Disclaimer

- This presentation is not intended to be a comprehensive program covering all aspects of this topic.
- All our participants are encouraged to read and follow applicable standards, codes and regulations related to this topic.
- The views and opinions following are the presenter's opinions and not necessarily the official position of the Maine IAQ Council, IAQnet LLC, or Healthy Indoors.

Humidity in Hindsight – Dialing in on a New Vision for Moisture Control

Paul H. Raymer

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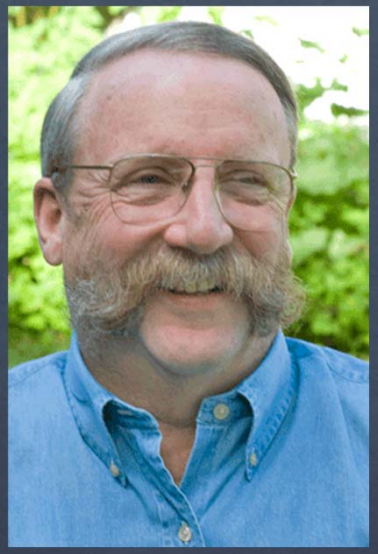
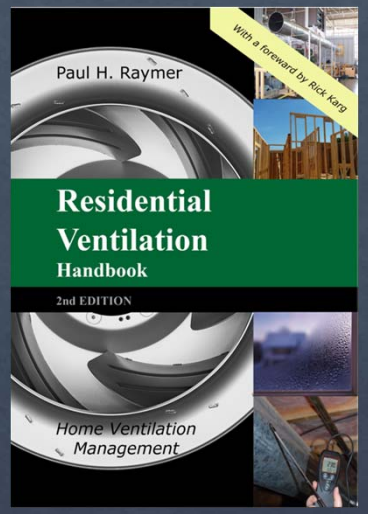
Indoor Air Quality (IAQ)

Paul H. Raymer



- Senior Building Science Advisor for ICF working with the EPA on the Indoor airPLUS Certification;
- Chief Investigator for Heyoka Solutions;
- HERS Rater
- Bunch of BPI certifications
- IREC Master Trainer
- Full member of ASHRAE on the 62.2 SSPC for more than 15 years
- Author of the Residential Ventilation Handbook, Recalculating Truth (a novel), and Death at the Edge of the Diamond (a novel)



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Humidity in Hindsight

Intelligent hindsight leads to effective foresight.

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Contents of this Session

- Moisture Fundamentals
- Indoor airPLUS Moisture Control
- Heating, Ventilating, Air Conditioning, and Dehumidifying Systems
- Summary

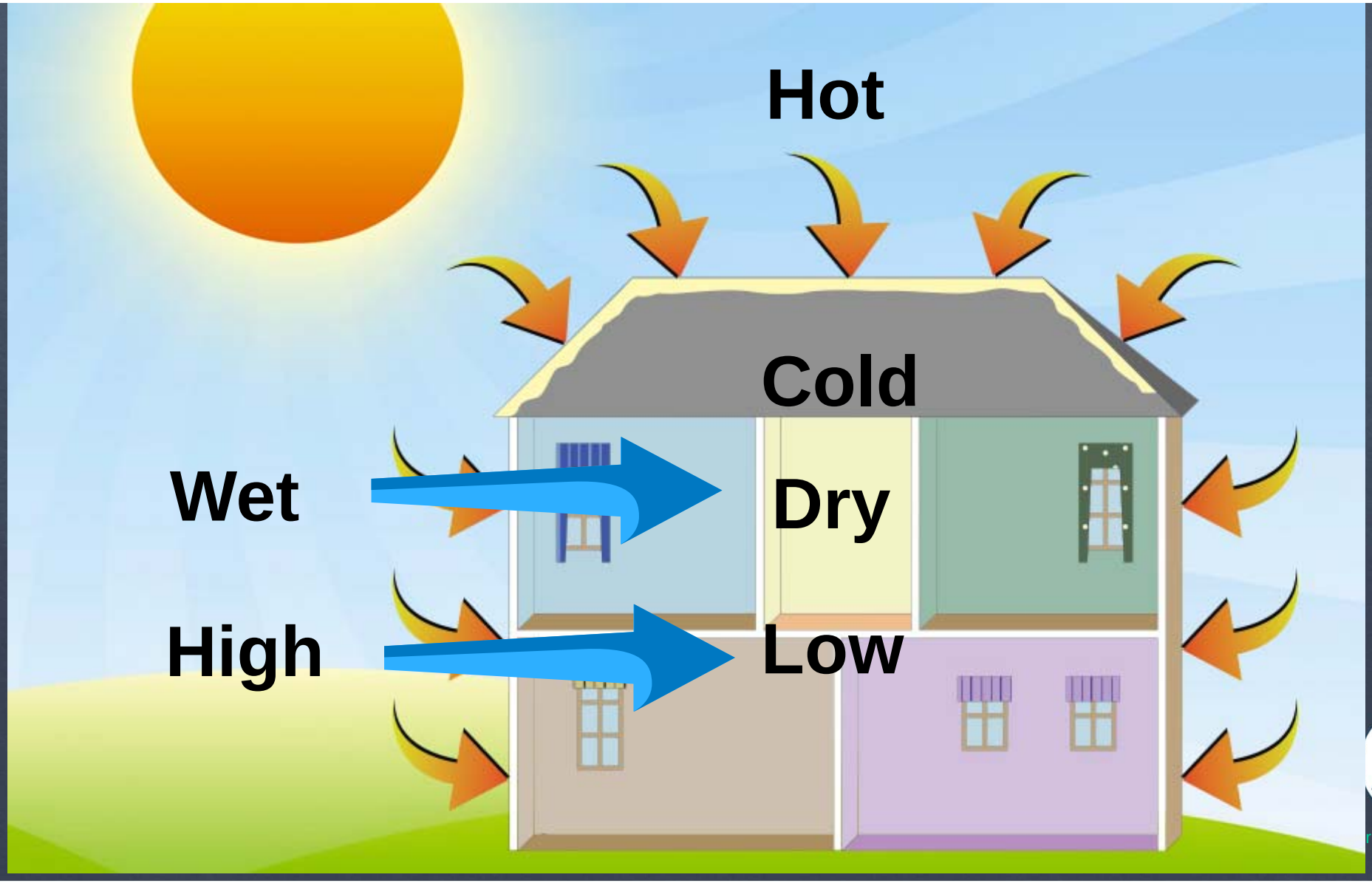
Definitions

Sensible Load is the temperature you feel on your body and measured by a dry bulb thermometer. This is controlled with the HVAC thermostat.

Latent Load is the moisture in the air often referred to as relative humidity. This is more challenging to control with the HVAC thermostat.

Fundamentals

- Air is made of gases including 78% nitrogen, 21% oxygen, water vapor, and other materials;
- Air has weight;
- Air is affected by temperature;
- It takes 1,054 btus to remove one pint of water from the air;
- To move 1 cfm out of the house, 1 cfm has to move in.

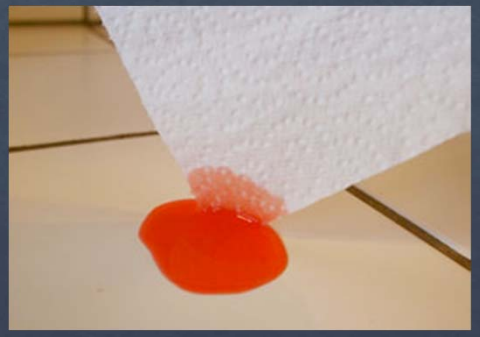


r Air Quality (IAQ)

Fundamentals

- 2nd Law: Everywhere in a house.
- Truly fundamental.

Heat melts
the cold ice



Moisture moves to the dry towel

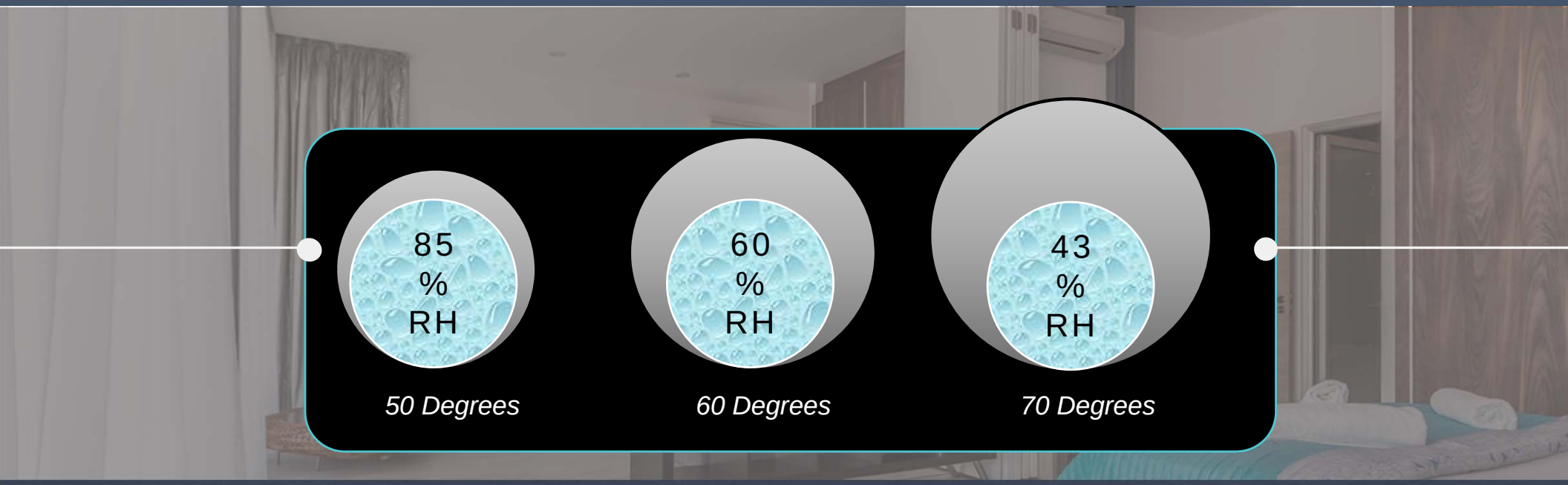
High pressure in the balloon quickly moves to the surrounding lower pressure

Relative Humidity

Air can only hold a certain amount of water per cubic foot. The amount of water relative to the volume of air is called “Relative Humidity” (RH). Cold air is denser and can hold less moisture.

