HVAC for Raters & Inspectors

A Practical Overview of HVAC Impacts On Home Performance With Useful Take-Away Tools

Presenter: David Slater

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Topics

1. **HVAC System Types & Fuels**
2. **HVAC Design Process & Load Calculations Overview**
3. **Duct Size Guidelines**
4. **Airflow, Variable Speed Blowers & Zoning**
5. **Combustion Venting & Carbon Monoxide Safety**
6. **Common Conditions For Fungal (Mold) Growth**
7. **Recognizing Great HVAC Systems**
8. Particulate Filtration
9. Fresh Air Ventilation
10. Dehumidification

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- Please consult a licensed professional HVAC contractor for *repairs, alterations* and *installations* requiring licensure in that state.

- Sub-system level diagnostics such as refrigerant pressures, temperatures, compressor current, etc. are useful in assessing performance or diagnostic issues and typically best performed by a certified HVAC technician.

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Residential System Types & Fuels

- Configurations: 1) Split systems 2) Packaged units

ODU

- Either configuration may be Gas furnace & AC, heat pump, or dual fuel ("hybrid"). Splits may have oil boiler with hydronic or forced air distribution.

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Residential System Types & Fuels

Furnaces vs. Heat Pump Air Handlers (AHU's)

- Furnaces have blower near inlet – most air leaks blow out.
- Air Handlers have blower nearer to outlet – most air leaks suck air in!

Air Handler Unit (AHU)

Furnace and Evaporator Coils

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Residential System Types & Fuels

- Furnace and air handler models are designed for specific orientations which may include upflow, downflow, left, right.
- Many newer popular furnace models have multiple stages of heating. Some now are "modulating".
- Higher end AC's (ODU) have two stage compressors, and some now are variable speed.
- Different thermostats must have multi-stage capability to suit.
- ODU label model numbers contain compressor size info as a multiple of 6. Since there's 12,000 BTUH per Ton of cooling, 6 represents a 0.5 Ton. E.g. TWR036A1000 is 3 Tons.
- Furnace/Boiler model numbers contain BTU/Hr inputs. E.g. TUD080A1000 is 80,000 BTUH input.

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Residential System Types & Fuels

<u>Gas Furnace Generations</u>

1. Natural Draft
   - Metal flue pipe, large slot for incoming combustion air under pipe.
   - Upflow configuration.

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Residential System Types & Fuels

Gas Furnace Generations

2. 75% Induced Furnaces
   - Inducer fan on outside of furnace cabinet.
   - 75% AFUE
   - Metal flue pipe.

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Residential System Types & Fuels

Furnace Types (By Generation)

3. "80%" Generation. Split furnaces are typically 86% AFUE. Inducer fan and metal flue pipe.

4. "90%" Generation (90 – 98%). A.K.A. condensing furnaces. These make water condensate during heating operation. Special precautions required for cold ambient unit locations. PVC flue pipe.

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Residential System Types & Fuels

- Mini-Splits ("ductless") units offer advantages in the proper application, such as larger open spaces, additions, sun rooms, etc. Most are variable speed with many other features.

