Understanding Basic Dew Point Calculations for High Performance Basements, Walls, and Roof Systems

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This program produced by

Maine Indoor Air Quality Council

www.maineindoorair.org

Building Science Basics

Bulk Water Management

Heat Flow Management

Vapor Management

Air Flow Management

Dew Point

Dew Point

The temperature at which water vapor condenses into liquid water

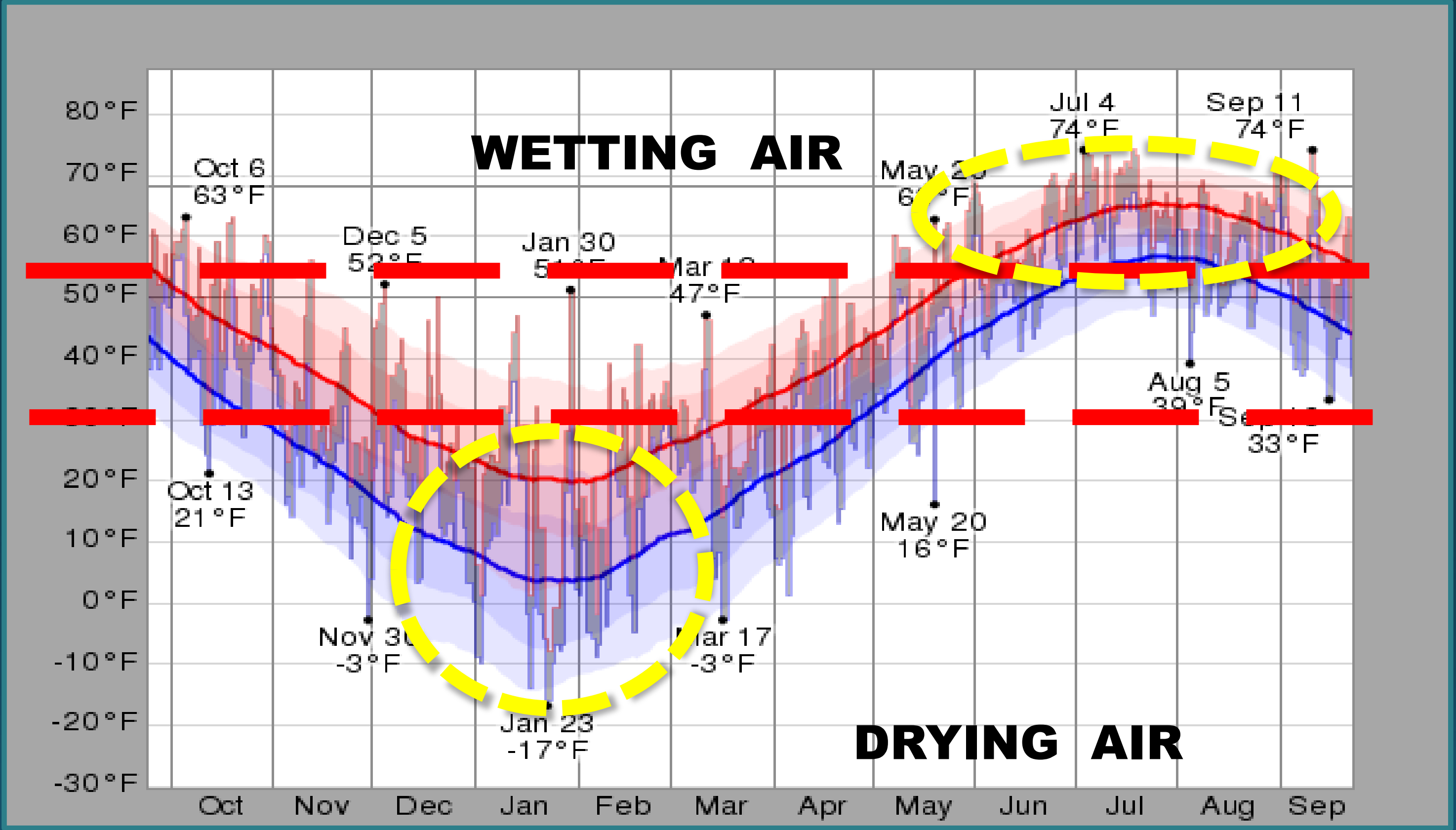
100% RH implies that the dew point temperature is equal to the current air temperature

Relative humidity is the ratio of the current absolute humidity to the highest possible absolute humidity

Relative Humidity

A reading of 100 percent relative humidity means that the air is totally saturated with water vapor and cannot hold any more

New England Dew Point Climate Graph



WeatherSpark.com

Rules of Moisture Movement

Moisture flow is from warm to cold

Moisture moves from more to less

Air carries moisture from high pressure areas to low pressure areas

Gravity pulls water down

Water wicks up

Drainage is critical

Moisture Issues

Liquid water and chronic moisture cause mold growth and building rot

Mold exposure may cause sinusitis, rhinitis, and is a common asthma trigger

Mold can affect the value of a home

Health and Mold

Health studies in North America and Europe show that damp houses and basements contribute to respiratory problems

Courtesy Fox

Moisture comes from...

Transient construction water

Concrete, drywall, temporary heat

Site water

Groundwater and rainwater

Condensation

High humidity and cold surfaces

Moisture comes from…

Leaks and Floods

Plumbing, roofs, ice dams, storms

Occupancy

Bathing, cooking, laundry
House plants
Respiration
Firewood storage

The Rules of Vapor Transport

Water vapor will always move from areas of higher concentration to areas of lower concentration

Drivers include…

Vapor pressure differential

Permeability of substrate

Air movement

...will surely migrate to the spaces above

Water vapor in a damp crawlspace or basement...

Condensation Issues from May through September

Summer Conditions

There are two ways to successfully construct basement foundations in a cold climate

Dry and Warm

or

Dry and Cold

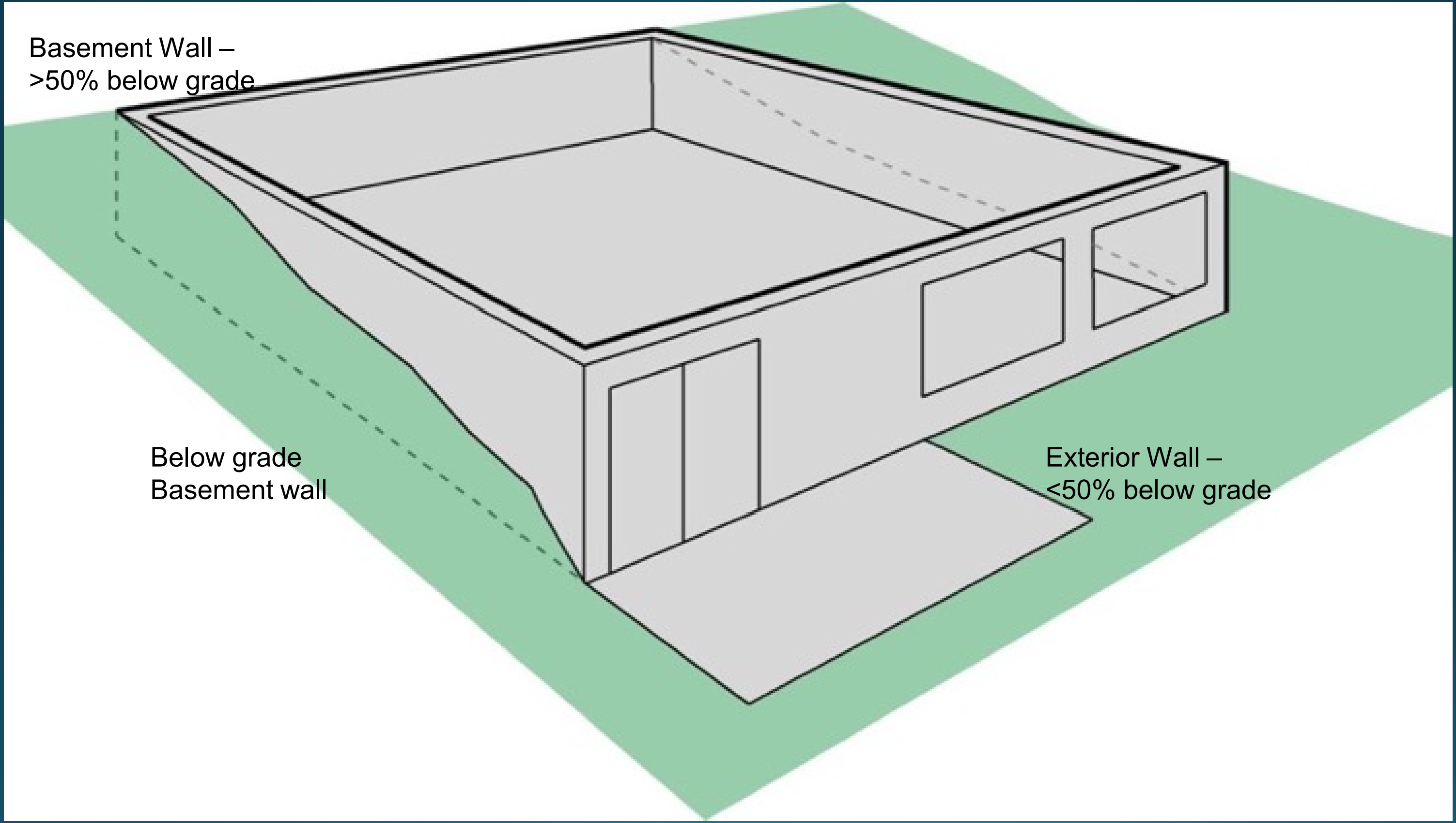
Dry and Warm

- Energy savings quickly pay for minor additional costs
- Significantly reduces the need for dehumidification
- Provides useable space
- Minimizes moisture and mold problems

Dry and Cold

- Provides no energy savings, especially if heating plant is located in unheated space
- Requires dehumidification during summer months
- Increases likelihood of mold and moisture problems

Defining Below-Grade Walls



Simple Approximation

In F° … $T_{dp} \approx T_{db} - 9/25(100\text{-}RH)$

For example… $T_{db} = 60°$ RH = 50%

$T_{dp} \approx 60° \ -(9x50/25) \approx 60° \ - 18° \ \approx 42°$

41.33° using Decatur.de calculator

Using the previous slide…

What is the temperature of the inside surface of exterior sheathing on a walkout wall?