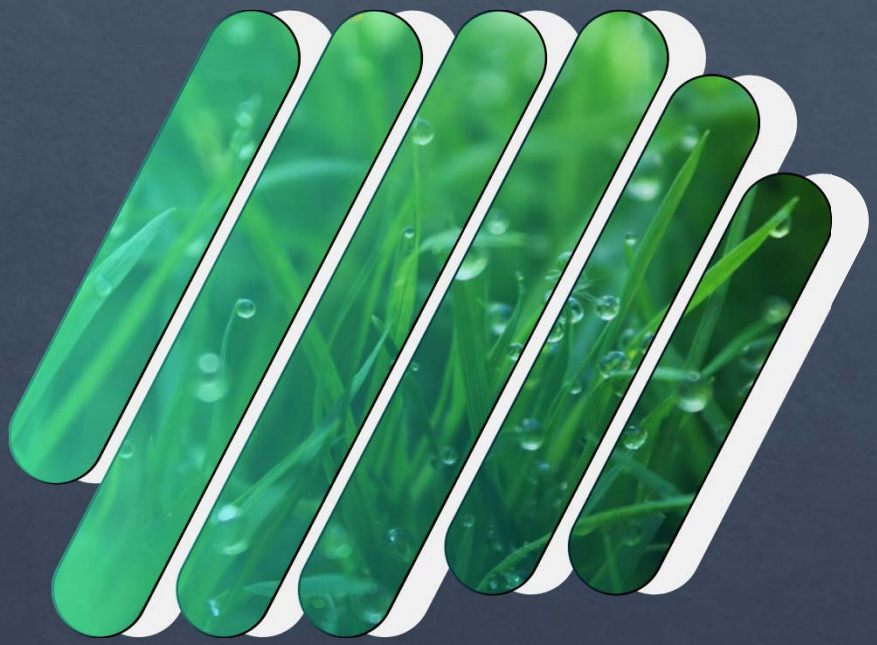
Relative Humidity

Humidity is relative to the temperature



While the amount of water in the air remains the same, the % of the air that the water occupies changes with the temperature; therefore, the amount of space that the water occupies is relative to the temperature of the air.

Dew Point



The dew point is what the air temperature would have to be for relative humidity to be at 100%.

Unlike RH, the dew point does not change with air temperature. In that sense it is an “absolute” measurement of the amount of water vapor in the air.

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What is Dry Air?

Dry air is air containing no water vapor.

People and their activities add moisture to the air in the home.

Materials in the home absorb and give off moisture – wet goes to dry.

Comfort Zone

The comfort zone is a range of dry bulb temperature, humidity, and air velocity through which the majority of people feel comfortable.

Comfort

Sweating and the resulting evaporation is a physiological mechanism to expel heat.

We can feel thermally comfortable within a range of temperatures, but this range is limited from about 68°F (20°C) to 78°F (25°C) .

Comfort

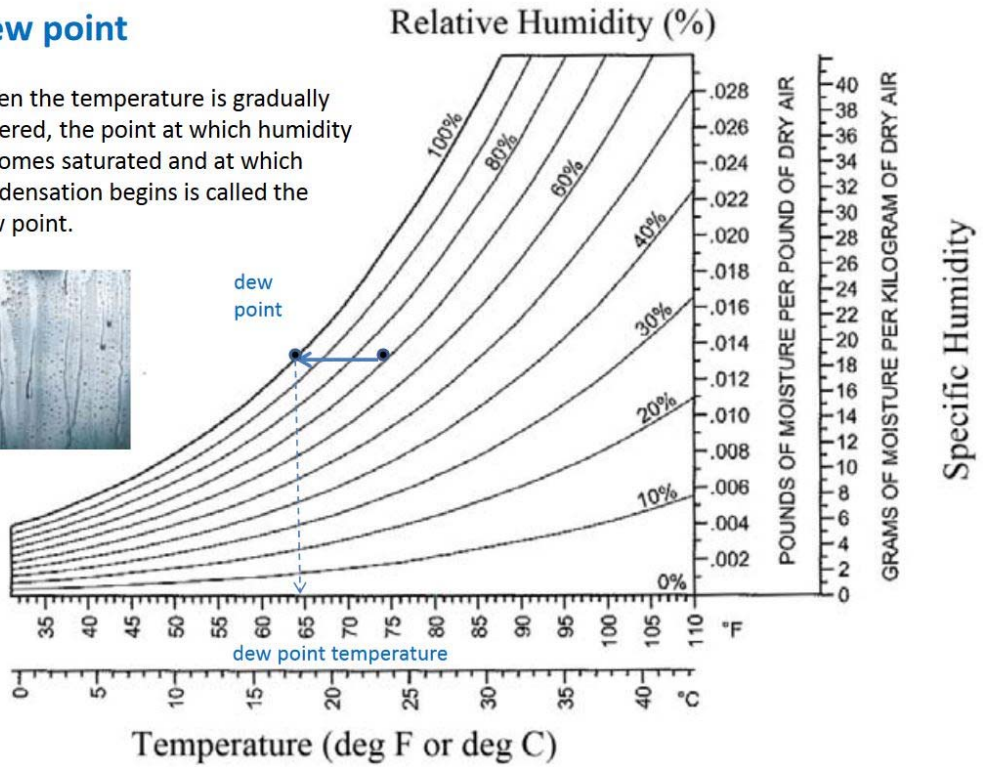
Comfort is best achieved within a range of relative humidity.

Minimum comfortable level is 20%.

Fundamentals

Dew point

When the temperature is gradually lowered, the point at which humidity becomes saturated and at which condensation begins is called the dew point.

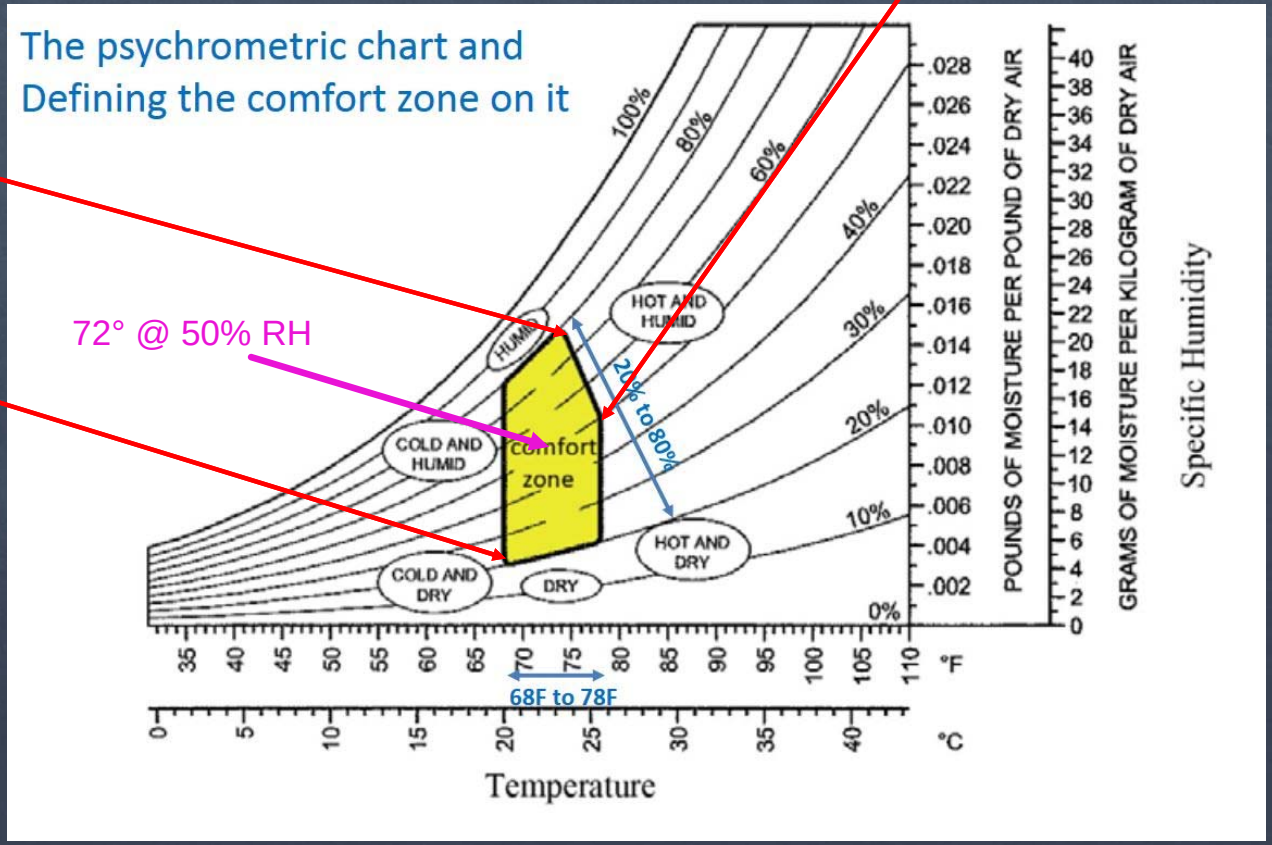


Fundamentals

78° F and 50% RH is still at the edge of the comfort zone

74° F and 80% RH is at the very edge of comfort

68° F and 20% RH is the lower limit point



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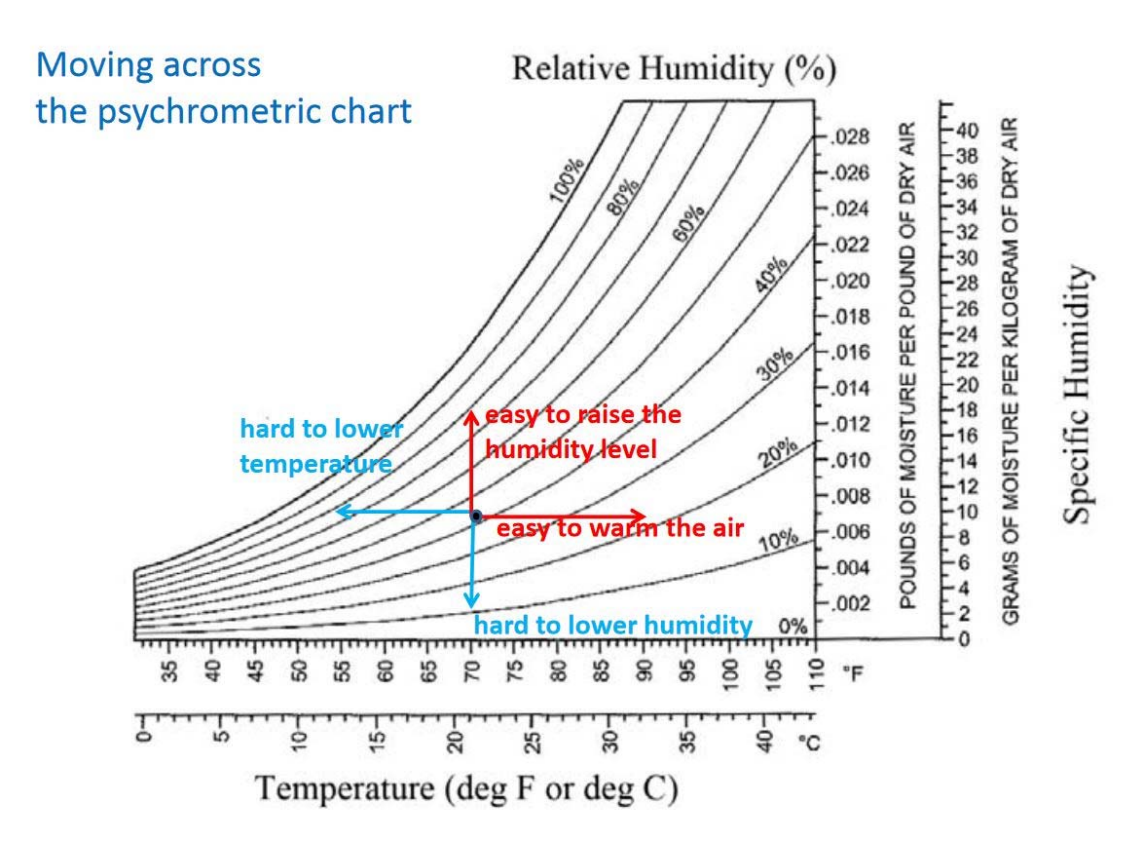
Fundamentals

