Thermal Bridge Modeling Using THERM+Grasshopper

Thurs, November 14, 2019. 2:30-3:30 PM
Rensselaer Polytechnic Institute

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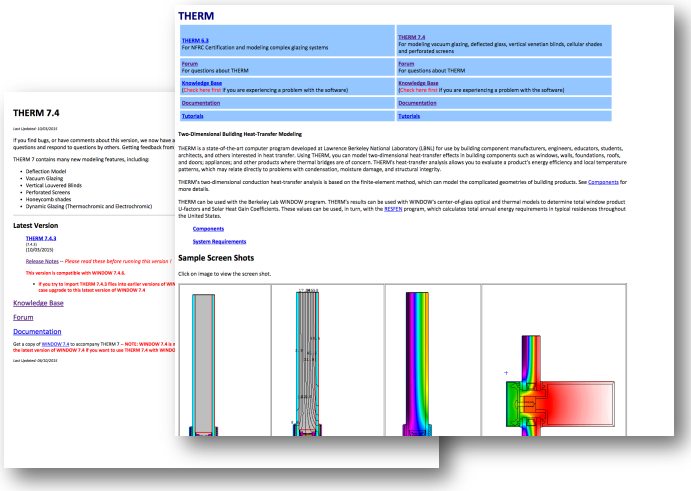
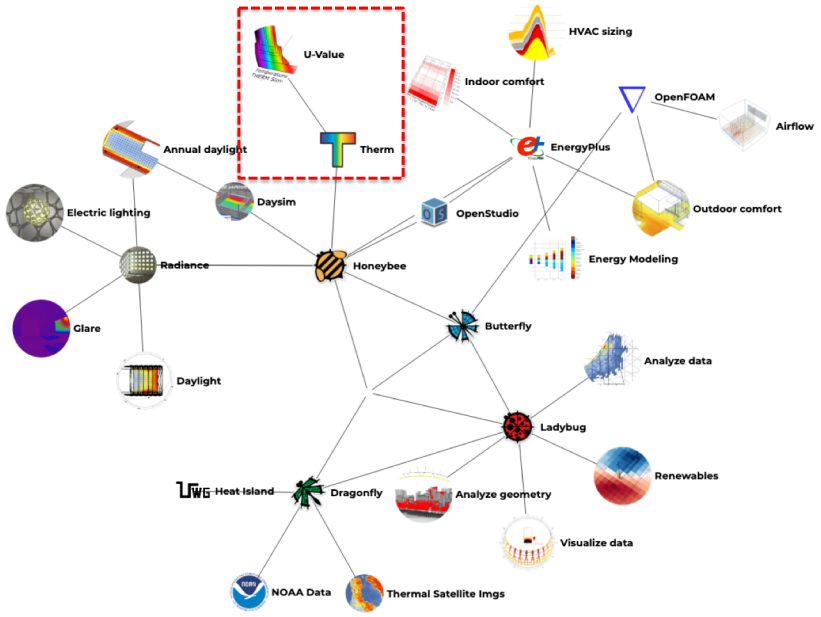
Outline

- Introduction to Thermal Bridges
- THERM Libraries, Underlays, Geometry
- THERM Materials & Boundary Conditions
- THERM Simulations
- Calculating Psi-Values

THERM (LBNL)

https://windows.lbl.gov/tools/therm/software-download





From ISO 10211

"***thermal bridge:*** *part of the building envelope where the otherwise uniform thermal resistance is significantly changed by full or partial penetration of the building envelope by materials with a different thermal conductivity, and/or a change in thickness of the fabric, and/or a difference between internal and external areas, such as occur at wall/floor/ceiling junctions*"

Thermal bridges, which in general occur at any junction between building components or where the building structure changes composition, have two consequences compared with those of the unbridged structure:

1. **a change in heat flow rate, and**
2. **a change in internal surface temperature.**

Although similar calculation procedures are used, the procedures are not identical for the calculation of heat flows and of surface temperatures.

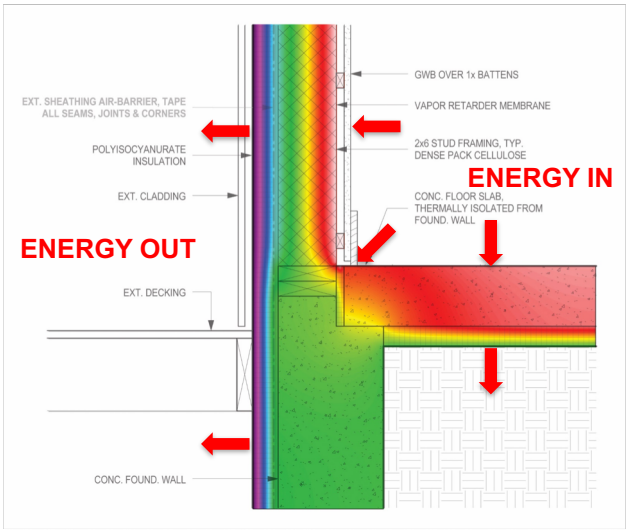
Any place in the building envelope where the otherwise uniform thermal resistance is significantly changed due to:

full or partial penetration of the insulating layers by materials with a different thermal conductivity

and/or
a change in thickness of the insulating layers

and/or
a difference between internal and external areas, such as occurs at wall/floor/ceiling junctions.