Determine total R-value

Determine ΔT

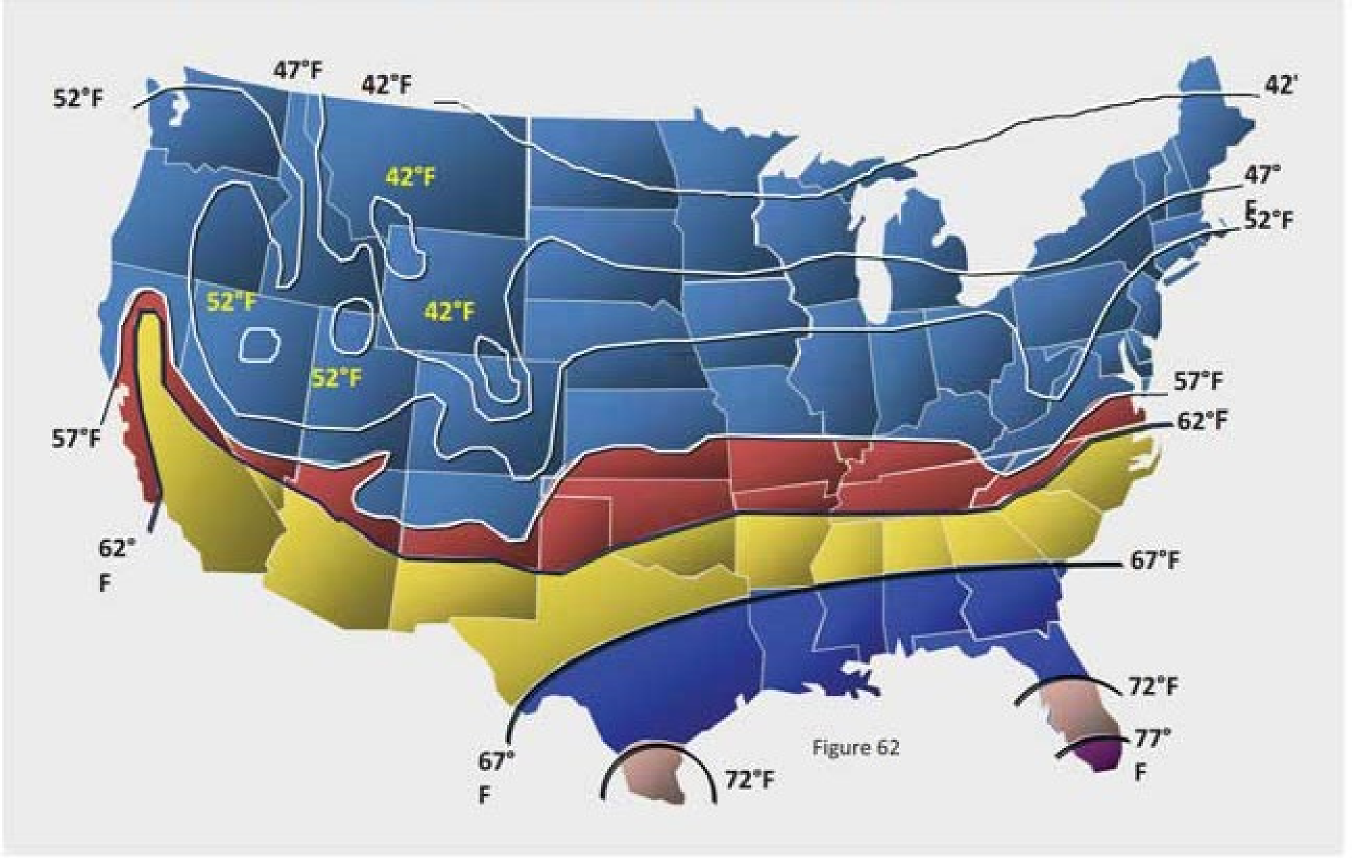
From outside… $T_{interface} = T_{ext} + (\% \text{ total R-value} \times \Delta T)$