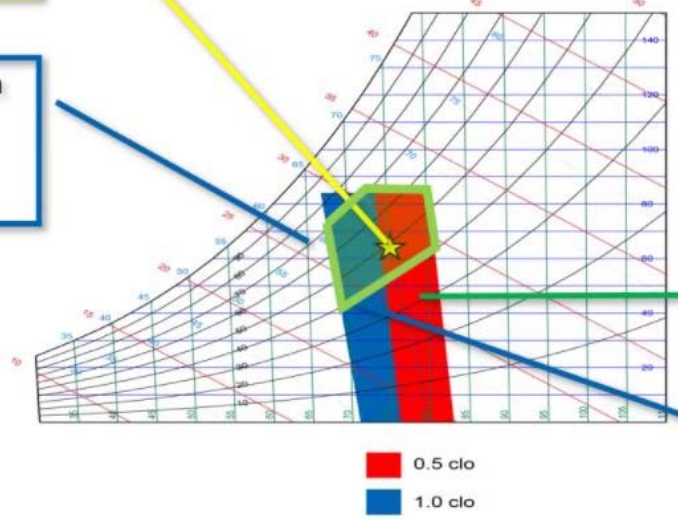


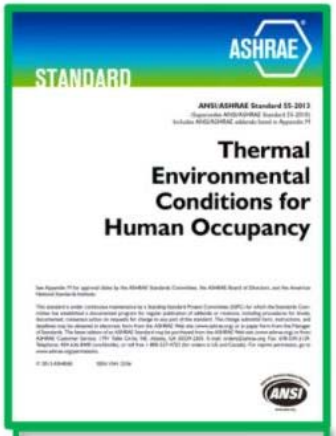
Fundamentals

INDOOR HUMIDITY
for comfort, health, resilience

Traditional indoor comfort design target "Setpoint"

60% Maximum RH Goal for building resilience





ASHRAE 55 Comfort target range

40% Minimum RH Goal of for human health

Relative Humidity & Health

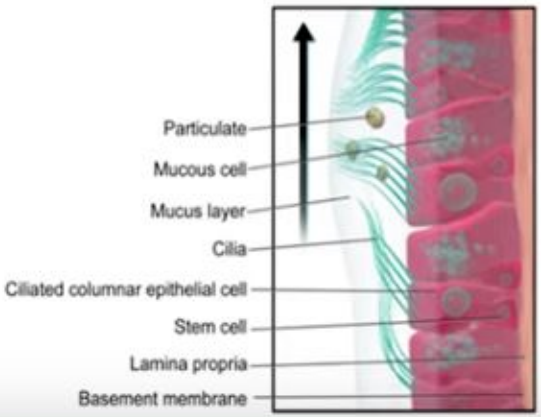
Mold needs liquid moisture
Remember 3 things need for mold growth:
1. Mold spores
2. Moisture
3. Mold chow

Relative Humidity & Health

Dry air impairs our respiratory system defenses

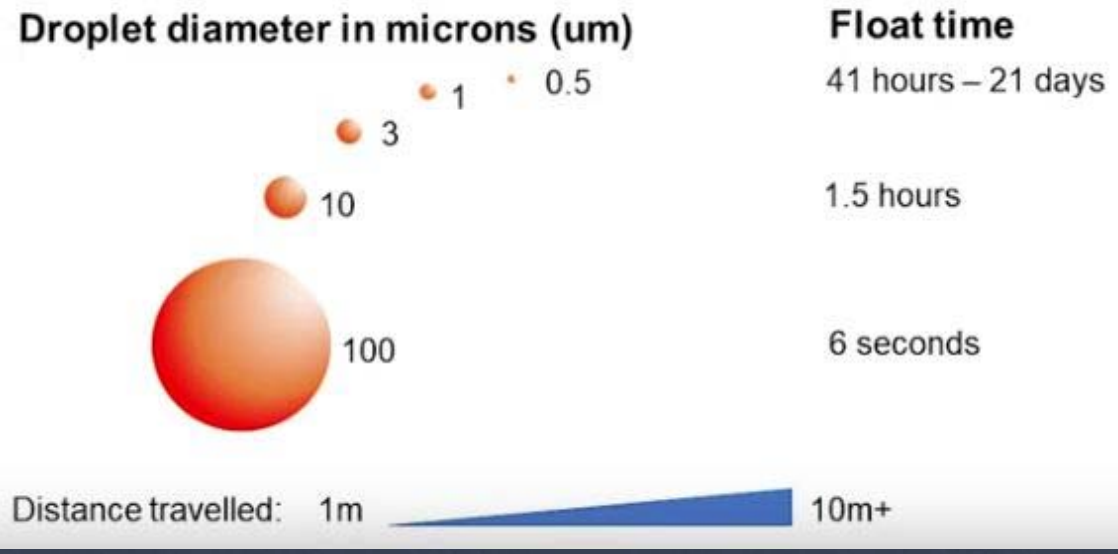
Dry inhaled air causes:

- Increased susceptibility to infections
- Increased wheezing from allergic disease



Relative Humidity & Health

Infectious droplets shrink, travel far and evade surface cleaning when the air is dry



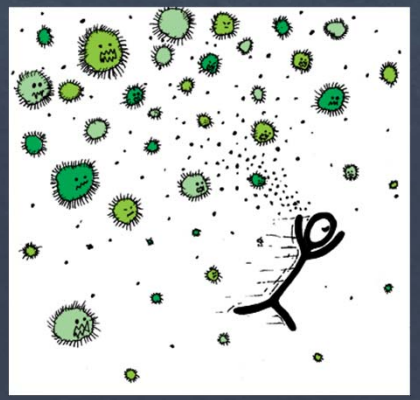
Water

2nd Law: Wet moves to dry

Moisture is the largest pollutant in the home.

Three things needed for mold growth:

- Mold spores;
- Mold chow;
- Moisture.



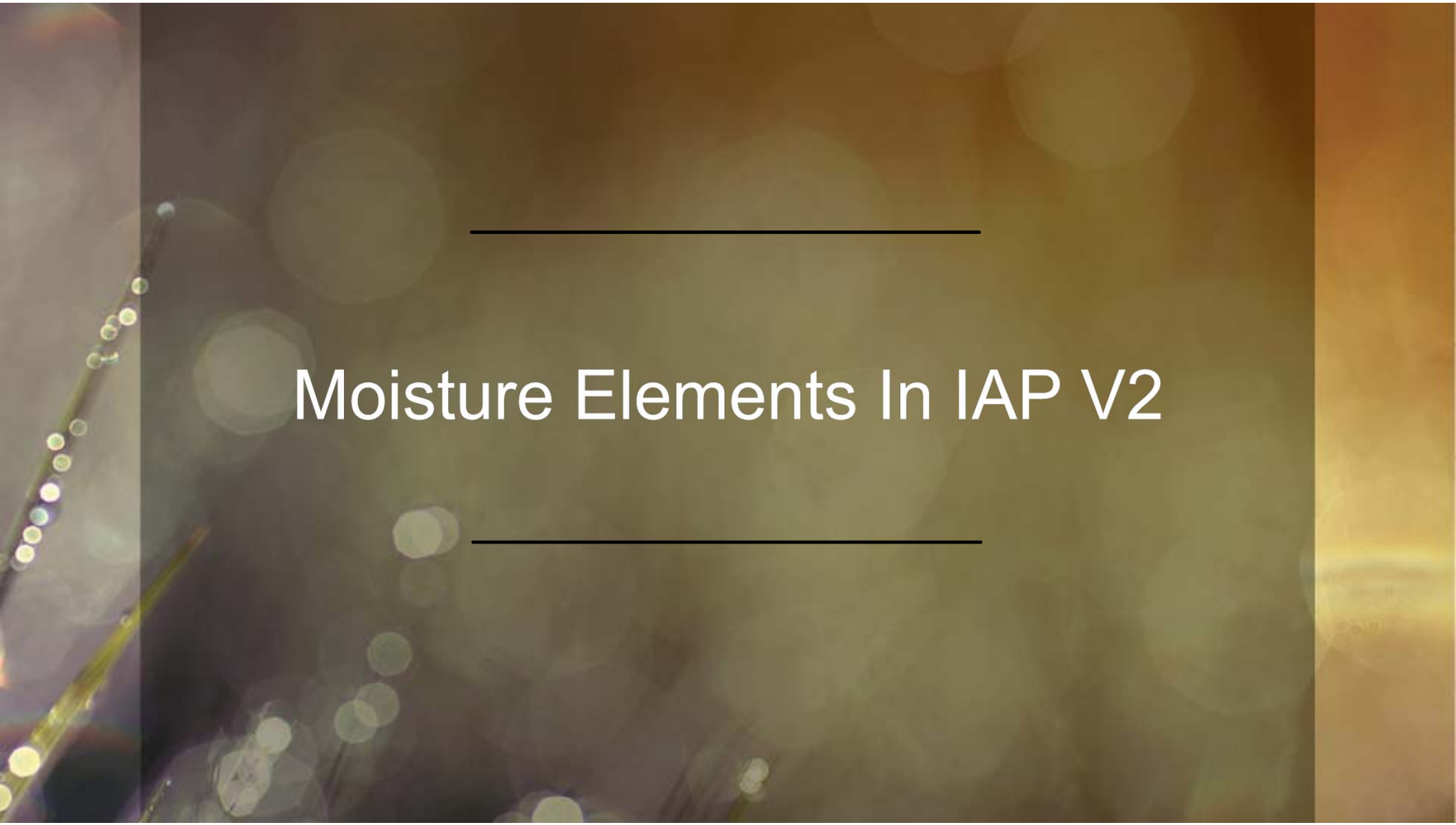
Moisture Movement

Types of moisture movement:

- Bulk moisture:
  - Plumbing leaks
  - Roof Leaks
  - Streams running through the basement
  - Moisture from poor site drainage

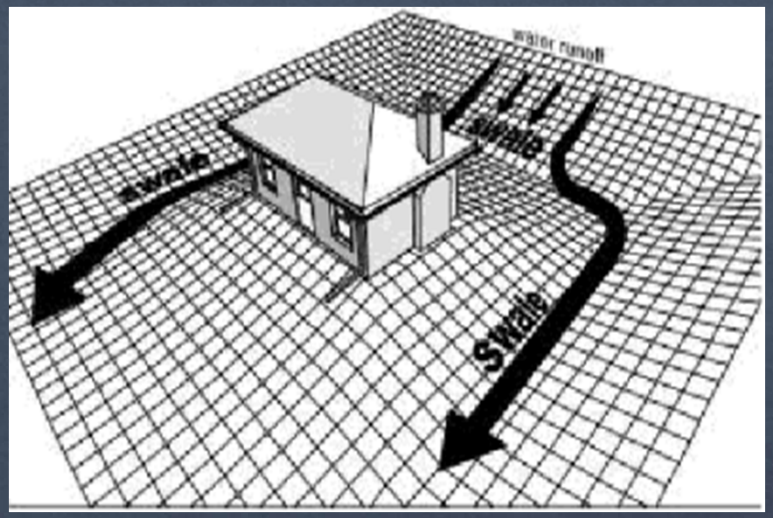
Water vapor:

- Cooking
- Showers
- Plant evaporation


Moisture Elements In IAP V2

Site Drainage

The first step is to keep the water out of the house.

