

First Lets look some Background Info that may be
Helpful

Three Properties of Air

- Ambient Temperature
- Relative Humidity
- Dew Point Temperature
- **Ambient Temperature/Sensible Temperature** is the measure of heat in the air by a thermometer.
- **Relative Humidity** is the percentage of how much vapor is in the air. There is always a limit to how much the air can be saturated before condensation will occur, which changes the state of water from a vapor to a liquid, or in layman's terms, condensation drops or "rain"

Three Properties of Air (cont.)

- Relative Humidity is the ratio of the actual water vapor in the air to the maximum amount of water vapor that can possibly be in the air at the current temperature.
- **Two things affect Relative Humidity** – (1) if the amount of water in the air changes and (2) if the temperature of the air changes.
- If the Relative Humidity in one location is 90% and 40% in another, we still cannot tell which has more water vapor unless we know the temperature. As temperature decreases the cold air is dense and can hold less water than air at a higher temperature with lighter expanded air.

Three Properties of Air (cont.)

- The term **Dew Point** is used which is a more direct indication of how much water vapor is in the air.
- If we change the temperature of air without adding or removing water vapor, the Dew Point stays the same but the ratio of actual water vapor in the air versus the air temperature will change.
- If we remove water vapor, the Dew Point decreases. If we add water vapor, the Dew Point increases.

Three Properties of Air (cont.)

- The **Dew Point** measurement tells you the **temperature at which the water vapor in the air will condense into a liquid** – either because the air cools down or because the air comes into contact with a cooler surface.
- We can calculate the 3rd unknown property if we know two of the three by using psychrometric charts, slide rules, and calculators.

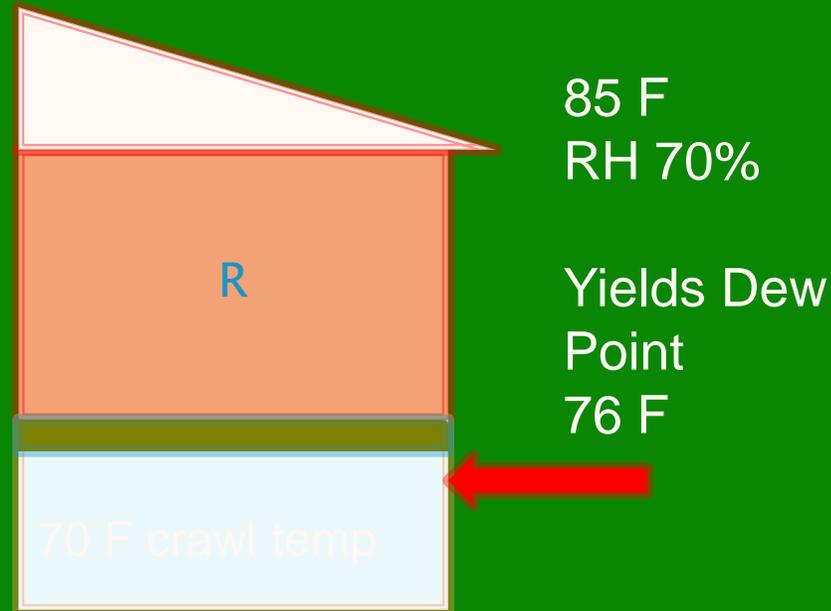
Typical Crawl Space Summer Environments

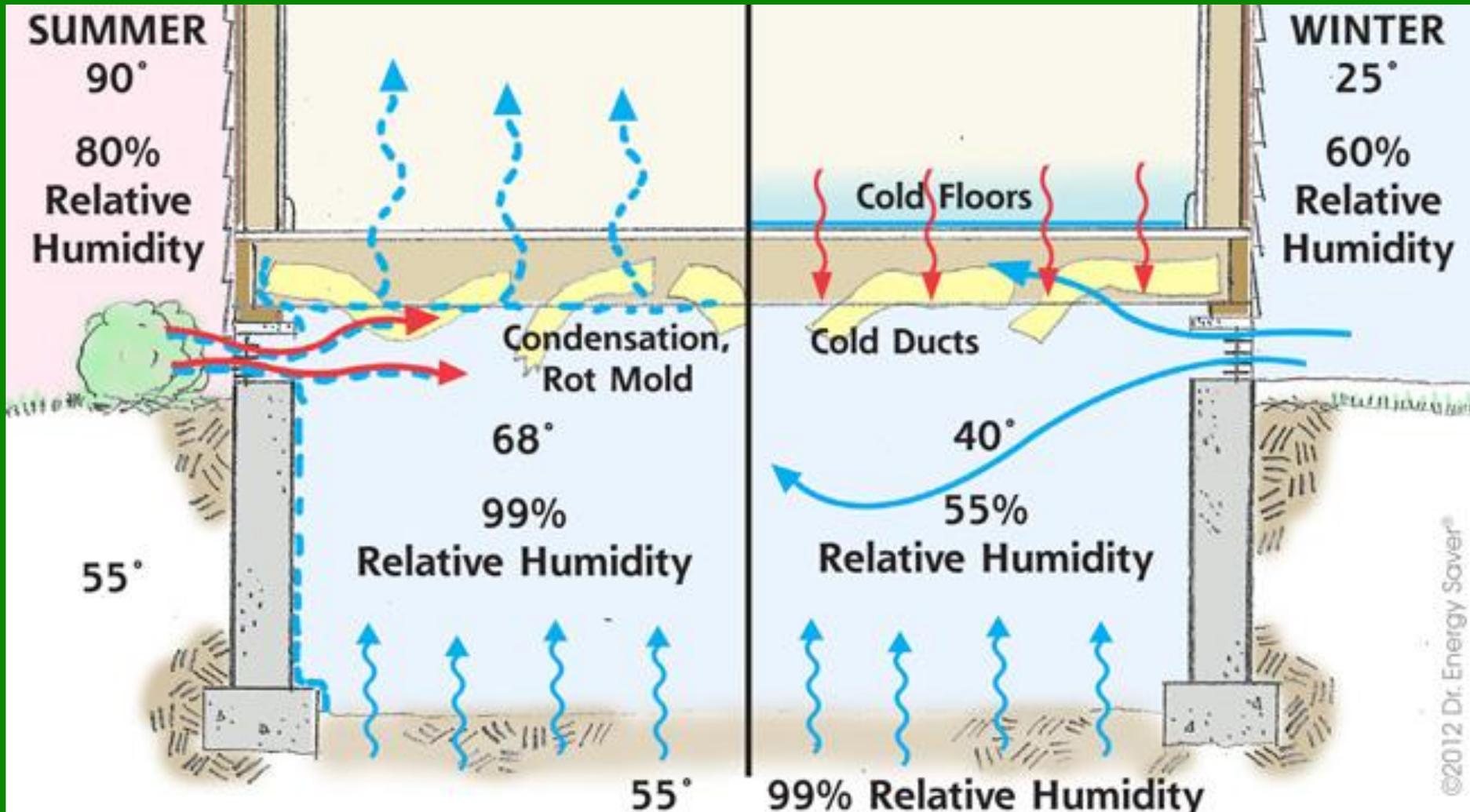
A typical summer day with 85F outdoor ambient temperature and Relative Humidity of 70% would yield a dew point of about 76 F.