Walk out wall with R-15 fiberglass, ½" CDX sheathing, T_{ext} *25°*

Total R value = 15.5   ΔT = 35°

$T_{interface} = 25° + (.032 \times 35°) = 26.12°$

How to avoid basement condensation…

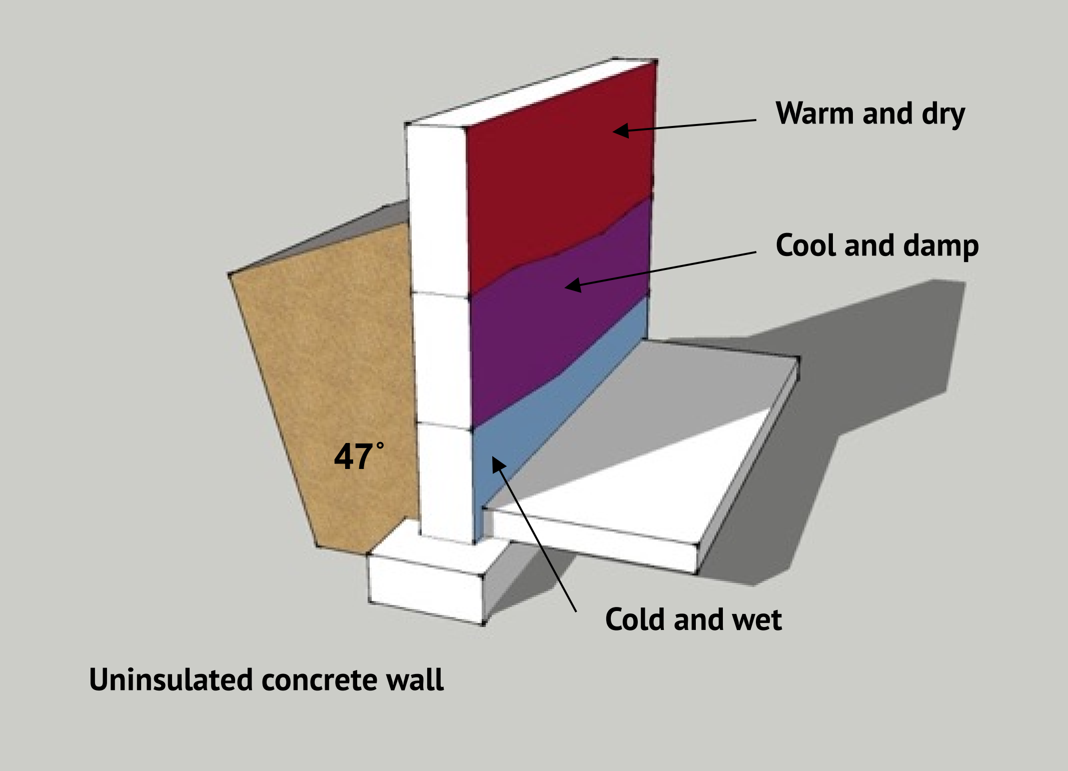


Ground water T° September 2012

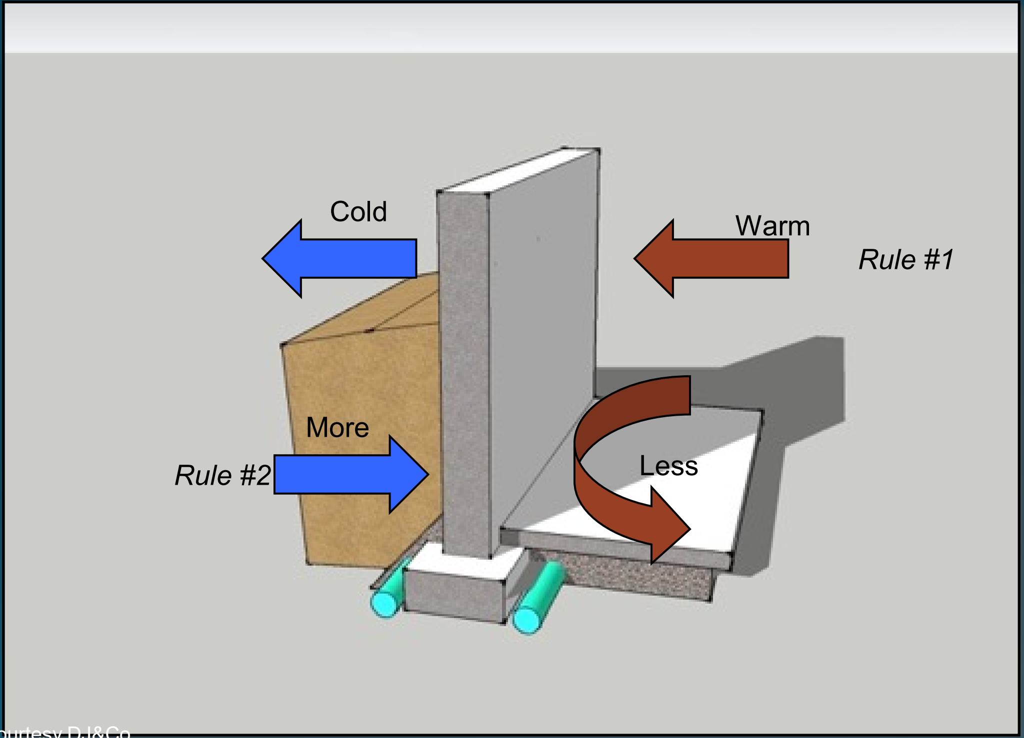
Humid air
and
cold pipes


PHIL BERRY
929-4370
GOULDS

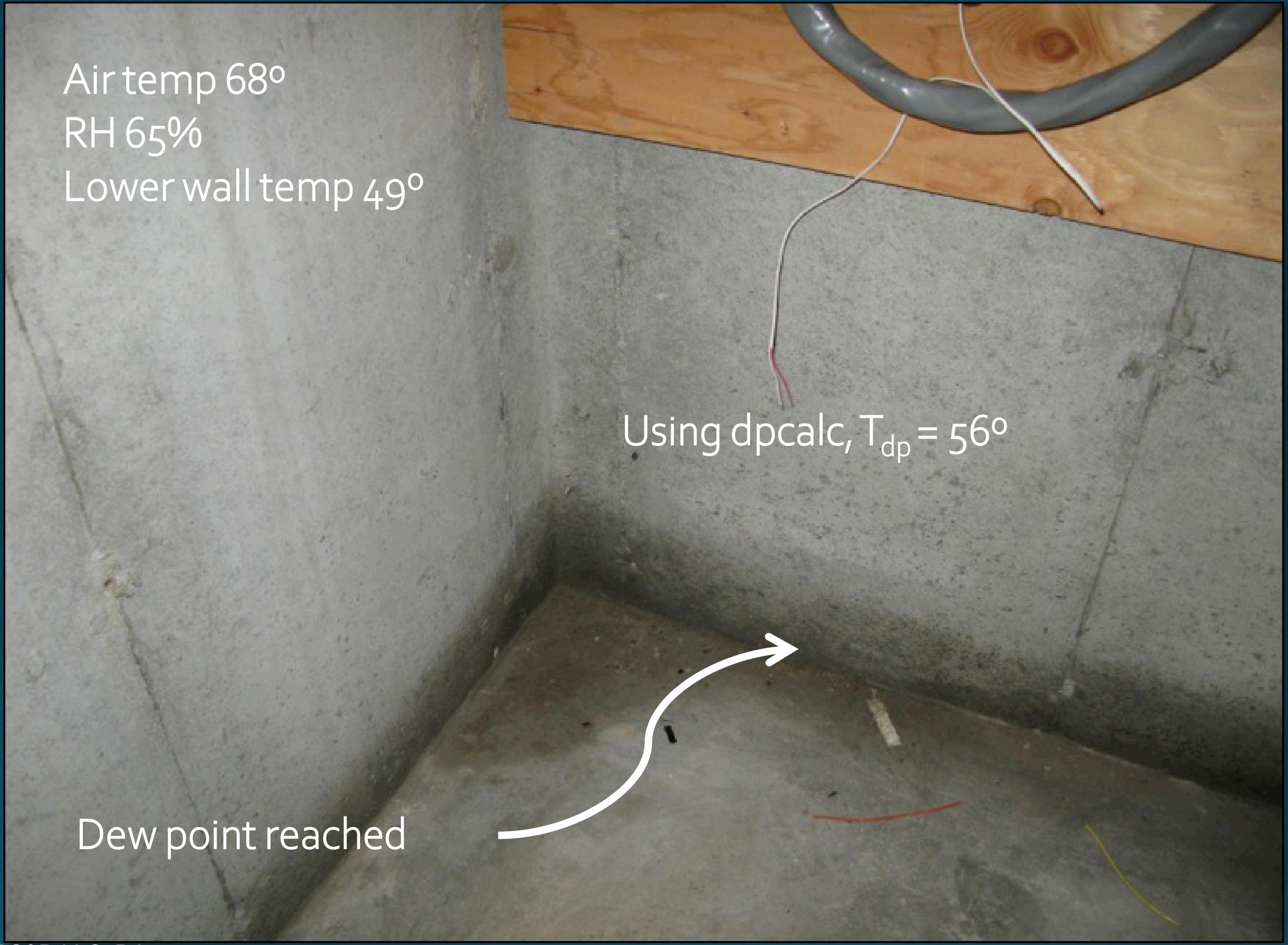
Temperature gradient
Summer conditions



Foundation wall drying pathways



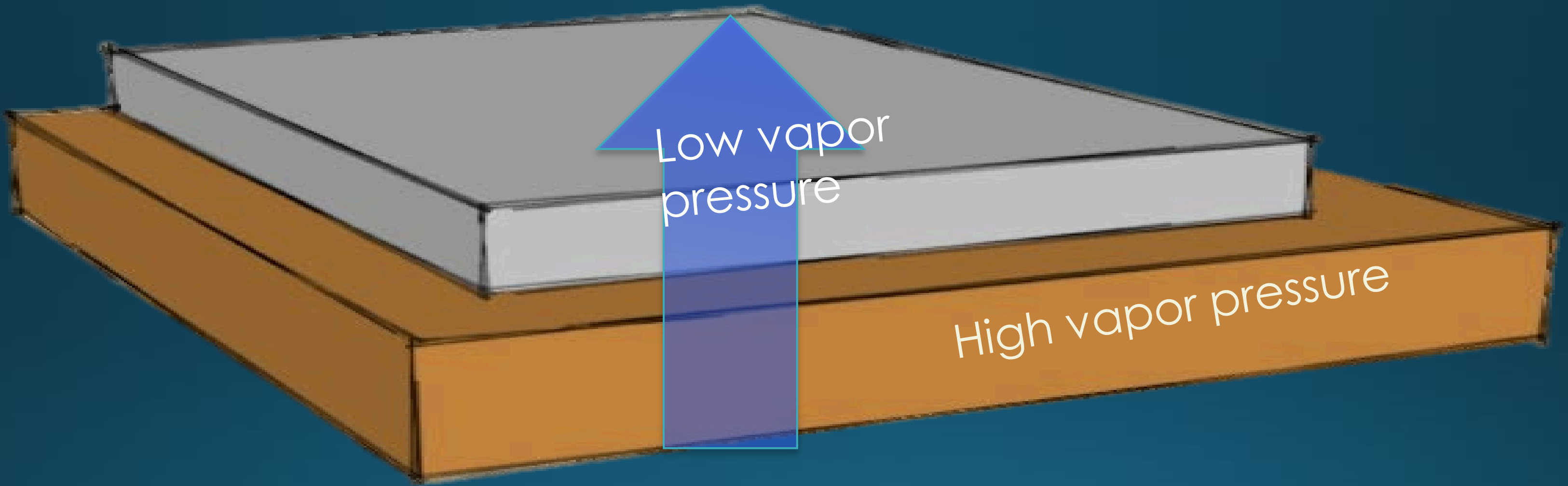
Courtesy DJ&Co


Air temp 68°
RH 65%
Lower wall temp 49°
Using dpcalc, T_{dp} = 56°
Dew point reached

Another example of new concrete and dew point

Existing Basement Floors

Most likely situation in older homes



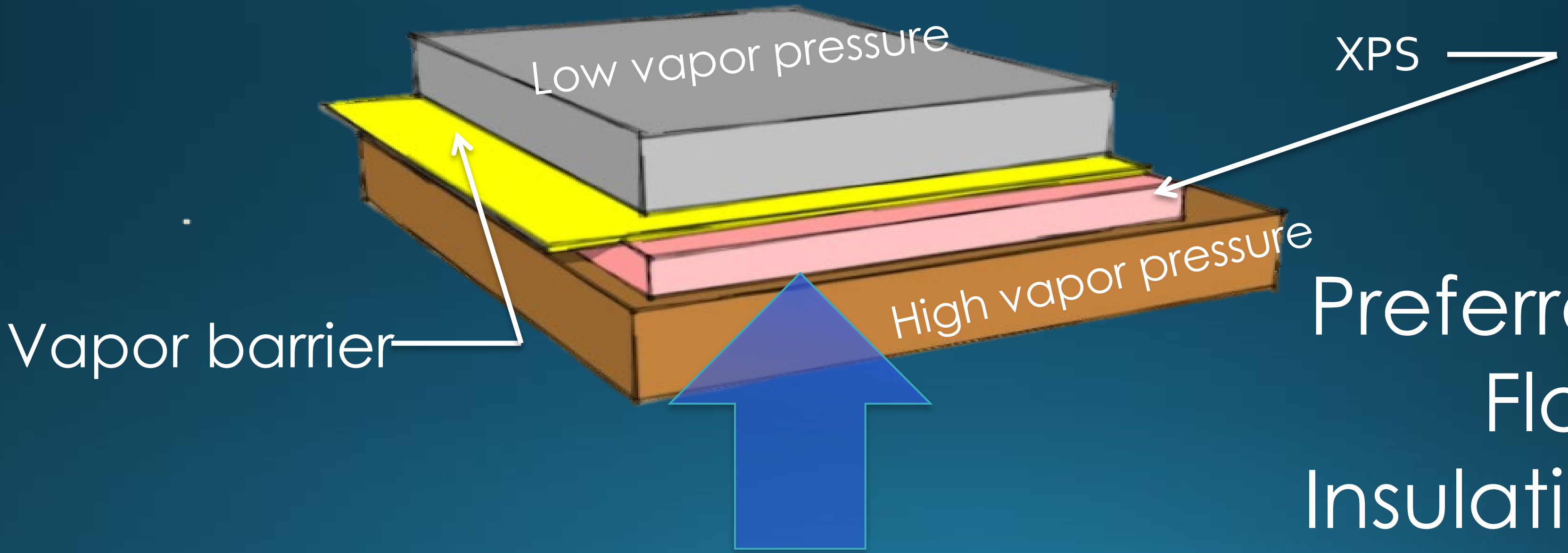
Water vapor diffuses through porous concrete… floor will never be quite dry, and always cold

Open windows, uninsulated floor

Constant high humidity below

Vapor diffusion is stopped… floor is warm and dry

Unlikely situation in older homes



Preferred Floor Insulation

In reality, this is <u>not</u> a dehumidifier

Stud wall rigid foam hybrid

PT plate

XPS behind studs

Cavity insulation?