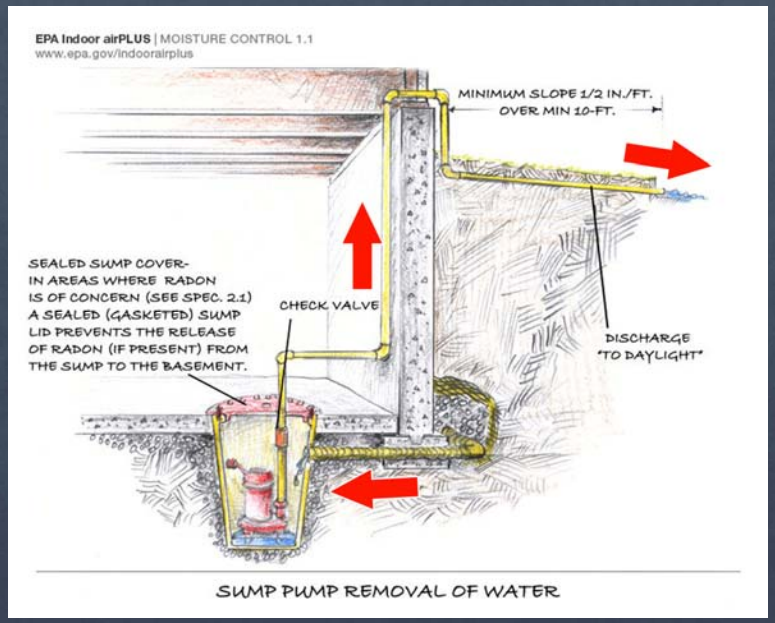


Foundation Drainage

- For all Radon Zones, if foundation drainage system discharges to daylight and is connected to passive or active radon system, include a backwater valve (check valve) or means to isolate the soil gas collection plenum
  - Gut rehabs may install foundation drainage on interior side of footing if water is carried to collection pit where it is pumped to the surface and released at least 10' from the structure or into approved drainage system

Slab Drain or Sump Pump

- Install a floor drain in the lowest floor area to mitigate risk from internal bulk water events.
- Sump pits are permitted to have drains integrated with the sump cover as long as the cover is mechanically attached with a full gasket seal.

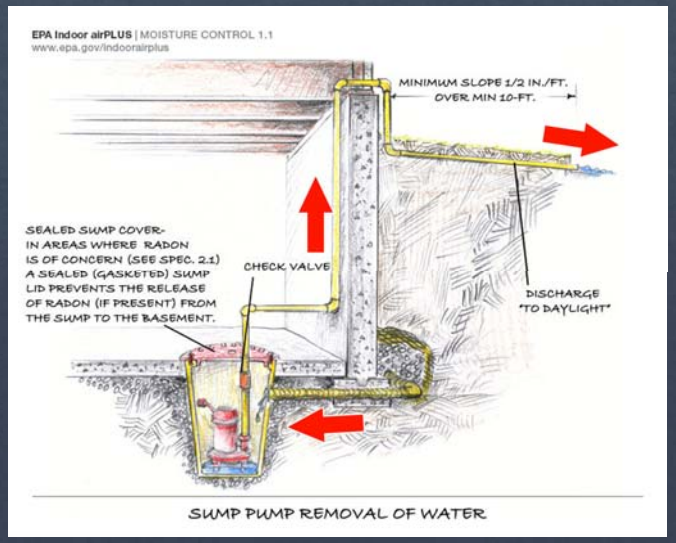


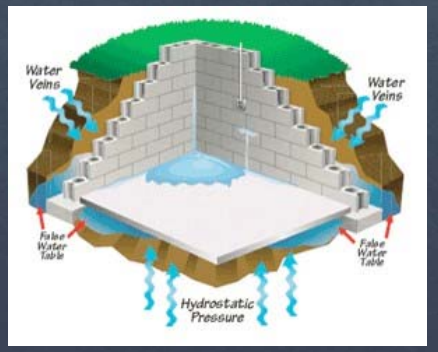
Floor Drain

Locate drains in basement or crawlspace in the lowest area; sump pits integrated with drains reduce soil gas entry (i.e. trap)

Sump pits are permitted to have drains integrated with the sump cover.

SuperSump





Capillary Break - Footers

Capillary break under or on top of footers Using either:

- 6 mil (or thicker) polyethylene sheeting: OR
- Bituminous membrane; OR
- Liquid waterproofing.

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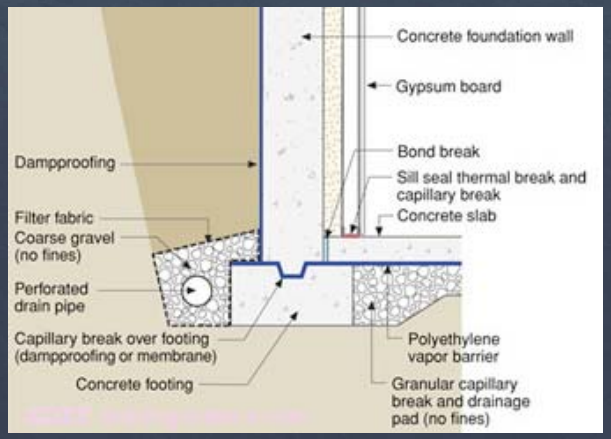

Image: BASC

Image: Fine Homebuilding

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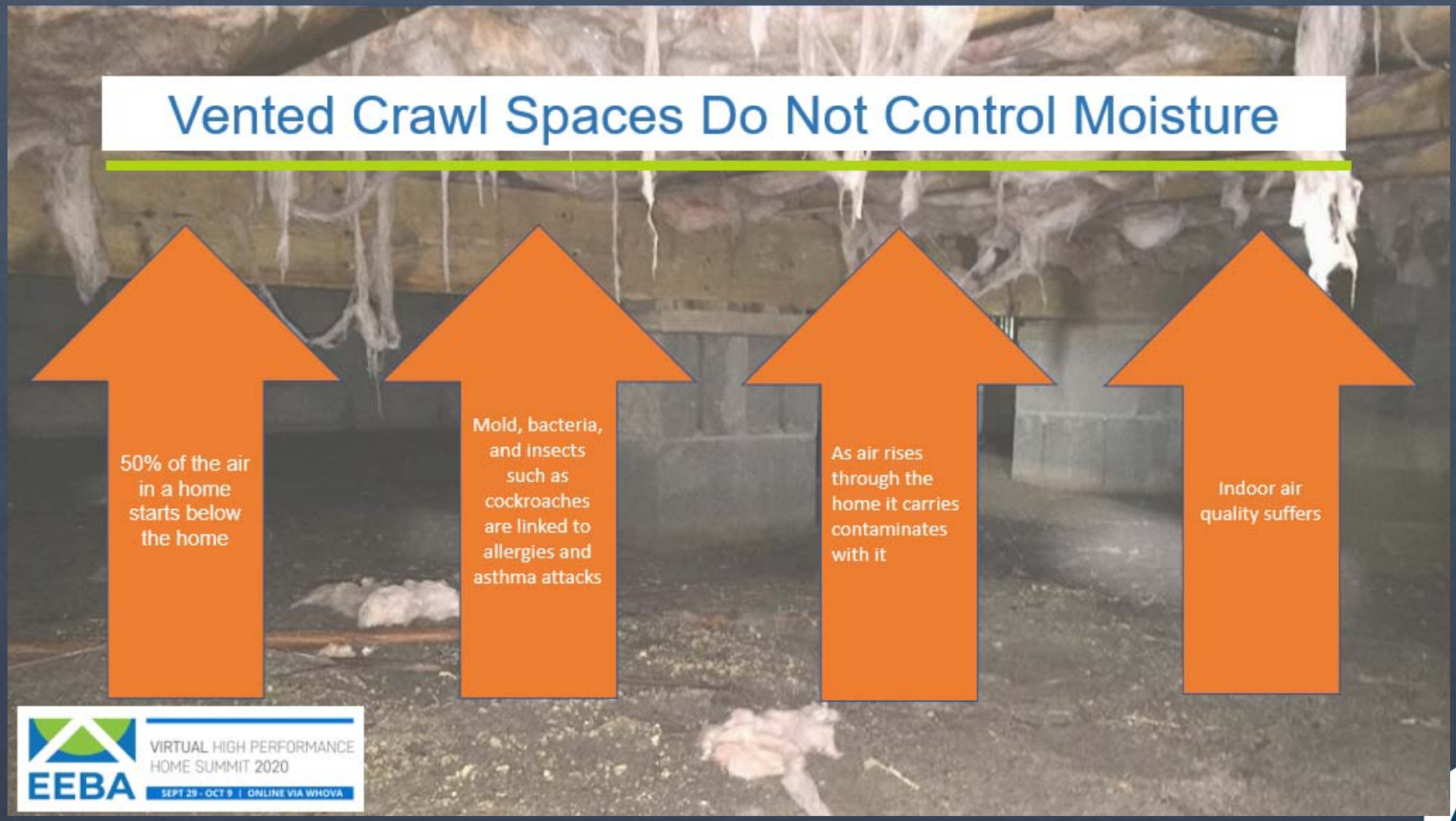
Class I Vapor Retarders

- Class I vapor retarders have a permeance level of 0.1 or less and considered impermeable. (Polyethelene, glass, sheet metal, foil faced insulated sheathing, etc.)
- Class II have a permeance between 0.1 and 1 perm and are considered semi-permeable. (Unfaced expanded polystyrene, fiber faced polyisocyanurate, asphalt-backed kraft paper facing on fiberglass batts, etc.)

Vented Crawl Spaces Do Not Control Moisture



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Basement and Crawlspace Sealing & Conditioning

Moisture zones A and C provide active dehumidification OR conditioned air for basements and crawlspaces.

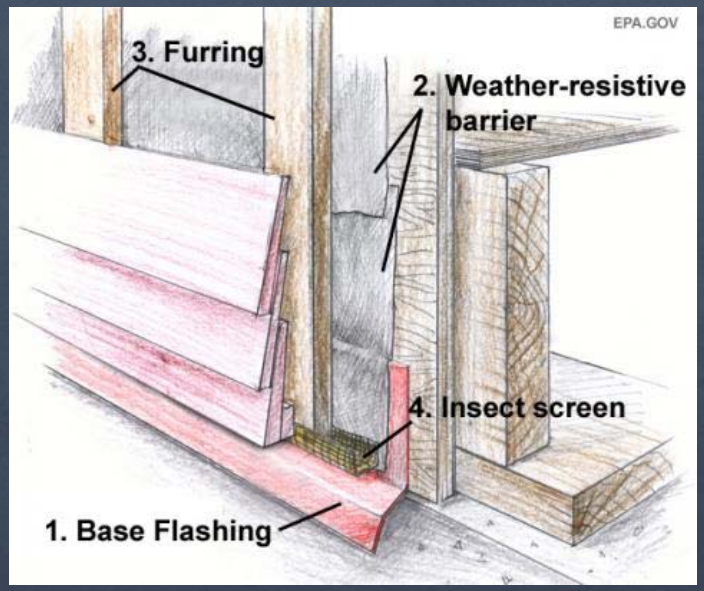
Provide conditioned air at a rate not less than 1 cfm per 50 sq feet of horizontal floor area.