With the ambient temperature in the crawl space of 70F and crawl space vent open or a fan to bring in outside air, what would happen?

The dew point of the air when entering the cooler crawl space will cause condensation inside the crawl area.

The relative humidity roughly increases about 2.2% for every degree of cooling.





NC Weather Example

- Average Mid-summer Day 85F with Relative Humidity of 60% – Weather Service typically gives us on TV
- Typical wisdom would tell us that this warm air and day could be helpful in crawl space ventilation.
- However 85F with 60% Relative Humidity has a Dew Point of 70F which generally is considered dry.

But let's look at NC Crawl Spaces

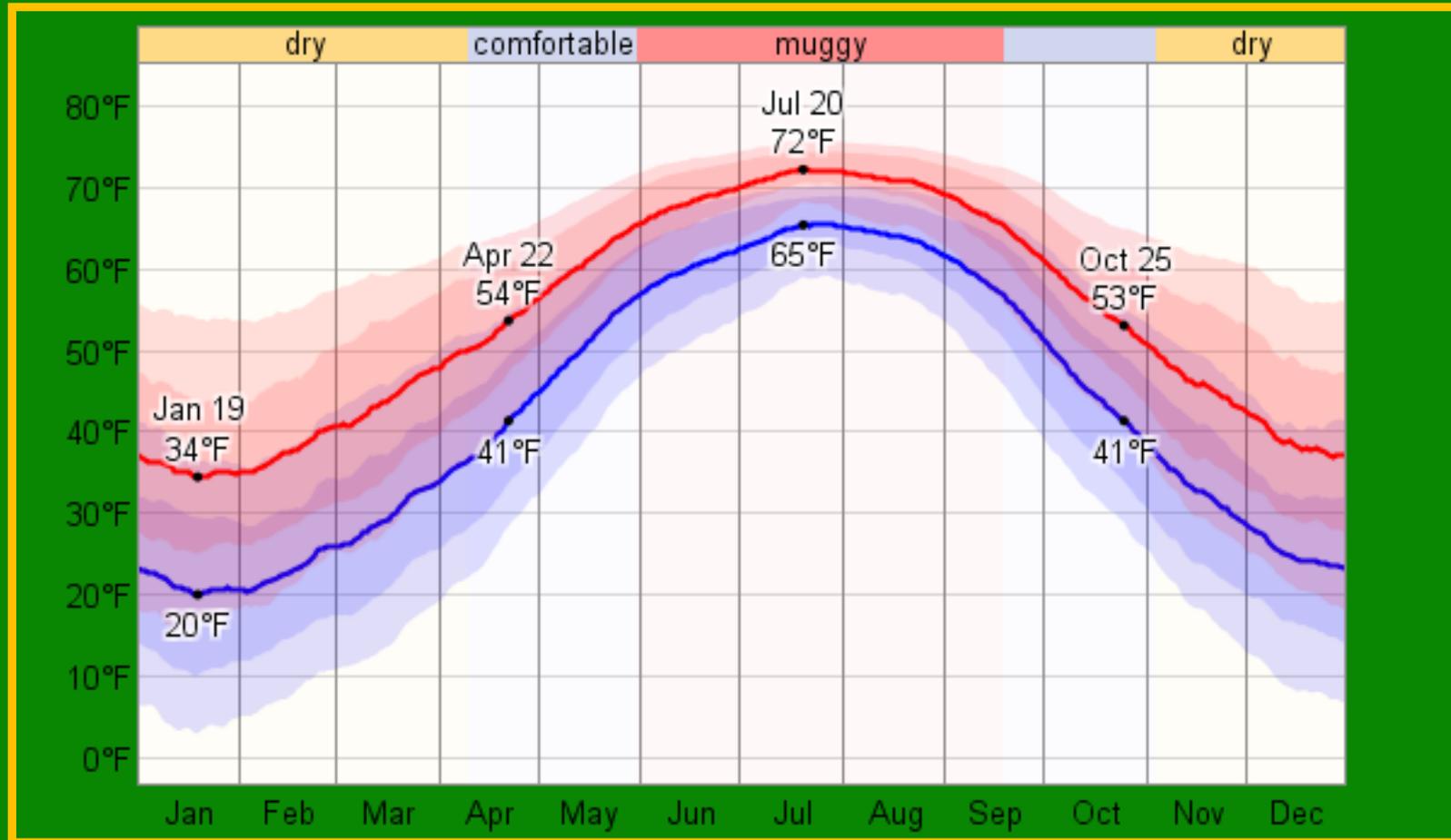
NC Crawl Spaces

- A well vented crawl space runs around 73F.
- Mixing outside air with crawl space air allows the air to move into the crawl space as cooling takes place without losing vapor.
- The dew point stays the same but now the Relative Humidity increases to 90%. With the temperature of the HVAC ducts and plumbing pipes typically below 70F then condensation will form on these components.
- Remember the **air supply temperature inside the duct would be around 50 – 55F and the ground water temperature is around 57 – 60 F. These temperatures can bring the outside skins of the HVAC duct work and plumbing pipes below the saturation dew point of 70F thus allowing condensation to form.**

