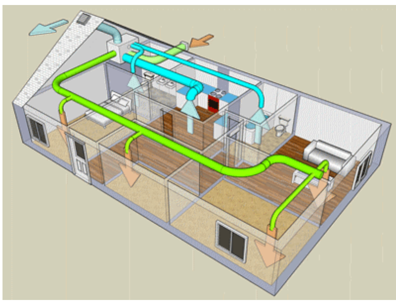
2019 EEBA Conference: Emerging Smart Ventilation Strategies & Indoor Air Quality Monitoring



Oct. 3, 2019

Bryant Hains

&

Mike Barcik

www.southface.org

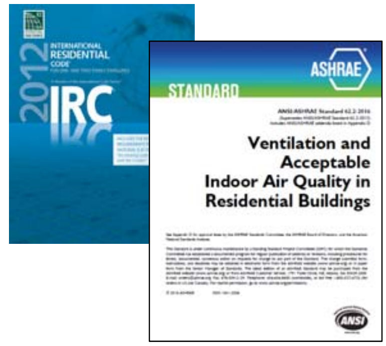
=> Education => Courses => Energy Code => GA Energy Code

Appropriate Ventilation Strategies for Mixed/Hot Humid Climate (White Paper)

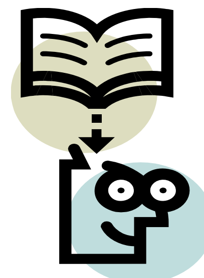
About Southface

https://vimeo.com/169382048/c973625071

Topics Covered



- Ventilation & Indoor Air Quality
- Using the IRC & ASHRAE 62.2
  to determine ventilation requirements
- What strategies have traditionally been used?
- Explaining the concepts of smart ventilation
- Research project details –
  ERV with smart controls
  in Charleston SC



Brett's Singer's IAQ Recommendations

"Our Hero"

- Understand people have the biggest impact on IAQ
- Keep home dry (and mold free); dehumidify as needed
- Avoid emitting large quantities of contaminants in home
- Ventilate when emitting (cleaning, hobbies, chemicals in consumer products)
- Use spot ventilation (kitchen, bath, toilet exhaust, laundry, clothes closet)
- NO UNVENTED COMBUSTION APPLIANCES!!! (no people air for combustion air)
- Use natural ventilation when outdoor conditions are "clean"
- Have tight envelope and ducts; close house when outdoors is polluted
- Check radon and formaldehyde
- Install good (thick, pleated) AHU filter with no leaks or bypass;
  (confirm low ΔP)
- Use efficient variable speed AHU motor (ECM)

Indoor Pollutant Sources

Biological agents

Chemicals

Combustion

Outdoor Pollutant Sources

Keys to good Indoor Air Quality

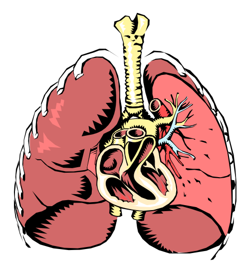
1. Eliminate (remove pollutant source)
2. Separate (seal or contain pollutants)
3. **Ventilate** (dilute pollutants)
4. Filter (clean and remove pollutants)

"Pollutants need a Pathway to People…"

"…and are pushed by positive pressure!"

What's the Purpose of Ventilation?

- Provide fresh air for the occupants

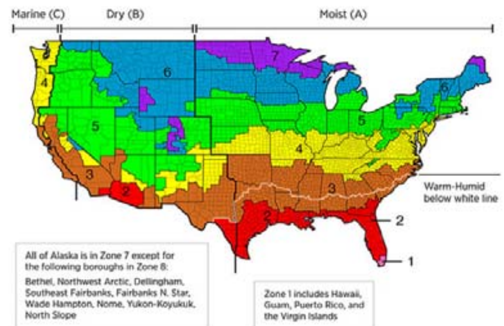


- Dilute pollutants

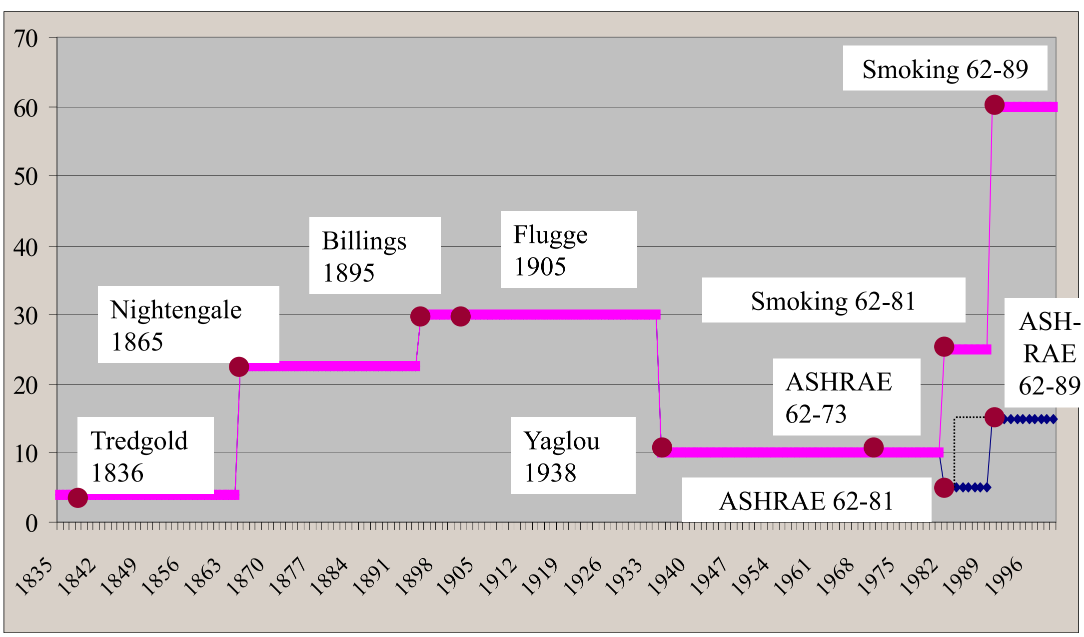
Ventilation Practicality

"Perfect can be the enemy of Good"

- Houses are tight (and getting tighter)
- Fresh air is important – want good ventilation!
- We don't know exactly how much
- We don't all agree on how to best ventilate
- What works in some places isn't necessarily good in other places



Historical Minimum Ventilation Rates
(cfm/person)



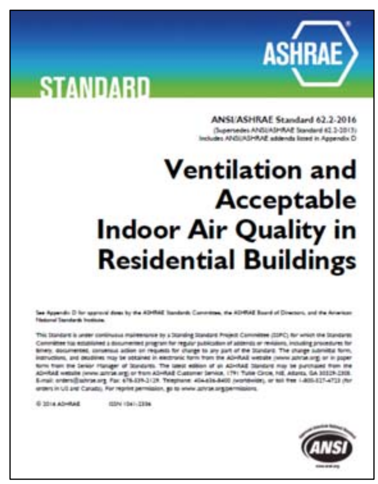
Commercial: Rules for Good Ventilation

- Bring in outdoor air from a clean source
- Provide filtered and dehumidified outdoor air to the breathing space
- Vary amount of ventilation based on the number of occupants and process loads
- Designs systems that separate ventilation and space conditioning
- Use heat/energy recovery to reduce system size and ventilation energy costs

ASHRAE Standard 62

ASHRAE 62-1989 (old!)

- Whole house: 0.35 $ACH_{Natural}$ or 15 cfm per person
- Kitchen: 100 cfm intermittent
  or 25 cfm continuous or operable window
- Bath: 50 cfm intermittent
  or 20 cfm continuous or operable window


STANDARD

ASHRAE

ANSI/ASHRAE Standard 62.2-2016

Ventilation and Acceptable Indoor Air Quality in Residential Buildings

ASHRAE 62.2-2004,7,10

- 7.5 cfm per person PLUS
- 1 cfm for every 100 s.f. of conditioned space

ASHRAE 62.2-2013, 16, 19

7.5 cfm/person + 3 cfm / 100 s.f.

- Qfan = Qtot - Qinf

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62.2-2010 Single Family Ventilation

$$CFM_{fan} = (0.01 \times A_{floor}) + (7.5 \times (\#\ bedrooms + 1))$$

OR

Floor Area (ft^2)	BEDROOMS				
	0 - 1	2 - 3	4 - 5	6 - 7	>7
< 1500	30	45	60	75	90
1501 – 3000	45	60	75	90	105
3001 – 4500	60	75	90	105	120
4501 – 6000	75	90	105	120	135
6001 – 7500	90	105	120	135	150
> 7500	105	120	135	150	165

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2012 IRC requires ventilation if…

ASHRAE 62.2 & IRC 2012 Ventilation

- Ventilation is REQUIRED
  - Any home tighter than **5 ACH_{50}**
- Between ‘12 IECC and ‘12 IRC, whole house mechanical ventilation is now mandated everywhere!

R303.4 Mechanical ventilation. Where the air infiltration rate of a dwelling unit is less than 5 air changes per hour when tested with a blower door at a pressure of 0.2 inch w.c (50 Pa) in accordance with Section N1102.4.1.2, the dwelling unit shall be provided with whole-house mechanical ventilation in accordance with Section M1507.3.