V2 Advisory: Active dehumidification is recommended in crawlspaces and basements (in lieu of or in addition to space conditioning) to avoid humidity issues during “swing seasons” or low-load periods where space conditioning systems may not be operating regularly.

V2 Advisory: A humidity monitoring device that includes a digital display of indoor temperature and RH and the ability to record data, either on-board or via a web-based app, is recommended in basements and crawlspaces in addition to similar RH monitoring in the main living area of the home.

Water-Managed Wall Assemblies

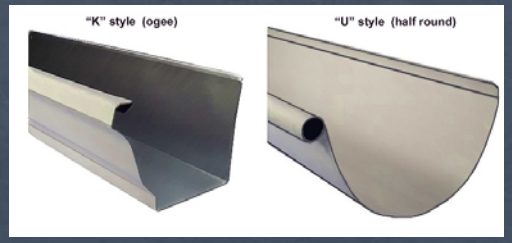
- Advisory: liquid and fluid applied membranes and integrated sheathing systems with sealed/taped seams should be applied on clean surfaces and according to manufacturer instruction to perform as a Water Resistive Barrier WRB).
- Advisory: rainscreen assemblies with a minium 3/8” gap between the cladding and the drainage plane are recommended behind wood and fiber cement siding.



BASC

Gutters, Downspouts & Roof Water Drainage

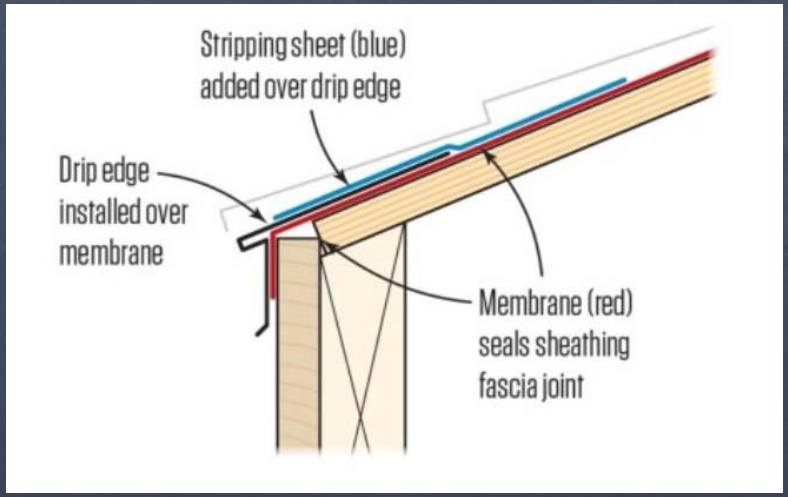
Direct roof water away from the building using gutters and downspouts and empty into lateral piping.



William Rose

Roof Eaves

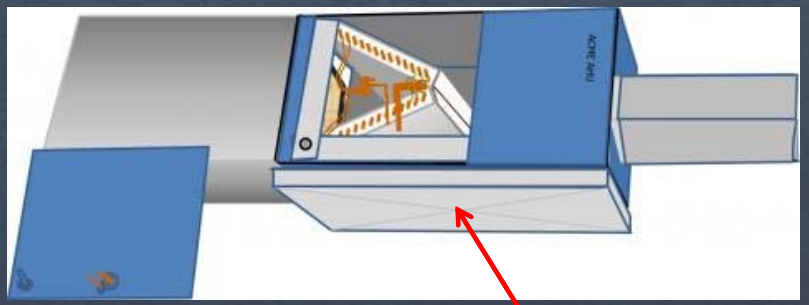
Advisory: Install the roof membrane **before** the drip edge at a min of 1” down the fascia.



The Journal of Light Construction

Appliance Drainage and Drain Pans

HAC equipment and appliances producing condensate must have a drain pan connected to a drain and non-vented dryers shall be plumbed to a drain.



BASC

Drain Pan

Water Supply Pipes

Insulate water supply pipes in exterior walls with minimum R4 pipe insulation.

Exceptions:

- Climate zones 1-3 located in dry climates, as defined by 2018 IECC Figure R301.1.
- When insulation in the wall cavity qualifies as an air barrier and pipes are located within the interior 50% of the wall cavity.

Advisory: Pipes should be installed as close as possible to conditioned space while maintaining Grade 1 insulation installation to reduce risk of freezing and/or condensation.

Materials with Signs of Water Damage or Mold

- Advisory, dry out buildings during construction, remove standing water, remove moisture using fans or dehumidifiers and store materials out of wet areas.

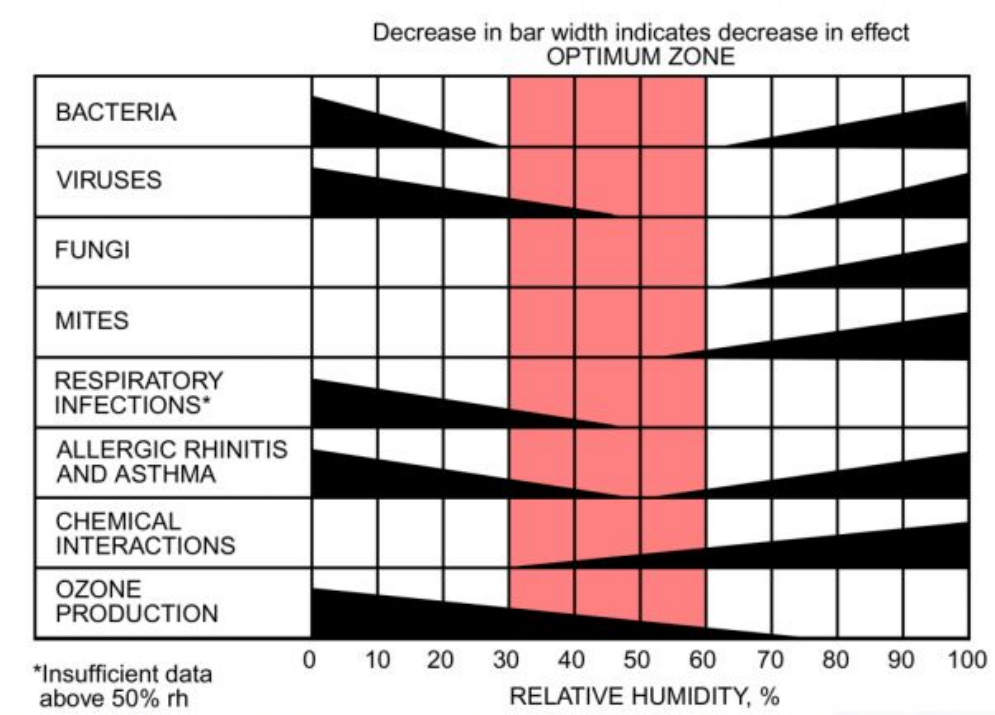
Occupant Education

Things that produce moisture in a house:

- People just standing there and breathing;
- People washing themselves/showering;
- Cleaning, mopping, spilling liquid;
- Burning things like candles and gas stoves;
- Cooking/boiling things;
- Plants;
- Fish tanks.
- Etc.

Venmar Ventilation Systems

Moisture & Pathogens



[2]2016 ASHRAE HVAC Systems and Equipment Handbook – Ch 22

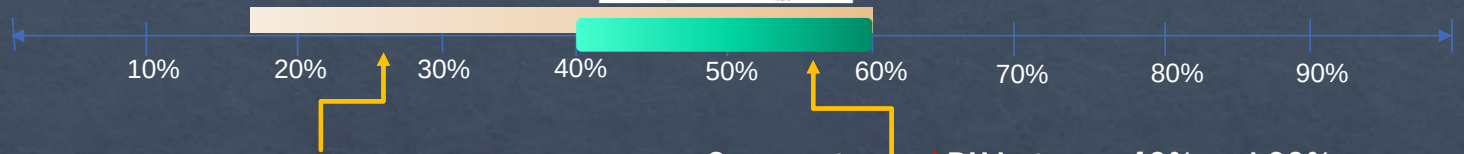
Indoor Air RH Struggle for Balance

Structure Perspective

Less Moisture

Human Perspective

More Moisture



Buildings have a wider humidity tolerance

- Can be drier;
- Tighter envelope provides improved control;
- Keep surfaces above the dew point.

Occupants need RH between 40% and 60% for health.

- Decreased infections;
- Fewer allergies;
- Fewer pathogens;
- Increased work performance.

HAC Systems

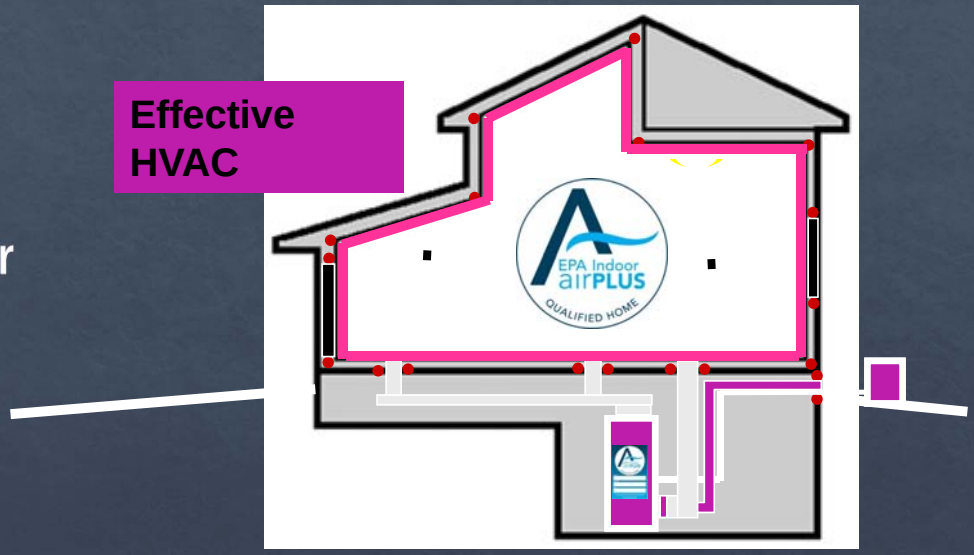
HAC

The water vapor in the air in the house can be dealt with by using mechanical equipment like the heating, cooling, and dehumidifying devices.

HAC Systems

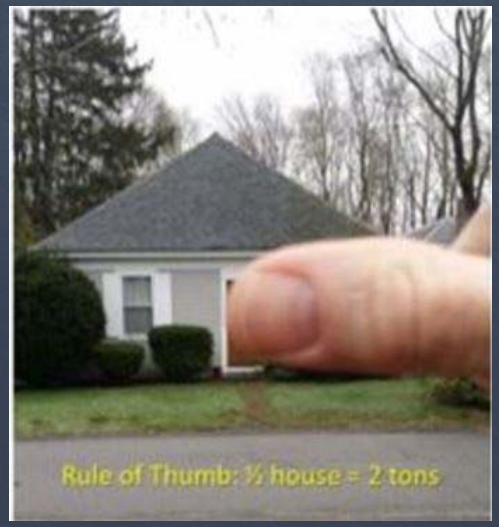
Note that Heating and Cooling are considered separately. Ventilation stands on its own.

