Themal Bridge Analysis

Chris Petit, CPHD, PHI-accredited Certifier

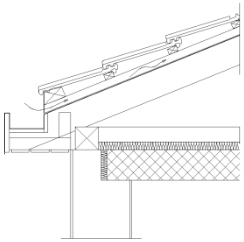
Regenerative Design, LLC
chris@regenerativedesign.com

Rolf Jacobson, LEED AP, CPHC

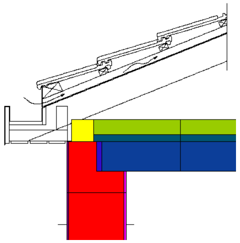
Research Fellow, Center for Sustainable Building Research, U of M
jaco0630@umn.edu

Basics of the Modeling

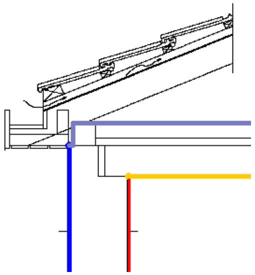
The definition of the calculation model according to the Standards consists of 3 parts:



Geometry



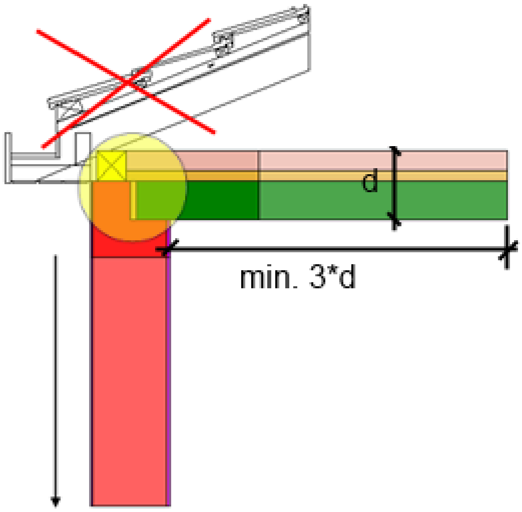
Materials



Boundary Conditions

Model: Geometry

Using flixo: either by DXF-Import, by connecting predefined components or by drawing directly inside flixo

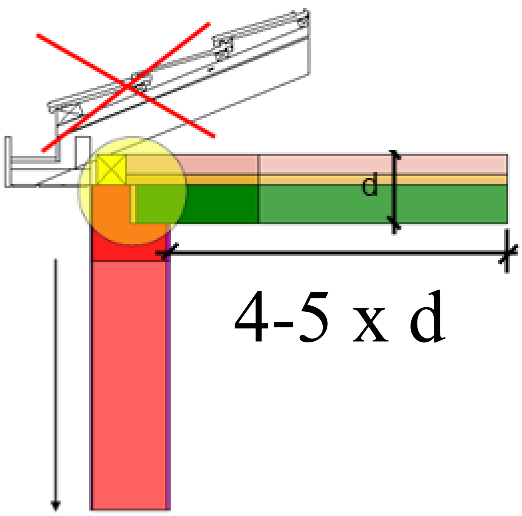


To check

- The model must be large enough, cut-off planes should be positioned concerning the central element as follows (EN ISO 10211):
  - In general at least 1 meter or if the thickness of the flanking element is greater than 33 centimeter, 3 times of the thickness of the flanking element
  - At the line of symmetry, if one is present
- Omit the cladding and the air layer if the air layer is well ventilated (EN ISO 6946)

Model: Geometry

Using flixo: either by DXF-Import, by connecting predefined components or by drawing directly inside flixo



PHI recommendations:

- Length of components should be **4-5 x width**, when measured using exterior dimensions
- Some components (with steel and concrete especially) may need even longer lengths.
- The goal is to achieve stable isotherms before they reach the cutoff plane.
- Inserting a cut-off plane before isotherms have achieved a stable pattern introduces error.

Model: Materials

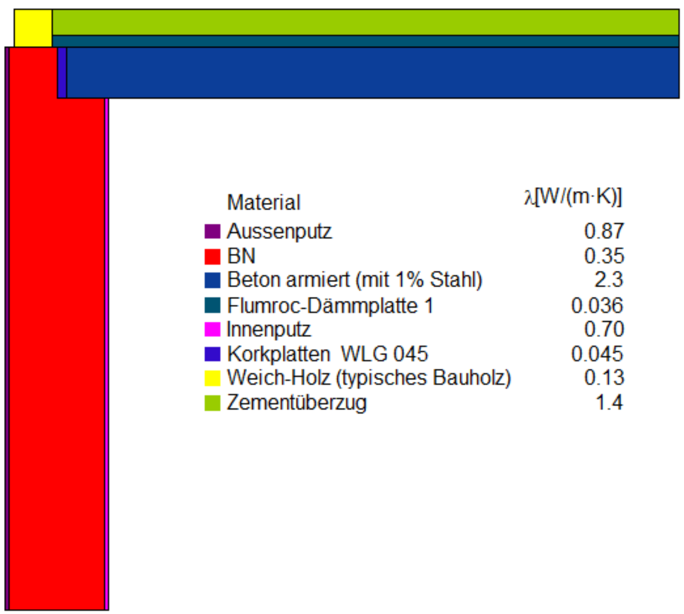
Using flixo: either by Drag & Drop materials from the material database or the material list or using the «Assign Property»-Tool

PHI recommendations:

- For unventilated air layers, use the still air U-value calculator built into PHPP U-values tab.
- Or use the database contained in Flixo (organized by direction of heat flow and offering large range of air layer thicknesses)

Model: Materials

Using flixo: either by Drag & Drop materials from the material database or the material list or using the «Assign Property»-Tool



To check

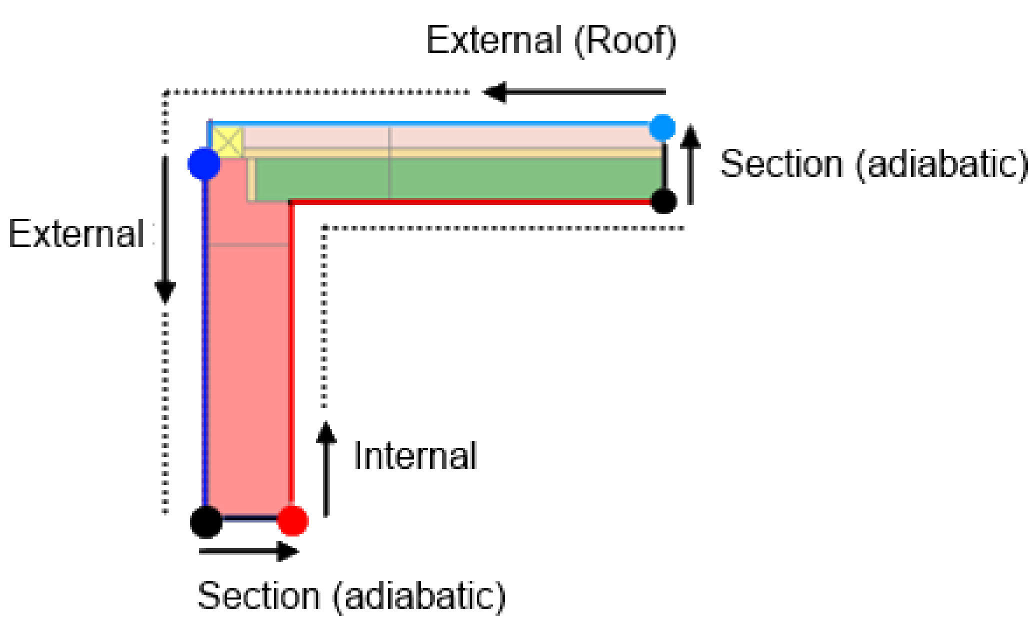
- Proper «Air»-Material:
  - Air cavities: equivalent conductivities according to EN ISO 10077-2
  - Air layers: equivalent conductivities according to EN ISO 6946
  - Well ventilated air layers: boundary conditions according to EN ISO 6946
  - Fillings of glazing: equivalent conductivities according to EN ISO 673 or by using the glazing wizard