NC Crawl Spaces

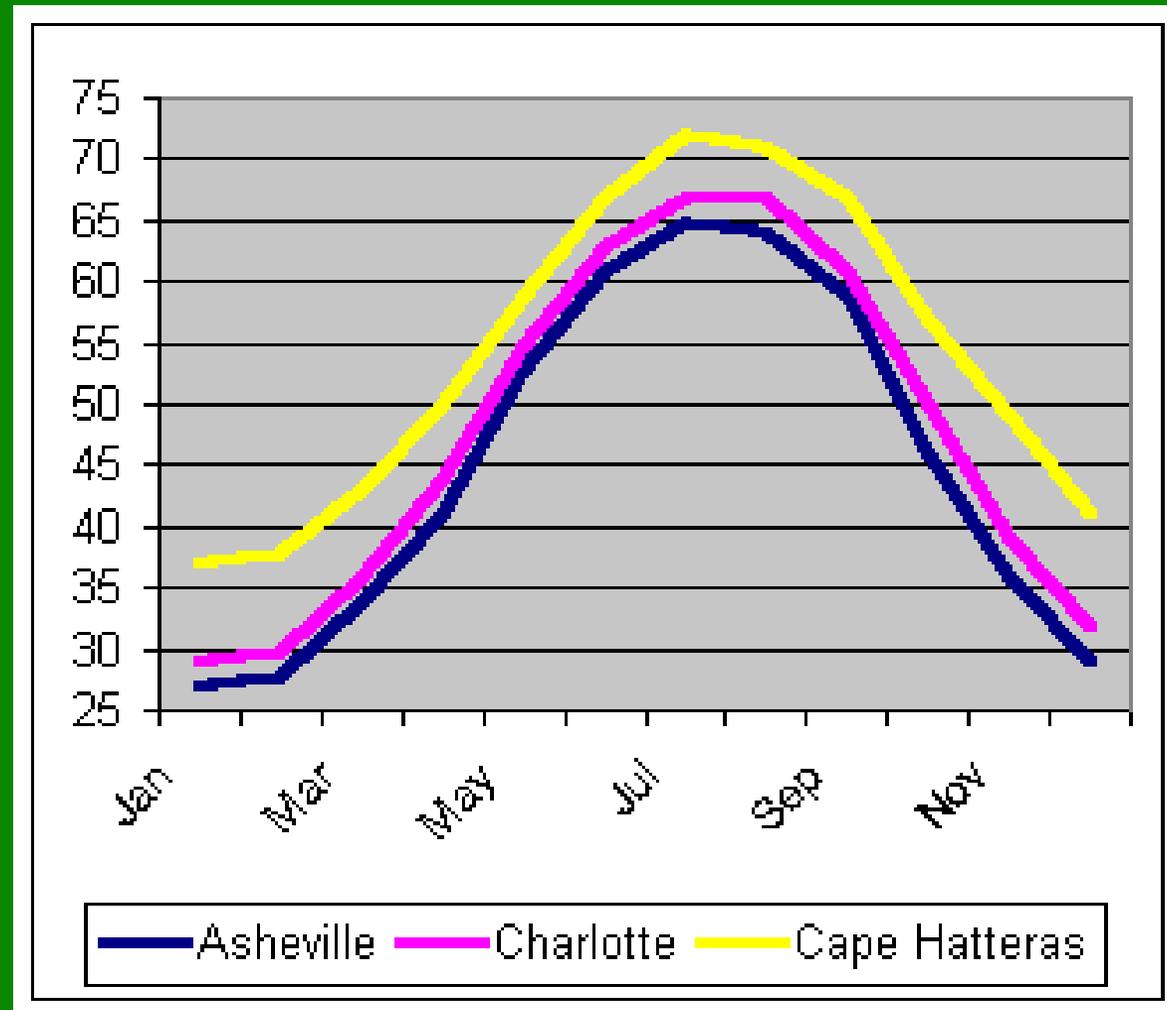
- In fact, with the crawl space temperature averaging around 73F, it is not unusual for condensation to form in the bottom of the floor insulation.

Typical Due Points for Average NC Summer Temperatures and Humidity



Typical Dew Points for Average NC Summer Temperatures and Humidity

- ▶ It is easy to see with these dew points where bringing in outside air into the crawl space environment can easily cause condensation.



Example of Crawl Space reaching Saturation Dew Point

- ▶ Noted in this crawl space the condensation formed on Plumbing drain pipes, water supply lines and on bottom of floor insulation



NC Crawl Spaces (cont.)

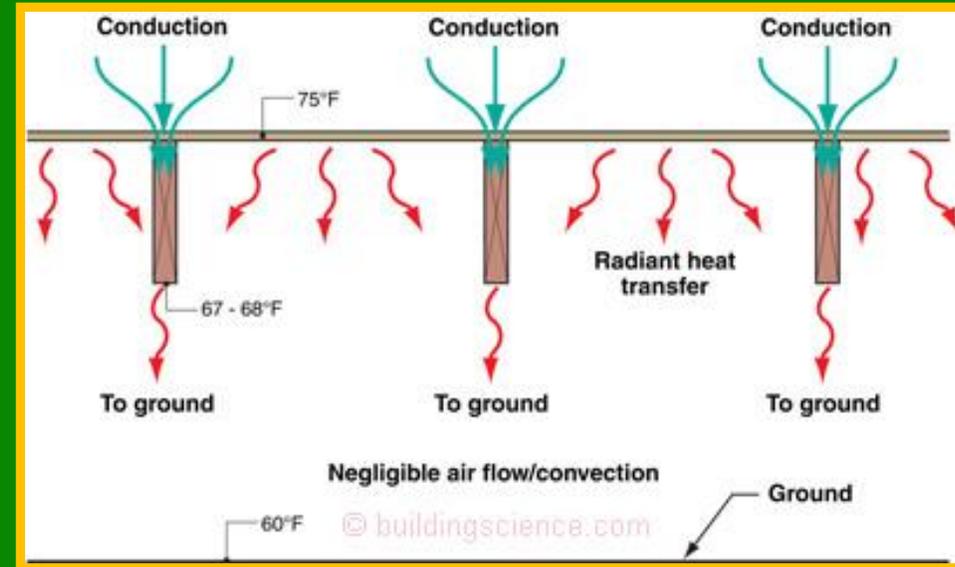
- A study done by Advanced Energy, found that in 2002, the outside air dew point exceeded 70F, 44% of the time during the drought of 2002.
- In 2003, with a record setting Rainfall year, the dew point exceeded 70F, 72% of the summer and was higher than the inside crawl space temperature almost 20% of the summer.
- **One could draw the conclusion that for North Carolina environments, whether a dry or wet summer, our state is very conducive to promoting condensation in crawl space environments with typical open ventilation.**

NC Crawl Spaces (cont.)

