rise (if installed supplemental dehumidification is integrated into the HVAC).
   - Don’t over ventilate during periods of extreme outdoor heat and humidity. High ventilation rates during these conditions could overcome the dehumidifier’s ability to maintain relative humidity at below 60% indoors.

How to Conduct a Manual J Calculation

A contractor can utilize one of the HVAC-industry adopted software programs based upon Manual J to assist with calculating
HVAC system design loads. Consult the ACCA website for a list of software programs to perform Manual J calculations.

A Manual J report includes climatic data, such as the “Outdoor Design Conditions” (found in Table 1 of Manual J 8). This information includes the local elevation, dry-bulb and wet bulb temperatures, and daily temperature range.

- Indoor design temperature and relative humidity for heating and cooling.
- Heat loss and gain for heating and cooling for each of the following elements of building loads:
  - windows and glass doors
  - skylights
  - wood and metal doors
  - above and below grade walls ceilings/roofs floors/foundations
  - air infiltration
  - internal gains – appliances and occupants duct location and tightness
  - ventilation loads.

Note: Indoor airPLUS Specification 7.3 requires the builder to provide the homeowner with a signed copy of the HVAC duct and ventilation system design documentation, including Manual J and Manual D analysis reports. (Manual D requirements are discussed in Indoor airPLUS Specification 4.2.) These reports should include room loads, duct system criteria by room, and duct layouts (e.g., drawings illustrating return sizes, supply trunks, run-out duct sizes, and the cubic feet per minute (cfm) of conditioned air delivered to each room).

**How to Size the Dehumidifier**

The Association of Home Appliance Manufacturers (AHAM) provides guidance on selecting dehumidifier capacity based on house square footage and indoor dampness conditions. Manufacturers provide recommendations based on house square footage, but recommendations vary by manufacturer. ACCA Manual S provides a method that uses the already required Manual J load calculation (Home Innovation 2017). Here is a more detailed methodology based on the Manual J calculation that takes into account performance at design conditions (from Calcs Plus).

1. After doing the Manual J, take latent load from the Manual J calculation (for example 3,868 Btu) and divide it by 1,054 Btu (which equals about 1 pint of water). This will give you pints per hour.

   \[
   \frac{3868}{1054} = 3.7 \text{ pints per hour}
   \]

2. Multiply this by 24 to get pints per day.

   \[
   24 \text{ Hours} \times 3.67 \text{ Pints per Hour} = 88.08 \text{ Pints per Day}
   \]

3. Then assume your air conditioner will cover about 15% of the humidity load if properly sized.

   \[
   \text{Multiply pints per day by } \frac{0.85}{1} = \text{ capacity of dehumidifier.}
   \]

   \[
   88.08 \text{ pints} \times 0.85 = 74.8 \text{ pints capacity}
   \]

4. You will want to size your dehumidifier for design conditions. Manual J design conditions are 75°F, 50% relative humidity (see Figure 8).

![Moisture Removal Adjustment](https://via.placeholder.com/150)

Figure 8. ACCA Manual S uses interior design conditions of 75°F and 50% relative humidity for specifying HVAC equipment. (Source
5. At these design conditions, the dehumidifier is operating at about 66% capacity. If the dehumidifier is only operating at 66% capacity, at design conditions, it is only removing 49.5 pints of water.

75 pints cap x .66 = only 49.5 pints in a day.

6. You want to size the dehumidifier so that when it reaches design conditions it will turn off rather than running constantly, so it must be sized for larger than 75-pint capacity.

75 pints / 0.66 = 113 pints capacity

7. Therefore, based on this example, you would install a dehumidifier that has a water removal capacity of at least 113 pints per day.
Ensuring Success

- The HVAC contractor is required to conduct a Manual J calculation of HVAC system design loads.
- Use ACCA Manual S to right-size the HVAC. Supplemental dehumidification is not intended to be used as a means for compensating for over-sized HVAC equipment or excessive building leakage rates.
- Show equipment and installation details on plans, specifications, and scopes of work for subcontractors.
- Specify recommended control set points, as required, for enhanced dehumidification (e.g., initiates at 55% RH) and supplemental dehumidification (e.g., dehumidifier initiates at 60% RH).
- Avoid exhaust-only ventilation as it tends to depressurize a house, which in turn may increase infiltration of outdoor air and indoor humidity.
Climate

The Warm-Humid region is the area below the white line, which includes all of climate zone 1, all of climate zone 2A, and portions of climate zone 3A, as shown in the IECC climate zone map below.

IECC Climate Zone Map

All of Alaska is in Zone 7 except for the following boroughs in Zone 8:
Bethel, Northwest Arctic, Dillingham, Southeast Fairbanks, Fairbanks N. Star, Wade Hampton, Nome, Yukon-Koyukuk, North Slope

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands
Training

Right and Wrong Images

Display Image: 2018-HabitatCat-6-Dehumidifier-in-Closed-Crawlspace.JPG
Compliance

The Compliance tab contains both program and code information. Code language is excerpted and summarized below. For exact code language, refer to the applicable code, which may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our webmaster if you find broken links.