Model: Boundary Conditions

Boundary Conditions consist of two elements:

1) Surface film resistance
2) Surface temperature

Using flixo: Defining the start points by using the «Boundary Condition»-Tool.
The boundary conditions will be applied counter clockwise up to the next start point



PHI Requirements

The boundary conditions depend on the type of analysis

1) **Energy balance** calculation (e.g. Uf-value, Psi-value)

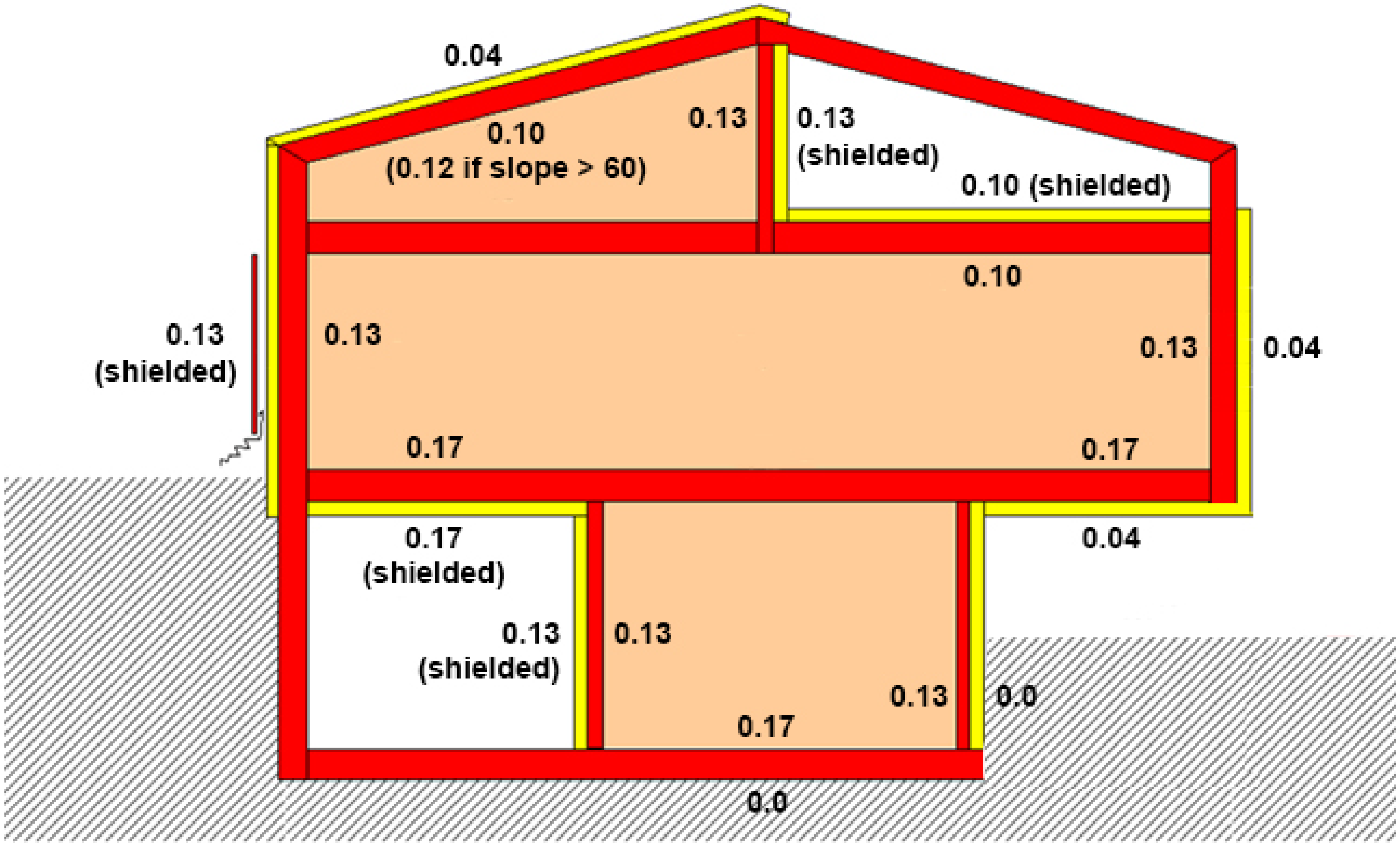
2) **Condensation risk** analysis

Model: B.C. for Energy Balance Calculation

Surface resistances R_{si} and R_{se} [m^2K/W]

Note:

- These surface film resistances change if conducting a condensation risk analysis (f_{rsi})