- But remember, vented crawl spaces have always, and still are allowed in the North Carolina Residential Building Codes.

Logic of a Conditioned Sealed Crawl Space

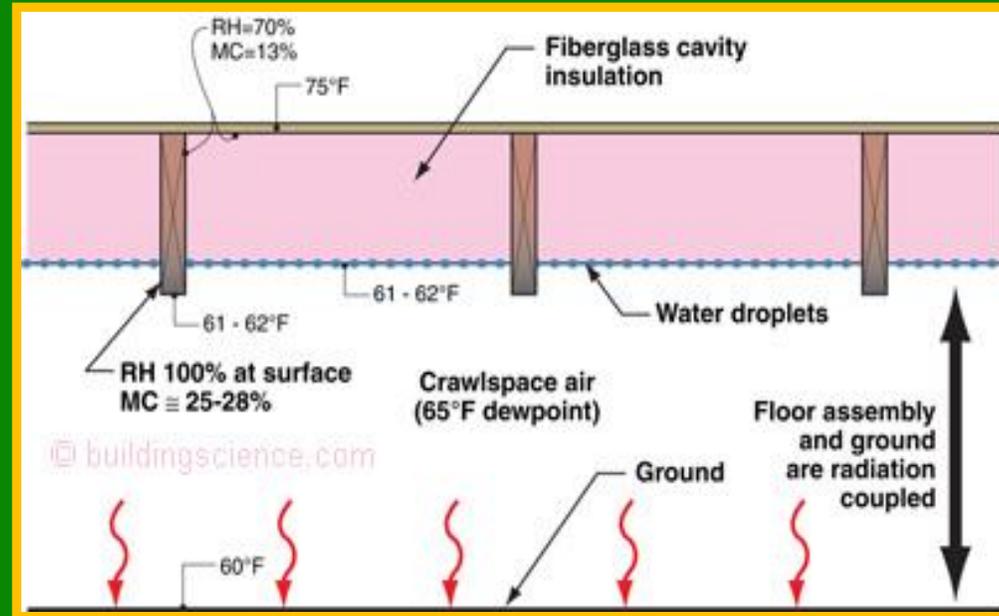
- ▶ **Old Crawl Spaces, No floor insulation**
- ▶ **Surface temperatures were warmed by conduction and radiation.**
- ▶ **Not only was the floor framing warmer than the ground but also warmer than the ventilation air dew point.**



Thus very little moisture problems with older crawl spaces but vary Energy Inefficient by today's standards increasing the Energy Cost of the home.

Logic of a Conditioned Sealed Crawl Space

- ▶ **Typical Insulated Crawl with Floor Insulation**
- ▶ Surface temperatures of the under side of the fiberglass batt insulation is colder than the floor sheathing and within 1 –2 degrees of ground temperature.
- ▶ The exposed surface temperature of the insulation batt and the exposed wood floor joists are below the dew point temperature of the air in the crawlspace.



Thus condensation forms on both the surfaces of the insulation and wood joists.

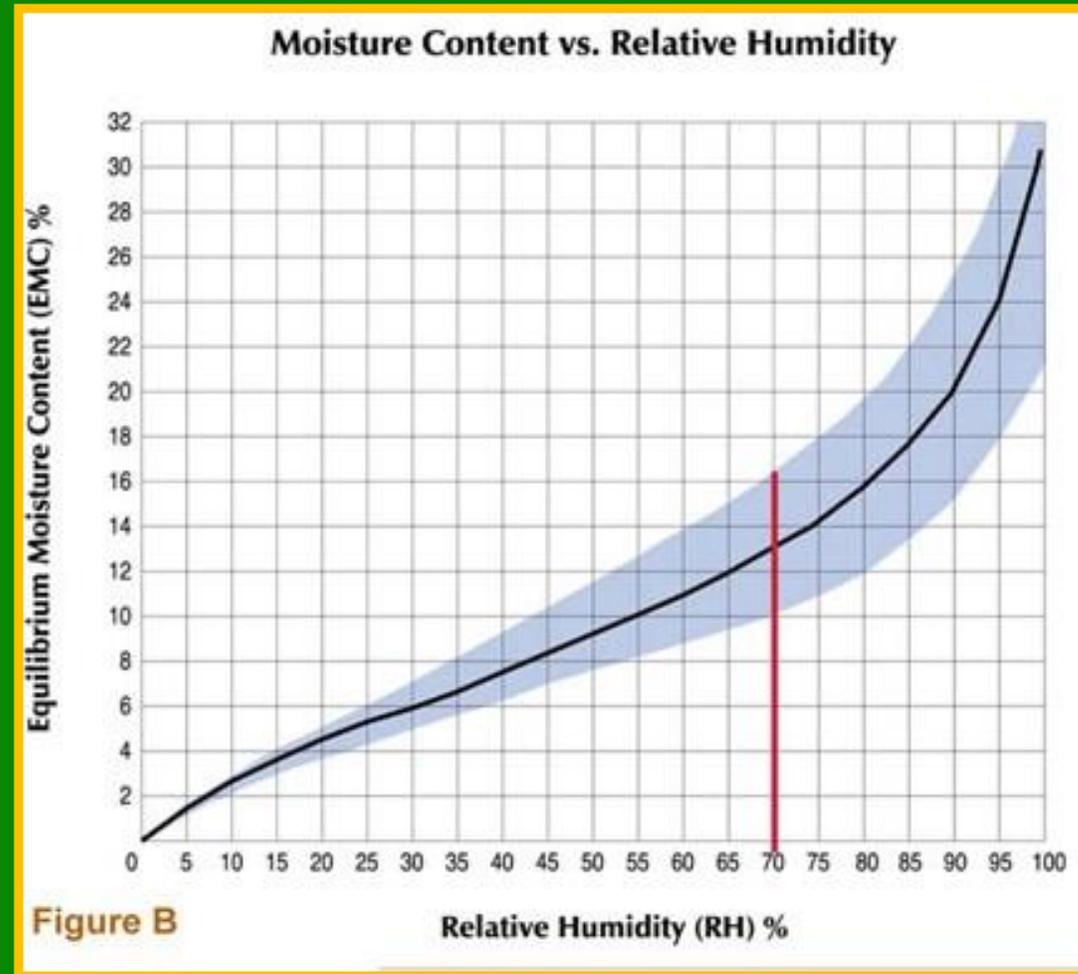
Logic of a Conditioned Sealed Crawl Space

Before we proceed let's look at wood floor moisture content.