DOE Zero Energy Ready Home (Revision 07)

Exhibit 1 Mandatory Requirements. 1) Certified under the ENERGY STAR Qualified Homes Program or the ENERGY STAR Multifamily New Construction Program. 6) Certified under EPA Indoor airPLUS.

EPA Indoor airPLUS

The Indoor airPLUS Verification Checklist, Item 4.1, states

NOTE: Completion of the ENERGY STAR checklists now satisfies the following Indoor airPLUS requirements:

Properly size all heating and cooling equipment to accommodate design loads for each room as determined using ACCA Manual J, ASHRAE Handbooks, or equivalent software, as well as the pressure drop from all specified filters (HVAC-C Section 2).

In "Warm-Humid" climates as defined by 2009 IECC Figure 301.1 (i.e., Climate Zone 1 and portions of Climate Zones 2 and 3A below the white line), equipment shall be installed with sufficient latent capacity to maintain indoor relative humidity (RH) at or below 60 percent. This requirement shall be met by either:

- Additional dehumidification system(s), OR
- A central HVAC system equipped with additional controls to operate in dehumidification mode.

Exception: Climate Zones 4-8, 3B, 3C and the portions of 3A and 2B above the white line as shown by 2009 IECC Figure 301.1.

Advisory: Although not required to meet this specification, independent dehumidification is recommended in Climate Zones 4A and 3A above the white line as shown in 2009 IECC Figure 301.1.
Case Studies

1. Technology Solutions Case Study: Improving Comfort in Hot-Humid Climates with a Whole-House Dehumidifier
   Author(s): CARB
   Organization(s): CARB
   Publication Date: November, 2013
   Case study describing how to decrease indoor moisture using an air conditioning unit with a dehumidifier in hot-humid climates.

References and Resources*

1. ACCA Manual D - Residential Duct Systems
   Author(s): Air Conditioning Contractors of America
   Organization(s): Air Conditioning Contractors of America
   Publication Date: December, 2013
   Standard outlining industry procedure for sizing residential duct systems.

2. ACCA Manual J - Residential Load Calculation
   Author(s): Air Conditioning Contractors of America
   Organization(s): Air Conditioning Contractors of America
   Publication Date: January, 2011
   Standard covering equipment sizing loads for single-family-detached homes, small multi-unit structures, condominums, town houses and manufactured homes.

3. ACCA Manual S - Residential Equipment Selection
   Author(s): Air Conditioning Contractors of America
   Organization(s): Air Conditioning Contractors of America
   Publication Date: April, 2013
   Standard covering sizing strategies for all types of cooling and heating equipment, as well as how to use comprehensive manufacturer’s performance data on sensible, latent, or heating capacity for various operating conditions.

4. DOE Zero Energy Ready Home National Program Requirements (Rev. 07)
   Author(s): Department of Energy
   Organization(s): DOE
   Publication Date: May, 2019
   Standard requirements for DOE’s Zero Energy Ready Home national program certification.

5. Humidity Control: Supplemental Dehumidification in Hot-Humid Climates
   Author(s): Home Innovation Research Labs
   Organization(s): Home Innovation Research Labs
   Publication Date: December, 2017
   Fact Sheet describing the need for supplemental dehumidification, dehumidifier configuration options, and design considerations.

6. Indoor airPLUS Construction Specifications Version 1 (Rev. 03)
   Author(s): U.S. Environmental Protection Agency
   Organization(s): EPA
   Publication Date: October, 2015
   Document outlining specifications that were developed by the U.S. Environmental Protection Agency (EPA) to recognize new homes equipped with a comprehensive set of indoor air quality (IAQ) features.

7. Residential Dehumidification Systems Research for Hot-Humid Climates
   Author(s): Rudd, Lstiburek, Eng, Ueno
   Organization(s): Building Science Corporation, National Renewable Energy Laboratory
   Publication Date: February, 2005
   Research study identifying the best performing, most energy-efficient and cost-effective techniques to provide controlled mechanical ventilation and humidity control in hot-humid climates with thermally efficient building envelopes.
8. **Supplemental Dehumidification in Warm-Humid Climates**  
   **Author(s):** Rudd  
   **Organization(s):** Building Science Corporation  
   **Publication Date:** July, 2013  
   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.

9. **Supplemental Humidity Control**  
   **Author(s):** Building Science Corporation  
   **Organization(s):** Building Science Corporation  
   **Publication Date:** May, 2009  
   Information sheet offering general recommendations on supplemental humidity control and outlines viable system configurations.

*Publication dates are shown for formal documents. Dates are not shown for non-dated media. Access dates for referenced, non-dated media, such as web sites, are shown in the measure guide text.

**Contributors to this Guide**  
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