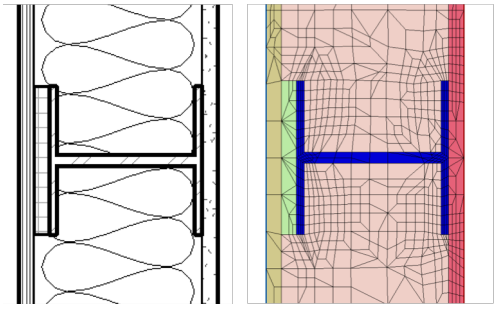
Simulating Thermal Bridges



THERM Model

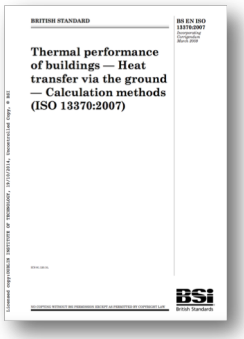
A model is made of the construction assembly and the conductivities / resistances are added for the relevant materials

The model is overlaid with a mesh and all elements are calculated. The thermal behavior of the construction elements can be calculated according to the 'grain' or scale of the mesh.

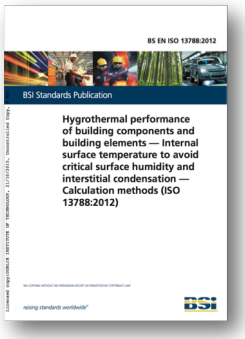


ISO Reference Standards

ISO 10211
- Thermal bridges in building construction.



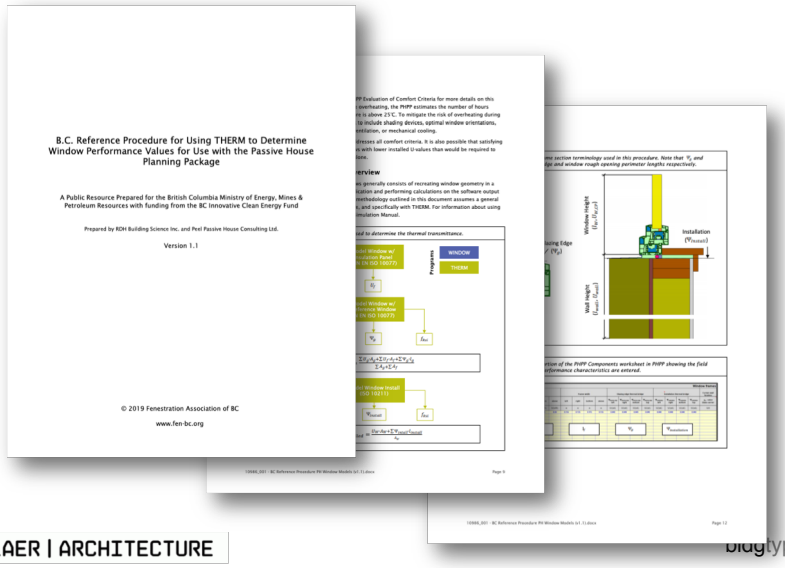
ISO 13370
- Heat transfer via the ground.



ISO 13788
- Hygrothermal performance of components

Fen-BC Window Guide

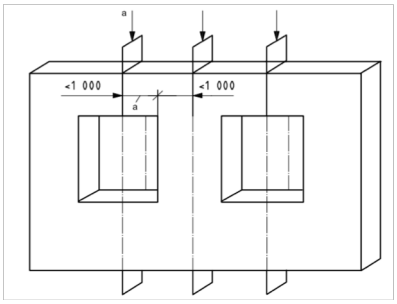
http://www.fen-bc.org/uploads/BC_Reference_Procedure_PHPP_Window_Values_Using_THERM_(1.1).pdf



How much to model?

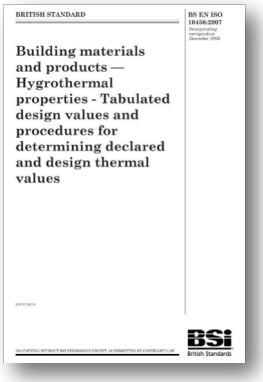
ISO 10211 Section 5.2.2 and 5.2.3 have detailed rules about how far to model, and where to 'cut' the model in order to ensure accurate simulation results.

- at least 3-ft from the central element if there is no nearer symmetry plane
- at a **symmetry plane** if this is less than 3-ft from the central element
- 'Rule of thumb': use at least 3x the wall thickness for length of the detail

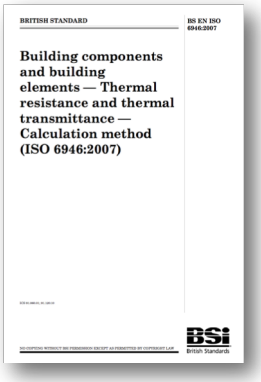


[a] Arrows indicate the symmetry planes.