This can be done by using a wood absorption chart showing Equilibrium Moisture content of Wood at various Relative Humidities.

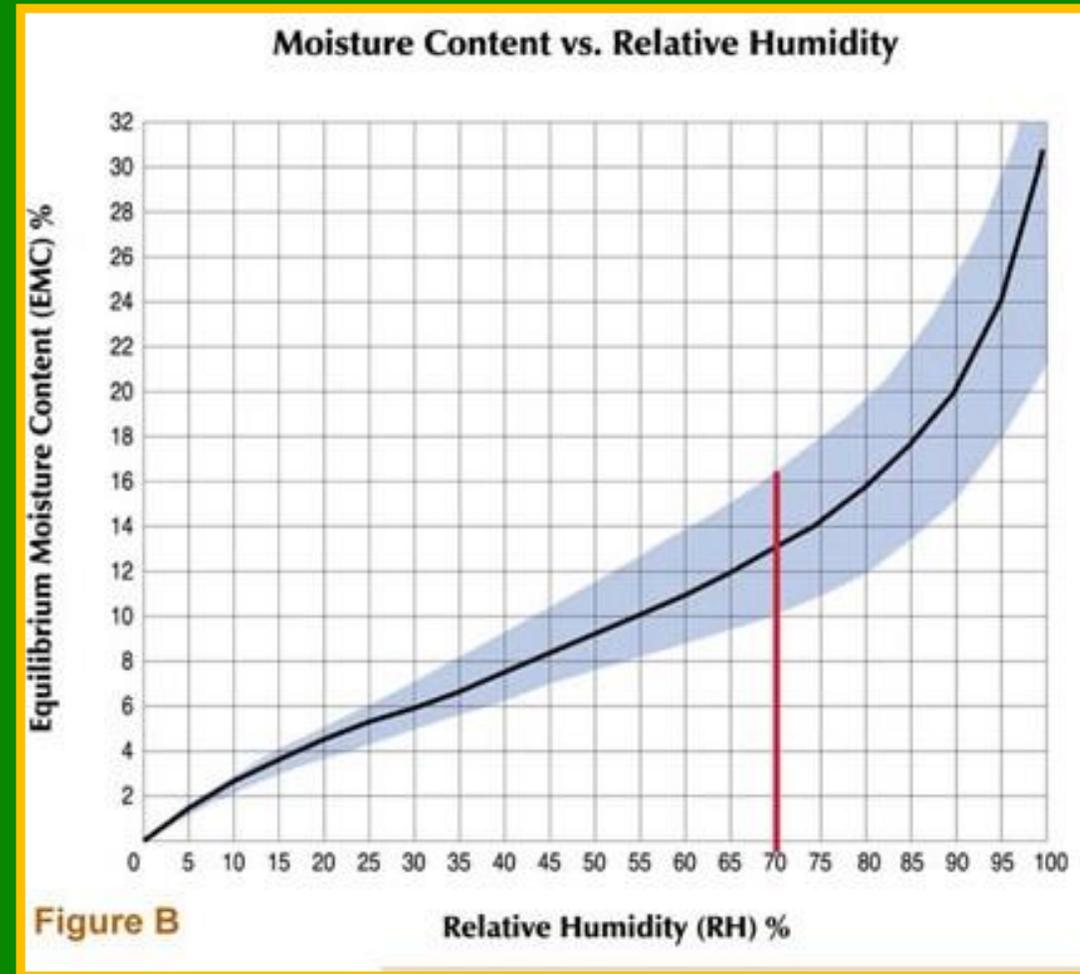
Typical Wood Absorption

- ▶ Note the range of wood moisture content for 70 % RH is 10 – 16 %.
- ▶ Remember the temperature of the wood also has a bearing on the moisture content.
- ▶ RH % of 85 or > yields 18% plus and is where fungi and wood destroying bacteria is supported.