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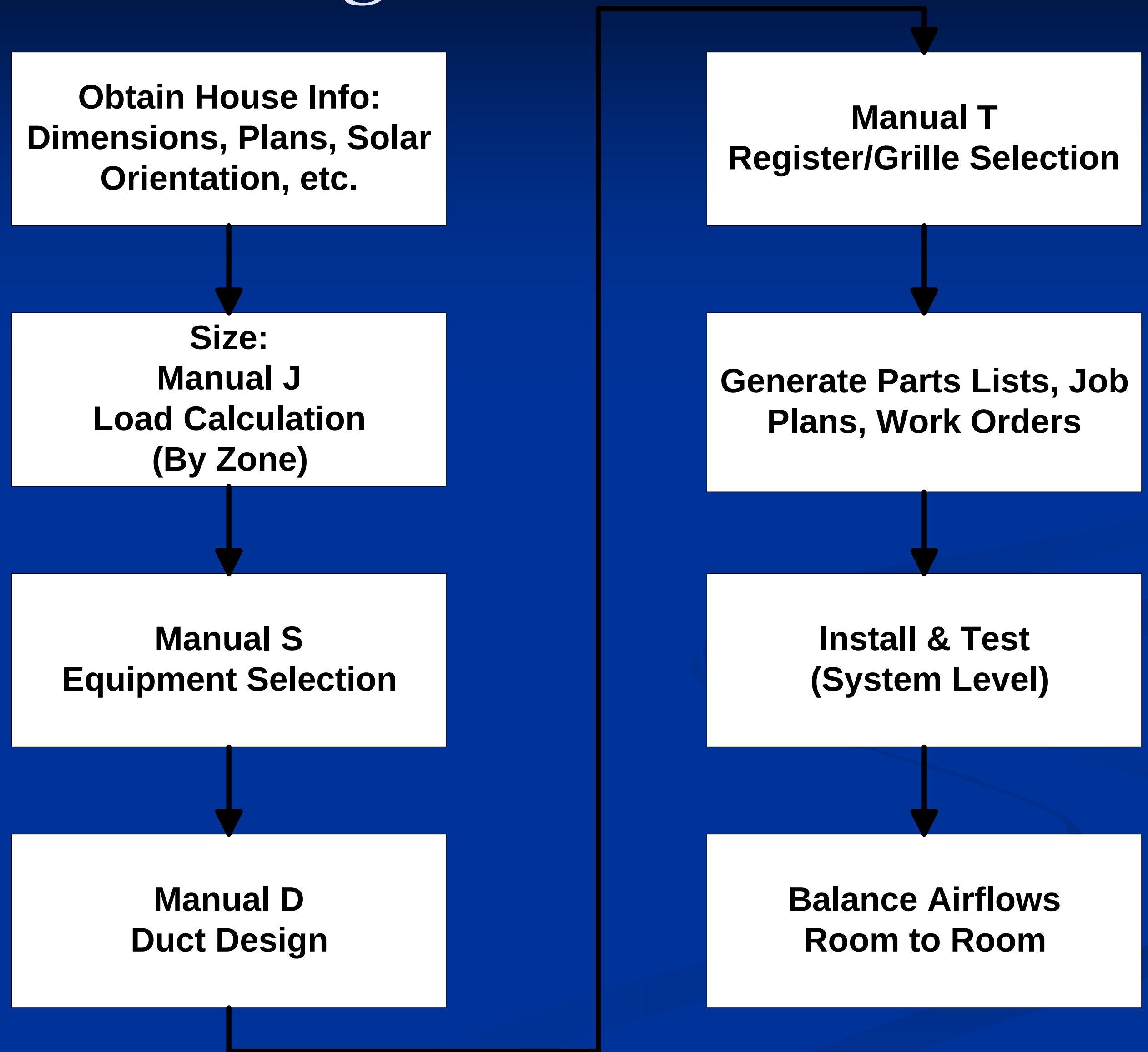
HVAC Design & Installation Process



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Anatomy of a Load Calculation

- Indoor target (design) temperatures can make an enormous difference in the resulting size of system. Should be 68° or 70°F heating, 75°F cooling, 50 or 55% RH summer.
- Heating, sensible cooling and latent cooling (moisture removal) must all be satisfied in selecting equipment.
- <u>Critical</u> inputs into Manual J Load Calculation:
  - Climate – use ACCA/ASHRAE table values
  - Duct system location, sealing and insulation levels
  - Solar gain
  - Window construction type and size

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Anatomy of a Load Calculation

- Other inputs into Manual J Load Calculation:
  - Envelope insulation and infiltration. Consider impact of holes in thermal or air barriers – fix the envelope!
  - Above grade vs. below grade walls
  - Occupant window treatments, behaviour
  - Architecture (e.g. open cathedral ceiling up to second floor)
- Field installation & problem solving experience usually improves the efficacy of the designer's calculations. Conversely, a load calculation's input numbers can be manipulated to produce a range of resulting "sizes".

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Equipment Selection

- Equipment is often selected as deliberately oversized for one or more required load "sizes" (heating, sensible, latent), usually due to limitations in equipment availability.
  - Example: very few if any furnaces are available in southern (mixed) climates which exactly meet both cooling and heating loads. Manufacturers typically make one or two furnace sizes for each cooling size. With a furnace that can handle a 3.0 Ton ODU, heating inputs are typically 60k – 100k BTU/Hr.
- Combinations of heating/cooling equipment must be tested by AHRI labs and show a certificate to meet Federal Tax Credit.