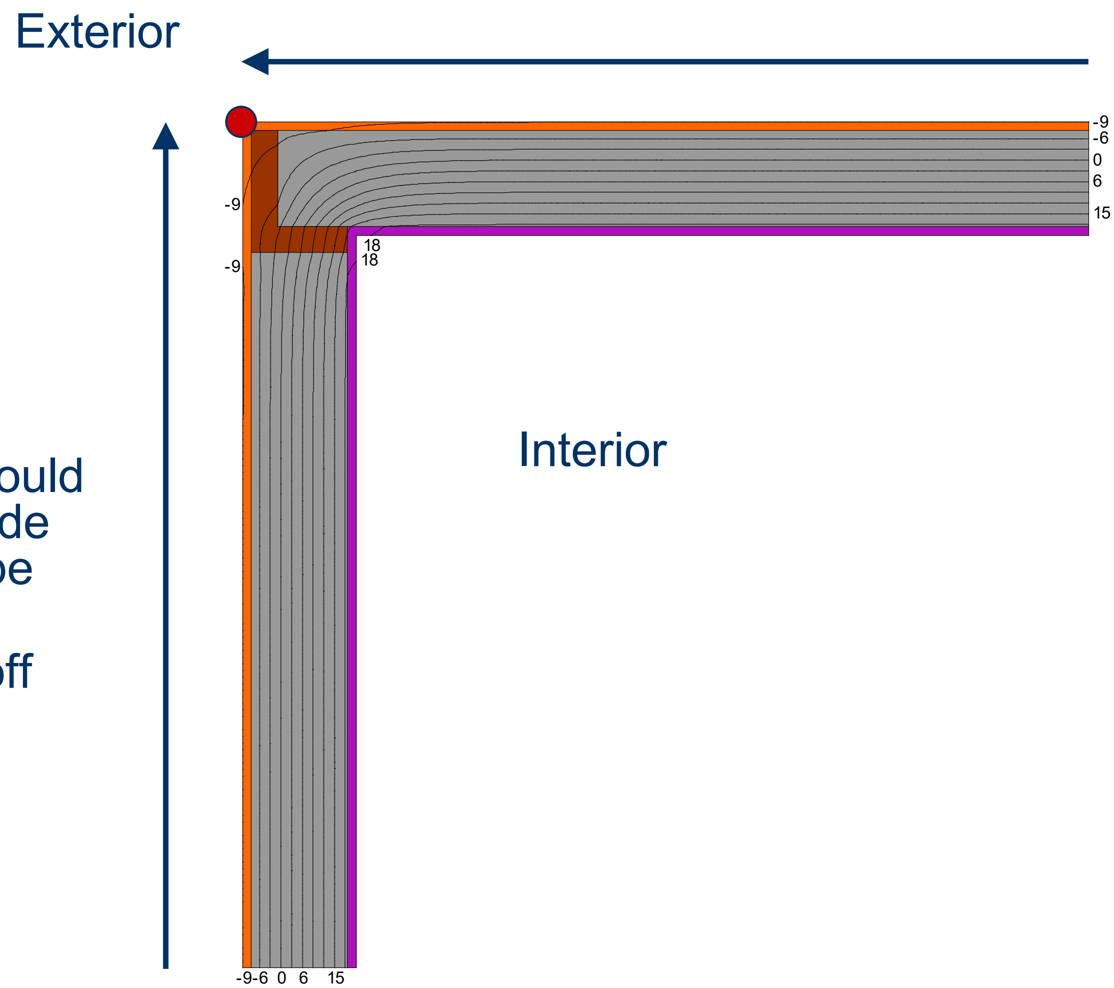
infomind

Model: B.C. for Energy Balance Calculation

Boundary Condition Temperatures for modeling constructions

Exterior temperature: -10 Celsius (14F)
Interior temperature: 20 Celsius (68F)

Ψ-Psi value calculation: Reference Point – Exterior Corner



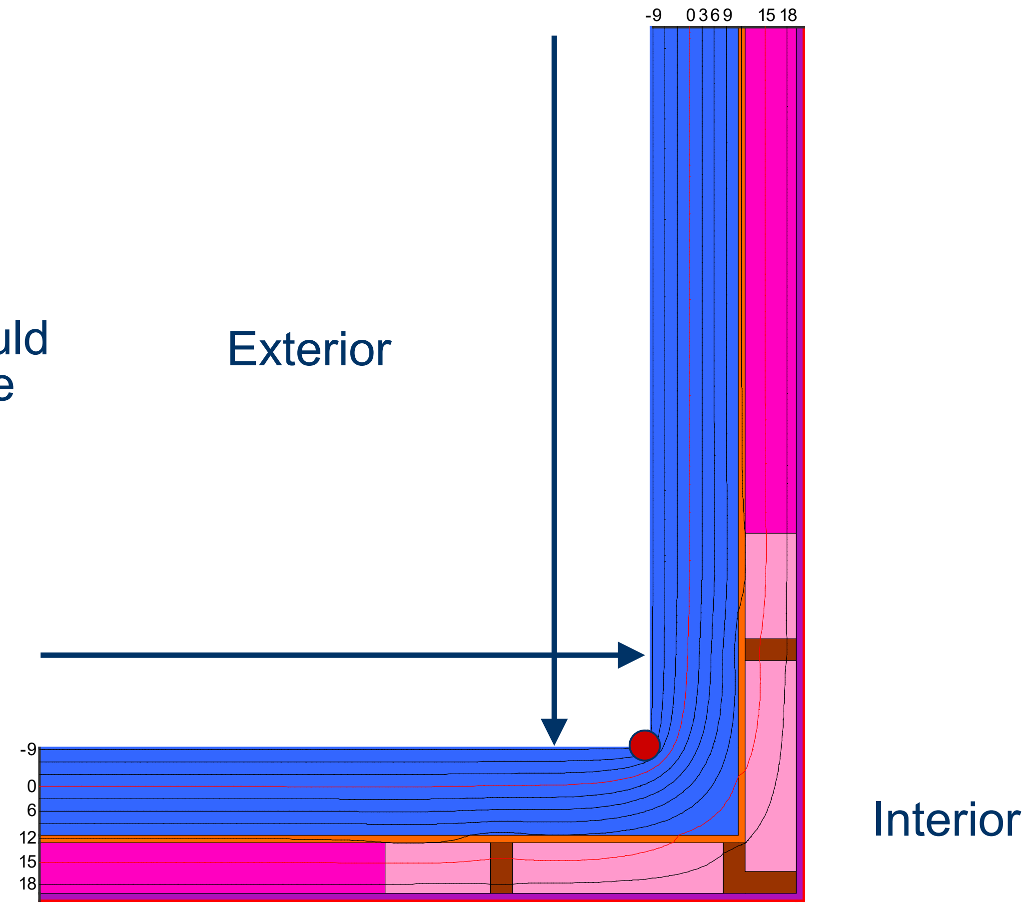
Reference Point

- Choose the reference point based on exterior dimensions
- Exterior dimensions should be taken from the outside face of thermal envelope
- Flixo will automatically measure from the cut-off planes to the reference point.