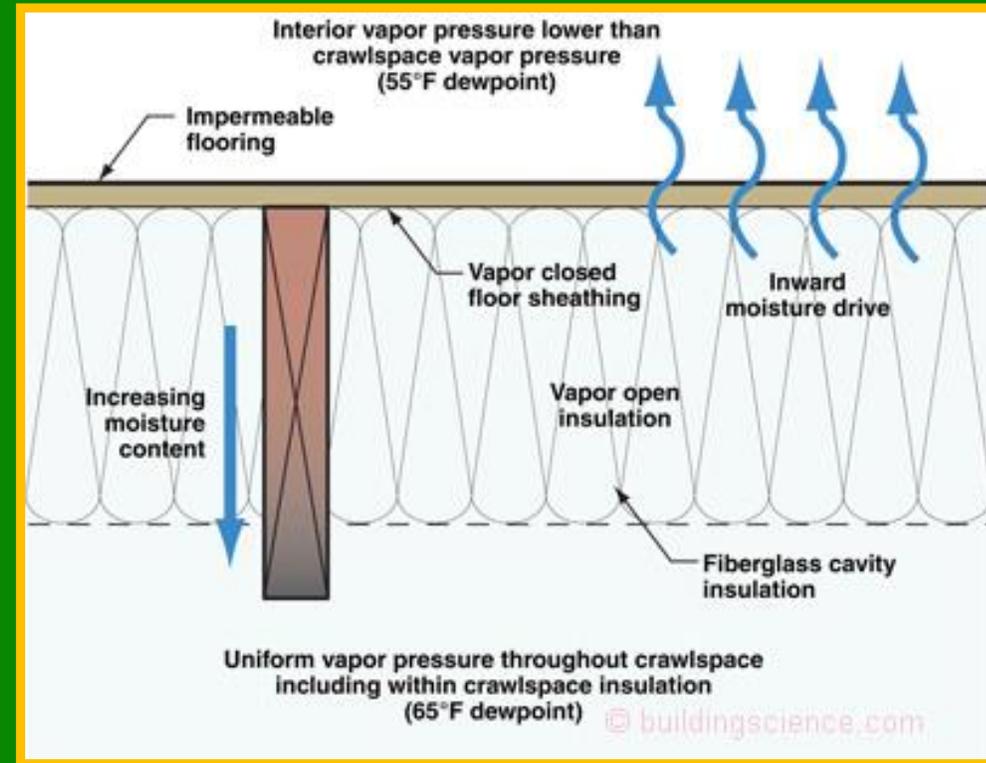
Typical Wood Absorption

- ▶ Ideal RH % for crawl space environments is around 40 – 70 % which yields moisture content in wood somewhere between 8 – 16%



Typical Wood Absorption

- ▶ Noted the wood moisture content increases in the downward direction as the wood becomes progressively colder or the warmer the wood, the drier the wood.

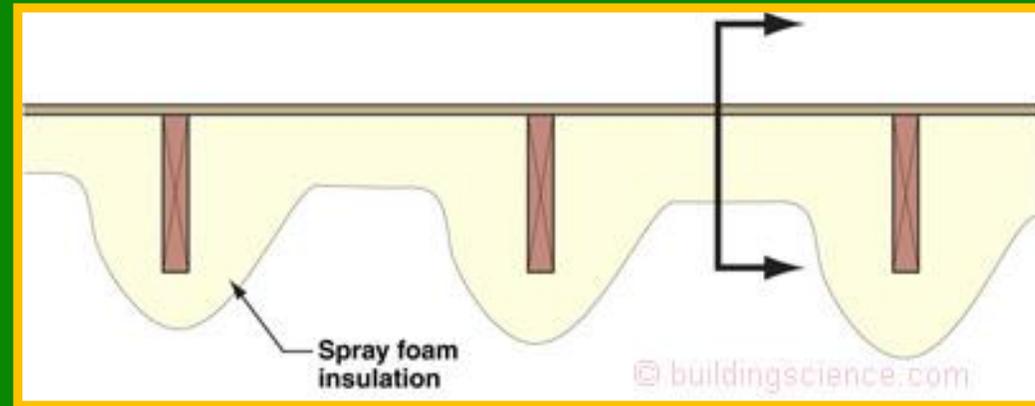


Thus, if the wood were completely wrapped in insulation, the floor joist would be warmer thereby lowering the moisture content of the wood.

Logic of a Conditioned Sealed Crawl Space

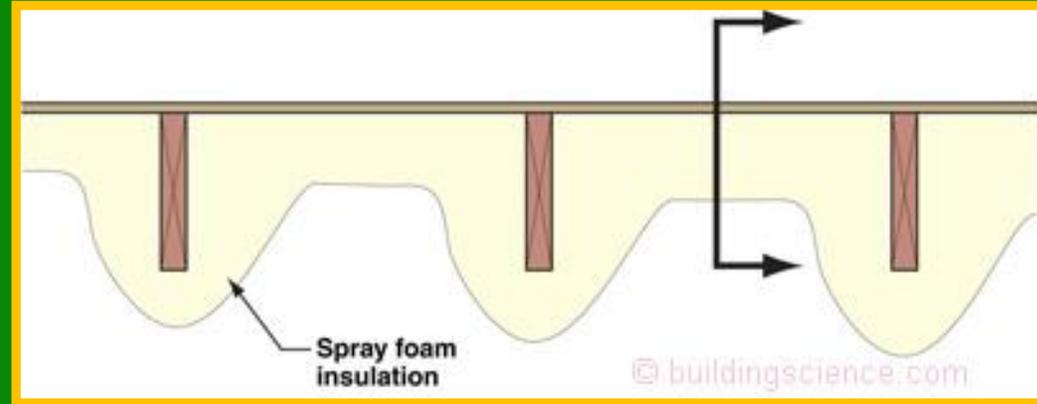
▶ Moisture Dynamics

- ▶ Remember that with water vapor, the moisture migrates from high moisture to low moisture, or is driven up in this example.
- ▶ **Warming the wood**
- ▶ Wrapping the floor joist or spraying the joist with a foam spray will insulate the wood, make the wood warmer and theoretically lower the equilibrium of the moisture content.