Materials and Conductivity Values



ISO 10456
- Building Materials and Products

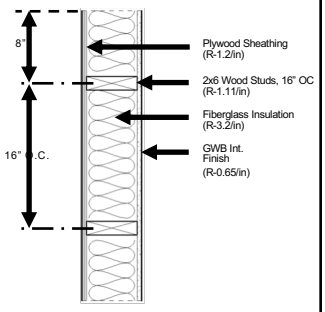


ISO 6946
- Thermal resistance and thermal transmittance

2x6 Stud Wall (Typ.)

For the 'normal' clear field assembly, we use THERM to give us an effective whole assembly U-Factor. This takes into account the effect of the repeating bridges (studs).

Our energy model's Transmission Heat Loss calculations are all executed using this value.

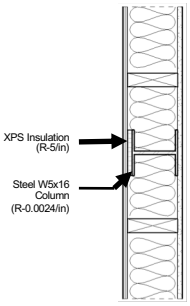


U-Factor = 0.0570 (Btu / hr·ft^2·F)

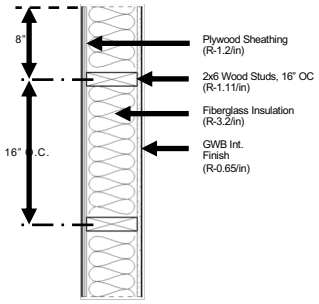
Structural Steel Thermal Bridge

EXAMPLE: For structural reasons, at several locations in the building the engineering team wants to insert steel columns in the walls which support beams above. They propose adding ½" of XPS foam to the exterior as a thermal break. What is the impact of adding these columns to the wall?

Bridged Assembly



'Typical' Assembly

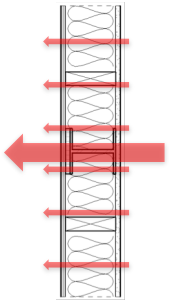


Calculating the PSI-Value

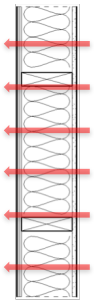
The PSI-Value (Ψ) accounts for the actual heat loss at the detail vs. the 'Typical' assembly – the one we used in the numerical energy model

The steel columns' disruption to this 'typical' construction will mean additional heat loss at this area

Bridged Assembly



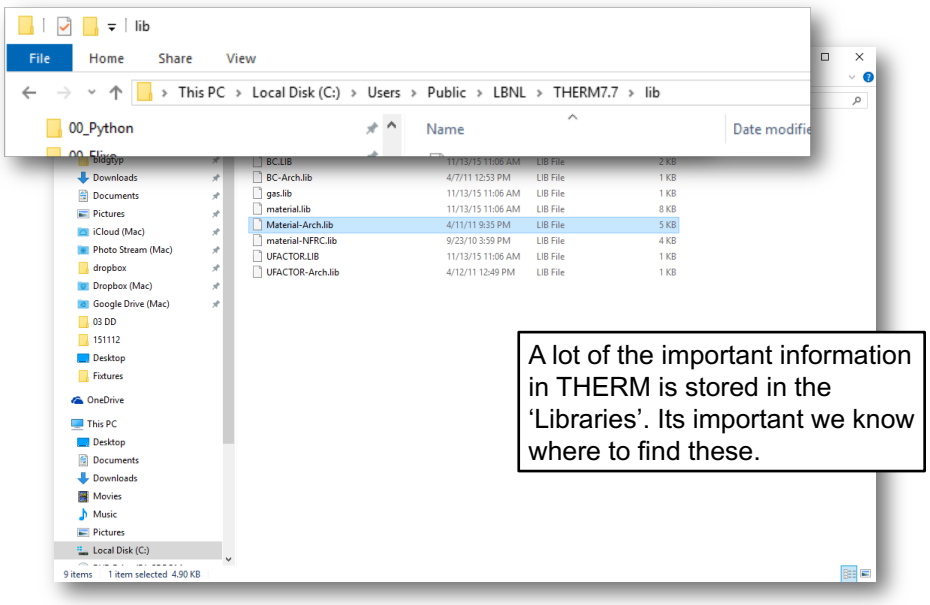
'Typical' Assembly



Actual Heat Loss - 'Typical' Heat Loss = Psi-Value

Setting Up THERM Libraries

…/Users/Public/LBNL/Therm7.7/lib/…



A lot of the important information in THERM is stored in the ‘Libraries’. Its important we know where to find these.