Ψ-Psi value calculation: Reference Point – Interior Corner

Reference Point

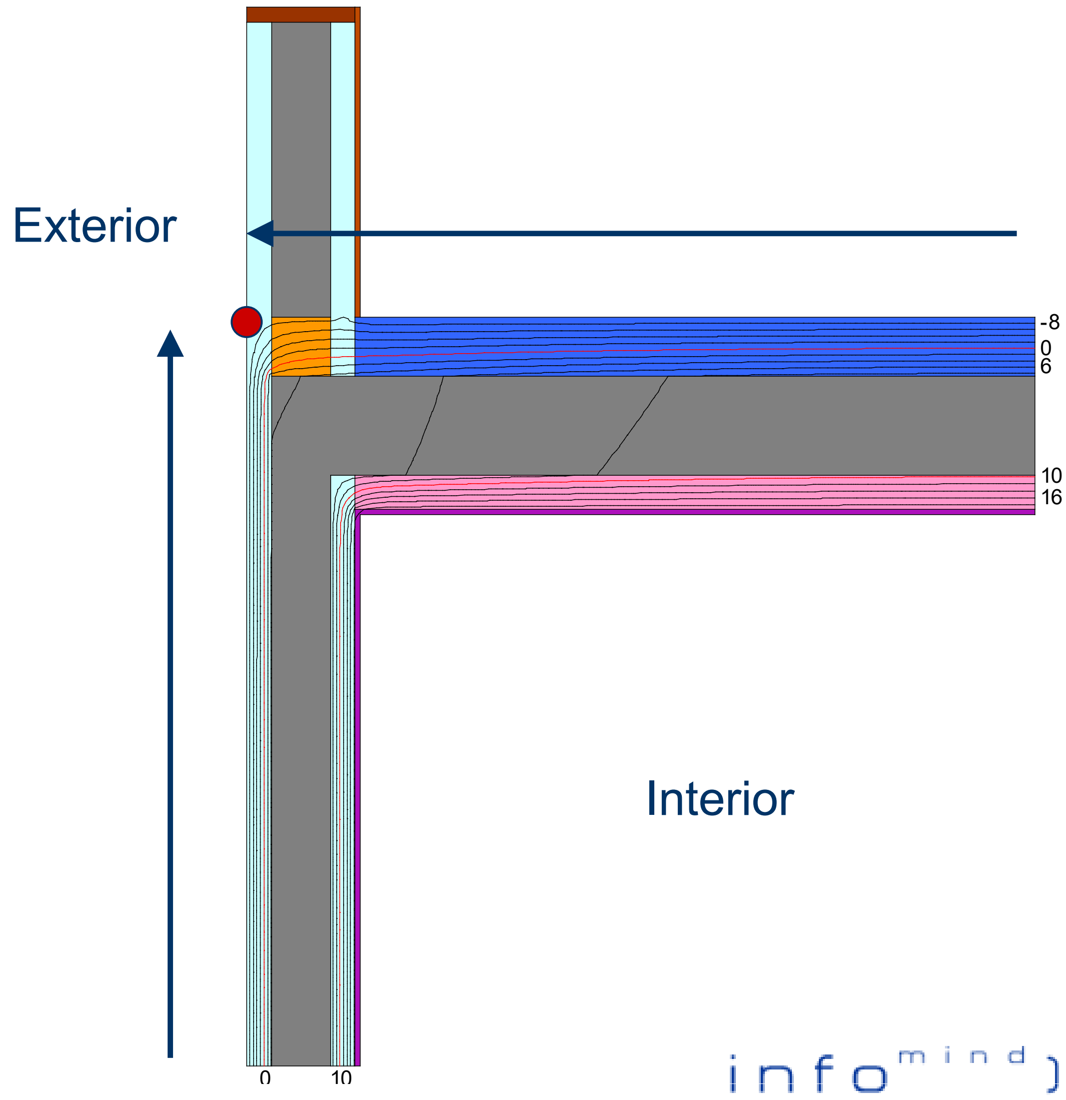
- Choose the reference point based on exterior dimensions
- Exterior dimensions should be taken from the outside face of thermal envelope
- Flixo will automatically measure from the cut-off planes to the reference point.



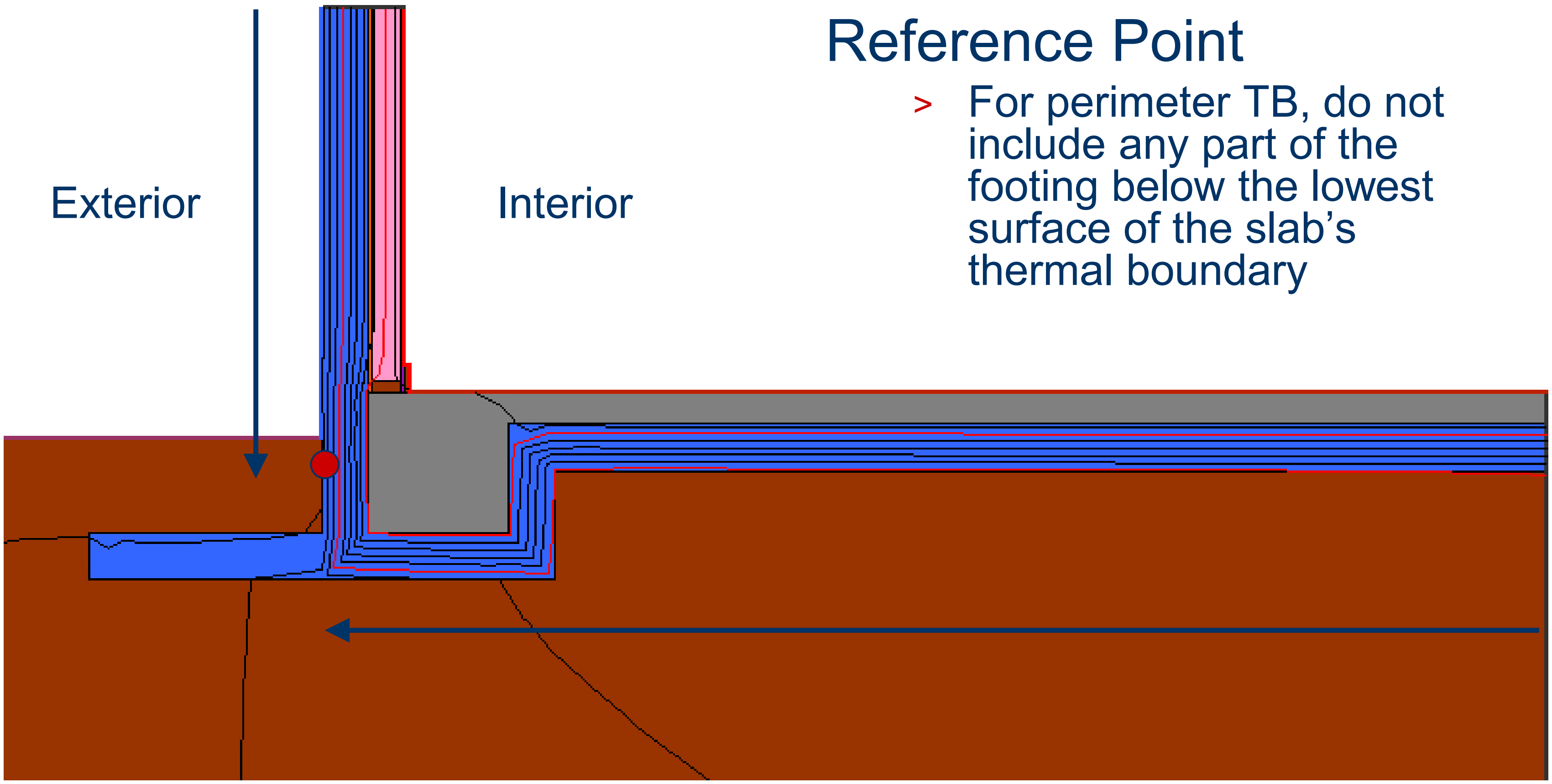
Ψ-Psi value calculation: Reference Point – Parapet