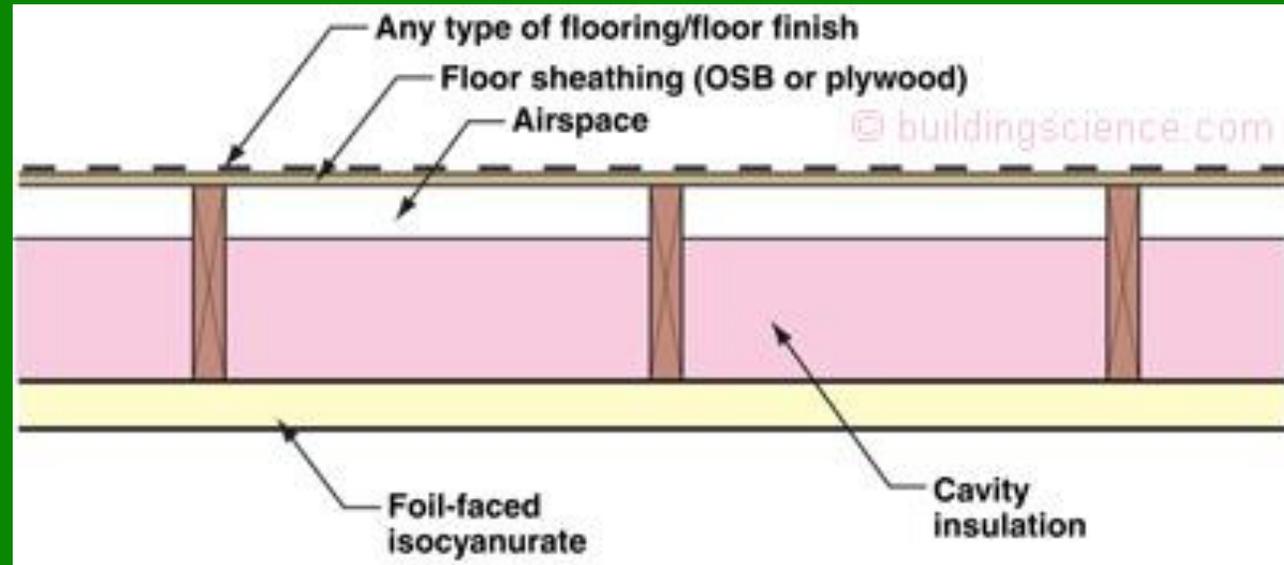


Logic of a Conditioned Sealed Crawl Space

- ▶ **But a more serious condition starts to occur.**
- ▶ Changing the temperature only helps but so much –
- ▶ The ground vapors that are driven upwards still need to be addressed.
- ▶ Use of vinyl flooring, hardwood flooring, or furniture with no under space can lead to build up of moisture in sub flooring and joist beyond safe levels.



Logic of a Conditioned Sealed Crawl Space



- ▶ **But a more serious condition starts to occur.**
- ▶ Ideally a floor insulation with a 3” foil faced foam panel attached under the floor joist would work as the insulation, would keep the wood warm, and the foam would have a perm of $< .1$ and prevent the vapor migration, but the issue is how to effectively seal the joints and maintain that seal as repairs and service work is performed.
- ▶ A limiting factor is no inspection can be made above the foam.

Logic of a Conditioned Sealed Crawl Space

- ▶ **A sealed conditioned crawl space**
- ▶ Keeps the wood floor temperature constant
- ▶ Minimizes the moisture entry into the crawl space area
- ▶ Uses a form of dehumidification to remove any moisture that should develop i.e. supply air from the HVAC system, dehumidifier, or ventilation from the conditioned area of the home



Thus the relative humidity is controlled in the ranges of 50 – 65% where the moisture content of the wood timbers is maintained within the range of 8 – 12%.

Logic of a Conditioned Sealed Crawl Space

- ▶ **A sealed conditioned crawl space**
 - Go back to Advanced Energy's Study for North Carolina
 - Well vented crawl spaces exceed 80% relative humidity for the majority of the spring and summer months.
 - Closed crawl spaces maintain humidity below 65% during the same period.
 - This fits very well in line with the Equilibrium Moisture Content of the wood chart where the MC would expect to be between 8 – 12%.



What can be done to Manage Moisture in Crawl Spaces

Typical Steps to Moisture Control and Prevention

Roofs and Gutter Management

- Overhangs should be at least 19" wide
- Install drip edge flashing at roof edges
- Terminate downspouts to drainpipe systems. Be sure they are clear of debris. Splash boxes are not as good as drainpipe systems as splash boxes allow large amounts of water close to the foundation walls. However splash boxes are better than nothing.
- Clay tile or flexible pipe should be used to divert water underground out from foundation wall at least 10 feet. Storm water drains, dry wells, or surface outlets are acceptable.

Typical Steps to Moisture Control and Prevention

Managing Rainwater without Gutters

Drip edge flashing should always be installed at the roof edge, even when gutters are used. (Prolong the life of the fascia boards)

Overhangs should be at least 30 " wide to protect siding from rainfall and to keep roof water away from the foundation

To control back splash, the ground surface underneath the roof edge should be covered with gravel or some other ground cover that will absorb the roof water runoff and reduce splash

Patios, porches, or deck should slop away from the house to promote good drainage.