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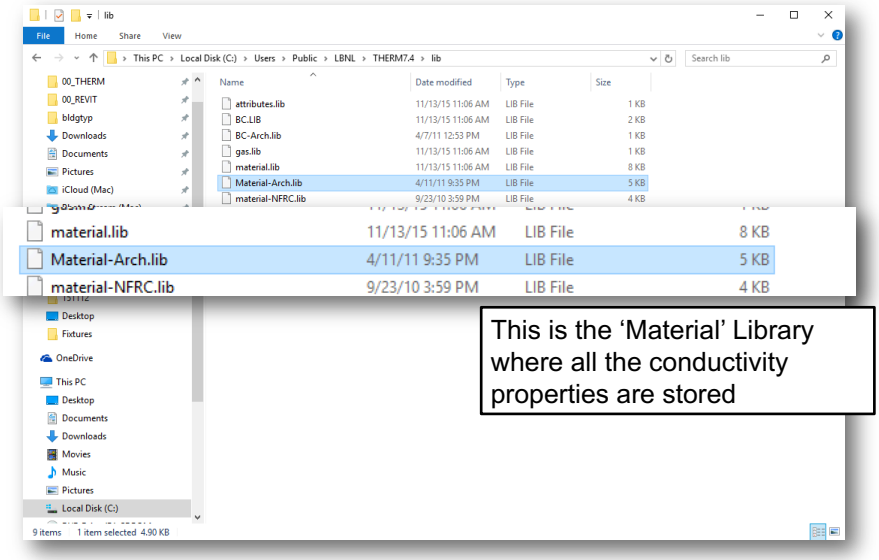
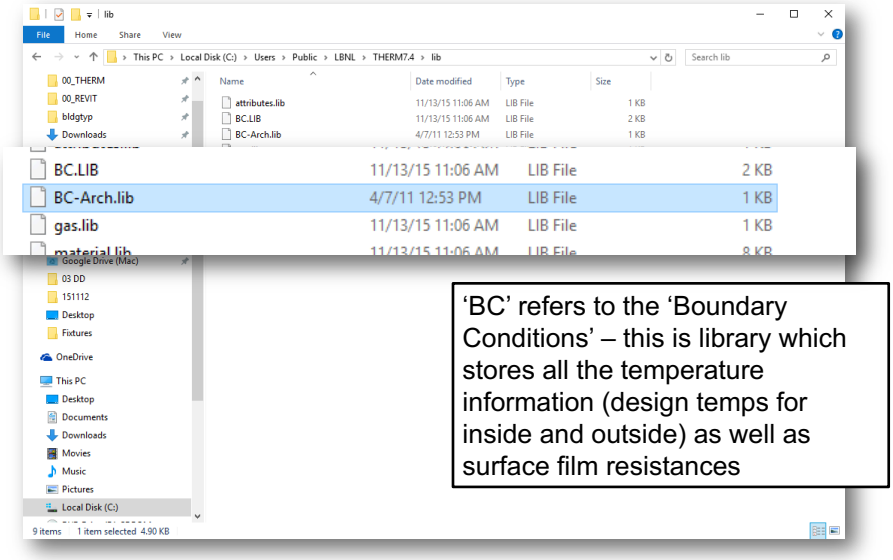
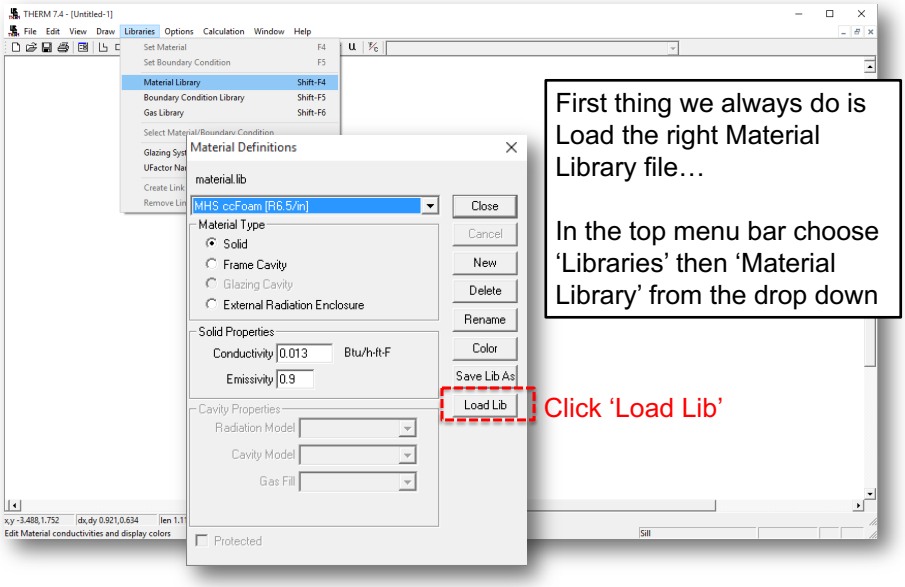