Space left for removable baseboard

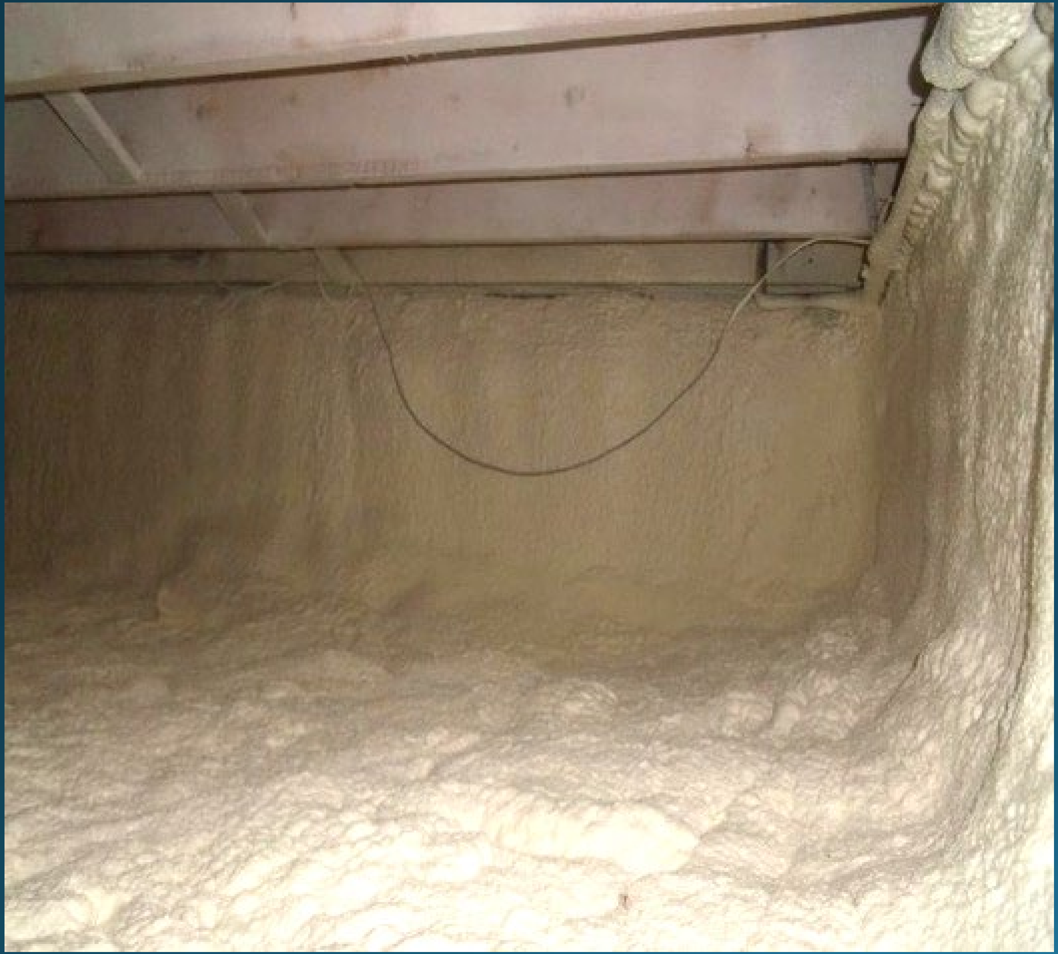
Easy wiring

Don’t open the vents

Summer humidity will condense

Winter cold defeats the purpose of insulating the crawlspace

Courtesy Foam-Tech



Spray foam works well in older crawlspaces

Insulation anchor

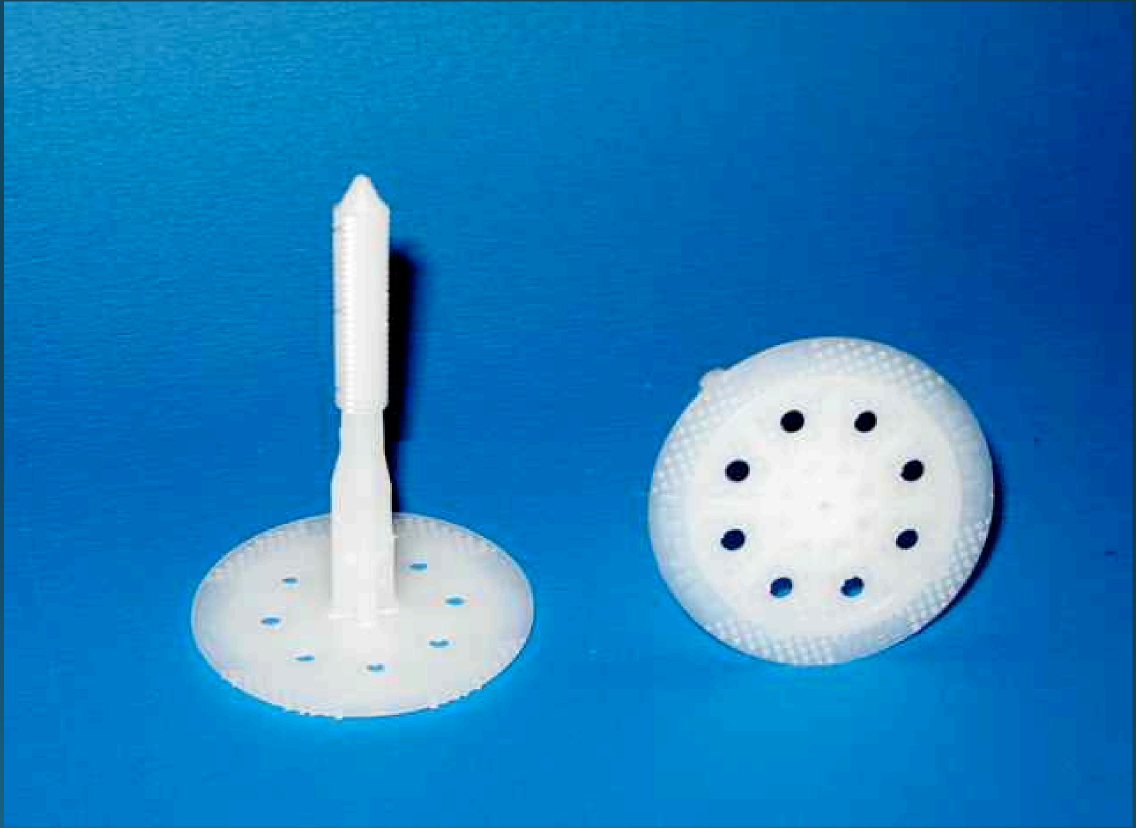
Plastic anchor designed to attach insulation board to concrete

110 lb pullout

Eliminates curing time

Handles irregular concrete surface

Adhesive might work



Attaching XPS with flat roof washers and and Tapcon™ screws

Santa Fe™ Crawlspace Dehumidifier

Crawlspace insulation

- Insulate the perimeter and seal air leakage
- Don’t insulate the ceiling
- Insulate the floor as feasible, or plan on a dehumidifier
- Don’t ventilate
  - Code problem
- Fire rating?

What if I insulate the basement ceiling?

Basement will be cold

Kraft face is likely to get wet and grow mold

Uninsulated basement walls may do the same

Dehumidification critical during humid and warm months

"Insulated" crawlspace ceiling

Less serious moisture problem? Lots of hot water use? Unfinished? Use a heat pump water heater

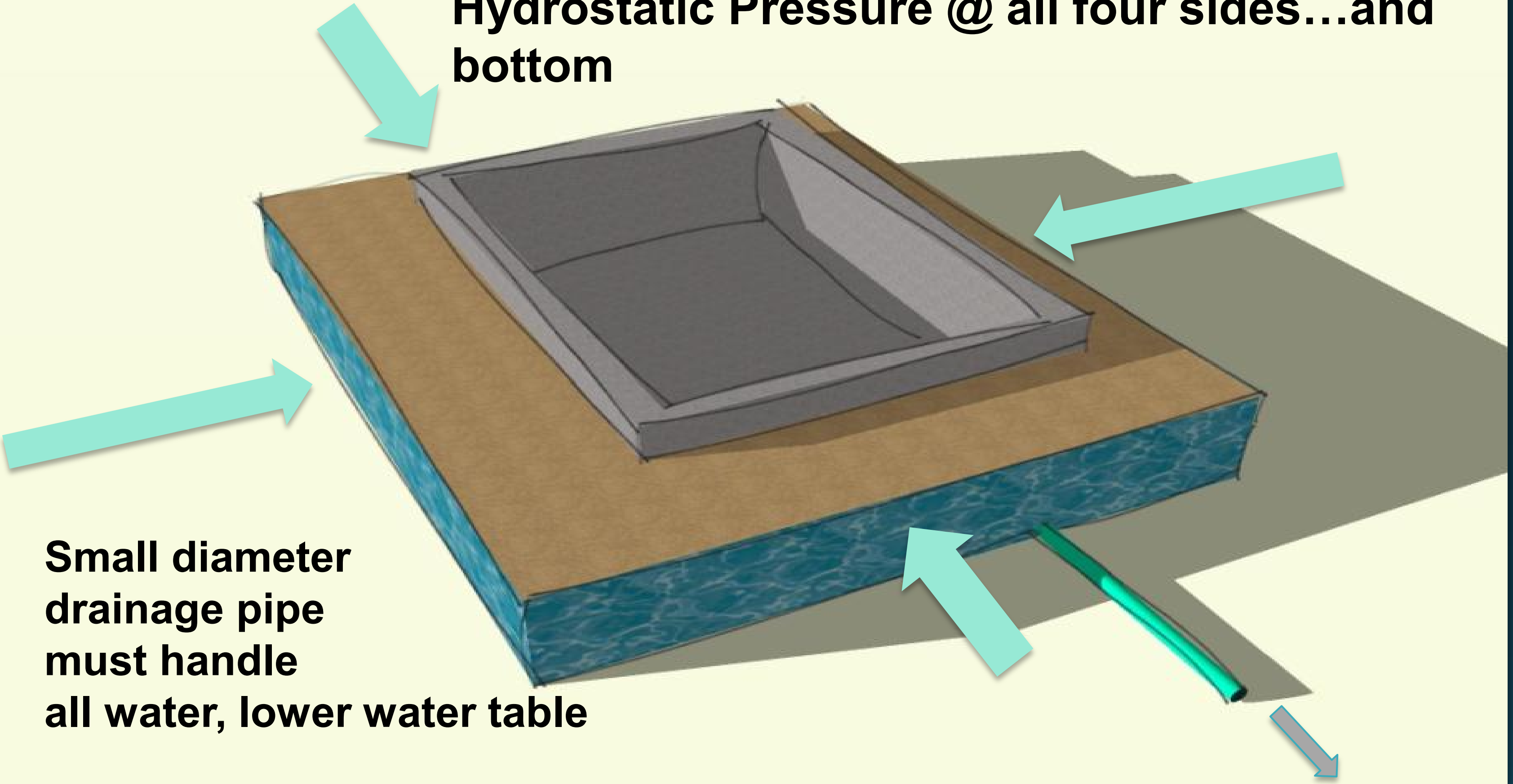
Courtesy Vaughn

Courtesy Rheem

Courtesy GE

Courtesy NYLE

Hydrostatic Pressure @ all four sides…and bottom



Small diameter
drainage pipe
must handle
all water, lower water table

Platon™ Foundation Waterproofing

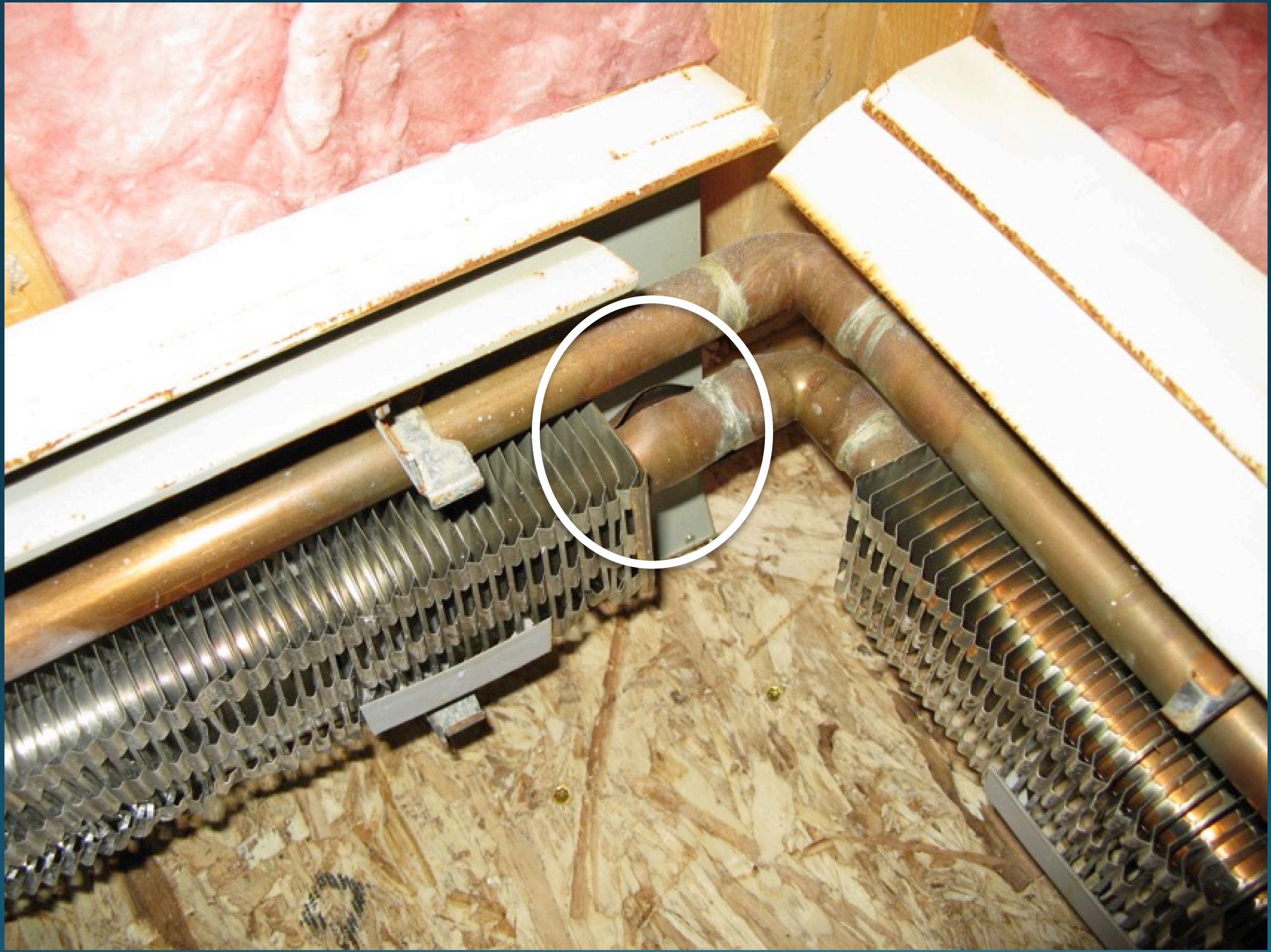
Condensation Issues from October through April