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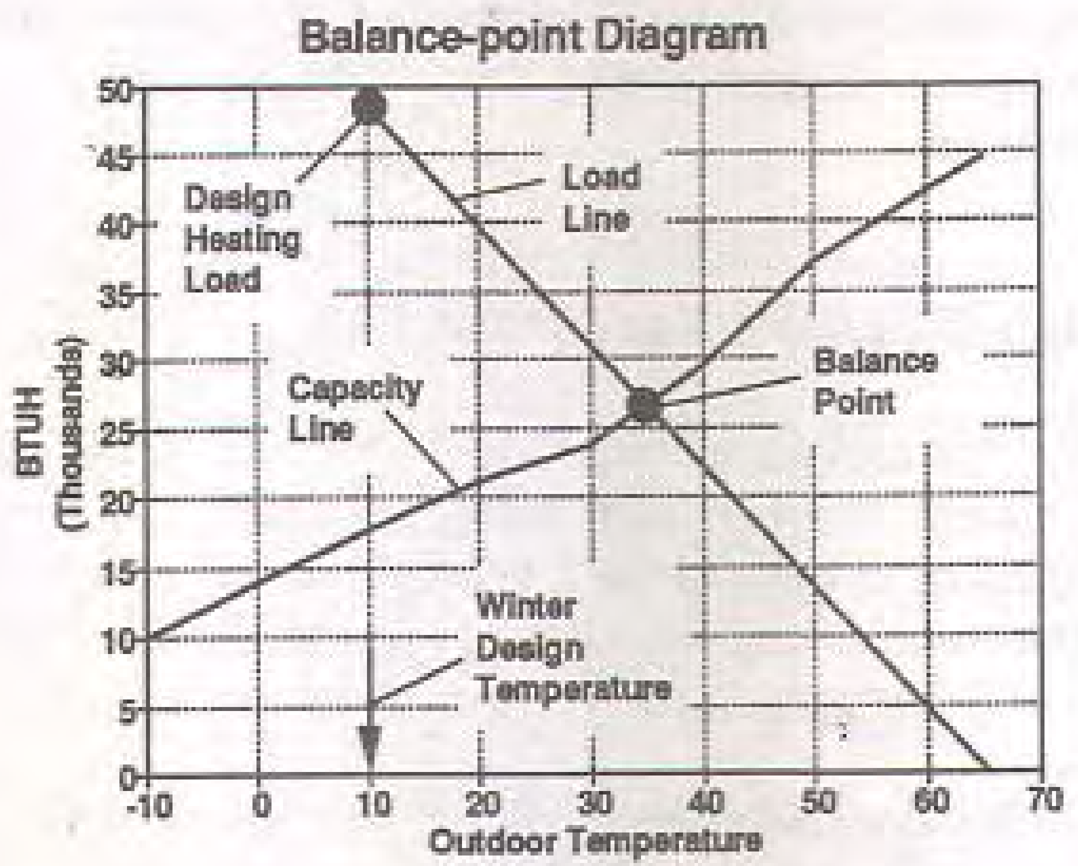
Air-to-Air Heat Pump Equipment Selection