This is the 'Material' Library where all the conductivity properties are stored



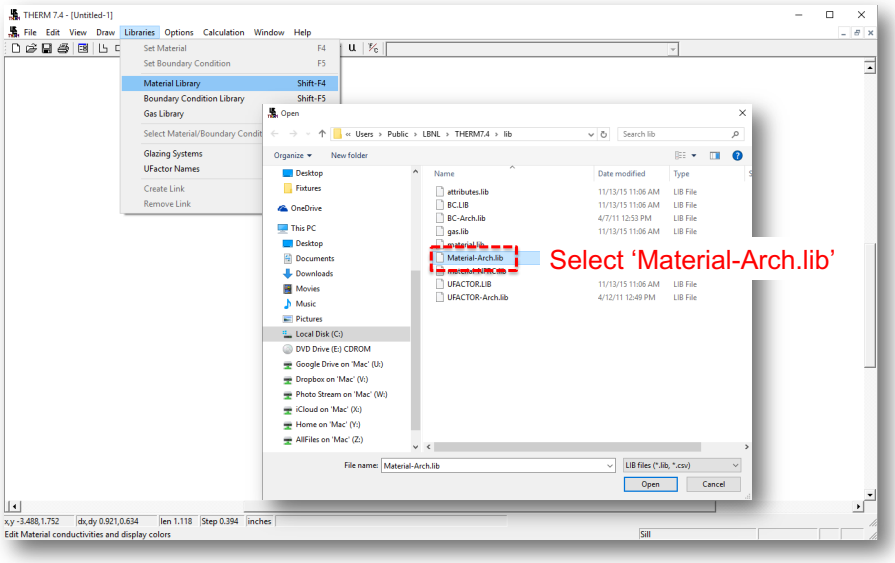
'BC' refers to the 'Boundary Conditions' – this is library which stores all the temperature information (design temps for inside and outside) as well as surface film resistances



First thing we always do is Load the right Material Library file…

In the top menu bar choose ‘Libraries’ then ‘Material Library’ from the drop down

Click ‘Load Lib’



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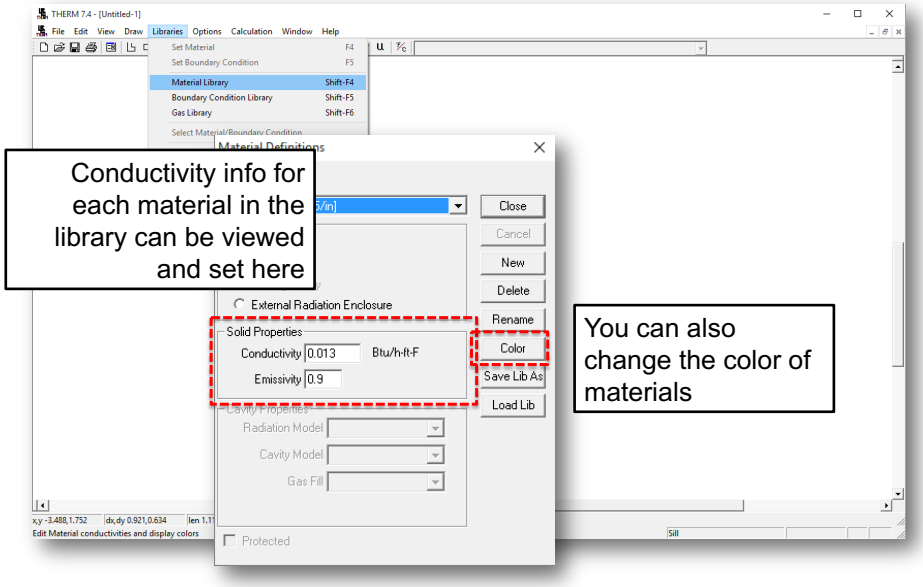

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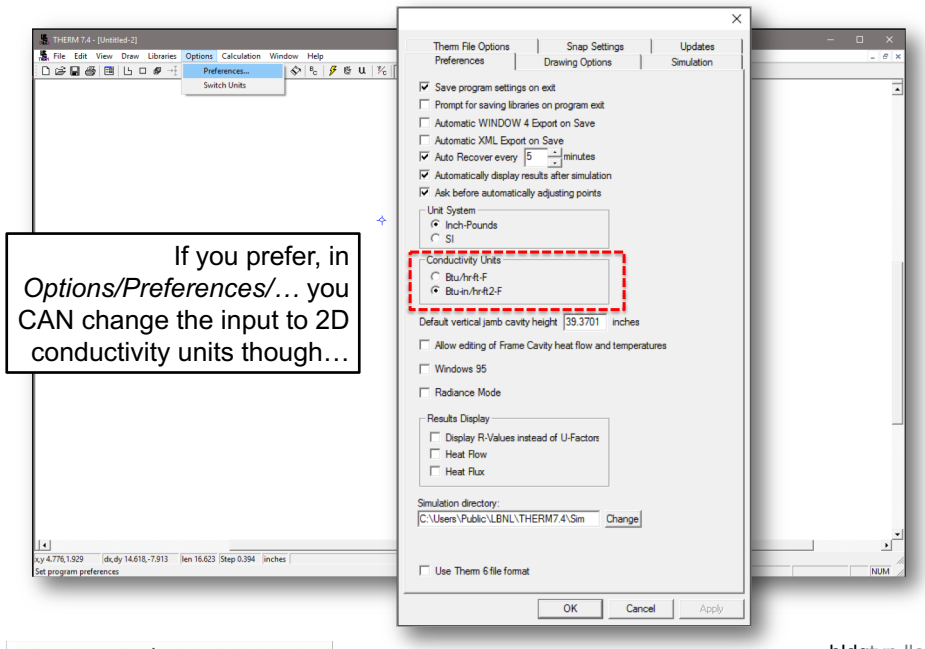
Conductivity?