Cost-effectively balance the energy efficiency approaches of tighter homes with the indoor air quality requirements of Indoor airPLUS.



Heating and Cooling (HAC) Sizing & Design

In detached one- and two-family homes and townhouses where ENERGY STAR does not require certain equipment to be selected per ACCA Manual S, systems such as boilers and mini-split / multi-split systems, must be selected per ACCA Manual S to meet Indoor airPLUS requirements.



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Duct System Design and Installation

- MF common space duct systems sized in accordance with ASHRAE
- Seal duct boots to finished surfaces
- Added to covering ducts during construction, ALSO vacuum out ducts prior to installing registers
- Advisories:
  - Right sized, fully ducted returns to air handling equipment is recommended
  - Air handling equipment less than 3,000 cfm should have air leakage less than 2% of the design airflow rate
  - Recommend the collection of Testing Adjusting Balancing (TAB) Reports within ±20% or ±25cfm of design flows

Location of Air Handling Equipment & Ductwork

- All air handling equipment and ductwork must be installed within the thermal and air barrier boundary of the dwelling unit

Exceptions:

- Essentially, all exceptions outlined by DOE Zero Energy Ready Homes, (e.g. buried ducts)
- Ducted systems serving multiple units in MF buildings
- Up to 10' of total duct length permitted outside boundary

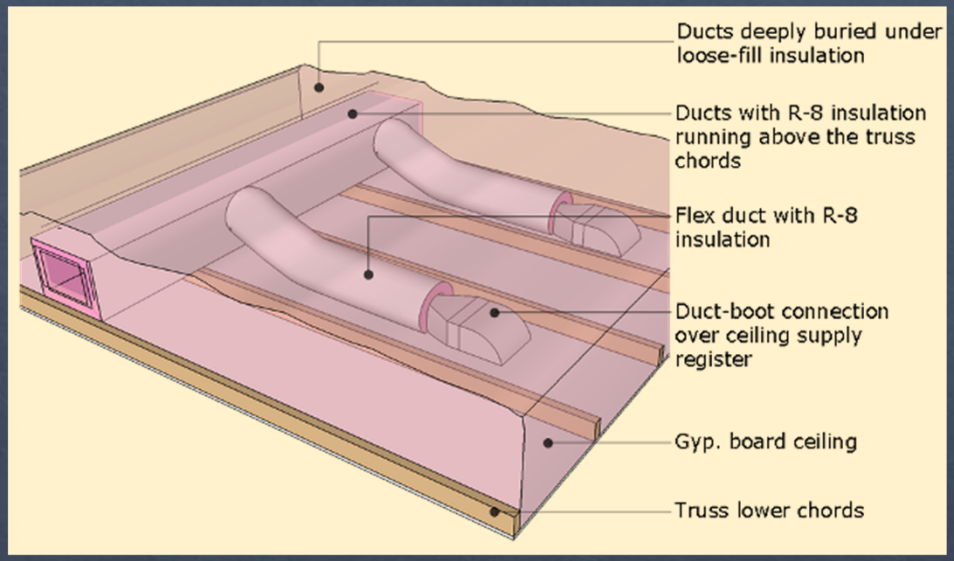


Image Source: BASC

Location of Air Handling Equipment & Ductwork

Some Exceptions to the location of the air handling equipment & ductwork:

Embedded ducts in vented attic if:

- Minimum R8 insulation; AND
- Duct leakage to outdoors is measured at ≤ 3 CFM_{25} per 100 ft^2 of conditioned floor area; AND
- Moist (A) & Marine (C) CZ add 1.5” min CCSF & is buried under 2” min blown-in: OR
- Dry (B) CZ, ducts buried under minimum 3.5” blown-in insulation.

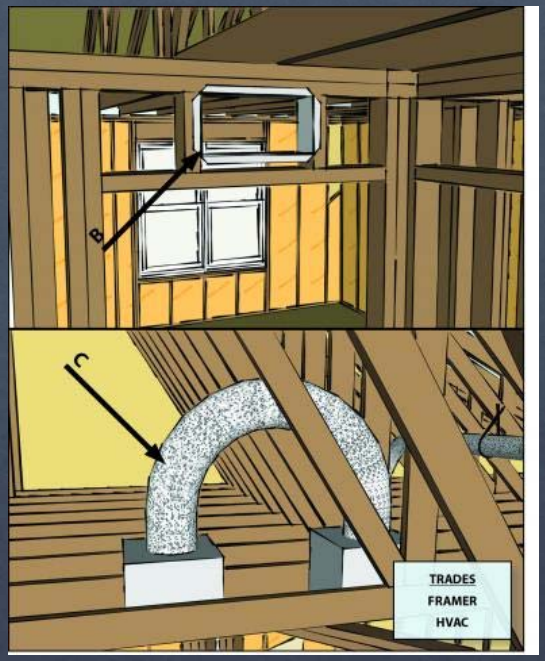
Location of Air Handling Equipment & Ductwork

Exceptions in locating the air handling equipment & ductwork:

- Ducts and air handlers located in uninsulated crawl or basement spaces meeting dehumidification requirements of items 1.6
- Air handling equipment located to facilitate cleaning, filter replacement, access to cores and condensate pan. If in attics, opening at least 20” x 30”, passageway to the system with solid flooring and permanent or pull-down stair or direct access < 9’ ceiling
- No air handling equipment or ducts in garages (SF & attached allowed if fully isolated)

Pressure Balanced Bedrooms

- **Jump ducts (not directly delivering conditioned air) are an exception to the location of the ductwork inside the conditioned space.**
- If certifying dwelling units through ENERGY STAR Multi-Family New Construction, bedrooms with a design supply airflow < 150 CFM, shall also achieve a Rater-measured pressure differential ≥ -3 Pa and ≤ +3 Pa with respect to the main body of the dwelling unit when all air handlers are operating.



Humidity Control

- Provide humidity monitor with digital display of indoor temp, RH and ability to record data (exception, MFNC projects with remote RH monitoring)
- CZ 1-4 Moist (A) must install equipment to maintain indoor RH at or below 60% (i.e. whole-home dehumidification or HAC with variable capacity & humidity sensor)

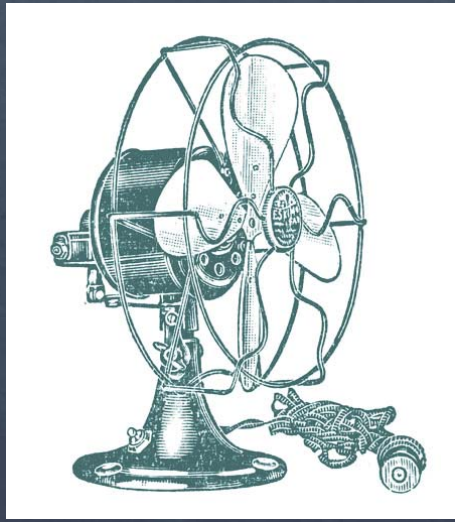
Humidity Control

Dwelling units in Moist (A) climate zones 1-4 , as defined by 2018 IECC Figure 301.1, shall have equipment designed and installed with sufficient latent capacity to maintain indoor RH at or below 60 percent. This requirement shall be met by either:

- A ventilating or whole-home dehumidifier plumbed to a discharge drain; **OR**
- A heating and cooling system equipped with additional controls to operate in dehumidification mode (i.e., variable capacity systems that utilize humidity sensor feedback in the control algorithm).

Ventilation

Ventilation & Humidity



Fans move air.

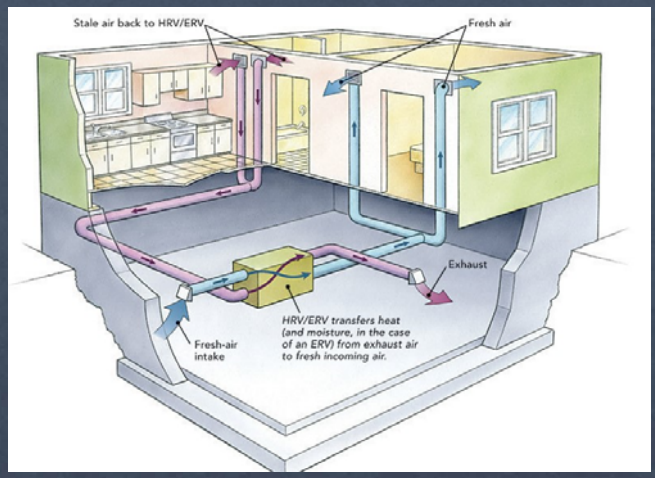
In and of themselves they do not change the air condition.

They can move air from a polluted source to a non-polluted place – like out of the building.

Dwelling Unit Mechanical Ventilation

Dwelling unit ventilation must be a BALANCED ventilation system (exhaust-only or supply-only not allowed).

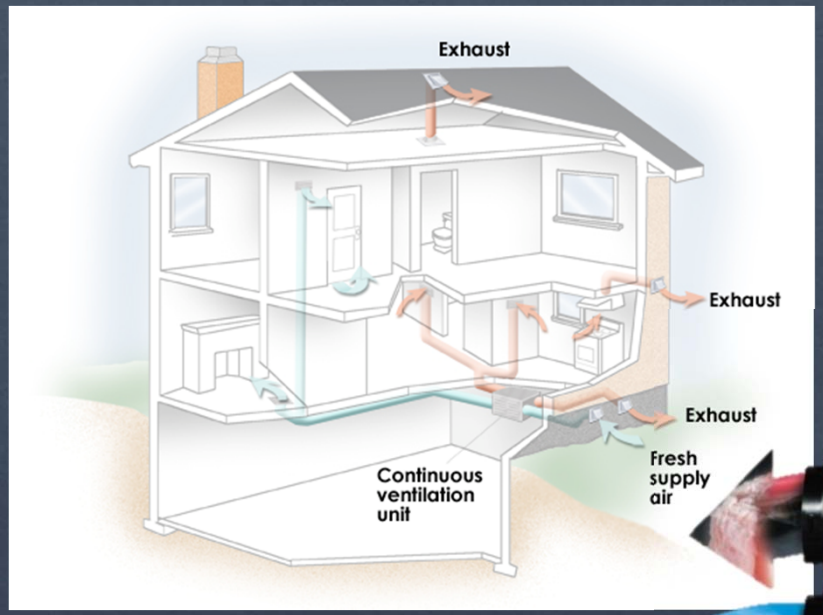
- System is considered balanced if the supply and exhaust flows measure within 10% or 10 cfm;
- Balanced system can be connected to the HAC air handler if controlled intermittently & automatically and airflow can be measured.