Winter Conditions

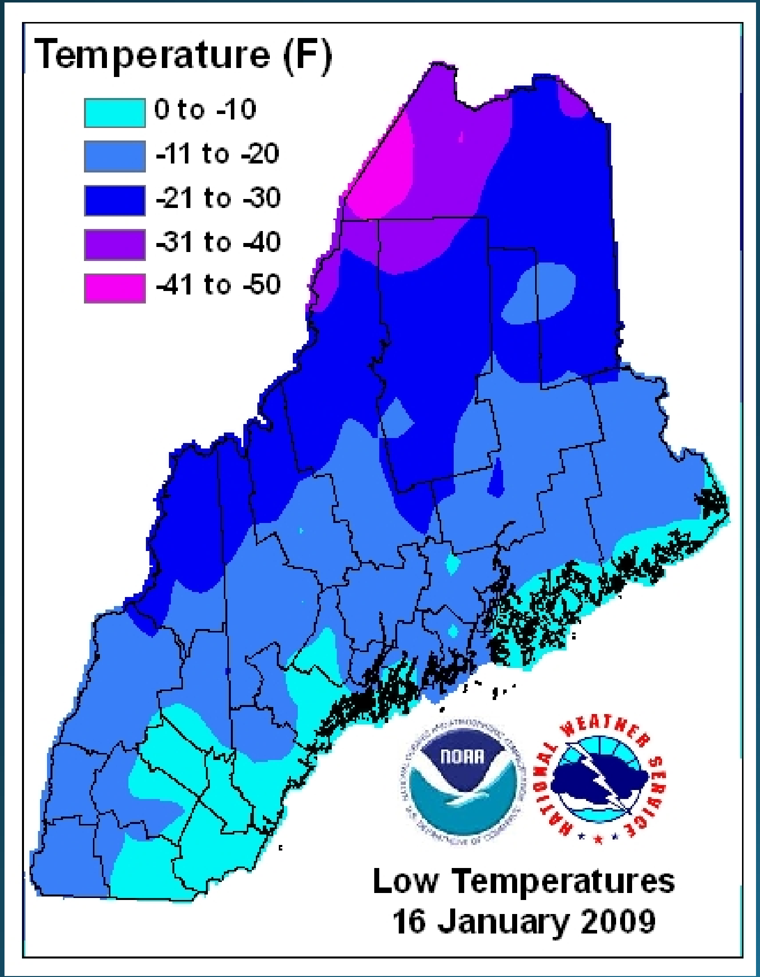
Cold wall

Damp basement

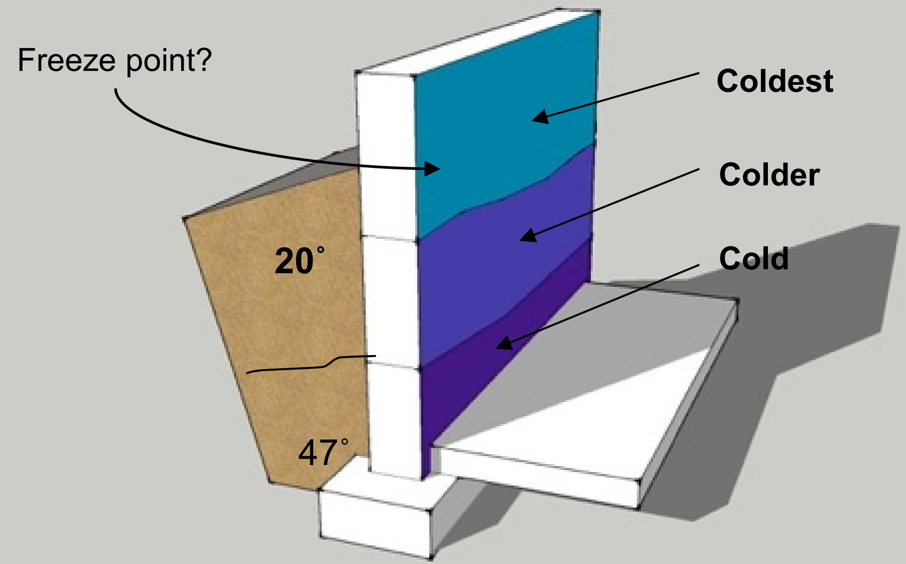

Lasko
Cyclone
Lasko
Cyclone



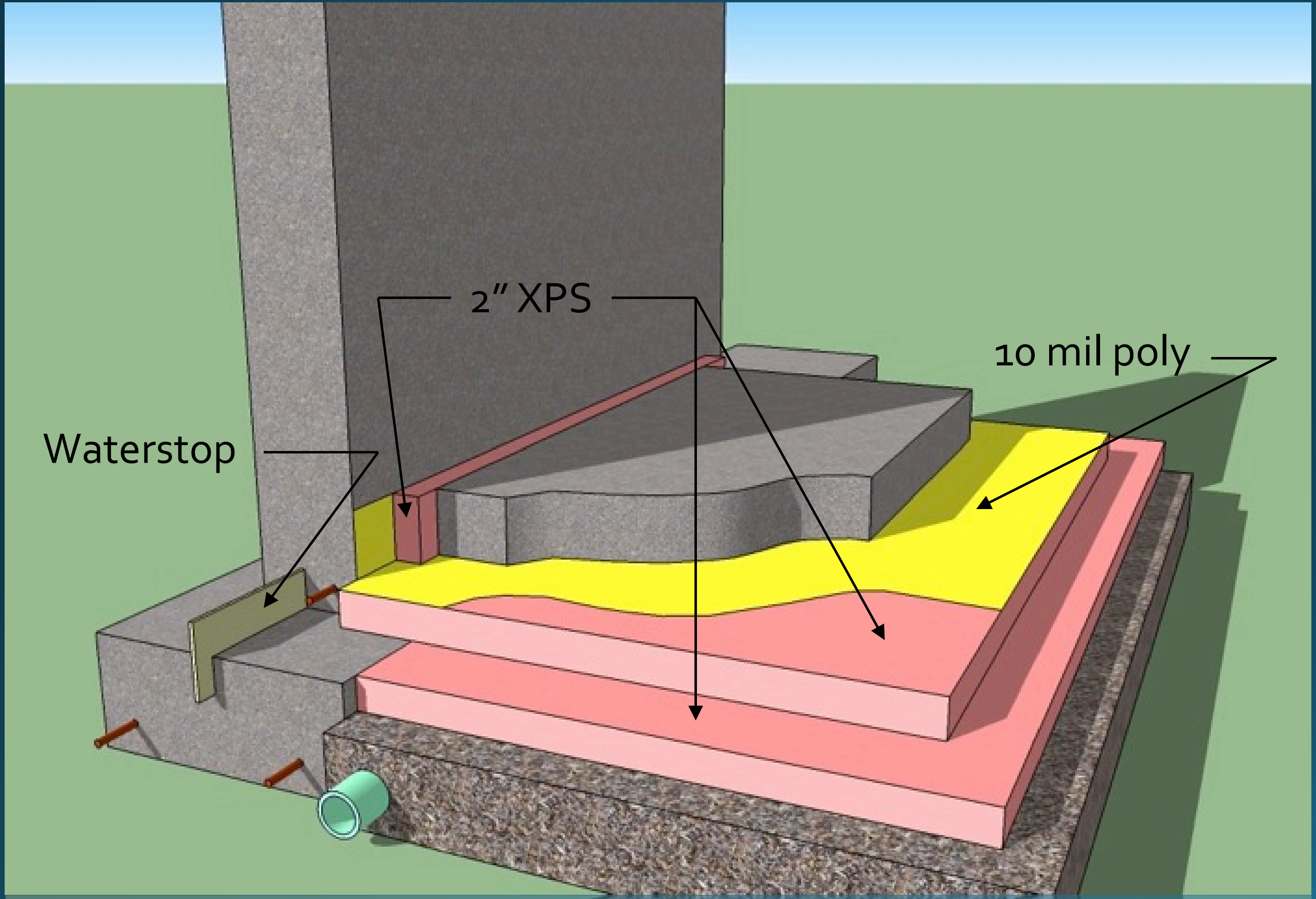
Air temperature



Temperature gradient
Winter conditions



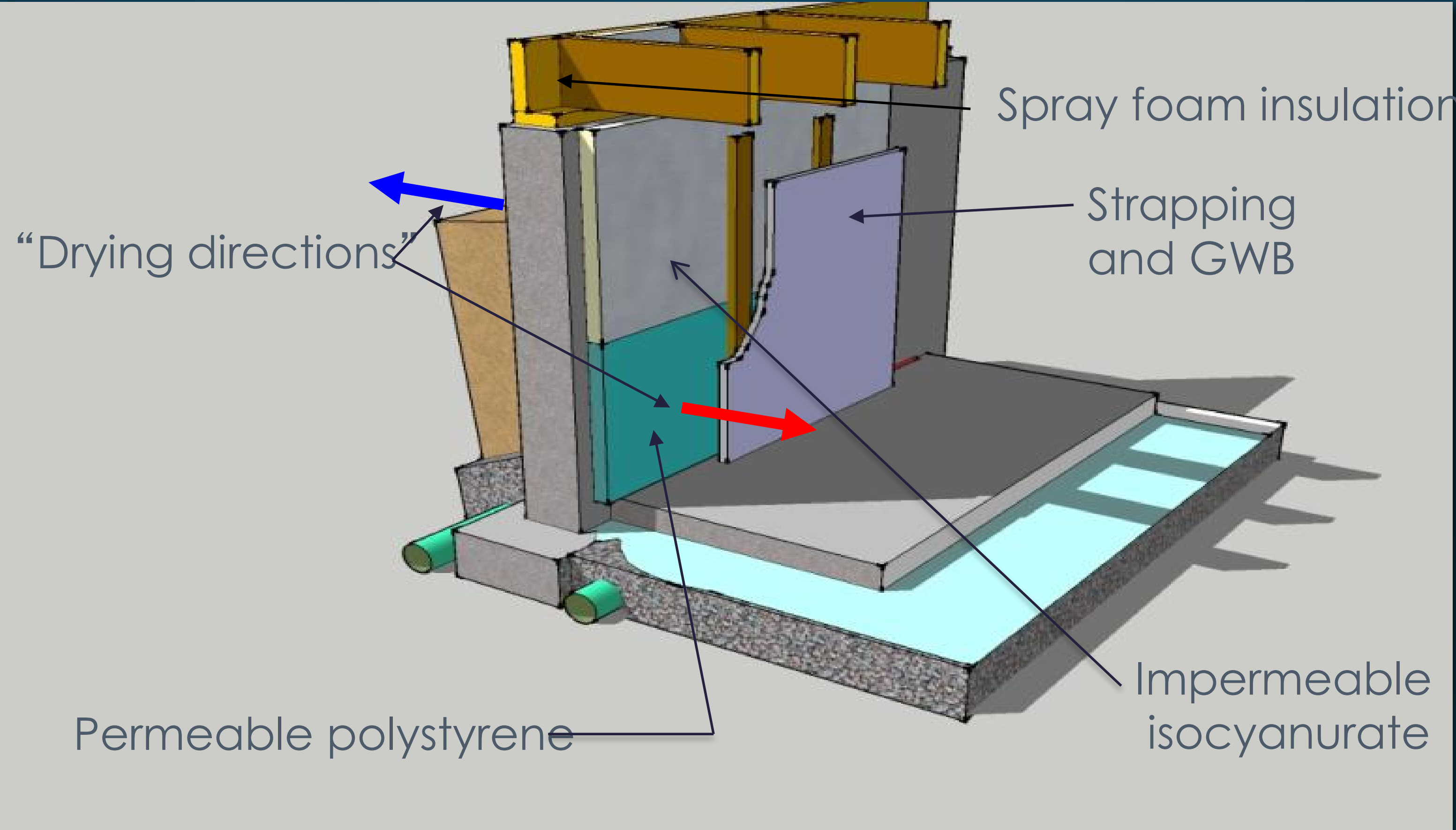
Uninsulated concrete wall



Isolating the footing

No insulation is shown on the basement interior wall

Rigid foam and strapping



Dew Point Calculation

Temperature scale

○ Celsius ◉ Fahrenheit ○ Kelvin

	Value	Accuracy
Temperature	68	
Relative Humidity [%]	50	± 3
Dew Point Temperature	48.69	± 1.56
Saturation Vapor Pressure [kPa]	2.3392	

Compute

www.decatur.de

Simplified dew point calculation

$$T_{dp} \approx T_{db} - 9/25\,(100 - RH)$$

or, in degrees Celsius,

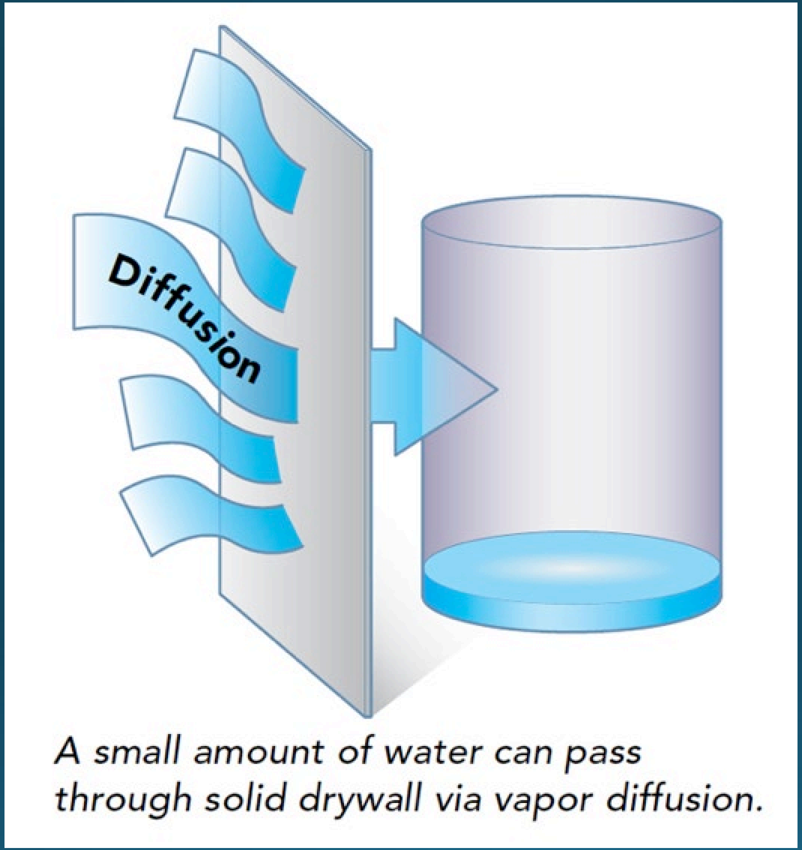
$$T_{dp} \approx T_{db} - \frac{100 - RH}{5}$$

T int = 60º

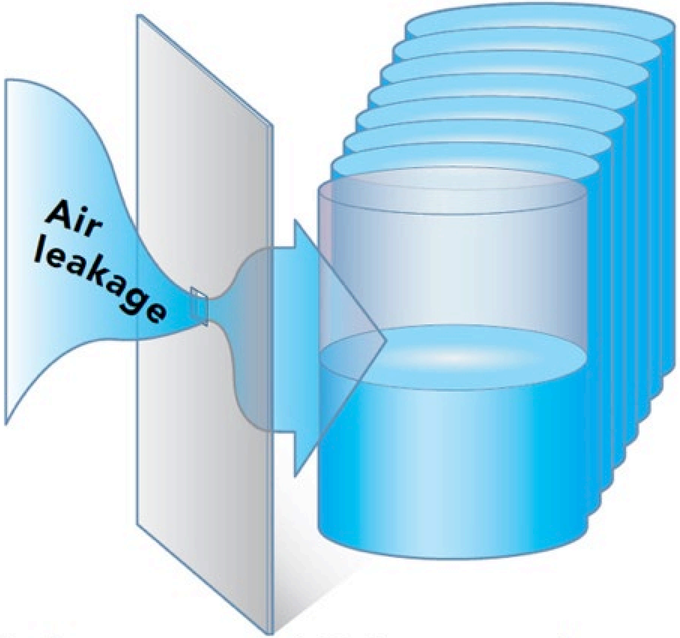
T ext = 50º

RH int = 70%

Dew point = 50.2



Vapor diffusion



Much more water—100 times as much—can pass through a 1-in. by 1-in. hole in drywall.