R303.5 Opening location. Outdoor intake and exhaust openings shall be located in accordance with Sections R303.5.1 and R303.5.2.

R303.5.1 Intake openings. Mechanical and gravity outdoor air intake openings shall be located a minimum of 10 feet (3048 mm) from any hazardous or noxious contaminant, such as vents, chimneys, plumbing vents, streets, alleys, parking lots and loading docks, except as otherwise specified in this code. Where a source of contaminant is located within 10 feet (3048 mm) of an intake opening, such opening shall be located a minimum of 3 feet (914 mm) below the contaminant source.

For the purpose of this section, the exhaust from *dwelling unit* toilet rooms, bathrooms and kitchens shall not be considered as hazardous or noxious.

R303.5.2 Exhaust openings. Exhaust air shall not be directed onto walkways.

2012 IRC

ASHRAE 62.2 & IRC 2012 Ventilation

- Basically, takes the 62.2-2010 table (but not the formula)

TABLE M1507.3.3(1)
CONTINUOUS WHOLE-HOUSE MECHANICAL VENTILATION SYSTEM AIRFLOW RATE REQUIREMENTS

DWELLING UNIT FLOOR AREA (square feet)	NUMBER OF BEDROOMS				
	0 – 1	2 – 3	4 – 5	6 – 7	> 7
	Airflow in CFM				
< 1,500	30	45	60	75	90
1,501 – 3,000	45	60	75	90	105
3,001 – 4,500	60	75	90	105	120
4,501 – 6,000	75	90	105	120	135
6,001 – 7,500	90	105	120	135	150
> 7,500	105	120	135	150	165

For SI: 1 square foot = 0.0929 m^2, 1 cubic foot per minute = 0.0004719 m^3/s.

TABLE M1507.3.3(2)
INTERMITTENT WHOLE-HOUSE MECHANICAL VENTILATION RATE FACTORS[a, b]

RUN-TIME PERCENTAGE IN EACH 4-HOUR SEGMENT	25%	33%	50%	66%	75%	100%
Factor[a]	4	3	2	1.5	1.3	1.0

a. For ventilation system run time values between those given, the factors are permitted to be determined by interpolation.
b. Extrapolation beyond the table is prohibited.

2012 INTERNATIONAL RESIDENTIAL CODE® 509

2012 IRC

ASHRAE 62.2 & IRC 2012 Ventilation

- CFM's are based on design and not on verified flow measurements

SECTION M1507
MECHANICAL VENTILATION

M1507.1 General. Where local exhaust or whole-house mechanical ventilation is provided, the equipment shall be designed in accordance with this section.

2012 INTERNATIONAL RESIDENTIAL CODE®

M1507.4 Local exhaust rates. *Local exhaust* systems shall be designed to have the capacity to exhaust the minimum air flow rate determined in accordance with Table M1507.4.

TABLE M1507.4
MINIMUM REQUIRED LOCAL EXHAUST RATES FOR ONE- AND TWO-FAMILY DWELLINGS

AREA TO BE EXHAUSTED	EXHAUST RATES
Kitchens	100 cfm intermittent or 25 cfm continuous
Bathrooms-Toilet Rooms	Mechanical exhaust capacity of 50 cfm intermittent or 20 cfm continuous

For SI: 1 cubic foot per minute = 0.0004719 m^3/s.

M1507.3 Whole-house mechanical ventilation system. Whole-house mechanical ventilation systems shall be designed in accordance with Sections M1507.3.1 through M1507.3.3.

M1507.3.1 System design. The whole-house ventilation system shall consist of one or more supply or exhaust fans, or a combination of such, and associated ducts and controls. Local exhaust or supply fans are permitted to serve as such a system. Outdoor air ducts connected to the return side of an air handler shall be considered to provide supply ventilation.

M1507.3.2 System controls. The whole-house mechanical ventilation system shall be provided with controls that enable manual override.

M1507.3.3 Mechanical ventilation rate. The whole-house mechanical ventilation system shall provide outdoor air at a continuous rate of not less than that determined in accordance with Table M1507.3.3(1).

Exception: The whole-house mechanical ventilation system is permitted to operate intermittently where the system has controls that enable operation for not less than 25-percent of each 4-hour segment and the ventilation rate prescribed in Table M1507.3.3(1) is multiplied by the factor determined in accordance with Table M1507.3.3(2).

IRC & 62.2-2016 Basic Example – 3 BR, 1400 s.f.

- Use IRC Table

(Originally from 62.2-2010)

- *45 CFM continuous*

TABLE M1507.3.3(1) CONTINUOUS WHOLE-HOUSE MECHANICAL VENTILATION SYSTE

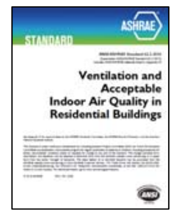
DWELLING UNIT FLOOR AREA (square feet)	NUMBER OF BEDROOMS				
	0 – 1	2 – 3	4 – 5	6 – 7	> 7
	Airflow in CFM				
< 1,500	30	45	60	75	90
1,501 – 3,000	45	60	75	90	105
3,001 – 4,500	60	75	90	105	120
4,501 – 6,000	75	90	105	120	135
6,001 – 7,500	90	105	120	135	150
> 7,500	105	120	135	150	165

For SI: 1 square foot = 0.0929 m^2, 1 cubic foot per minute = 0.0004719

- 62.2-2016 Ventilation formula:

$$CFM_{fan} = (0.03 \times A_{floor}) + (7.5 \times (\#\ bedrooms + 1))$$

$$= 42\ CFM + 30\ CFM = \mathbf{72\ CFM}\ \text{continuous}$$



62.2-2016 Ventilation Calculator

- Qfan = Qtot - Qinf

EarthCraft Single Family Ventilation Calculator based on ASHRAE 62.2-2016

3 Blue fields - entry required
4 Green fields - entry optional

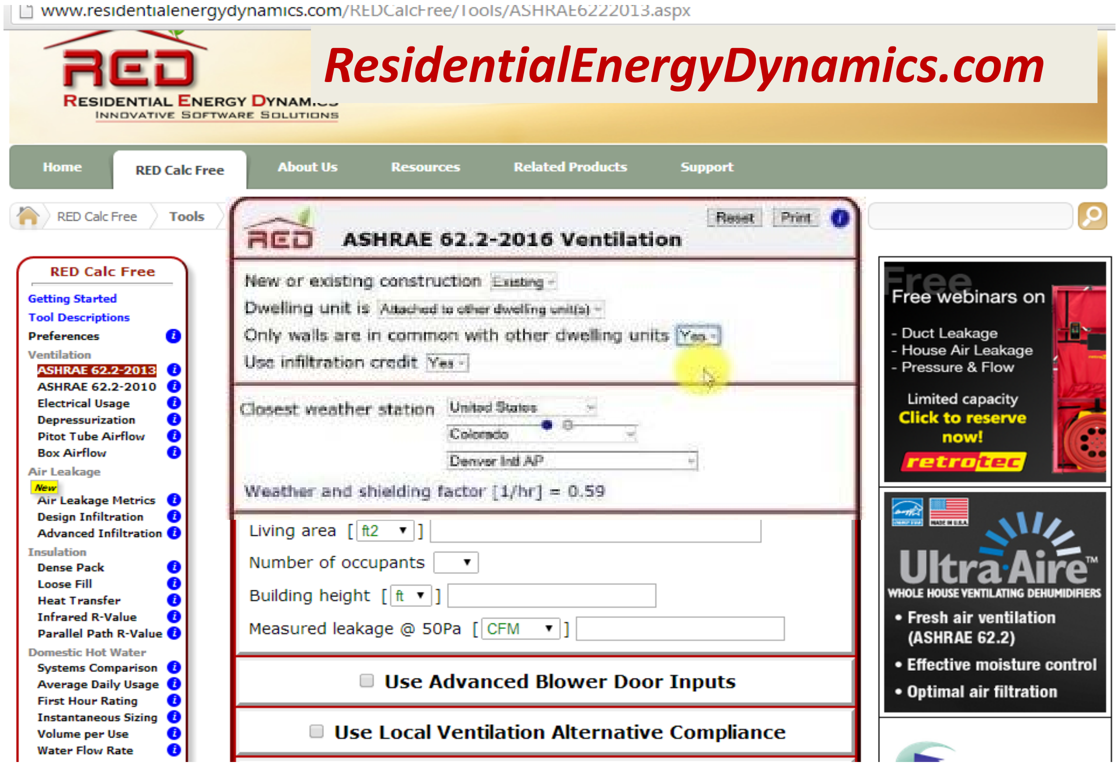
OPTIONAL: Back out your CFM50:

Enter the Volume:	12000	cubic feet	
Enter target ACH50:	5		
Estimated CFM50:	1000	cfm50	
Enter Floor Area:	1400	sq. feet	
Enter # Bedrooms:	3		
Enter Building Height:	9.0	feet	(e.g., 17' for 2 story)
Enter Avg Ceiling Height	9.00	feet	(used to calculate volume only)
Conditioned Volume	12600	cubic feet	
Enter Blower Door CFM50:	1050	cfm50	
ACH50	5.00	ACH	(for reference/comparison only)
Enter Location wsf:	0.46		(use Chart from Appendix B) =>
Qtot	72		Starting Ventilation Amount (before adjusting for infiltration)
---Hidden slides determine Qinf---			
Qinf	26.2	cfm	(infiltration CFM that will be credited)
Qinf, limit	48		(maximum that could be subtracted)
Enter Aext	1		(for single family, assume Aext = 1)
Qfan	45.8	cfm	