Reference Point

- For parapet TB, do not include any part of the parapet above the top surface of the roof's thermal boundary



Ψ-Psi value calculation: Reference Point – Perimeter



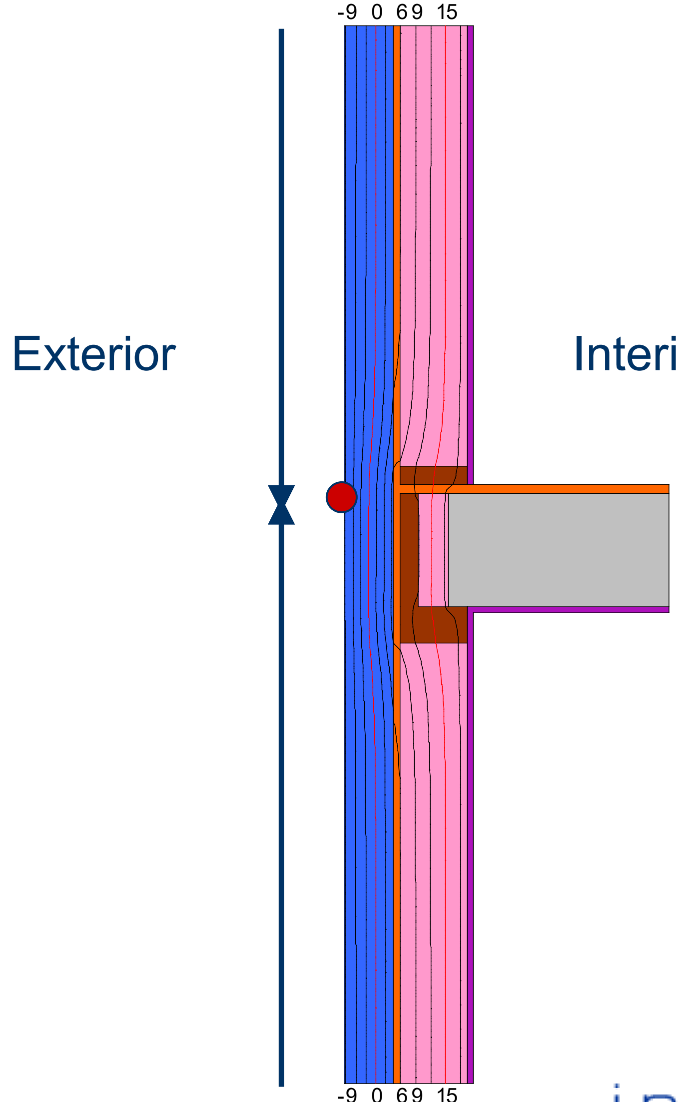
Reference Point

- For perimeter TB, do not include any part of the footing below the lowest surface of the slab's thermal boundary

Ψ-Psi value calculation: Reference Point – Rim joist

Reference Point

- For rim joist, position of the reference point doesn't matter if the two wall assemblies are the same.



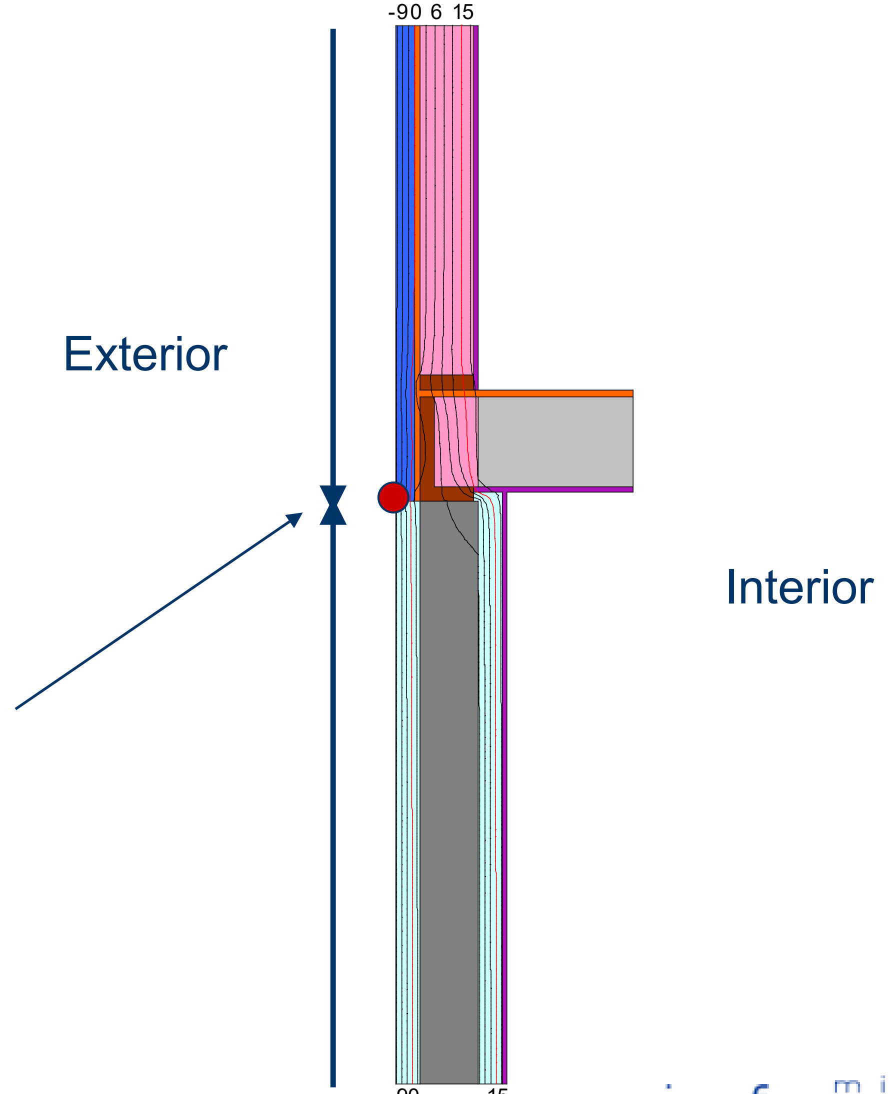
Ψ-Psi value calculation: Reference Point – Rim joist

Reference Point

- For rim joist with two different assemblies, the reference point needs to be aligned according to the assembly dimensions used in PHPP.