ACCA Manual S

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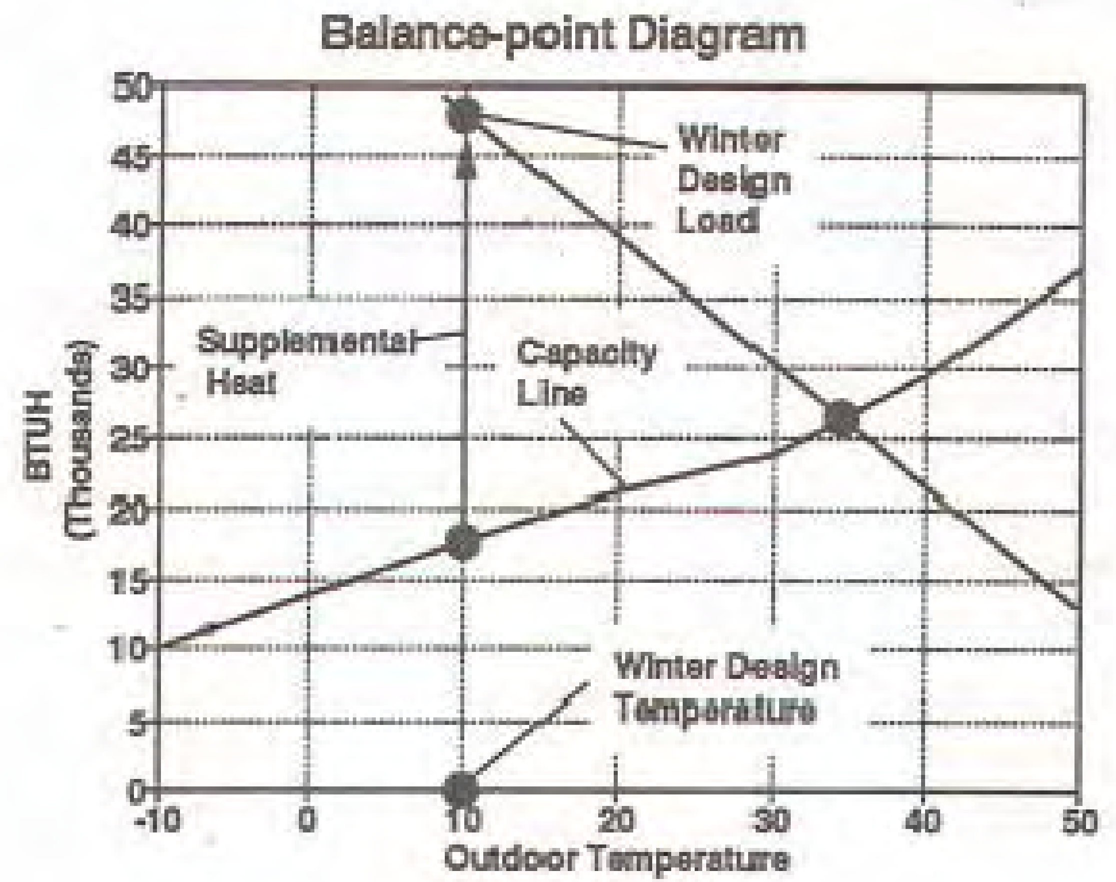
Air-to-Air Heat Pump Equipment Selection



ACCA Manual S

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North Carolina Mech. Code Update

- New general statute enforcement as of Jan. 1, 2010 requires load calculations and floor-to-floor zoning for all new construction and retrofit installations. New construction room by room; retrofit may be by whole house "block load" calculations. Zoning may be achieved by a separate HVAC system or zoning controls.
- "…designed and installed to maintain a maximum temperature differential of 4 degrees Fahrenheit room-to-room and floor-to-floor."
- "If a load calculation was not performed or if a load calculation was performed and it is later determined by the Board that the unit installed was undersized or oversized, the installation will be considered as evidence of incompetence." - NCDOI

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Duct Design & Sizing

- Ducts are to be designed based on ACCA Manual D.
- Equipment size determines required airflow for cooling and heating.
- Undersized air Return grilles, return building cavities and return trunks typically create the most common "bottle necks" in duct systems.
- Problems from undersized duct systems include:
  - Low airflow
  - Reduced energy efficiency, capacity and comfort
  - Noisy air existing registers
  - Increased risk of mold growth inside ductwork

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Duct Sizing

- Other duct system problems include: air leaks, poor air flow balancing, comfort issues, poor indoor air quality, poor mixing of air, un-insulated ductwork.
- Poorly designed ductwork often can't balance airflow room to room.
- Properly designed ductwork often is balanced with very little or no adjustment necessary of the volume control dampers to each room.
- 1" return air filters must not be too restrictive for any given size.

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Return Air Filters

- Common 1" furnace filters often reduce system airflow due to infrequent replacement, undersized return filter grille design, and/or too high MERV rating of filter.
- 1" furnace filters are NOT designed with the adequate surface area to perform as a "whole house" air cleaner.
- May increase duct leakage due to high pressure drop.
- Recommend the cheapest pleated furnace filter available, and then have an HVAC contractor install a suitable whole-house filtration system, resulting in cleaner evaporator coils, lower risk of mold in ducts, higher energy efficiency, cleaner air, lower filter costs.

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Flex Duct Field Guide

- "Typical maximum duct sizes are listed below. See Manual D for details. ***Caution: Duct connections, fittings, other design and installation aspects will significantly impact the validity of these rules of thumb.*** "
- See hand-out.