ASHRAE 62.2-2016 Appendix B wsf Values for Georgia

wsf	Weather Station	Latitude	Longitude	State
0.37	Alma Bacon County AP	31.53	–82.50	Georgia
0.40	Brunswick Golden Is	31.25	–81.47	Georgia
0.40	Brunswick Malcolm McKinnon AP	31.15	–81.38	Georgia
0.38	Albany Dougherty County AP	31.53	–84.18	Georgia
0.36	Valdosta Wb Airport	30.78	–83.28	Georgia
0.41	Macon Middle Ga Regional AP	32.68	–83.65	Georgia
0.39	Warner Robins AFB	32.63	–83.60	Georgia
0.41	Augusta Bush Field	33.37	–81.97	Georgia
0.46	Atlanta Hartsfield Intl AP	33.63	–84.43	Georgia
0.37	Fulton Co Arpt Brow	33.77	–84.52	Georgia
0.39	Dekalb Peachtree	33.87	–84.30	Georgia
0.35	Fort Benning Lawson	32.35	–85.00	Georgia
0.39	Columbus Metropolitan Arpt	32.52	–84.95	Georgia
0.40	Marietta Dobbins AFB	33.92	–84.52	Georgia
0.40	Athens Ben Epps AP	33.95	–83.33	Georgia
0.38	Rome R B Russell AP	34.35	–85.17	Georgia
0.40	Hunter AAF	32.00	–81.15	Georgia
0.36	Moody AFB/Valdosta	30.97	–83.20	Georgia
0.40	Savannah Intl AP	32.12	–81.20	Georgia

62.2-2016 Ventilation Calculator



Types of Ventilation

- **Exhaust** only
  - Single or multiple ventilation fans
- **Supply** only
  - Outside air into building
    - Outside air into AHU return plenum
    - Inline fan
- **Balanced**
  - Fan in/fan out
  - Energy/Heat Recovery

Exhaust only

- Usually a larger CFM, more quiet bath exhaust fan with timer switch
- Ventilation layout and installation is critical to airflow
  - Upsize fan to be sure of airflow
    - If 55 cfm is required, spec 70 cfm fan

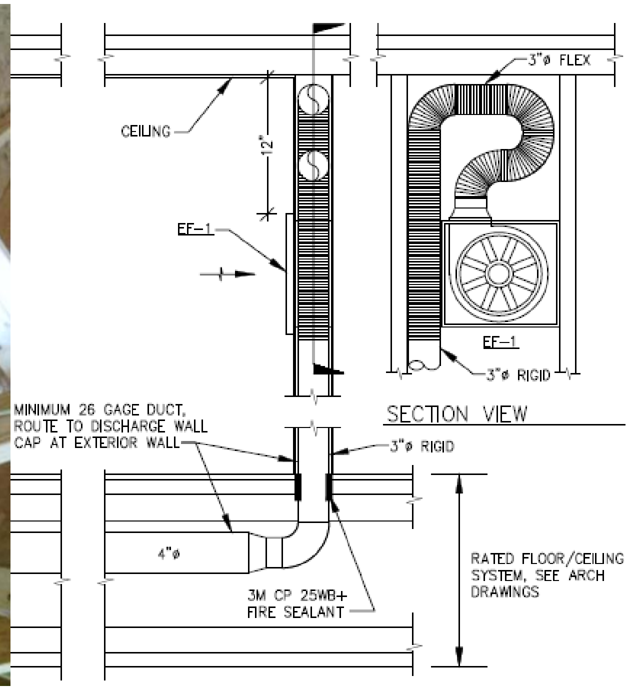


Exhaust only

- Plus- Inexpensive to buy and operate, especially with DC motor; runs continuously
- Plus- If quiet, occupant might not unplug it
- Minus- Negative pressure pulls unconditioned air from largest, most available holes and leaks
- Minus- How will incoming air be filtered and conditioned?
- Minus- Potential combustion safety issues

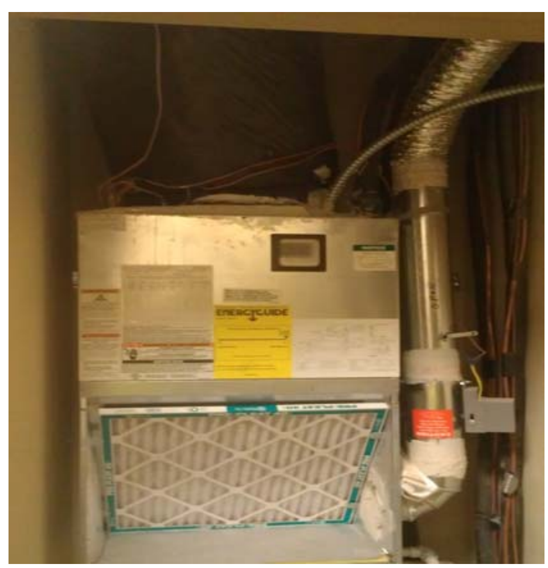
Ventilation Ducting Matters!

- Our “real world” concerns…
- Never use 3” duct!

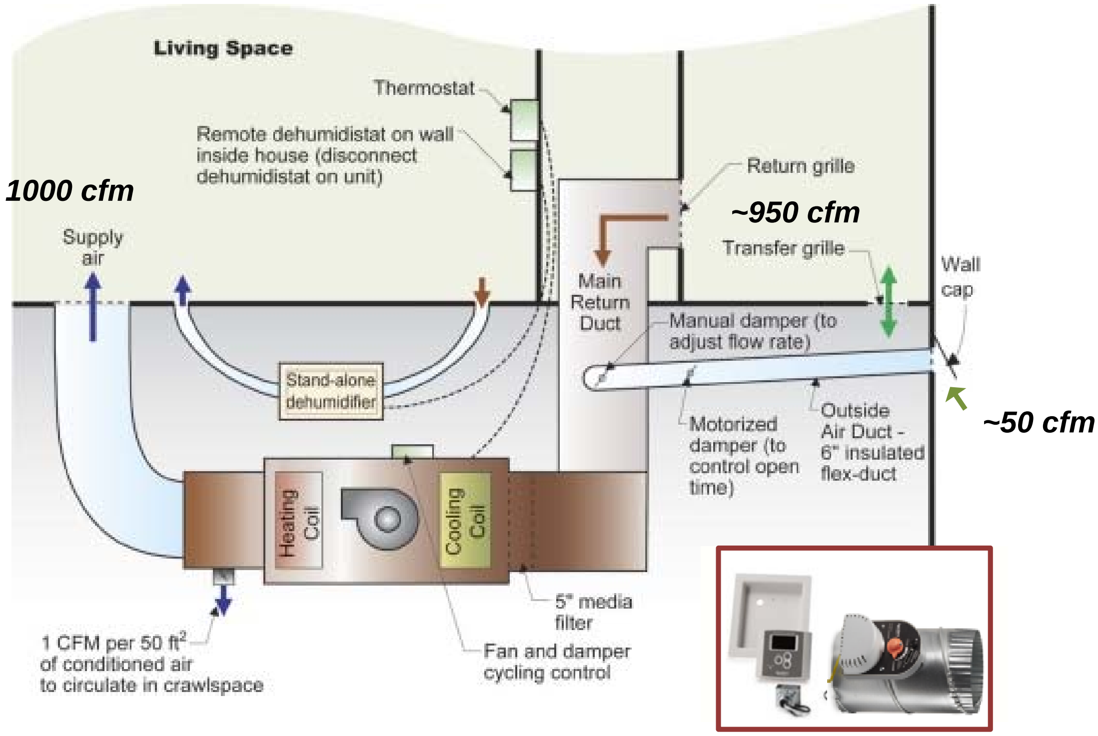


Supply Only

- Vent from outside to house or return plenum
- Air needs to be filtered
- Need manual (balancing) damper, motorized damper and timer/controller
- Insulate vent duct



Supply - Positive Pressure Ventilation



Positive Ventilation Supplied via O.A. Ducted to Return

Supply Only

- Plus- If designed & installed correctly, this approach should supply the intended ventilation cfm
- Plus- Air can be filtered and pre-conditioned
- Plus- Slight positive pressure inside house keeps pollutants at bay (good in humid climate zones)
- Plus- Ventilation air is well mixed and distributed throughout house by duct system
- Plus- Mitigates combustion safety issues
- Plus- Fairly doable retrofit

Supply Only

Duct Diameter (in)	Maximum Capacity Flex (cfm)	Maximum Capacity Metal (cfm)
4	25	35
5	45	60
6	70	100
7	100	150
8	150	200

- Minus- Energy penalty of using big fan to bring in a small amount of air (affects HERS Index)
- Minus- In MF, may yield inadequate air flow due to low pressure in HVAC closet – consider a shroud
- Minus- Size of vent duct affects run-time
- Minus- More pieces to design, install, operate
- Minus- Exterior vent placement with filtration

R403.6 Mechanical ventilation (Mandatory). The building shall be provided with ventilation that meets the requirements of the *International Residential Code* or *International Mechanical Code*, as applicable, or with other approved means of ventilation. Outdoor air intakes and exhausts shall have automatic or gravity dampers that close when the ventilation system is not operating.