Notes:

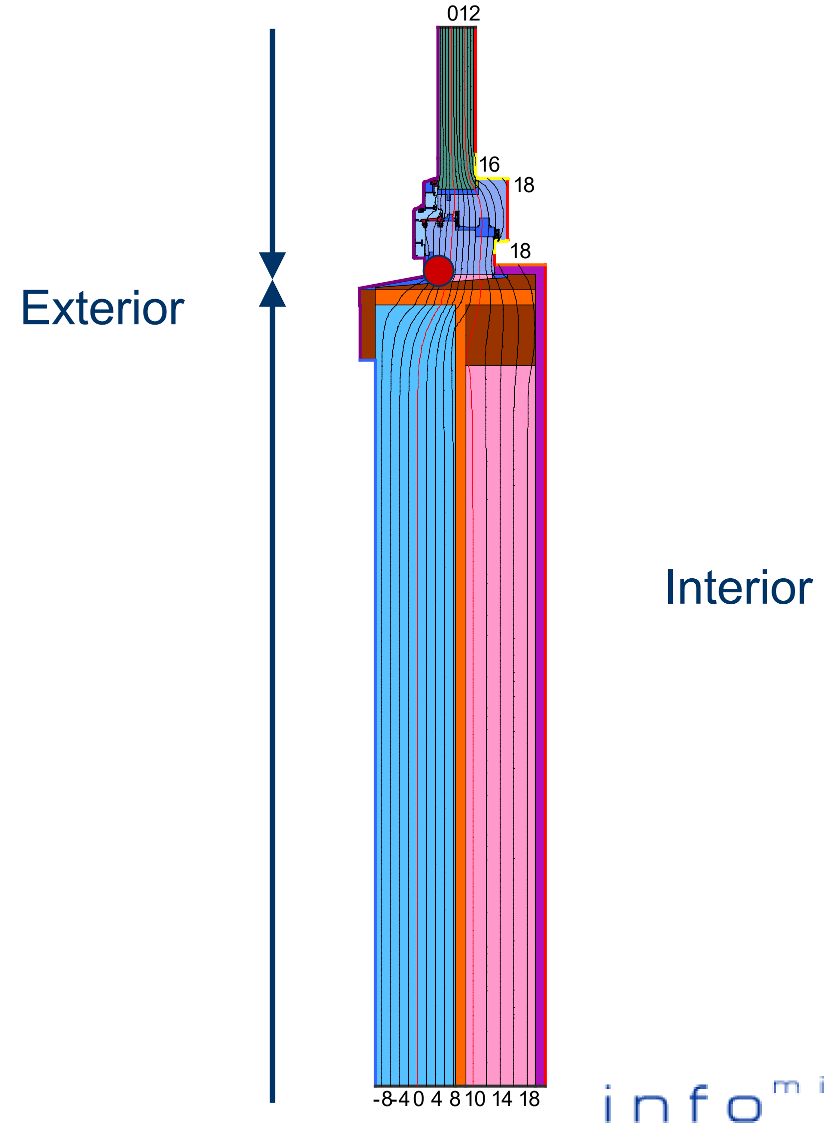
- Does the above grade wall extend to here in PHPP?



Ψ-Psi value calculation: Reference Point – Windows

Reference Point

- For the window install psi value, the reference point is aligned with the bottom of the window frame, even if the frame is overinsulated.



Condensation Risk Analysis f_{Rsi}

The f_{Rsi} factor allows us to evaluate a given construction to determine mold resistance at the interior surface. To meet PHI criteria, the f_{Rsi} factor must be greater than the value shown for the project's corresponding climate zone

$$fRsi = (tsi - te) / (ti - te)$$

With:

f_{Rsi} Temperature factor at the internal surface

t_{si} Interior Surface Temp

t_e Exterior Air Temp

t_i Interior Air Temp

Table 6 Criteria for moisture protection

Climate zone	Min. temperature factor $f_{Rsi=0.25\ m^2K/W}$ []
Arctic	0.80
Cold	0.75
Cool-temperate	0.70
Warm-temperate	0,65
Warm	0.55
Hot	-
Very hot	-

Surface resistances R_{Frsi} [m²K/W]

› 0.25 [m²K/W] for all interior surfaces

Note:

- This surface film resistance is set to create a conservative (worst case) condition that would make the interior surface of the wall colder and increase risk of condensation.

infomind

Condensation Risk Analysis f_{Rsi}

Boundary Condition Temperatures for Condensation Risk Analysis

In theory - any set of interior and exterior temperatures can be used for the f_{Rsi} calculation since it is the ratio that's important, not the actual surface temperatures. The ratio will (theoretically) remain the same no matter what temperatures are chosen for the simulation.

In practice - standard PHI boundary conditions for modeling constructions are used, since the f_{Rsi} calculation uses the same model created for the psi value calculation

Exterior temperature: -10 Celsius (14F)
Interior temperature: 20 Celsius (68F)

Condensation Risk Analysis

It's possible to do other types of condensation risk analysis as well.

- locate the isotherm that is at the dewpoint (condensation risk)

- locate the isotherm that is at 80% RH (mold growth risk begins)

For those, we're not restricted to using standard PHI boundary conditions (although we can, and should, if checking $\mathbf{f_{Rsi}}$)

Exterior temperature: -10 Celsius (14F)

(or) : average temp of coldest 3 months (18.7F for MSP)

(or) : a design temperature (-10F for MSP)

(or) : another temperature that makes sense to you or your client

Interior temperature: 20 Celsius (68F)

(or) : another temperature that makes sense for your building

Condensation Risk Analysis

It's possible to do other types of condensation risk analysis as well.

- locate the isotherm that is at the dewpoint (condensation risk)

- locate the isotherm that is at 80% RH (mold growth risk begins)

To determine those isotherms, we also need to assume an interior relative humidity. What makes sense for your building? What conditions will the riskiest zone see?

Heating season interior RH:

50% - quite challenging – perhaps a high occupancy unit in a multifamily building