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Flex Duct Size	Max Airflow [CFM]	Cooling [Tons]	Typical Grille
Supply Branch 6”	100	0.2	4x10, 4x12
Supply Branch 7”	130	0.3	4x12, 4x14, 6x10
Supply Branch 8”	180	0.4	4x14, 6x12, 6x14
Supply Trunk 10”	280 - 360	0.9	
Supply Trunk 12”	440 – 520	1.3	
Supply Trunk 14”	580 – 720	1.8	
Supply Trunk 14” Short/Plenum	700 - 850	2.1	
Supply Trunk 16”	800 – 1,000	2.5	
Supply Trunk 16” Short/Plenum	960 – 1,200	3.0	
Return Trunk 14”	600	1.5	14x25, 16x20
Return Trunk 16”	780	2.0	20x20
Return Trunk 18”	1,000	2.5	

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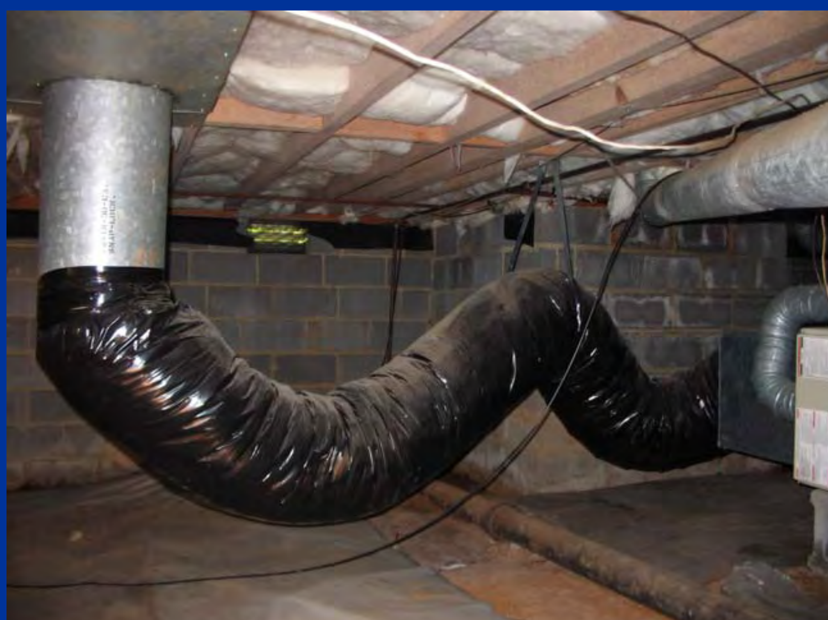

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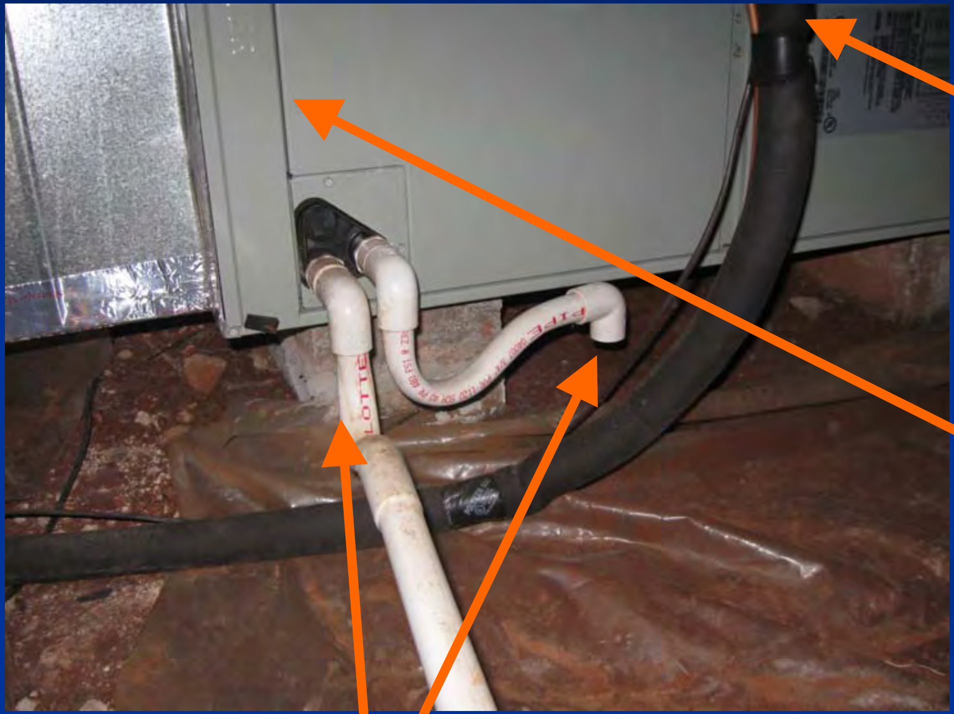
Duct Air Loss – The Sneaky Leaks