Note: Conductivity (k) is a measure of the material properties measured over 1 inch of thickness, measured in Btu-in/hr-ft^2-F

By default Therm uses 1D Conductivity values, rather than the 2D Transmittance values (U-Values) we are more familiar with. You'll need to convert all your materials to a 1D value to be able to input them into a new Therm material.

Resistivity			**Conductivity (2D)**			**Conductivity (1D)**
hr-ft^2-F/Btu-in			Btu-in/hr-ft^2-F			Btu/hr-ft-F
5	→ 1/5	=	0.20	→ 0.20 / 12	=	0.017

*Note: In order to use in THERM, first convert your material R/in values to a conductivity value, then divide by **12 inch / foot** to correct the units*



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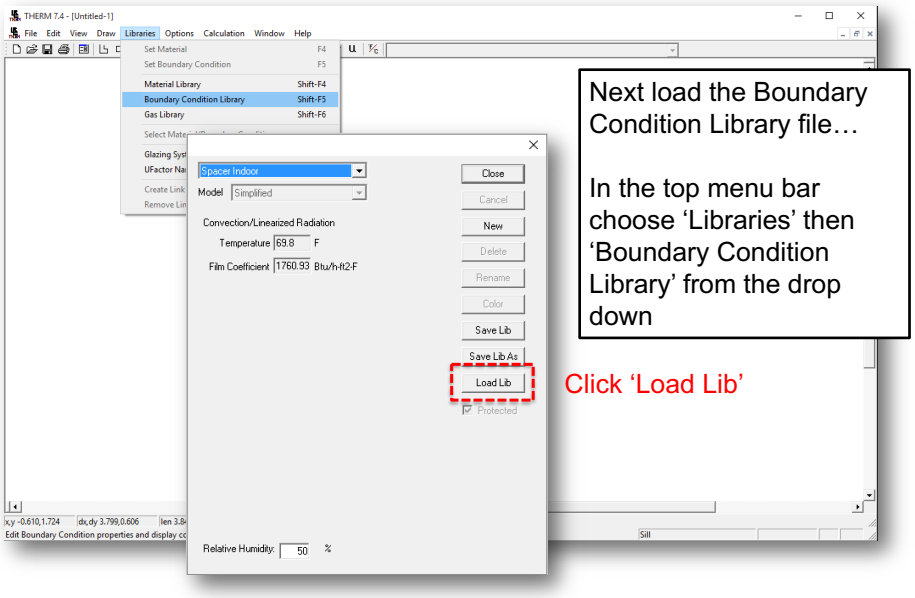

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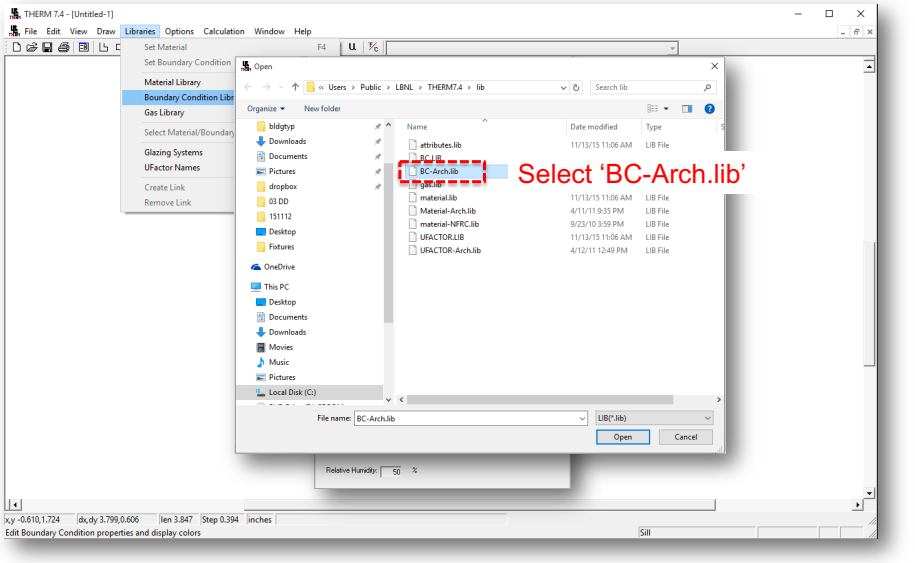