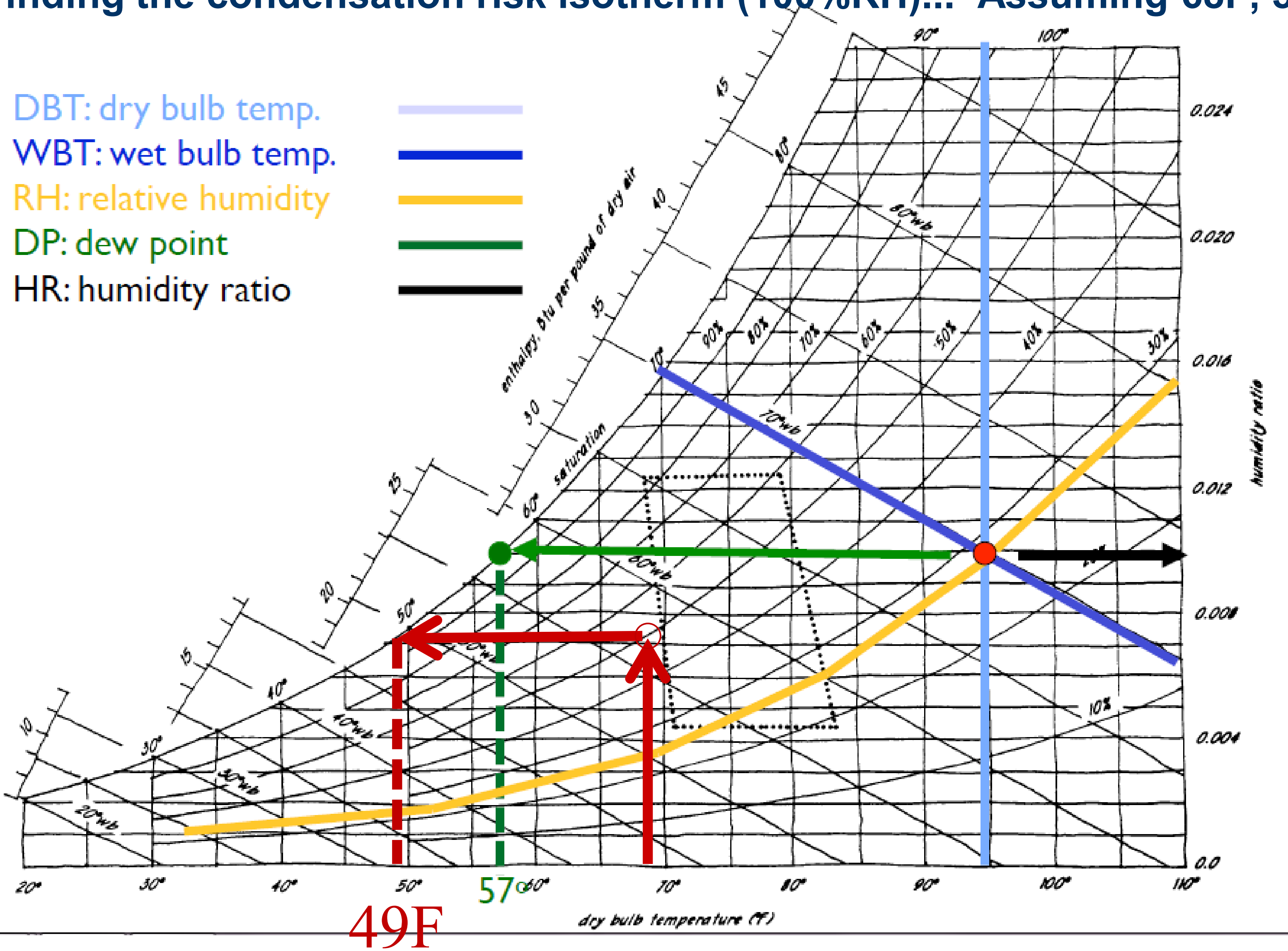
40% - still challenging – perhaps the highest RH in a new (more airtight) single family home

30% - standard indoor RH in winter for many buildings

20% or lower - common indoor RH in older (less airtight) buildings

Condensation Risk Analysis

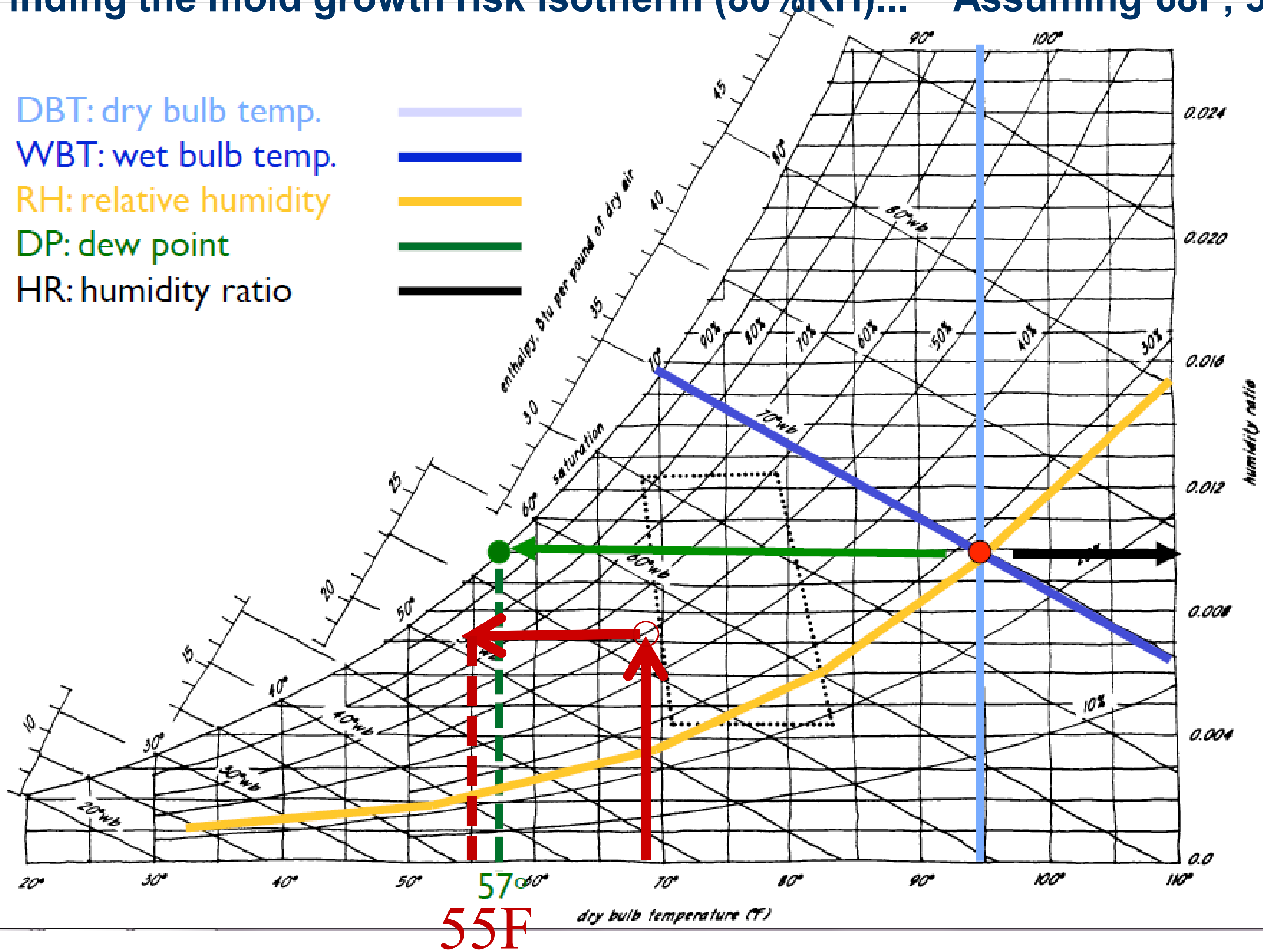
Finding the condensation risk isotherm (100%RH)... Assuming 68F, 50%RH