R403.6.1 Whole-house mechanical ventilation system fan efficacy. Mechanical ventilation system fans shall meet the efficacy requirements of Table R403.6.1.

Exception: Where mechanical ventilation fans are integral to tested and listed HVAC equipment, they shall be powered by an electronically commutated motor.

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Supply Only With In-Line Fan+

Sensor-based controls

- Plus- Likely to have correct ventilation cfm that is filtered & from known source
- Plus- Low initial and operating cost
- Plus- Can be set to not ventilate during “bad” times (too hot, too cold, too humid, too dry)

QUFRESH BY AirKing
Patents Pending

HVI CERTIFIED PERFORMANCE

MODEL	DUCT SIZE	STATIC PRESSURE	SPEED	WATTS
QFAM	6"	0.2	40 CFM	12.9
			50 CFM	13
			60 CFM	15.1
			70 CFM	17.1
			80 CFM	19.5
			90 CFM	21.8
			100 CFM	26.3
			110 CFM	27.5
			120 CFM	30.1

HVI CERTIFIED

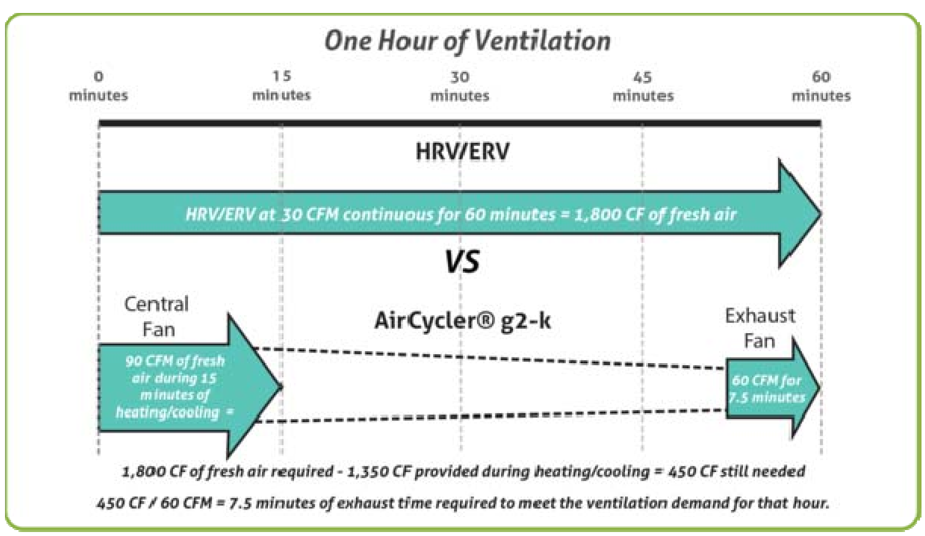
Southface

Hybrid

- Uses exhaust fan with intake air controlled by electric damper
- Doesn't necessarily contribute to pressure imbalances inside house
- Air needs to be filtered
- Insulate vent pipe

Hybrid

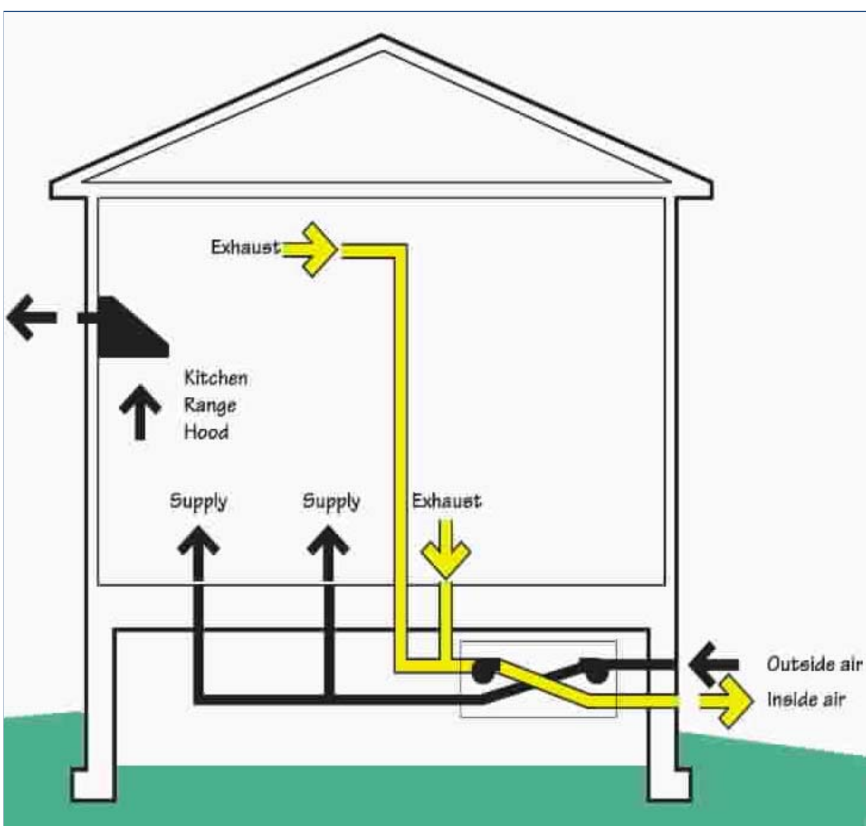
- AirCycler g2/g2-k



Balanced - ERV/HRV

- Doesn't contribute to pressure imbalances inside house
- Tempers humidity and temperature of incoming air
- Can be tied into duct system but best when independently ducted

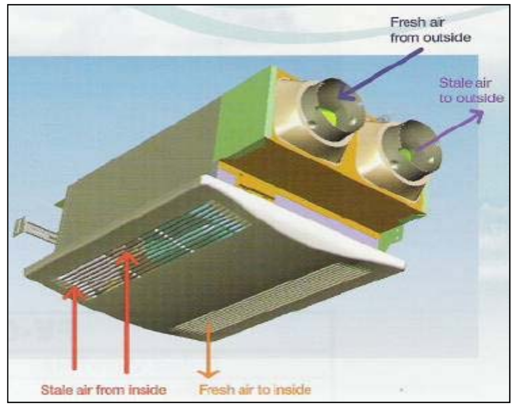
Balanced Ventilation



Energy Recovery Ventilator (ERV) – transfers both heat (Sensible) and moisture (Latent)

Balanced ERV - Spot Unit

- Plus- Doesn't create pressure imbalances
- Plus- Low energy use
- Plus- Relatively low cost
- Plus- Ease of set-up and operation
- Plus- 2 pipe design, lower install cost
- Minus- Low moisture transfer
- Minus- Distribution?



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Balanced - ERV-Whole Unit

- Plus- Doesn't create pressure imbalances
- Plus- Low energy use
- Plus- Good mixing, so-so moisture transfer
- Plus- 4 ports, can be tied into duct system
- Minus- Removes some of the OA moisture but ultimately still adds humidity to house
- Minus- Higher cost

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What is New(er) with Ventilation?

- Mini-splits are becoming more established in the market
- ERV's have gotten much more affordable
- ECM for variable speed AHU's
- "Smart Ventilation" controls with sensors for temperature, moisture, particulates, etc.
- Loads have shifted
  - High performance homes don't need cooling
  - Homes need drying
- In-wall dehumidifiers for MF
- Ventilation dehumidifiers

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Exception: Where mechanical ventilation fans are integral to tested and listed HVAC equipment, they shall be powered by an electronically commutated motor.

HVAC and Moisture

- Don't expect HVAC to fix bad envelope moisture issues
- Remember Psychrometrics
  - "It ain't the heat, it's the humidity"
  - Southern weather example
- HVAC controls can help
  - Humidistat
  - Variable speed blower
  - Variable capacity equipment (staged or variable speed compressors)

Example Problem – Room Temperature

Find 75°F and 50% Relative Humidity.