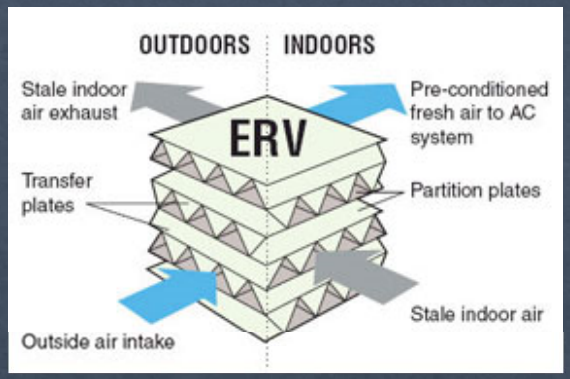


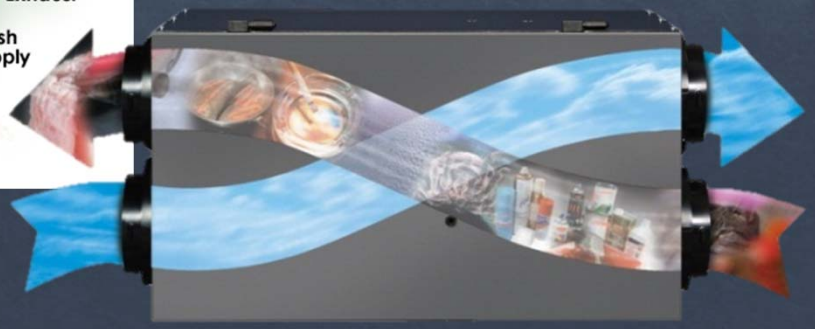
HRV/ERV

- Equal amounts of air move in and out of the house;
- They are NOT make-up air systems. They do NOT add air to the house.
- An HRV is a Heat Recovery Ventilation – exchanges heat in the warmer air stream to the cooler air stream;
- An ERV is an Enthalpy Recovery Ventilator – exchanges both heat and moisture from the warmer and wetter air stream to the cooler and drier air stream.

Whole Building Ventilation – Balanced with Heat or Energy Recovery







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HRV/ERV Installation

Three basic installation approaches:

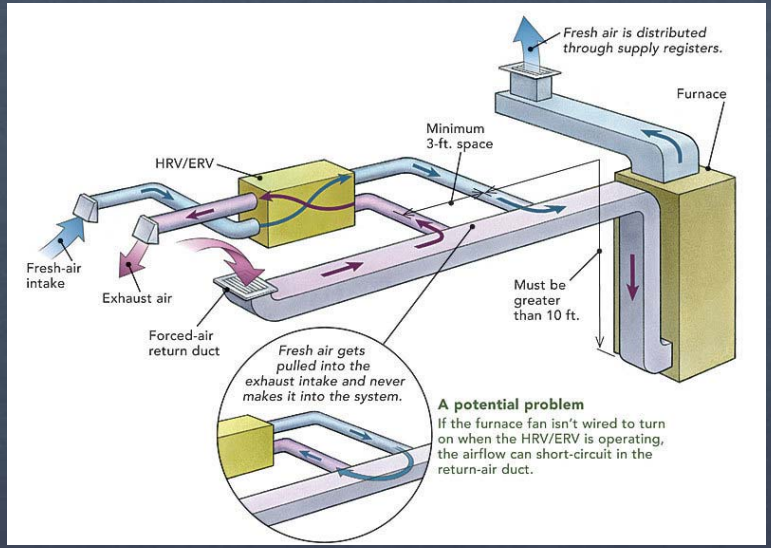
- Fully ducted system
- Fresh air to the HVAC supply
- Both sides to the HVAC system

HRV/ERV Installation

Both supply & exhaust to HAC ducting

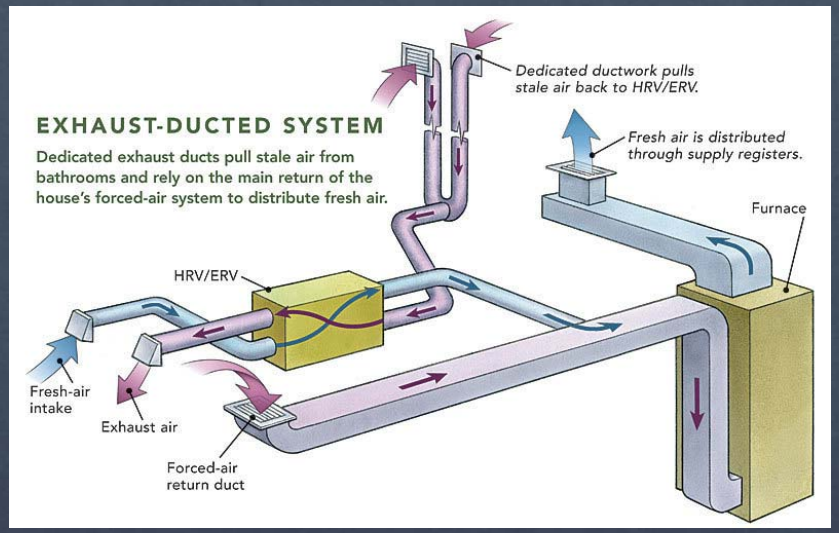
Fresh, pre-conditioned air is delivered to the return duct, drawn through the filter by the air handler, and distributed to the rooms.
Stale air is drawn out of the return ducting into the HRV.

Difficult to balance;
May put the house under negative or positive pressure
Difficult to measure airflow;
Short circuit if air handler not running;
Expensive to operate if the air handler fan has to run.



HRV/ERV Installation
Fresh air to HAC ducting

Fresh, pre-conditioned air is delivered to the return duct, drawn through the filter by the air handler, and distributed to the rooms.
Stale air is drawn out of polluting spaces like bathrooms



Good stale air extraction;
Difficult to balance;
Difficult to measure the flow;
Not fully distributed when air handler isn't running;
Expensive to operate if both devices have to run at the same time.

HRV/ERV Installation
Fully ducted

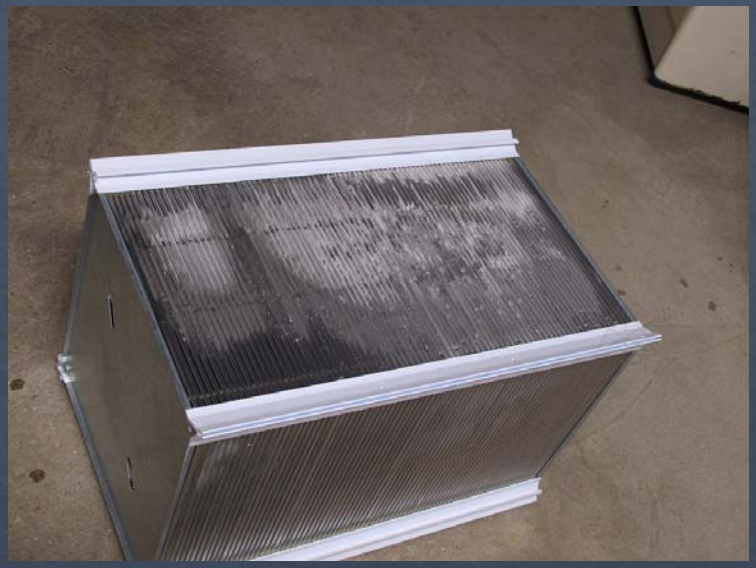
This is the best installation of an HRV/ERV.
Fresh pre-conditioned air is delivered to the living spaces like bedrooms.
Stale air is drawn out of polluting spaces like bathrooms.
System can be balanced for optimum performance.

Expensive to install because of added ductwork;
Least expensive to operate – fan power;
Most efficient – balanced.

HRV/ERV Installation

Must be located where it can be serviced;
Filters must effective;
Filters must be cleaned;
HRV drain pans must be maintained;
Exchanger cores must be cleaned.

HRV/ERV Installation



Outside air well below freezing;
Inside air full of water;
Moisture condenses on the core – and freezes.

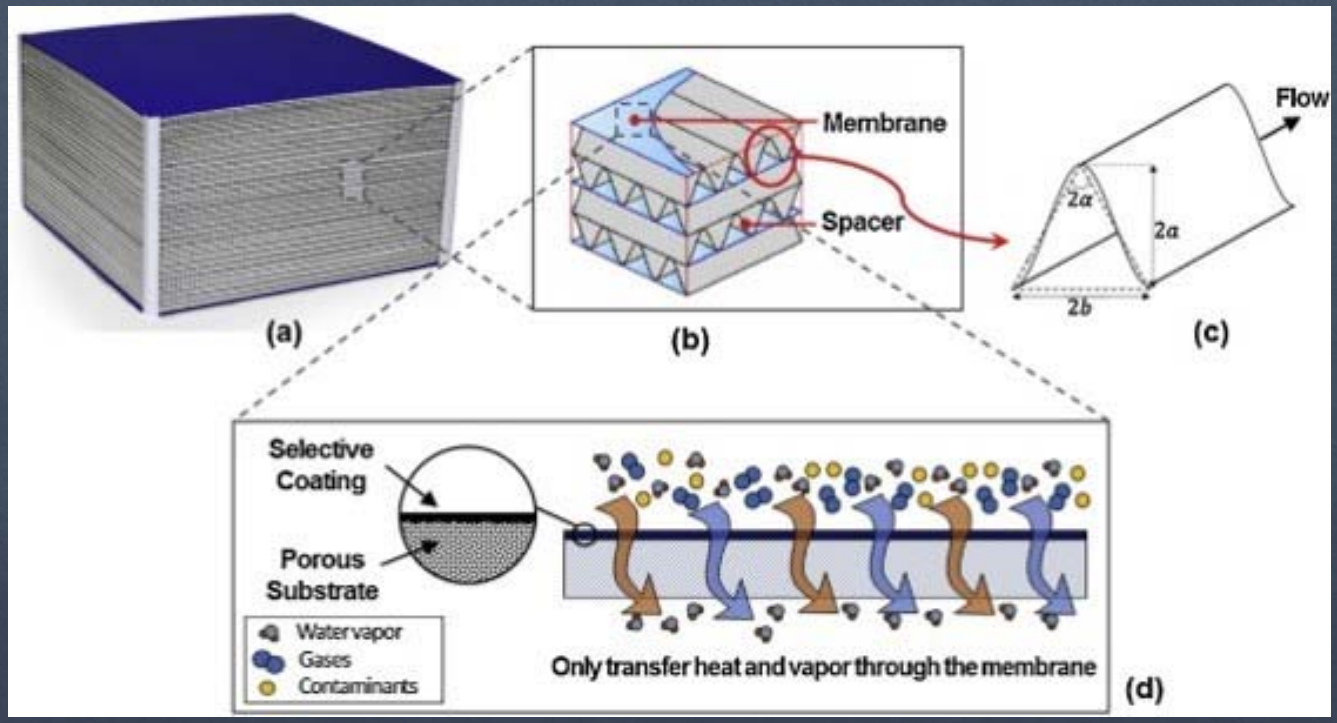
Defrost can be either a heating element or reversing the flow with internal dampers.
HRVs have drains.

Dwelling Unit Mechanical Ventilation

Balanced system can be connected to the HAC air handler if controlled intermittently & automatically and airflow can be measured

Advisory, outdoor air ducts to the return side are permitted but return air temperature flowing across heat exchanger should meet manufacturer rec's (~ 60°).

ERV Impact on Moisture



Dwelling Unit Mechanical Ventilation

Advisory, HRV or ERV installation:

Locate exchanger element and outdoor air intake in accessible location, minimize intake duct lengths, run simultaneously with the HAC system if connected to the HAC ducting, install exhaust at high points in the rooms, install HRV with trapped condensate drain.