Leaks Around Line Set Entry Holes

Leaks In Cabinetry

Air Sucking In P-Traps on Air Handlers

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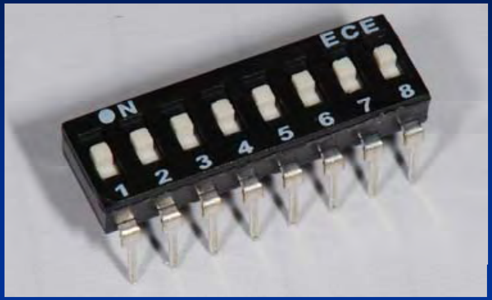
Airflow and Blowers



- "Single speed" blowers have a few hard wired speeds to choose from but does not change once field wired. If duct system presents too much resistance to blower, lower air flow will occur.
- Variable speed blowers automatically try to adjust speed to meet selected airflow requirements via DIP switch settings on the control circuit board. If duct system presents too much resistance, blower will try to accommodate using more energy, increasing duct leakage and noise.
- Variable speed blowers don't guarantee actual airflow! You must measure airflow directly if you need to know actual airflow.
- There's no substitute for properly designed ductwork!

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Measuring Air Flow

Methods:

1. Static Pressure and Manufacturer's performanace table data. Accurate and quick.
2. Heat Pump Heat Rise Method – measure temperature differential of Return and Supply air temperatures when only resistance heat is on, avoid radiant energy, measure current and voltage and calculate kilowatts, then convert to BTUH. Accurate, takes time.
3. Duct Pressurization Test on "zero cruise". Accurate with a skilled field technician, takes time.

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Measuring Air Flow

Methods:

4. Airflow Capture Hood – typically used for commercial. Can be within +-15% accuracy with training and quick.

5. Furnace Heat Rise Method – measure temperature differential of Return and Supply air temperatures and calculate heat input from timing the gas meter and furnace AFUE. Inaccurate and cumbersome at best.

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Static Pressure Measurement Overview

- Measure positive air pressure in supply plenum. Measure negative air pressure in return plenum. Add numbers and reference the manufacturer’s performance tables.
- Example: TESP = +0.45 + 0.35 = 0.8 w.c. (inches water col.)

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Tips For Measuring Air Flow

- Ensure HVAC fan is on at 100% speed. Many variable speed blowers will be set for 50% speed when the thermostat is set to "FAN ON". Set for maximum cooling and wait for variable speed blower to reach 100%.
- If outdoor ambient below 65°F, pull the disconnect on the ODU to prevent damage to ODU compressor!
- If Zoned, ensure all zones calling for maximum cooling.
- Many "single speed" blowers set for two different speeds for heating than cooling. Which are you measuring?

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Recognizing Zoned Systems

- Zoning panel (circuit board), zone motorized dampers, and (hopefully) a by-pass duct/damper.
- Multiple thermostats for one HVAC system - One thermostat per zone.




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Combustion & "CO"

- Flue pipes must be intact and installed properly
- Back-drafting other appliances – e.g. natural draft water heater in same space as non-direct vented furnace and space is tight.
- Certified Combustion Analyses can be performed on all combustion appliances to determine performance and safety factors.
- Get certified and work with HVAC contractor

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Combustion Safety Issue Examples

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Combustion Safety Issue Examples

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Fungal Growth In HVAC

Some common conditions for fungal growth may include:

- Low airflow with unsealed ductwork during A/C
  - Low airflow, due to a variety of reasons, produces overly chilled air temps and an introduction of humidity may create condensation inside ductwork.
- Evaporator coils and drain pan
- Unsealed vent boots at registers – allows attic/crawl space humid air into cool air stream at registers.

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Fungal Growth In HVAC

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Recognizing Great HVAC Systems

- Right size capacity
- Matched system components
- High efficiency
- Right duct sizes & design
- Sealed ductwork
- Meets all Codes
- Full system test performed post-installation
- Condensate water overflow safety switches and sensors

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Recognizing Great HVAC Systems

- Air balanced room to room, accessible volume control dampers
- Direct vented furnaces
- Variable speed blowers
- Accessibility for future service
- Access to clean evaporator coils
- Quiet operation
- Level solid mounting
- Ducts insuled on outside with "wrap"

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Hard To Recognize

The difficult things to identify are technician installation best practices, control strategy and wiring accuracy, and correct refrigeration:

- Technicians *should* always pull a "triple vacuum" in the refrigeration system, nitrogen purge during brazing, oil removal, accurate weight scales, measure correct refrigerant charge.