Record the grains: _______

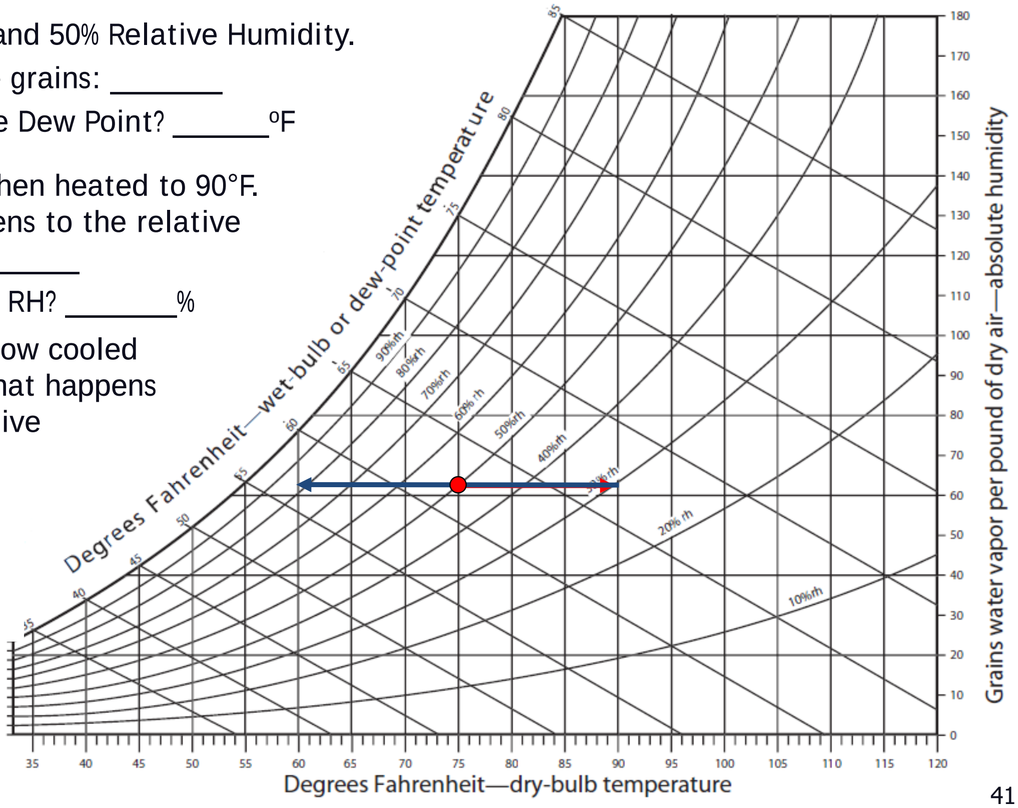
What is the Dew Point? ______ºF

This air is then heated to 90°F. What happens to the relative humidity? ______

What is the RH? _______%

This air is now cooled to 60°F. What happens to the relative humidity?

What is the relative humidity? ______%



Example Problem – Winter

Find 40°F and 90% Relative Humidity.

Record the grains: _______

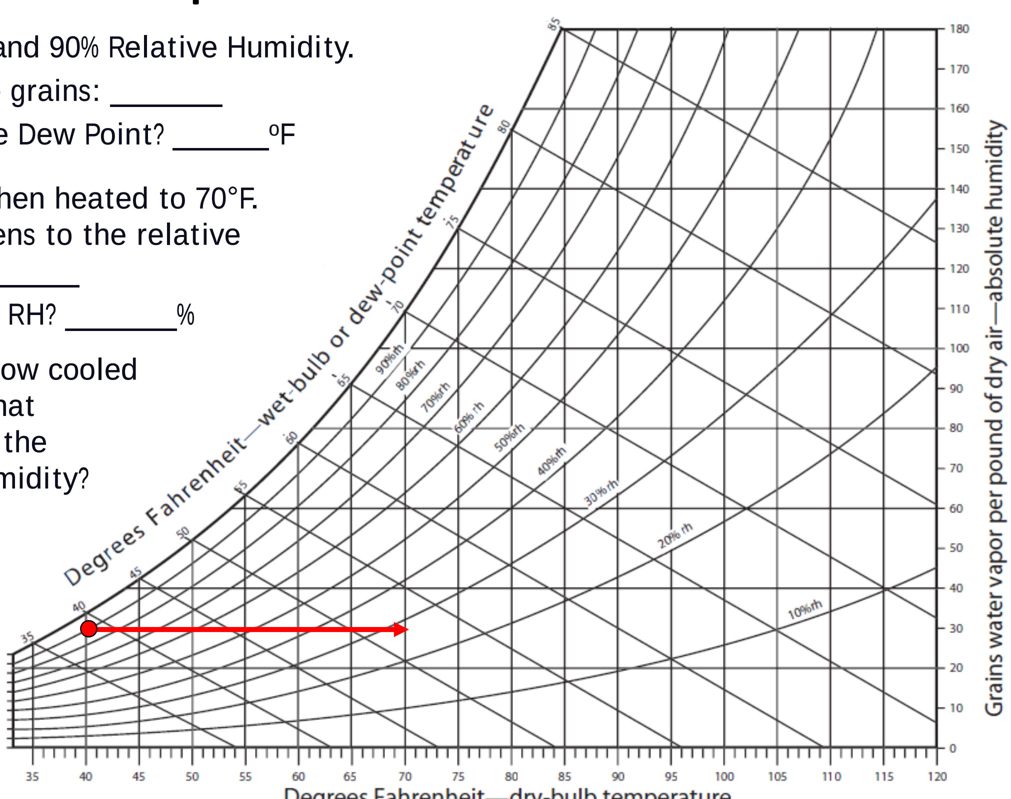
What is the Dew Point? ______ºF

This air is then heated to 70°F. What happens to the relative humidity? ______

What is the RH? _______%

This air is now cooled to 38°F. What happens to the relative humidity?

What is the relative humidity? _______%



Example Problem – Summer

Find 80°F and 80% Relative Humidity.

Record the grains: _______

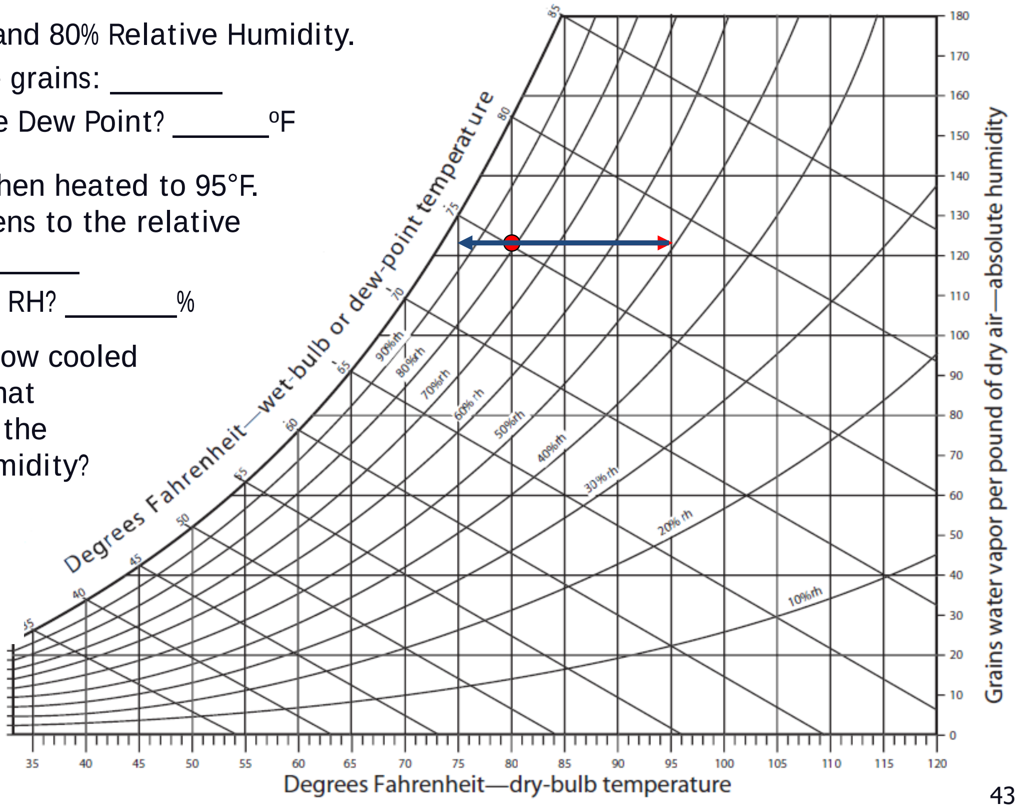
What is the Dew Point? ______ºF

This air is then heated to 95°F. What happens to the relative humidity? ______

What is the RH? _______%

This air is now cooled to 75°F. What happens to the relative humidity?

What is the relative humidity? _______%



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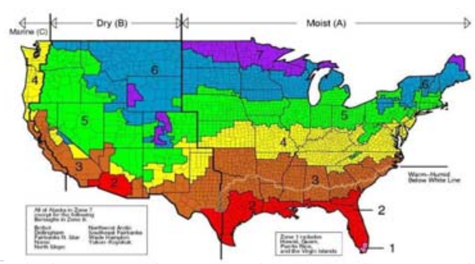
HVAC and Moisture



Atlanta, GA									
Bin Temperature	70-75	75-80	80-85	85-90	90-95	95-100	100-105	105-110	Total
# of Hours of Occurrence	1188	880	620	361	172	23	2	0	3246
	37%	27%	19%	11%	5%	1%	0%	0%	
		83%				17%			
Manual J Design, Load based on Temperature					92°	99	gr/lb		
ASHRAE Humidity Design, Load based on Moisture					82°	133	gr/lb		
Approximate Extra Moisture Added per 100 CFM Of O.S.A.					3.9	pts/hr	or	93.9	pts/day

Mixed Air (filtered, dehumidified)

Fresh Air

House Air

Southface

Dehumidifier/Ventilator

- Pulls air from house and from outside
- Filters & mixes two streams
- Dehumidifies as needed
  - 70 to 100+ ppd
  - Ideal for efficient houses with lower sensible loads but similar latent loads