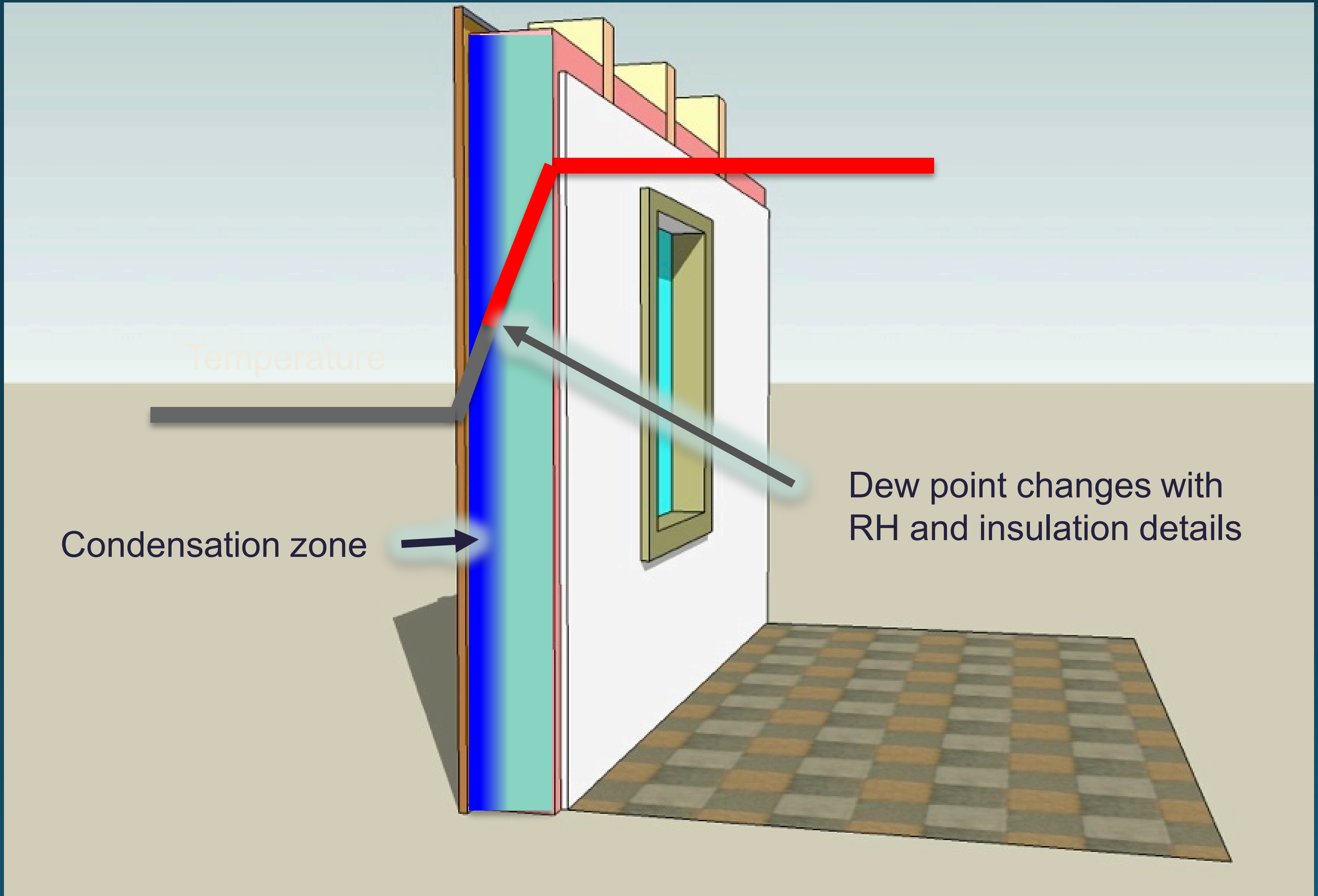
The importance of air leakage…

Windows can be a very good indicator of indoor humidity levels

30% - 35% RH Recommended in winter

Cold Weather Condensation

“Collapsed Glass”


Temperature
Condensation zone
Dew point changes with
RH and insulation details

Dew-Point Temperature (°F)															
Relative Humidity	Design Dry Bulb (Interior) Temperature (°F)														
	32	35	40	45	50	55	60	65	70	75	80	85	90	95	100
100%	32	35	40	45	50	55	60	65	70	75	80	85	90	95	100
90%	30	33	37	42	47	52	57	62	67	72	77	82	87	92	97
80%	27	30	34	39	44	49	54	58	64	68	73	78	83	88	93
70%	24	27	31	36	40	45	50	55	60	64	69	74	79	84	88
60%	20	24	28	32	36	41	46	51	55	60	65	69	74	79	83
50%	16	20	24	28	33	36	41	46	50	55	60	64	69	73	78
40%	12	15	18	23	27	31	35	40	45	49	53	58	62	67	71
30%	8	10	14	16	21	25	29	33	37	42	46	50	54	59	62
20%	6	7	8	9	13	16	20	24	28	31	35	40	43	48	52
10%	4	4	5	5	6	8	9	10	13	17	20	24	27	30	34

Adapted from ASHRAE Psychrometric Chart, 1993 ASHRAE Handbook—Fundamentals.