TXV (Thermal Expansion Valve) now comes standard on all high efficiency equipment, usually found on evaporator coils; also on ODU for heat pumps. Need to know this to measure sub-cooling or super heat for refrigerant charge.

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Recognize TXV

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Filtration Device Types

- Media Filter – media physically captures particulate
- "Electronic" – electro-statically charged plates capture particulate
- Hybrid media and electro-static
- In-line vs. By-pass type: By-pass air cleaners have their own blower motors and require different ducting, connections and controls

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Fresh Air Ventilation Methods

1. Duct into Return plenum
2. Duct into Return plenum with fixed dampers, filters, etc.
3. Duct into Return plenum with automated damper and better controls
4. Energy Recovery Ventilator (ERV) or Heat Recovery Ventilator (HRV)

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Energy Recovery Ventilators (ERV)

ERV is an indoor air quality device that delivers the fresh outdoor air of opening a window but without the loss of energy.

- Removes stale air from house
- Introduces same amount of fresh air
- Has an enthalpic core (special heat exchanger) which transfers the heat and humidity from incoming air stream to outgoing stream.

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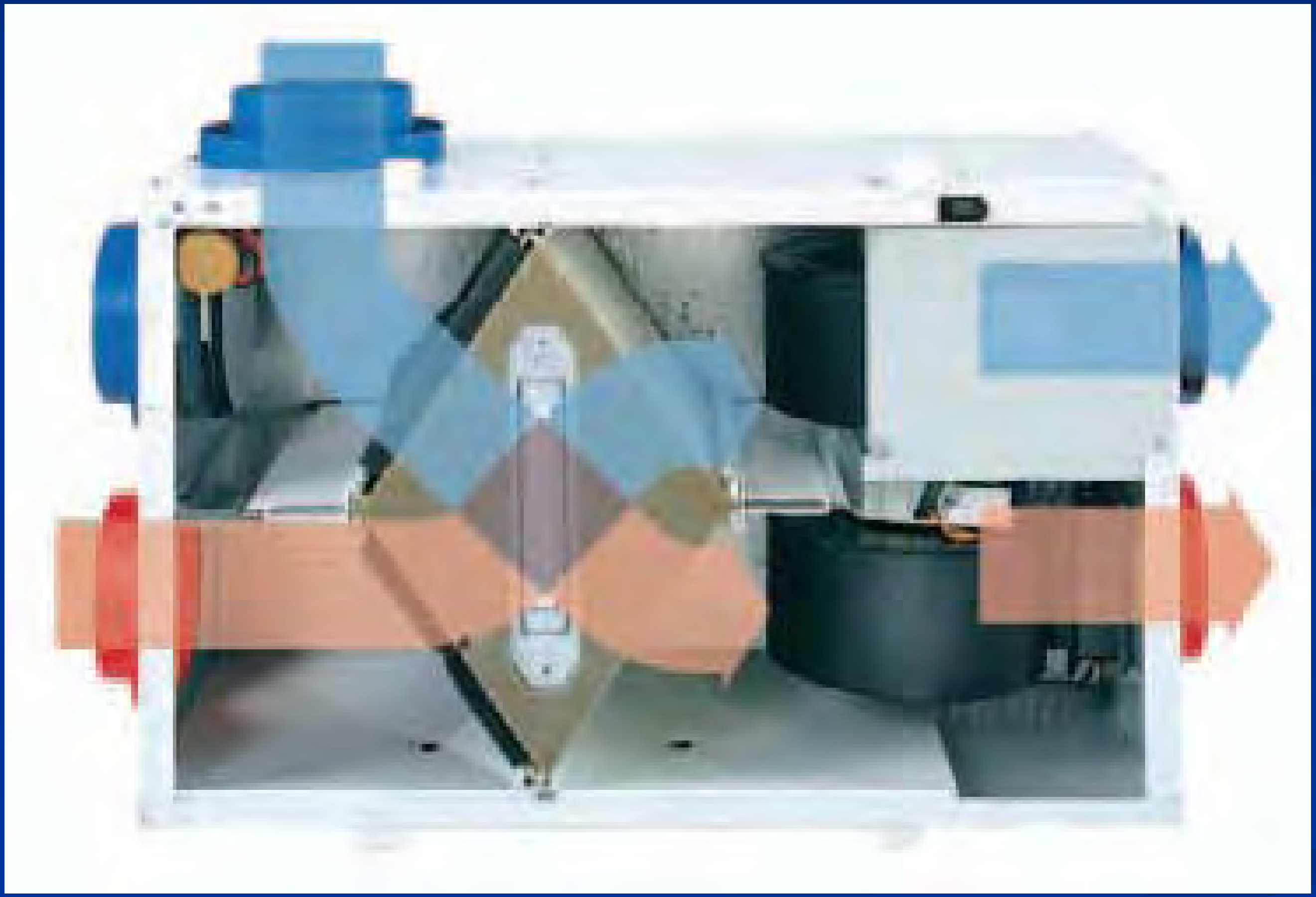
Energy Recovery Ventilators