Supplemental Dehumidification

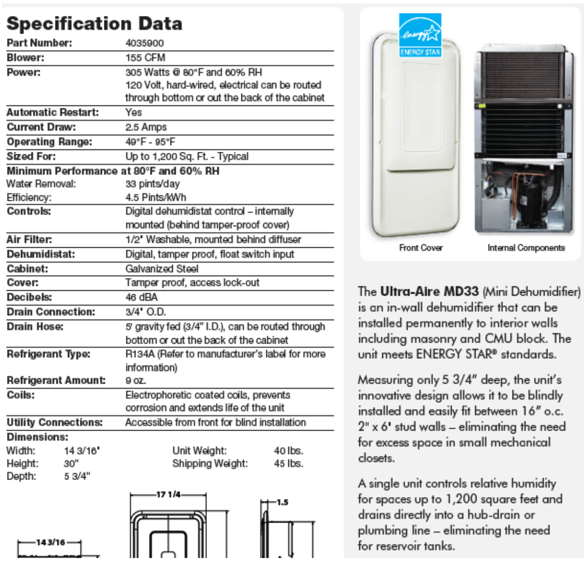
- Stand alone
- Innovative Dehumidifier
  - In-wall
  - Tamper-resistant
  - 25 ppd
- UltraAire MD33
  - 33 ppd
  - Easier install

Front Cover

Internal Components

MF Dedicated Dehumidification

- Ultra-Aire MD33
  - In-wall Dehumidifier



Specification Data

Part Number:	4035900
Blower:	155 CFM
Power:	305 Watts @ 80°F and 60% RH 120 Volt, hard-wired, electrical can be routed through bottom or out the back of the cabinet
Automatic Restart:	Yes
Current Draw:	2.5 Amps
Operating Range:	49°F - 95°F
Sized For:	Up to 1,200 Sq. Ft. - Typical
Minimum Performance at 80°F and 60% RH	
Water Removal:	33 pints/day
Efficiency:	4.5 Pints/kWh
Controls:	Digital dehumidistat control – internally mounted (behind tamper-proof cover)
Air Filter:	1/2" Washable, mounted behind diffuser
Dehumidistat:	Digital, tamper proof, float switch input
Cabinet:	Galvanized Steel
Cover:	Tamper proof, access lock-out
Decibels:	46 dBA
Drain Connection:	3/4" O.D.
Drain Hose:	5' gravity fed (3/4" I.D.), can be routed through bottom or out the back of the cabinet
Refrigerant Type:	R134A (Refer to manufacturer's label for more information)
Refrigerant Amount:	9 oz.
Coils:	Electrophoretic coated coils, prevents corrosion and extends life of the unit
Utility Connections:	Accessible from front for blind installation

Dimensions:

Width:	14 3/16"	Unit Weight:	40 lbs.
Height:	30"	Shipping Weight:	45 lbs.
Depth:	5 3/4"		

14 3/16 — 17 1/4 — 1.5

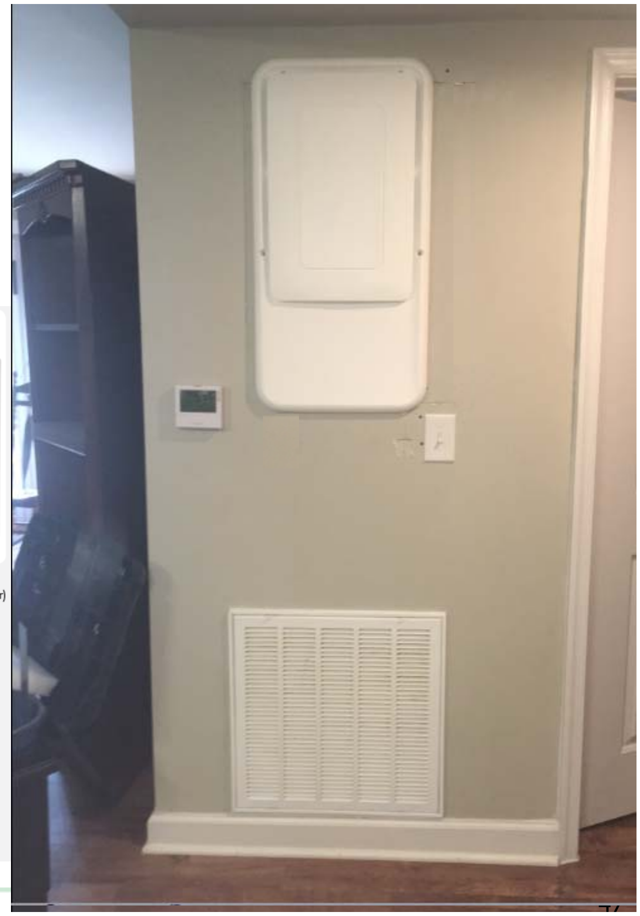
ENERGY STAR

Front Cover — Internal Components

The **Ultra-Aire MD33** (Mini Dehumidifier) is an in-wall dehumidifier that can be installed permanently to interior walls including masonry and CMU block. The unit meets ENERGY STAR® standards.

Measuring only 5 3/4" deep, the unit's innovative design allows it to be blindly installed and easily fit between 16" o.c. 2" x 6' stud walls – eliminating the need for excess space in small mechanical closets.

A single unit controls relative humidity for spaces up to 1,200 square feet and drains directly into a hub-drain or plumbing line – eliminating the need for reservoir tanks.



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What's the best ventilation system?

- Smart, sensor based controller- Likely temperature + moisture plus other pollutants, adjusts based on conditions and activity; alerts when needed
- Energy recovery- preconditions entering fresh air with energy of exhausted air
- Supplemental dehumidification- Can assist with house drying as well as incoming fresh air
- Quality filter- Accessible for easy cleaning/replacement
- Low 1st cost + low operating cost
- Easy to install + tested to verify airflow
- Easy to maintain + alerts if maintenance issue occurs

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Current Building America Project

- Field validation, using low-cost Indoor Air Quality (IAQ) sensors, of a smart ERV that can help low-load homes in humid environments maintain acceptable indoor humidity conditions while providing adequate ventilation according to ASHRAE 62.2.

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The Challenge

- Building air tightness is crucial to lowering the energy use of homes, but mechanical ventilation is necessary to provide optimal IAQ.
- However, resistance to mechanical ventilation is one of the reasons for builder push-back on increasing building enclosure air tightness requirements for state energy codes, as seen in Florida, Georgia, Louisiana, and others.
- Builders are resistant to cost increases, but, perhaps more importantly, they fear the introduction of humidity from outside, especially in the hot-humid climate.
- **Smart Ventilation solutions that minimize indoor humidity at an acceptable cost to production builders have the potential to overcome this barrier while providing the important IAQ benefits necessary for occupant health.**

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Approach

- Collect field data for one year in 4 Charleston, SC new construction Energy Star homes in order to determine the differences in:
    1. Occupant comfort (surveys) and comfort metrics (T/RH measurements)
    2. IAQ
    3. HVAC energy consumption
- When toggling bi-weekly between an ERV operating continuously and an ERV operating with smart, time-varying humidity control logic.

- Measuring:
- T, RH, CO_2, PM2.5, and Radon
- ERV energy consumption, duct T/RH, and airflow
- HVAC and whole-house energy consumption

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Experimental Setup

- **What is "Smart Mode"?**
- Using T/RH sensors in outdoor air stream, Smart Mode triggers the unit into standby for 50 minutes when the dewpoint is above a threshold
- Unit turns back on after 50 minutes, sampling for 10 minutes to determine if it will go into Standby again

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Experimental Setup

- Two-story, single family detached houses with similar square footage, in the same neighborhood.

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Experimental Setup

- All 4 houses performance tested, have sensors and monitors installed, and the ERVs are online, switching bi-weekly.

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Experimental Setup

- Broan/Venmar ERV model ERVS100S modified to remotely toggle between “Smart” and “Continuous” modes using the Senseware platform
  - Senseware controls and T/RH probes installed in ERV ductwork

- Senseware IAQ packages located throughout house and outdoors
- Measure T, RH, PM2.5, and CO2
  - T/RH: Sensirion SHT21
  - PM2.5: Plantower PMS5003
  - CO2: Telaire T6713-5K

Experimental Setup

- T/RH probes installed in AHU supply/return ducts

- Airthings Wave Radon Sensor on first floor

Comfort Metrics Annual Results

House	Comfort Metric	Continuous Mode	Smart Mode
House 1	Temperature (F)	72.2	73.3
	Relative Humidity (%)	48.5	48.0
	% of Time over 60% RH	0.3%	0.1%
House 2*	Temperature (F)	71.8	71.5
	Relative Humidity (%)	53.2	52.3
	% of Time over 60% RH	18.5%	7.2%
House 3*	Temperature (F)	73.4	73.0
	Relative Humidity (%)	52.8	52.6
	% of Time over 60% RH	10.3%	5.5%
House 4*	Temperature (F)	75.0	75.1
	Relative Humidity (%)	46.3	46.1
	% of Time over 60% RH	0.2%	0.0%

*Full year not yet complete

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Comfort Metrics Annual Results

House	Comfort Metric	Continuous Mode	Smart Mode
House 1	Temperature (F)	72.2	73.3
	Relative Humidity (%)	48.5	48.0
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House 2*	Temperature (F)	71.8	71.5
	Relative Humidity (%)	53.2	52.3
	% of Time over 60% RH	18.5%	7.2%
House 3*	Temperature (F)	73.4	73.0
	Relative Humidity (%)	52.8	52.6
	% of Time over 60% RH	10.3%	5.5%
House 4*	Temperature (F)	75.0	75.1
	Relative Humidity (%)	46.3	46.1
	% of Time over 60% RH	0.2%	0.0%

*Full year not yet complete

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Comfort Metrics Seasonal Results

		Spring		Summer		Fall		Winter	
	Comfort Metric	Continuous Mode	Smart Mode	Continuous Mode	Smart Mode	Continuous Mode	Smart Mode	Continuous Mode	Smart Mode
Outside	Temperature (F)	75.7	76.7	84.3	84.2	66.1	67.8	60.0	59.3
	Relative Humidity (%)	65.6	72.8	75.3	74.7	73.9	71.1	69.8	66.6
	% of Time over 60% RH	65.6%	78.9%	88.5%	87.0%	81.2%	77.3%	73.1%	65.6%
	Dew Point (F)	63.5	67.3	75.7	75.3	57.6	58.2	50.2	48.2

It's humid in Charleston!