Temperature Calculation
within the wall

1. Determine total R-value
2. Determine ΔT across the wall
3. Starting from outside… $T_{interface} = T_{outside}$ + (percent of total R value x ΔT)

Total R value = 24.52
Inside temperature = 70º
Outside temperature = 10°

R value outside surface layer is 0.17, or 0.7%

0.007 x 60º = 0.4º

10º + 0.4º = 10.4º (Outside surface temperature)

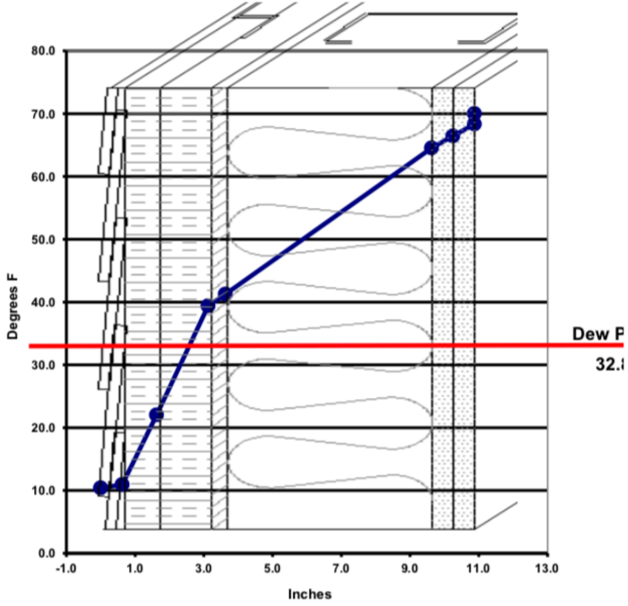
Next layer = 0.009 x 60° = 0.5º

10.4º + 0.5º = 10.9° (Inside siding temperature)

And so on...

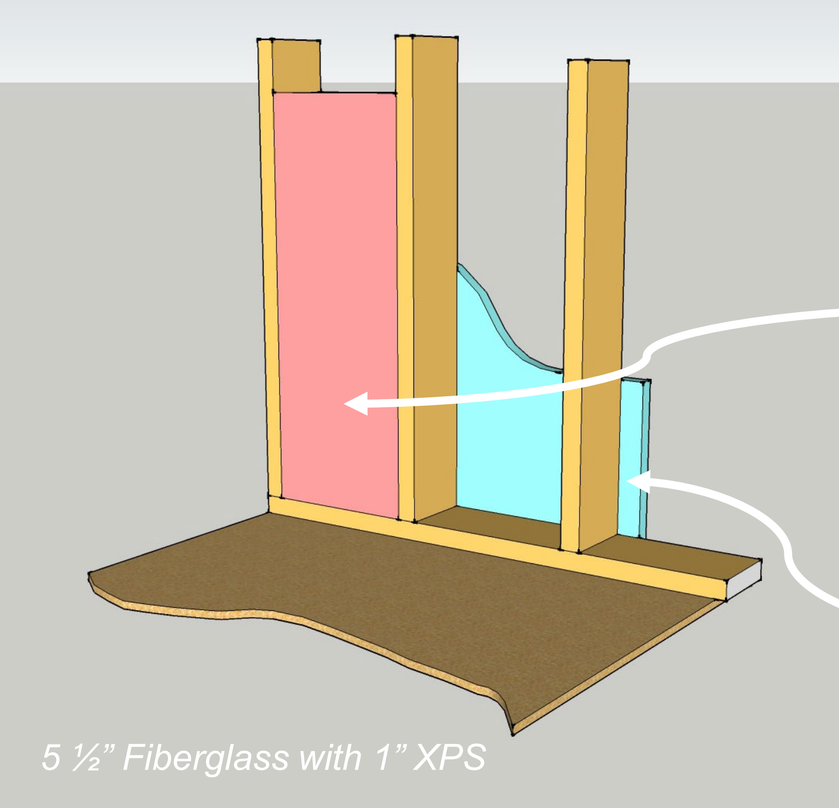
Wall Type 1 W/ 2.5" Rigid Insul.

Layers	R value	% off total	Thickness	Temp profile
outside surface	0.17	0.7	0.0	10.4
cemeticious fiber board siding	0.21	0.9	0.6	10.9
1" extruded polyiso. w/ z channels	4.53	18.5	1.0	22.0
1-1/2" extruded polyiso. W/ fasteners	7.1	29.0	1.5	39.4
1/2" plywood	0.77	3.1	0.5	41.3
6" stud W/ FG insul.	9.5	38.7	6.0	64.5
5/8" gyp.	0.78	3.2	0.6	66.4
5/8" gyp.	0.78	3.2	0.6	68.3
inside surface	0.68	2.8	0.0	70.0
	24.52	100	10.9	



Note: Dew Point Based on Indoor winter conditions of 70F at 25% RH

Exterior Foam Sheathing System



What temperature here?

What temperature here?

Calculating interface temperatures

Total R value = R19 + R5 = R24

ΔT = 68° (68° interior, 0° exterior)

Step One

XPS R-value % = 20.8%

.208 x 68° = 14.14°

0° + 14.14° = 14.14°

Step Two

Fiberglass R-value % = 79.2%

.792 x 68° = 53.86°

0° + 14.14° + 53.86° = 68°

Dew-Point Temperature (°F)															
Relative Humidity	Design Dry Bulb (Interior) Temperature (°F)														
	32	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
100%	32	35	40	45	50	55	60	65	70	75	80	85	90	95	100
90%	30	33	37	42	47	52	57	62	67	72	77	82	87	92	97
80%	27	30	34	39	44	49	54	58	64	68	73	78	83	88	93
70%	24	27	31	36	40	45	50	55	60	64	69	74	79	84	88
60%	20	24	28	32	36	41	46	51	55	60	65	69	74	79	83
50%	16	20	24	28	33	36	41	46	50	55	60	64	69	73	78
40%	12	15	18	23	27	31	35	40	45	49	53	58	62	67	71
30%	8	10	14	16	21	25	29	33	37	42	46	50	54	59	62
20%	6	7	8	9	13	16	20	24	28	31	35	40	43	48	52
10%	4	4	5	5	6	8	9	10	13	17	20	24	27	30	34

Adapted from ASHRAE Psychrometric Chart, 1993 ASHRAE Handbook—Fundamentals.

Total R value = R19 + R10 = R29

ΔT = 68° (68° interior, 0° exterior)

Step One

XPS R-value % = 34.5%

.345 x 68° = 23.46°

0° + 23.46° = 23.46°

Step Two

Fiberglass R-value % = 65.5%

.655 x 68° = 44.54°

0° + 23.46° + 44.54° = 68°

Dew-Point Temperature (°F)															
Relative Humidity	**Design Dry Bulb (Interior) Temperature (°F)**														
	32	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
100%	32	35	40	45	50	55	60	65	70	75	80	85	90	95	100
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60%	20	24	28	32	36	41	46	51	55	60	65	69	74	79	83
50%	16	20	24	28	33	36	41	46	50	55	60	64	69	73	78
40%	12	15	18	23	27	31	35	40	45	49	53	58	62	67	71
30%	8	10	14	16	21	25	29	33	37	42	46	50	54	59	62
20%	6	7	8	9	13	16	20	24	28	31	35	40	43	48	52
10%	4	4	5	5	6	8	9	10	13	17	20	24	27	30	34

Adapted from ASHRAE Psychrometric Chart, 1993 ASHRAE Handbook—Fundamentals.

Climate zone	Minimum R-value for exterior foam installed on an existing 2x4 wall	Minimum R-value for exterior foam installed on an existing 2x6 wall
Marine 4	2.5	3.75
5	5	7.5
6	7.5	11.25
7 and 8	10	15

Courtesy BuildingGreen, Inc

Minimum R-values for exterior foam applications

What temperature here?

Total R value = R11 + R7

$\Delta T = 68^\circ$

Step One

CCF R-value % = 38.9%

$.389 \times 68^\circ = 26.45^\circ$

Step Two

FG R-value % = 61.1%

$.611 \times 68^\circ = 41.55^\circ$

Dew-Point Temperature (°F)															
Relative Humidity	Design Dry Bulb (Interior) Temperature (°F)														
	32	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
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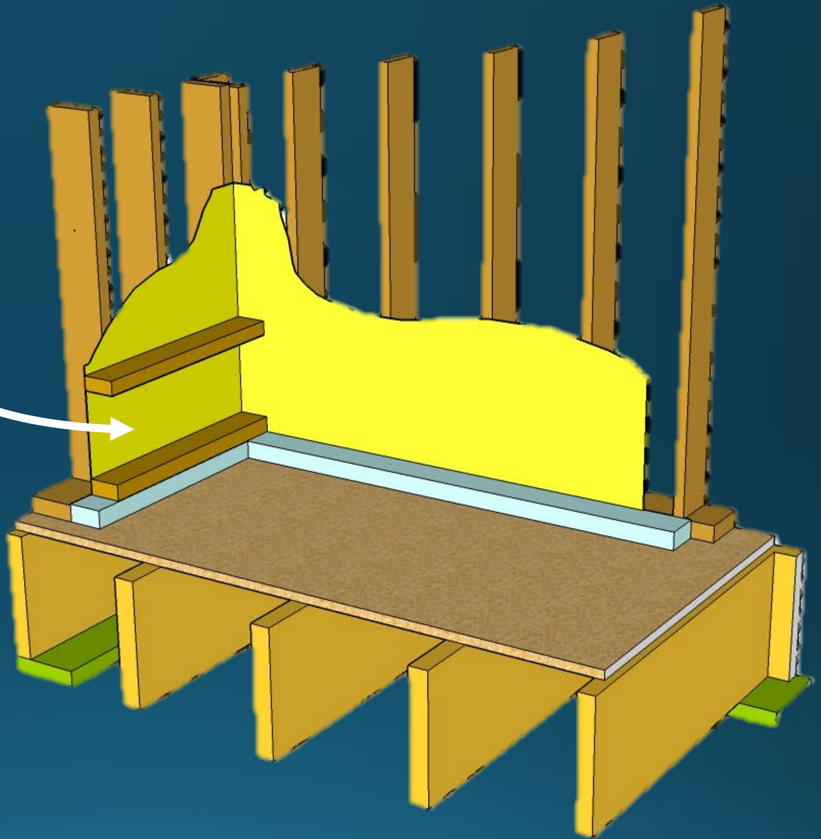
10%	4	4	5	5	6	8	9	10	13	17	20	24	27	30	34

Adapted from ASHRAE Psychrometric Chart, 1993 ASHRAE Handbook—Fundamentals.