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Energy Recovery Ventilators

The Necessity of Fresh Air Ventilation

Nearly every building research, government and industry expert agrees that fresh air ventilation is recommended in homes. It removes and dilutes polluted air and restores proper carbon dioxide levels. It is part of a total indoor air quality strategy. ERV's are the best method of fresh air ventilation.

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Energy Recovery Ventilators

<u>The Necessity of Fresh Air Ventilation</u>

- Older homes with “leaky” envelopes experience significant natural air infiltration. However, the source of the air usually comes from the crawl space or attic. This does not improve IAQ.
- New high performance homes have ultra-tight envlopes and require fresh air ventilation.
- Typical new homes with “tight” envelopes have some of both problems above.

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Energy Recovery Ventilators

ERV vs. HRV:

- HRV (Heat Recovery Ventilator) designed for colder climates.
- ERV designed for warmer climates with longer more humid cooling seasons. Enthalpic core transfers moisture as well as heat.

Cost: $1,500 to $3,000

Brands: Honeywell, Venmar, Carrier, Broan, Aprilaire, Ultimate Air, etc.

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Energy Recovery Ventilators

Common Problems:

- Airflow is “short circuiting” due to poor duct design (on either side of a plenum)
- Exhaust stream intake grille is located in bathroom or kitchen
- Low Total Recovery Effectiveness performance (leading to higher indoor humidity)

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Energy Recovery Ventilators

Common Problems:

- Fresh air from ERV ducted into a small heating/cooling air handler plenum (results in re-evaporation)
- Installed so that ERV blower is fighting against heating/cooling air handler blower

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Energy Recovery Ventilators

Proper Design and Installation of ERV's are CRITICAL to their effective operation and resulting improvement in indoor air quality!

Topic Q&A

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Central Dehumidifiers

The Benefits: Maintains proper indoor humidity levels (50-60% RH) whenever,

- A/C system does not run (spring, fall, equipment failure)
- A/C system is oversized
- House envelope or duct system are so leaky that A/C cannot wring out the enormous amounts of infiltrating humidity before its thermostat shuts it off

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Central Dehumidifiers

Oversized A/C systems won't control humidity. Evaporator coils require 8-10 minutes to produce condensate; if system short-cycles and runs less than 10 minutes, air will become cold and clammy (uncomfortable). Mold growth on walls may result. Oversized systems also cost more, cycle more and fail sooner.

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Central Dehumidifiers

<u>Cost:</u> $1,500 to $3,000

<u>Brands:</u> Aprilaire, Thermastor, Honeywell, etc

<u>Common Problems:</u>

- Installed before fundamental problems (such as duct leakage, envelope leakage, moisture issues, etc.) are resolved first
- Installed with blower fans fighting each other

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Central Dehumidifiers

<u>Common Problems:</u>

- No auxilliary drain pan or overflow safety switch for attic installation
- Ducting resulting in too much airflow by-passing around A/C evaporator coils (proper A/C airflow is critical)
- Poor maintenance or operation by homeowner

<u>Topic Q&A</u>

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Q & A

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"House As A System"

Building Performance is the new broadly-scoped industry that promotes designing, building and retrofitting homes to be healthy, comfortable, energy efficient, durable and sustainable.

A key concept of building performance is to see the *house as a system* with the various parts interacting with one another. Example: sealing air ducts improves indoor air quality, energy efficiency and comfort.

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