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Comfort Metrics Seasonal Results

		Spring		Summer		Fall		Winter	
House	Comfort Metric	Continuous Mode	Smart Mode	Continuous Mode	Smart Mode	Continuous Mode	Smart Mode	Continuous Mode	Smart Mode
House 1	Temperature (F)	73.1	74.1	75.0	73.9	71.6	74.7	70.2	70.0
	Relative Humidity (%)	46.9	47.9	49.3	50.7	49.2	47.4	49.0	47.3
	% of Time over 60% RH	0.0%	0.1%	0.3%	0.2%	0.2%	0.0%	0.7%	0.0%
House 2	Temperature (F)	73.4	74.3	74.8	75.0	-	-	70.5	70.1
	Relative Humidity (%)	51.2	52.4	53.1	52.1	-	-	54.8	50.8
	% of Time over 60% RH	2.5%	3.0%	1.5%	1.5%	-	-	30.8%	5.8%
House 3	Temperature (F)	73.8	73.4	73.7	74.2	-	-	73.3	72.8
	Relative Humidity (%)	53.6	54.0	56.1	55.1	-	-	51.9	49.0
	% of Time over 60% RH	11.2%	8.2%	30.1%	22.2%	-	-	9.5%	1.0%
House 4	Temperature (F)	74.8	75.4	75.5	75.6	-	-	74.5	73.3
	Relative Humidity (%)	49.2	50.8	52.9	52.1	-	-	48.1	47.0
	% of Time over 60% RH	0.6%	0.8%	0.8%	2.0%	-	-	0.2%	0.1%

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Comfort Metrics Results

- **Takeaways:**
- Smart mode *does not* make a consistent, directional difference during Cooling season
- Smart mode *does* make a consistent, directional difference during Heating season

- **Why?**
  – Active dehumidification provided by A/C is enough to negate any difference between the modes (next slides)

- Upshot: this technology might be more widely applicable than just Hot-Humid climates for which it was designed and may be well suited for Mixed-Humid and Marine climates

ERV Performance Results (House 1)

		Annual	
	Metric	Continuous Mode	Smart Mode
Actual	Induced Water vapor flow (lbs/hr)	0.9	0.9
	Induced Latent Load Average (Btu/hr)	930.7	908.2
	Induced Sensible Load Average (Btu/hr)	123.4	141.8
A/C Average Condensation Rate (lbs/hr)		**1.7**	**1.9**
Ratio of Condensation Rate to ERV-Induced Water Vapor Flow		**187%**	**220%**

- Energy Savings of Smart over Continuous: 47kWh/yr

ERV Performance Results (House 1)

		Annual	
	Metric	Continuous Mode	Smart Mode
Actual	Induced Water vapor flow (lbs/hr)	0.9	0.9
	Induced Latent Load Average (Btu/hr)	930.7	908.2
	Induced Sensible Load Average (Btu/hr)	123.4	141.8
Ideal	Induced Water Vapor Flow (lbs/hr)	0.6	0.6
	Induced Latent Load Average (Btu/hr)	594.5	583.1
	Induced Sensible Load Average (Btu/hr)	112.3	120.0

- Actual: 93.1 CFM Supply, 111.4 CFM Exhaust
- Ideal: Balanced 93.1 CFM Supply and Exhaust

ERV Performance Results (House 1)

- Takeaway: Importance of balancing an ERV

- 18.3 CFM more Exhaust than Supply results in:
  - 335 more Gallons/yr if using Continuous mode
  - 325 more Gallons/yr if using Smart mode
  - ~60% higher Latent Load
  - ~10-20% higher Sensible Load

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ERV Performance Results (House 1)

		Spring		Summer		Fall		Winter	
	Metric	Continuous Mode	Smart Mode	Continuous Mode	Smart Mode	Continuous Mode	Smart Mode	Continuous Mode	Smart Mode
Actual	Induced Water vapor flow (lbs/hr)	1.0	0.9	2.2	2.0	0.7	0.4	0.1	-0.1
	Induced Latent Load Average (Btu/hr)	1,059.6	991.2	2,347.7	2,097.1	685.9	411.0	61.7	-78.9
	Induced Sensible Load (Btu/hr)	313.1	271.9	708.5	658.6	-64.4	-86.9	-326.3	-368.3
% Time in Standby		**0%**	**8.6%**	**0%**	**4.4%**	**0%**	**6.2%**	**0%**	**1.3%**

- In Standby the most in Spring, least in Winter
- However, largest difference in Indoor RH was Winter

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ERV Performance Results (House 1)

		Spring		Summer		Fall		Winter	
	Metric	Continuous Mode	Smart Mode	Continuous Mode	Smart Mode	Continuous Mode	Smart Mode	Continuous Mode	Smart Mode
Actual	Induced Water vapor flow (lbs/hr)	1.0	0.9	2.2	2.0	0.7	0.4	0.1	-0.1
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	Induced Sensible Load (Btu/hr)	313.1	271.9	708.5	658.6	-64.4	-86.9	-326.3	-368.3
A/C Average Condensation Rate (lbs/hr)		**1.3**	**1.3**	**5.2**	**4.9**	**1.2**	**0.8**	**0.1**	**0.1**
Ratio of Cond. Rate to ERV Induced Water Vapor Flow		**128%**	**142%**	**236%**	**245%**	**190%**	**205%**	**195%**	**-73%**

- In Winter
  - Close to zero water vapor flow into house in Continuous mode, net water vapor flow <u>out of house</u> in Smart mode
  - Close to zero condensation rate from A/C in winter
- Other Seasons
  - Average A/C condensation rate is 1.3-2.5X the net water vapor flow into house

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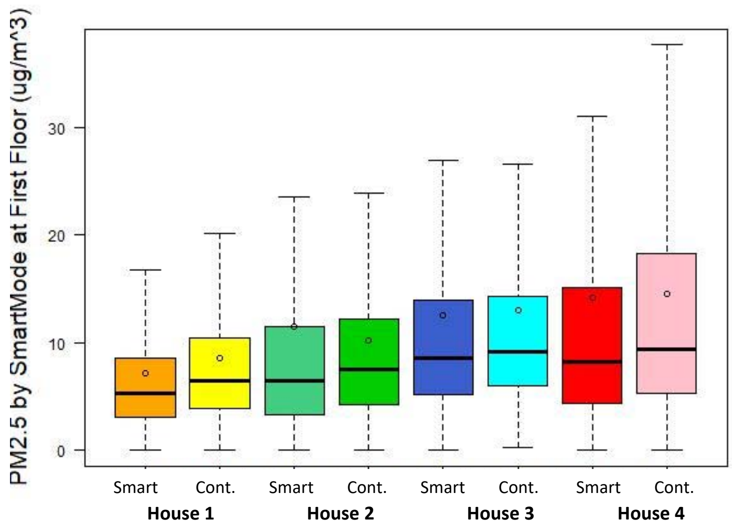
IAQ Results (PM2.5)

- First Floor PM2.5



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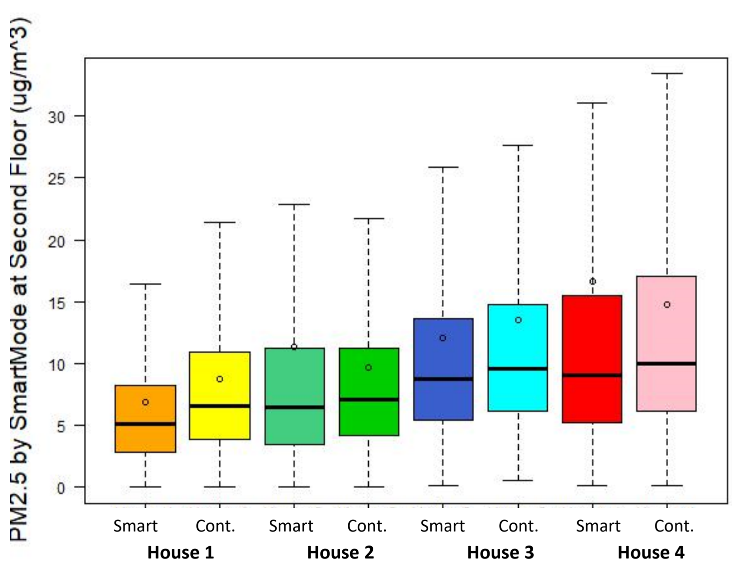
IAQ Results (PM2.5)