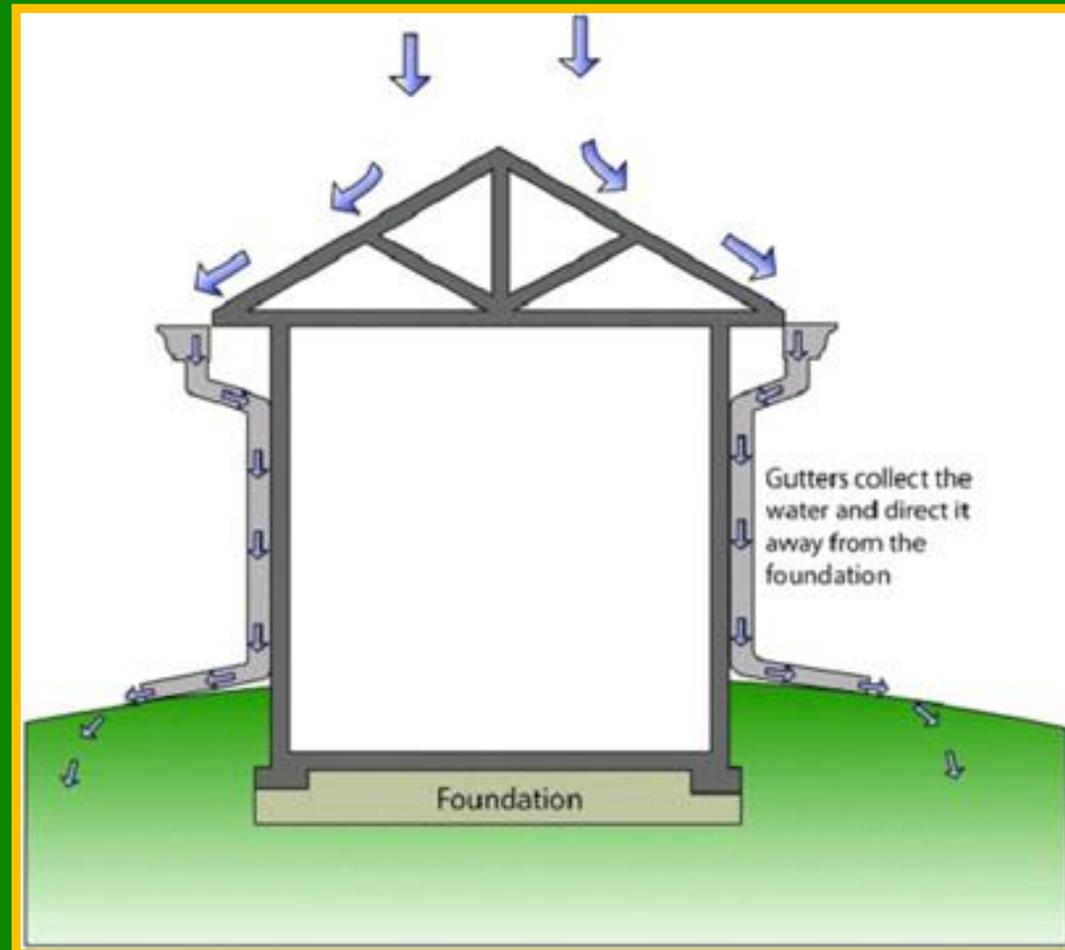
Moisture Management in Crawl Spaces

- Roof water runoff
 - Use a system to direct roof water runoff away from the building structure and prevent the runoff water from entering the crawl space area.
 - Can be done by a gutter system.
 - Can be done by foundation waterproofing and a perimeter gravel bed and a drain.
 - NC Building Code says if gutter or subsurface drains are used, they must not be connected to the crawl space drain. This eliminates any blockage or heavy rains to back up into crawl space.

Moisture Management in Crawl Spaces

Roof water runoff

- Plan to effectively divert all roof water runoff away from foundation through
 - Downspouts
 - Splash boxes
 - Drainage piping
 - Slope of ground around foundation
 - Foundation water proofing.



Moisture Management in Crawl Spaces

- Exterior Ground and Surface Water
 - NC Building Code says the slope of the perimeter has to be a minimum of 6" of fall over 10 ft. horizontal run away from house.
 - Swells or drains may be used if lot lines, slopes, walls or other barriers prohibit the required grading.
 - It is also wise to not install flower beds, tree mulch, mulch pile or other landscaping features that prevent draining away from the building structure.

Moisture Management in Crawl Spaces

- **Exterior Ground and Surface Water (cont.)**
 - Yard irrigation systems must be planned and installed so as not to put water into crawl space walls.
 - NC Building Code requires a foundation drain system wherever the exterior grade is 12” or more above the interior crawl space.
 - Foundation drain system must be kept separate from crawl space drain system.
 - Damp proofing or water proofing foundation walls when exterior grade is above the interior crawl space grade to prevent capillary action of wicking through the foundation walls.

Moisture Management in Crawl Spaces

- **Exterior Ground and Surface Water (cont.)**
 - Option: Raise the crawl space above the exterior grade to eliminate the need for an end drain, damp protector or wet protector.
 - Plan and install the crawl space door or gable end of structure and bottom of access at least 4" above finished landscape grade.
 - Both options are recommended by Advanced Energy.

Typical Steps to Moisture Control and Prevention

Landscape Planting

- Landscaping can add beauty and value to a home as long as it is installed to avoid moisture problems.
- Landscape plants should not block free air flow through crawl space vents, if installed.
- **Plants should be placed beyond the drip edge of the roof, and foliage should be at least 5 feet from the foundation walls.**
- Finished planting beds and mulches should be lower than the ground level in the crawl space and should be kept away from the foundation wall.
- Keep any organic mulch or ground cover at least 12” away from foundation wall.

Moisture Management In Crawl Spaces

Typical things that can be done inside the crawl space environment:

Typical Steps to Moisture Control and Prevention

Crawl Space Grading

- Crawl space grade should be higher than outside surface but rarely is in NC crawl spaces.
- A minimum of 18" clearance from the bottom of the joists to the soil surface for untreated wood. Preferably 2 – 3 feet.
- NC Residential Building code requires that outside surface grades away from the foundation wall a minimum of 6" within the first 10 feet with some exceptions.
- Vent wells to be used if foundation vents area within 4" of exterior grade.

Typical Steps to Moisture Control and Prevention

Sump Pumps

- Install sump pumps only in extreme cases where drainage cannot exit to exterior grade.
- Locate the sump pump at the lowest point in the basement or crawl space and ensure crawl space soil slopes towards the sump well.
- Any sump water is to be discharged into a storm drain, dry well or exterior grade away from the foundation wall.

Typical Steps to Moisture Control and Prevention

Insulating Heating and Cooling Ducts

- Insulate exposed HVAC ducts, and plumbing pipes to at least R 6 in order to prevent condensation build up on the duct and plumbing supply piping.
- Periodically check ducts for air leaks at joints which may cause the ducts to sweat/condense.
- Properly seal ducts at joints and along floor penetrations.

Typical Steps to Moisture Control and Prevention

Flashings

Use sheet metal, plastic, or rubber membrane to cover joints and openings and protect against water seepage.

Controlling Humid Air

- N.C Code requirements
- Seal all gaps between foundation perimeter walls and sill plates, sill plates and band joints, & band joints to subflooring.
- Seal penetrations through the foundation perimeter walls for water service, electrical service, plumbing fixtures, ductwork, etc.
- Seal connections from crawl space to access under attached porches or decks.

Controlling Humid Air (cont.)

- **Evaporation from the ground and perimeter wall**
- Cover all crawl space ground with a minimum 6 mil polyethylene vapor retardant with seams lapping a minimum of 12" (required in NC Residential Building Code).
- Advance Energy recommends also covering perimeter walls with a minimum 6 mil polyethylene vapor barrier leaving 3" of exposed masonry at the top.
- Mechanically attach vapor barrier and seal it to wall with duct mastic – can use power drill nails/pins through a strip or wall insulation.

Controlling Humid Air (cont.)

- **Evaporation from the ground and perimeter wall**
- Advance Energy also recommends sealing the vapor retarder to the interior foundation piers at least 4” above the crawl space floor.
- And install the ground and wall vapor retarders as a sealed liner by sealing all seams and connections to masonry with fiberglass mesh tape embedded in the duct mastic.

Controlling Humid Air (cont.)

- Evaporation from the ground and perimeter wall



Controlling, Managing, and Removing Moisture

- ▶ Even after performing all items covered in the previous slides to minimize the effects of Water/Moisture Entry into the crawl space from
 - Drainage
 - Roof Water Runoff
 - Exterior Ground and Surface Waters
 - Evaporation from the ground and perimeter foundation walls
- ▶ **Moisture Still migrates into any crawl space whether ventilated, closed or sealed.**