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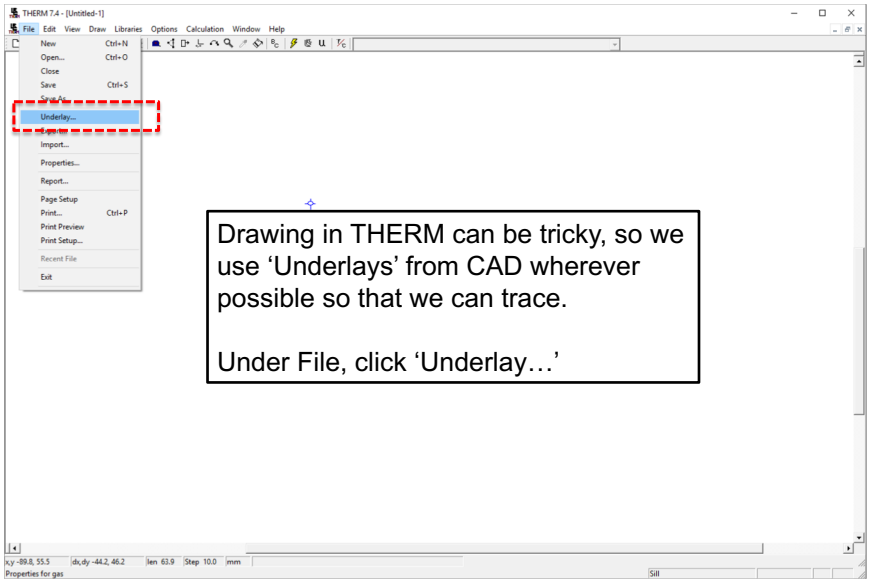
Importing Underlays



Drawing in THERM can be tricky, so we use 'Underlays' from CAD wherever possible so that we can trace.

Under File, click 'Underlay…'

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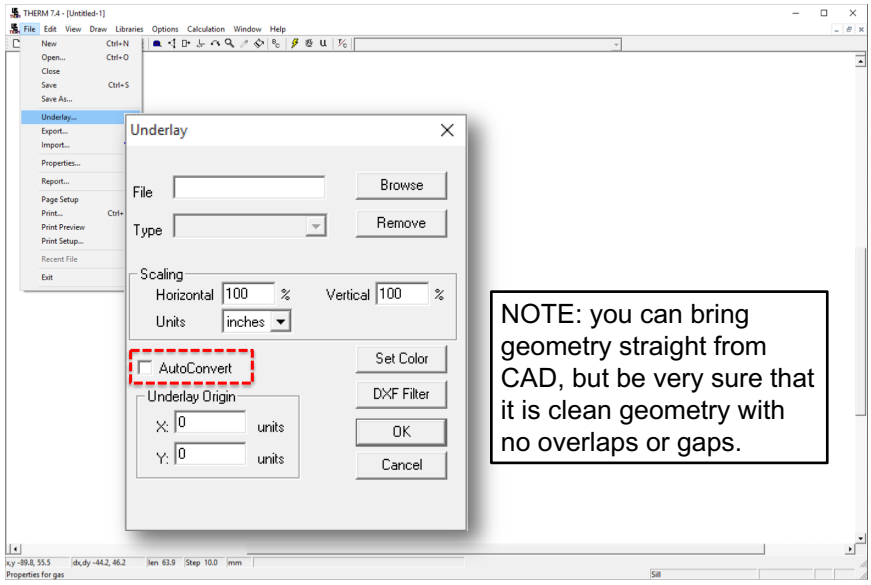
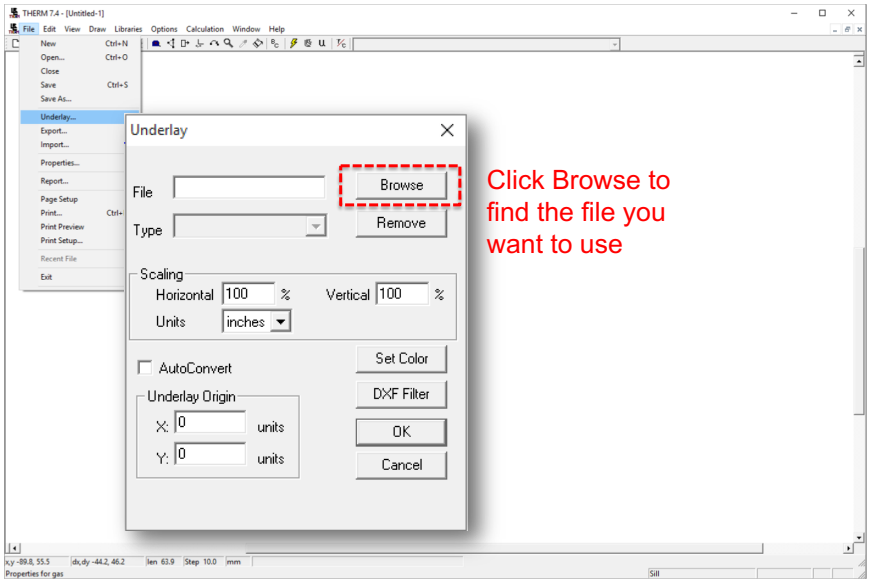
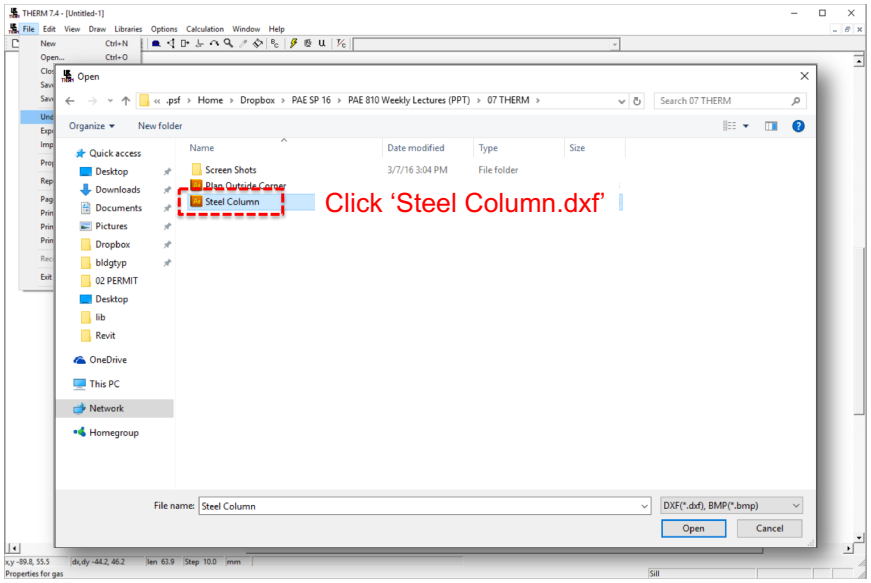
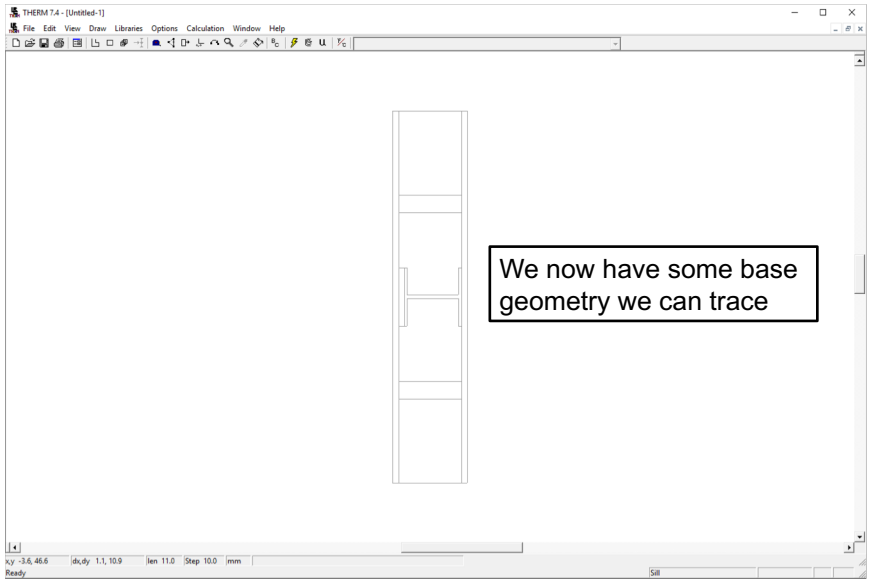