Advisory, Where installing powered supply as part of a balanced ventilation system:

Locate fan unit so that it is accessible to service and locate supply air considering occupant thermal comfort.

MERV 13 filter for HAC in accessible location for maintenance

ERV Codes cont.

IMC § 514 ENERGY RECOVERY VENTILATION SYSTEMS

IMC § 514.3 Access.

A means of access shall be provided to the heat exchanger and other components of the system as required for service, maintenance, repair or replacement.

IMC § 514.4 Recirculated Air

Air conveyed within energy recovery systems shall not be considered as recirculated air where the energy recovery ventilation system is constructed to limit cross-leakage between air streams to less than10 percent of the total airflow design capacity.

Dwelling Unit Bathroom and Kitchen Exhaust

Intermittent bath exhaust max 2 sones at 50cfm (exception, remote mounted)
Control bath exhaust to run for min 30 minutes after use or humidity < 60%
Demand control at kitchens by range hood or appliance range hood combo, vented to outdoors minimum 100cfm or downdraft min 300cfm

NOTE: detached one and two family & town homes, continuous exhaust may be used with, but not instead of, demand controlled (i.e. can't locate exhaust in the kitchen "area" with recirculating (head greaser) over the range)

Common Space and Other Ventilation

Advisories, install a booster fan if dryer duct exceeds manufacturer lengths and provide make-up air with auto switch.

Actual length – tape measured
Equivalent length – allowance for each fitting, 5 feet for each 90° elbow, and 2.5 for each 45° elbow

Termination fitting or hoods can add as much as 40 feet!

Controls, Sensors & Dehumidifiers

Controls & Sensors

Gut Rehabs requires a digital hygrometer or RH monitoring device if the walls are not excavated.

Hygrometers

Dehumidifiers

Energy Star Dehumidifiers

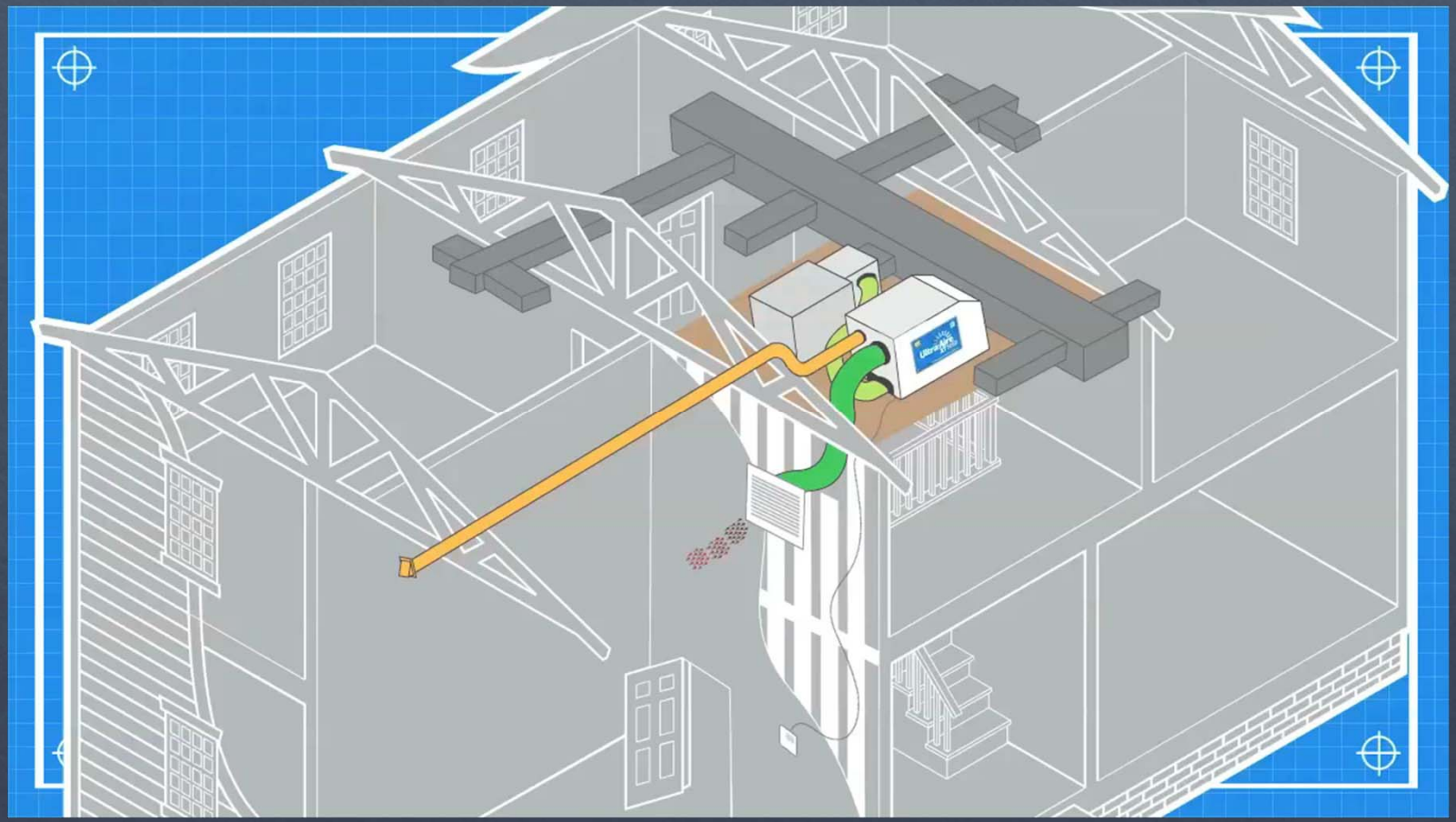
Whole House Ventilating Dehumidifier

A whole house ventilating dehumidifier is a dehumidifier designed to work with the home's HVAC system to bring in outdoor air, filter it, and dehumidify the air in the entire home to maintain a set relative humidity (RH) level.

IAQ & Energy 2020 CONFERENCE

EPA Indoor airPLUS

Indoor Air Quality (IAQ)



Santa Fe/Ultra-Aire

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EPA Indoor airPLUS

Indoor Air Quality (IAQ)

Heat Pump Water Heater

Laboratory Performance Evaluation of Residential Integrated Heat Pump Water Heaters

B. Sparn, K. Hudon, and D. Christensen
National Renewable Energy Laboratory

Table 7. Cooling Capacity and SHR Comparison

HPWH Mfr.	Sensible Cooling Capacity (W)	Total Cooling Capacity (W)	SHR
Unit A	1680	1704	0.986
Unit B	672	768	0.875
Unit C	905	1350	0.670
Unit D	1015	1027	0.988
Unit E	1048	1051	0.997

Natural Humidification

People: Average person about 0.4 pounds of water/hour

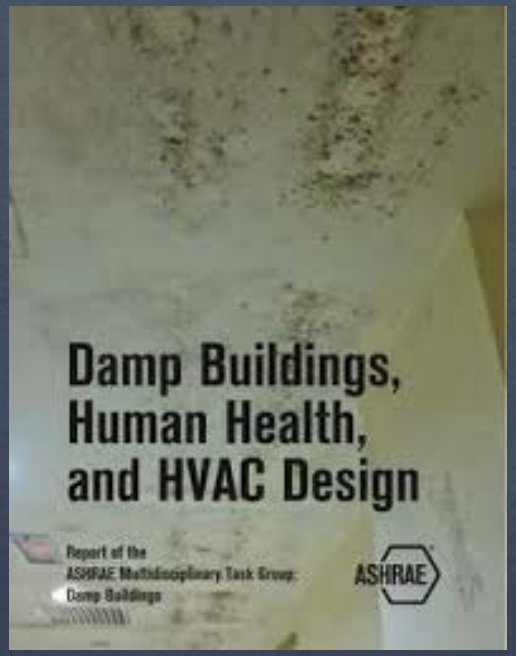
Three things about dry buildings:

1. If it's located in a cold climate, the house is probably too leaky. Air seal it before venturing into a humidifier.
2. It's probably not the fact that it's heated with hot air if the HAC system has been designed and installed properly.
3. If the house has been built tightly, it is generally true that the occupants and their activities can generate enough moisture.

Summary

- Keep the fundamentals in mind – you can't fool mother nature;
- Indoor airPLUS is raising the bar on moisture control in Version 2;
- Keep the water out – source control
- Reduce the indoor moisture sources - dilution
- Dehumidify and ventilate the remainder - removal

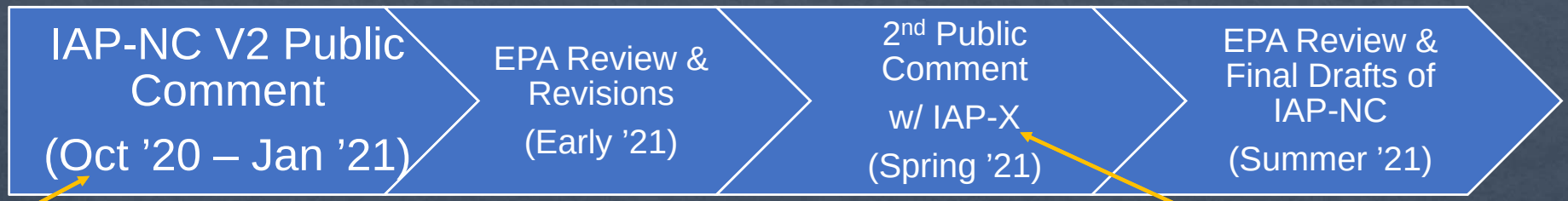
ASHRAE Damp Buildings



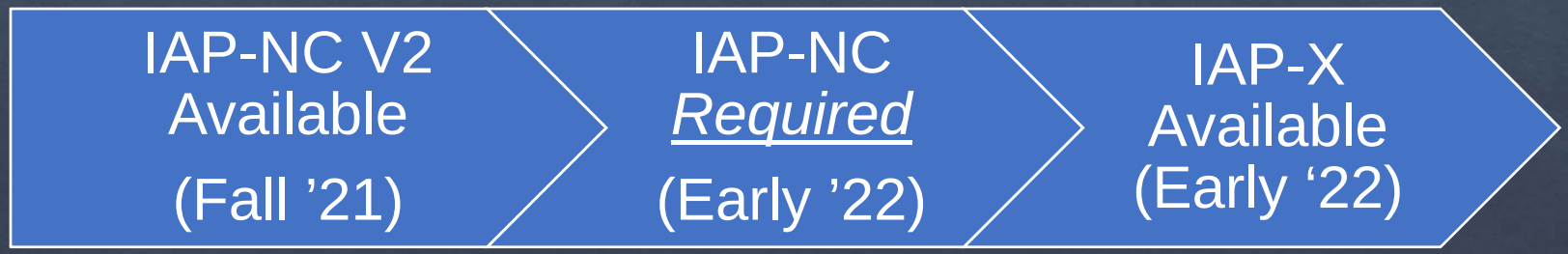
https://www.ashrae.org/File%20Library/Technical%20Resources/Bookstore/DampBldgs-HumanHealth-HVACdesign.pdf

Indoor airPLUS Version 2 Timeline

- **Public Comment & Final Development**



- **Implementation**



**Caveat – Does anyone really know what 2021 holds?*

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