“Wrap and Strap” System

What temperature here?



Dense packed cellulose both cavities

Total R value = R22 + R14 = R36

ΔT = 68° (68° interior, 0° exterior)

Step One

Ext. cavity R-value % = 61.1%

.611 x 68° = 41.55°

0° + 41.55° = 41.55°

Step Two

Int. cavity R-value % = 38.9%

.389 x 68° = 26.45°

0° + 41.55° + 26.45° = 68°

Dew-Point Temperature (°F)															
Relative Humidity	**Design Dry Bulb (Interior) Temperature (°F)**														
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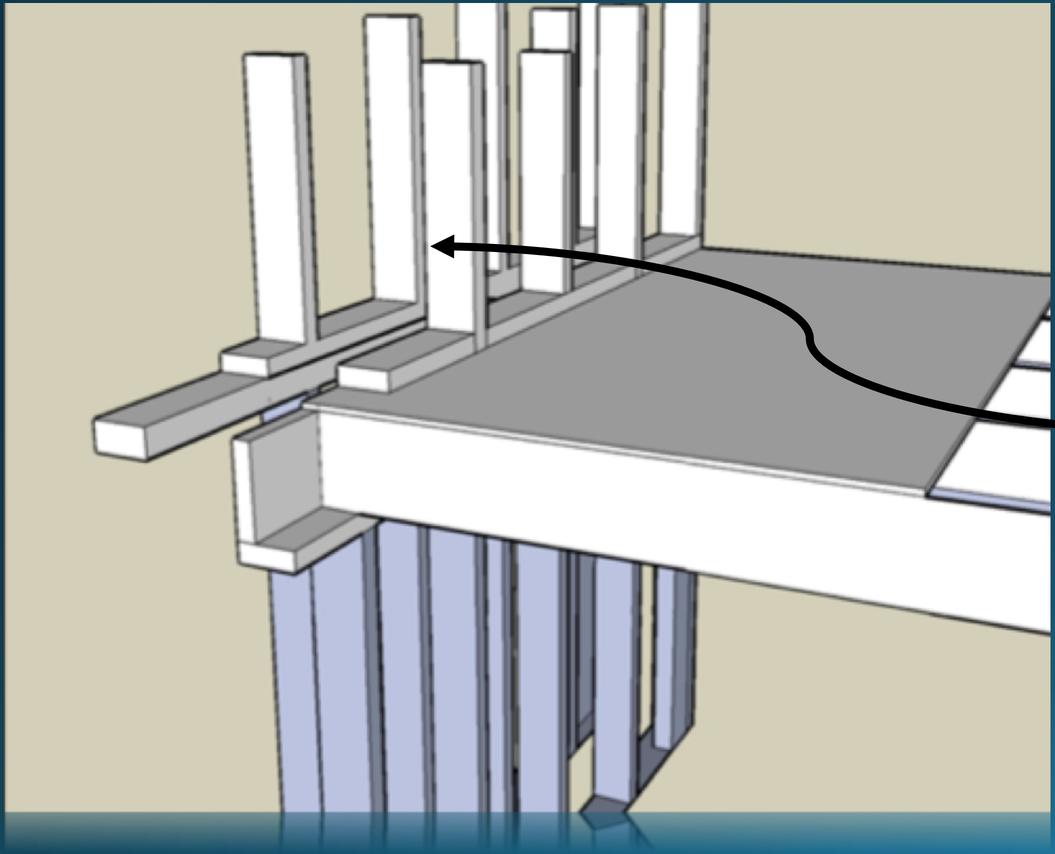
70%	24	27	31	36	40	45	50	55	60	64	69	74	79	84	88
60%	20	24	28	32	36	41	46	51	55	60	65	69	74	79	83
50%	16	20	24	28	33	36	41	46	50	55	60	64	69	73	78
40%	12	15	18	23	27	31	35	40	45	49	53	58	62	67	71
30%	8	10	14	16	21	25	29	33	37	42	46	50	54	59	62
20%	6	7	8	9	13	16	20	24	28	31	35	40	43	48	52
10%	4	4	5	5	6	8	9	10	13	17	20	24	27	30	34

Adapted from ASHRAE Psychrometric Chart, 1993 ASHRAE Handbook—Fundamentals.

Double Wall System



What temperature here?

Total R value = R26 + R11 = R37

ΔT = 68° (68° interior, 0° exterior)

Step One

Ext. cavity R-value % = 70.3%

.703 x 68° = 47.8°

0° + 47.8° = 47.8°

Step Two

Int. cavity R-value % = 29.7%

.297 x 68° = 20.2°

0° + 47.8° + 20.2° = 68°

Dew-Point Temperature (°F)															
Relative Humidity	Design Dry Bulb (Interior) Temperature (°F)														
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80%	27	30	34	39	44	49	54	58	64	68	73	78	83	88	93
70%	24	27	31	36	40	45	50	55	60	64	69	74	79	84	88
60%	20	24	28	32	36	41	46	51	55	60	65	69	74	79	83
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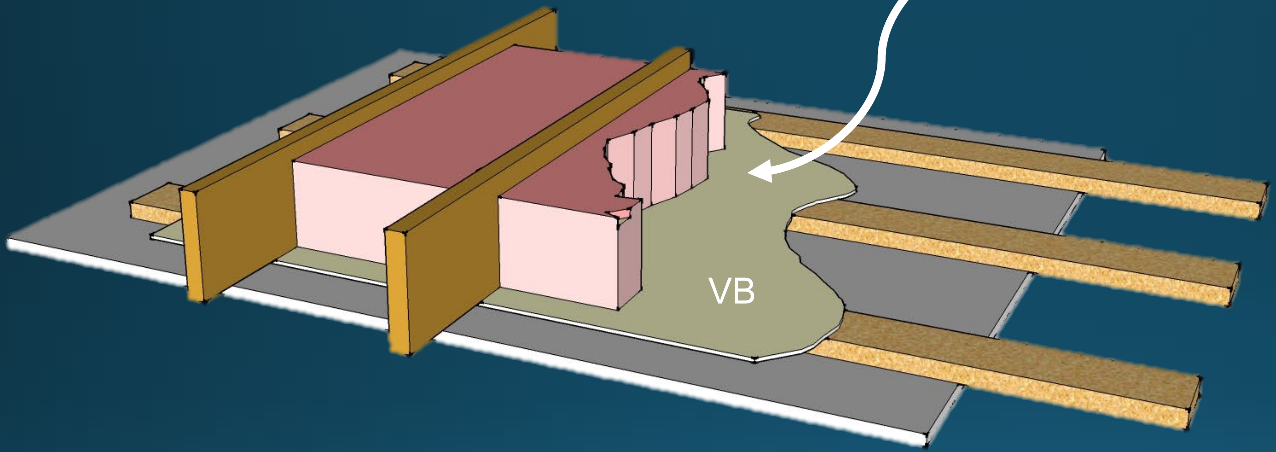
10%	4	4	5	5	6	8	9	10	13	17	20	24	27	30	34

Adapted from ASHRAE Psychrometric Chart, 1993 ASHRAE Handbook—Fundamentals.

Attic insulation of the 1970's

What is temperature here?



Gypsum ceiling = R .45

Air space = R 4.2

Fiberglass = R 19

Total R value = 23.65

Why old time builders avoided vapor barriers at ceiling

Total R value = 23.65

ΔT = 68° (68° interior, 0° exterior)

Step One

Fiberglass R value = 19/23.65 x 100 = 80.33%

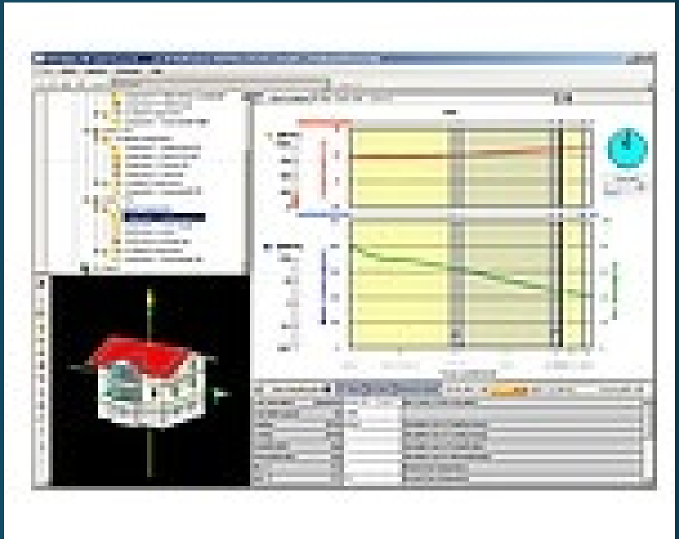
.803 x 68° = 54.6°

Temperature at joist

7.5/12.15 x 100 = 61.7%

.617 x 68 = 41.9°

WUFI



Wärme Und Feuchte Instationär

"Heat and Moisture Transiency"

Computer software used to determine humidity and moisture effects on buildings

Southern Maine Problem House

New house with siding issues

Painter noticed lose clapboards

Re-siding contractor noticed rotten sheathing boards

Further investigation showed the following…

Siding came off in sheets

Lack of ventilation, high interior RH

Diagonal board sheathing was found to be rotten

Structural elements were compromised

Post and Beam Construction

Green timbers shrank away from infill walls, up to ½" for 8"x8"

Moisture laden air leaked through the cracks to the outside

Exterior XPS with insufficient thickness

Dew point reached

Exterior sheathing, studs, timbers, all rotted in 5 years

End result.. Demolition, Recrimination, and Litigation

Any questions?

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When you have exhausted all possibilities, remember this… *you haven't*

Thomas Alva Edison