- Second Floor PM2.5



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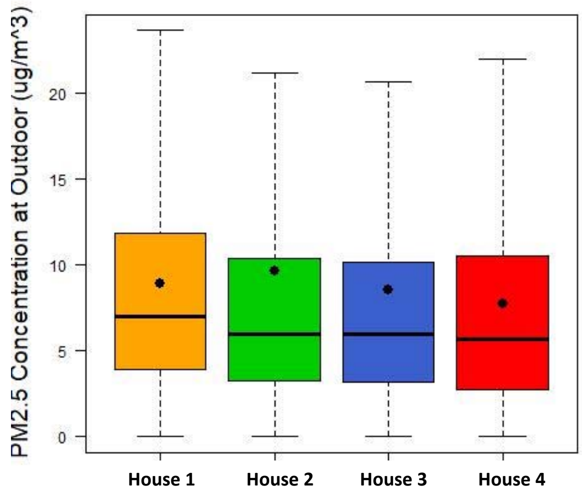
IAQ Results (PM2.5)

- Outdoor PM2.5



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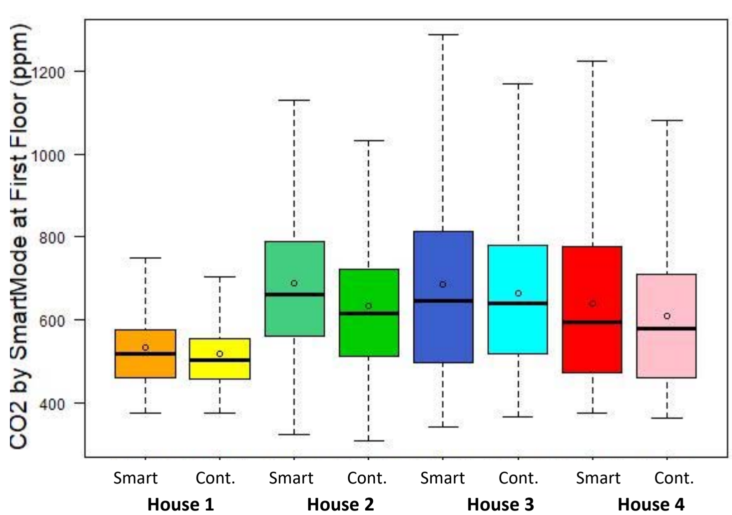
IAQ Results (CO2)

- First Floor CO2



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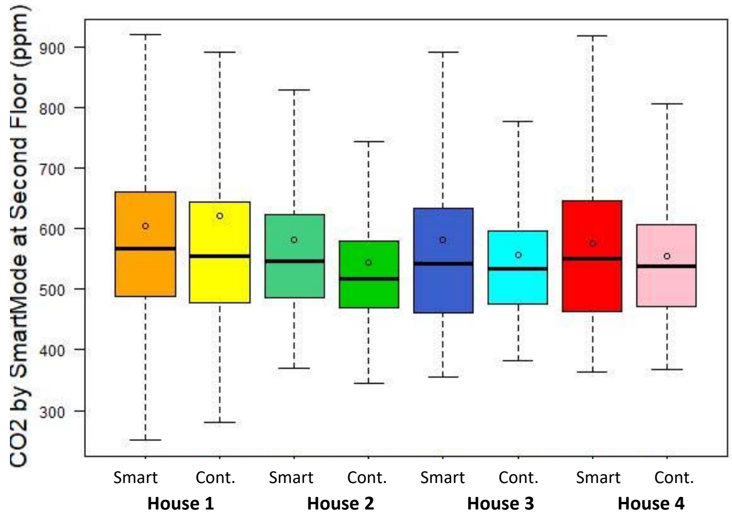
IAQ Results (CO2)

- Second Floor CO2



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IAQ Results

Multivariate Linear Mixed Regression Modeling Initial Results

PM2.5 ~ β_1(ERV Mode) + β_2(Outdoor) + β_3(Microenvironment) + β_4(Temp.) + β_5(Humidity) + β_6(House #)

PM2.5 : Indoor PM2.5 Concentration

Coefficients

β_1 : Influence of ERV Mode
β_2 : Influence of Outdoor PM2.5 Concentration
β_3 : Influence of Microenvironment (individual sensors throughout house)
β_4 : Influence of Temperature
β_5 : Influence of Humidity
β_6 : Influence of House #

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IAQ Results

Multivariate Linear Mixed Regression Modeling Initial Results

Model 1: Different households modeled as fixed effects
Model 2: Different households modeled as random effects

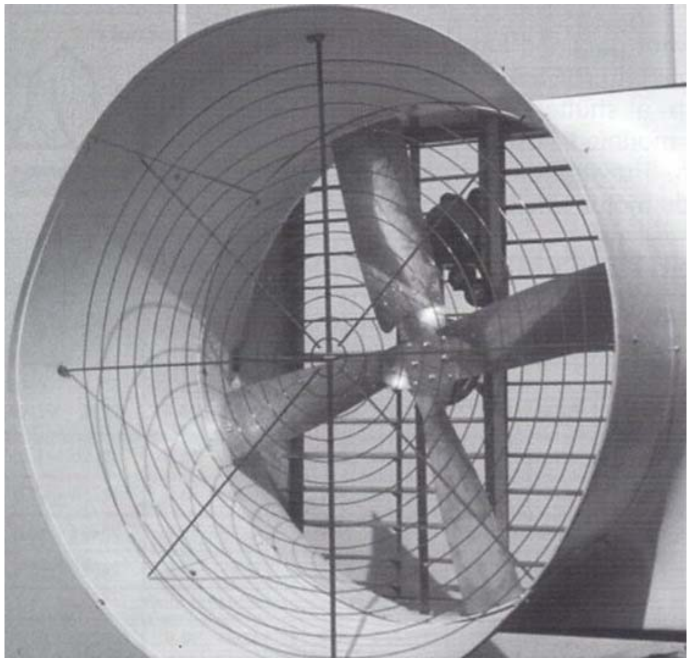
	Model 1	Model 2
PM2.5 : Smart Mode vs Continuous	0.77 μg/m³ lower	0.84 μg/m³ lower
p value	0.059	0.045

Takeaway: for both model types, the magnitude and significance of PM2.5 difference are similar and show Smart mode leading to a lower indoor PM2.5 concentration

Remaining Work

- Complete 1 year of monitoring for final 3 houses
- ERV performance and comfort metrics for final 3 houses
- Comparison of ERV modeled behavior to actual
- Effect of smart mode on HVAC energy consumption
- Regression modeling for CO2
- Other IAQ analyses
- Comparison of PM sensor performance with gravimetric measurements
- Low-cost sensor drift analysis

Thanks, We're Your Biggest Fans!!!



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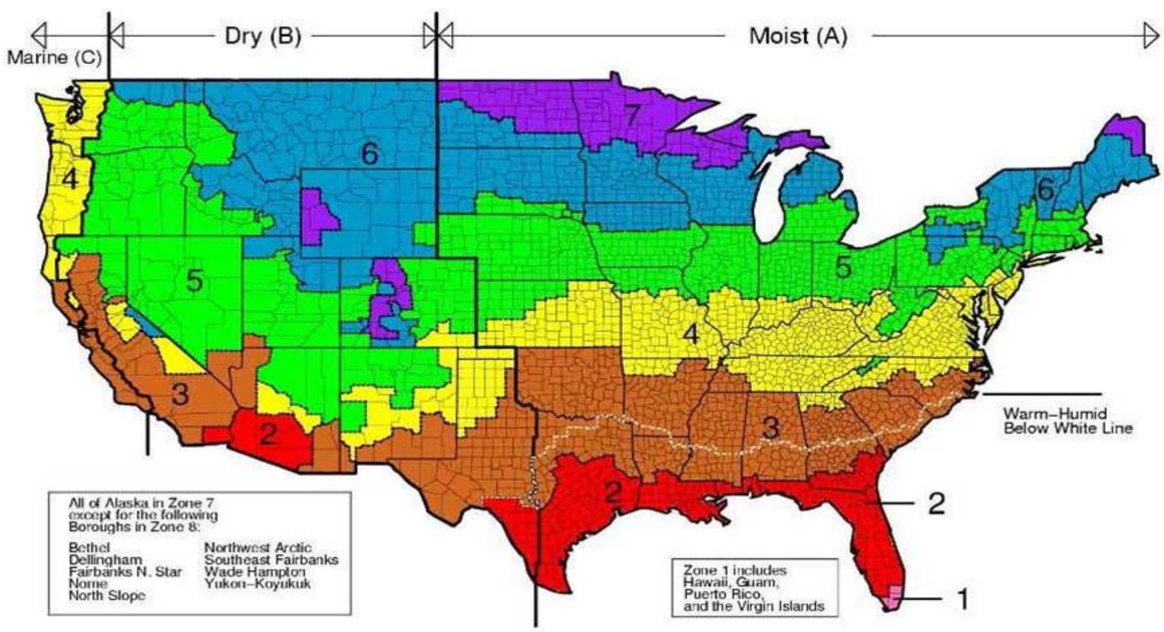
Climate Zone Map



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