Condensation Risk Analysis

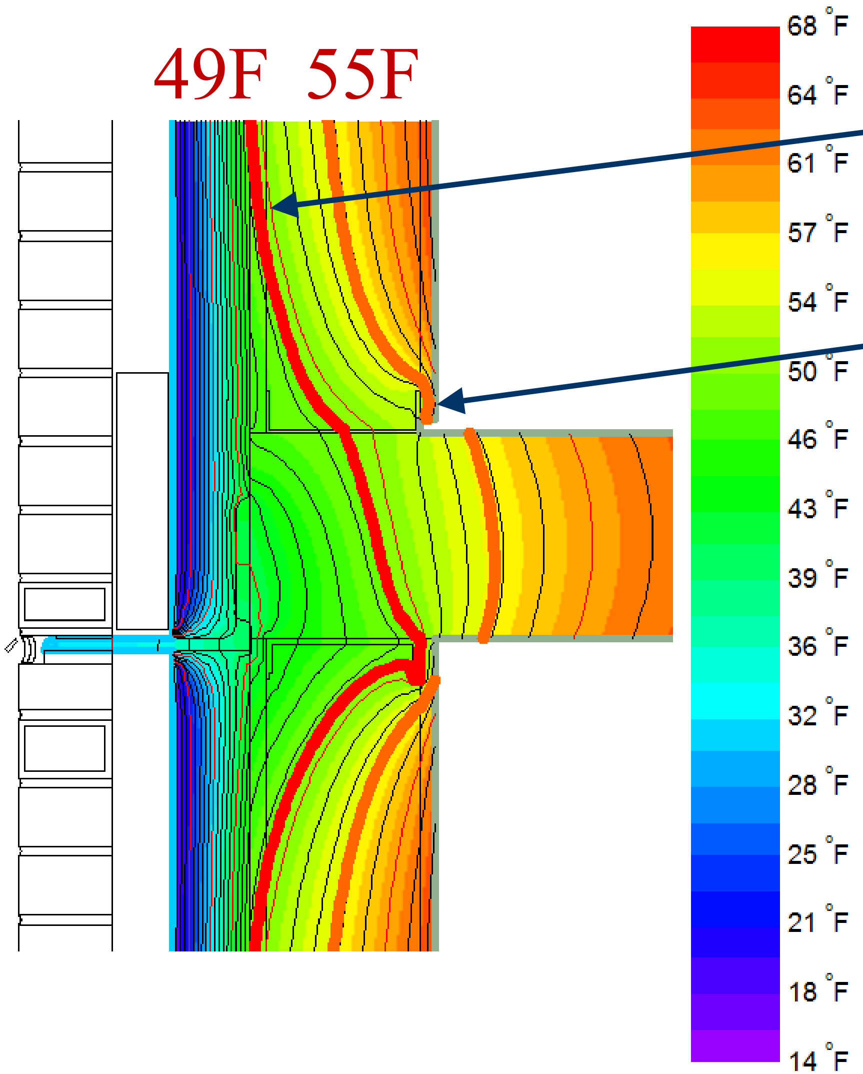
Finding the mold growth risk isotherm (80%RH)... Assuming 68F, 50%RH

- DBT: dry bulb temp.
- WBT: wet bulb temp.
- RH: relative humidity
- DP: dew point
- HR: humidity ratio



infomind

Condensation Risk Analysis



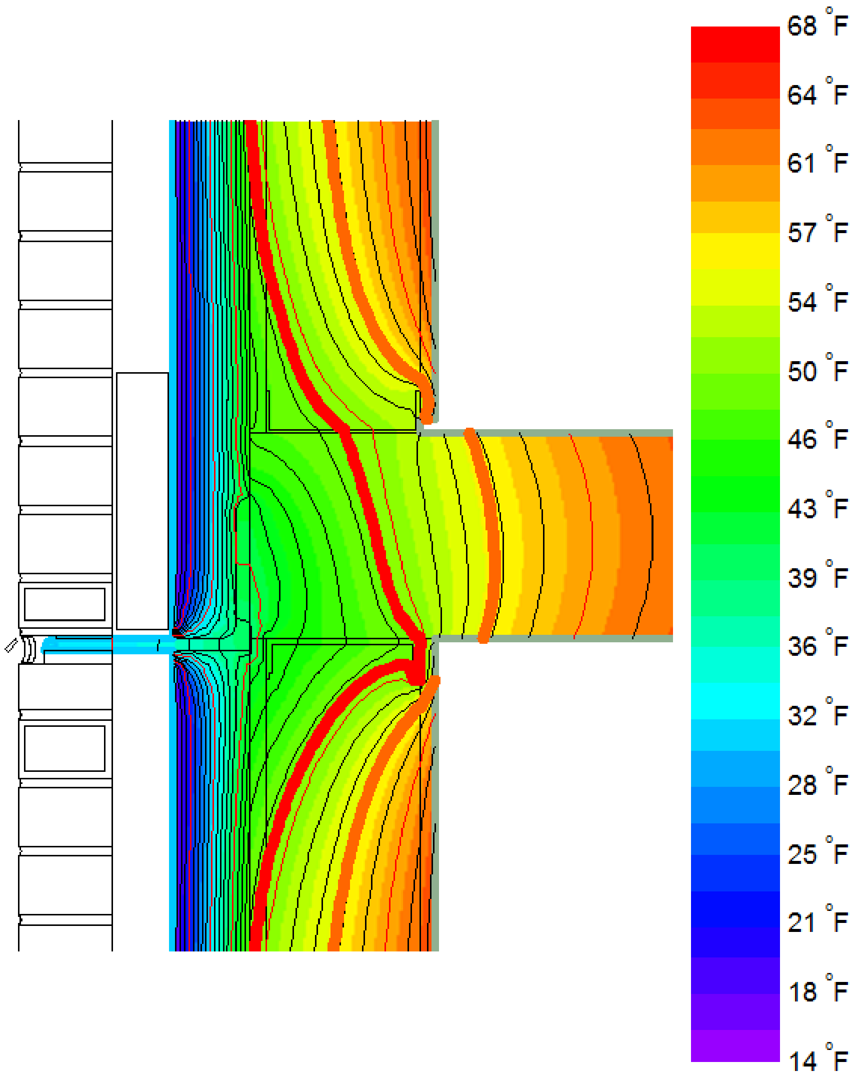
100% RH (condensation risk) isotherm

80% RH (mold growth risk) isotherm

Look for these to come to the interior surface or cross a condensation surface within the wall assembly.

infomind

Condensation Risk Analysis



100% RH (condensation risk) isotherm – this is essentially a 2-D version of the condensation risk calculation from the Glaser calculator. (ie – where is the dewpoint?)

We are NOT modeling moisture flow. Flixo has no capacity for that. It simply maps temperatures. **It's up to you to determine if air leakage is likely to bring moisture into contact with these locations.**

Model: Standards

Thermal Bridge, Model

- EN ISO 10211 (geometry, mesh, accuracy, ground)
- EN ISO 10077-2 (frame U-value, edge Ψ-value)
- EN ISO 12631 (Ucw-value, 3D elements like screws)

Materials

- EN ISO 10456 (general materials)
- EN ISO 6946 (air layers)
- EN ISO 10077-2 (frame)
- EN ISO 673 (filling of glazing)

Boundary Conditions

- EN ISO 6946 (general)
- EN ISO 13788 (mold, condensation)
- EN ISO 10211 (ground)
- EN ISO 10077-2 (frame)