NOTE: you can bring geometry straight from CAD, but be very sure that it is clean geometry with no overlaps or gaps.



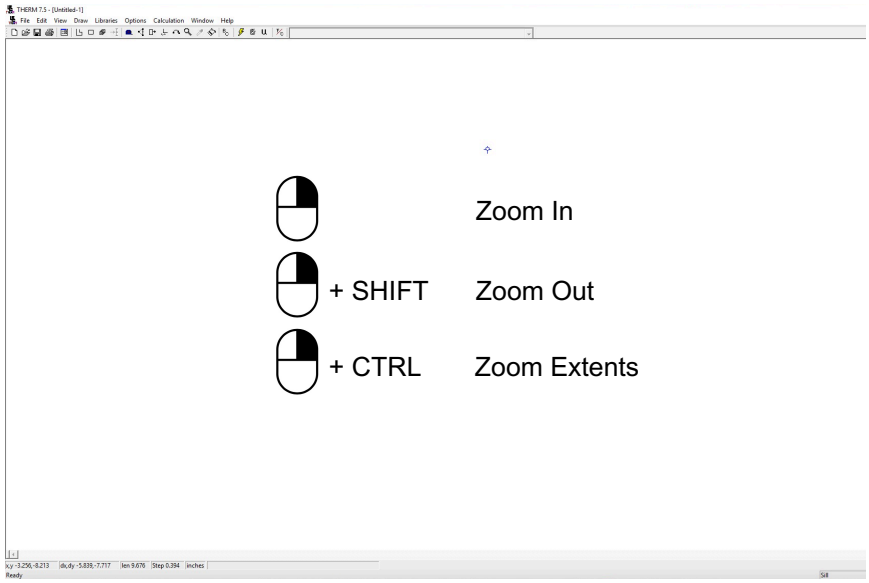
Click Browse to find the file you want to use


THERM 7.4 - [Untitled-1]
Open
Steel Column
Click 'Steel Column.dxf'
File name: Steel Column
Open
Cancel


THERM 7.4 - [Untitled-1]
We now have some base geometry we can trace

Creating Geometry

… /Share/THM files/01 Beginner/Therm Example_1_Geometry.THM



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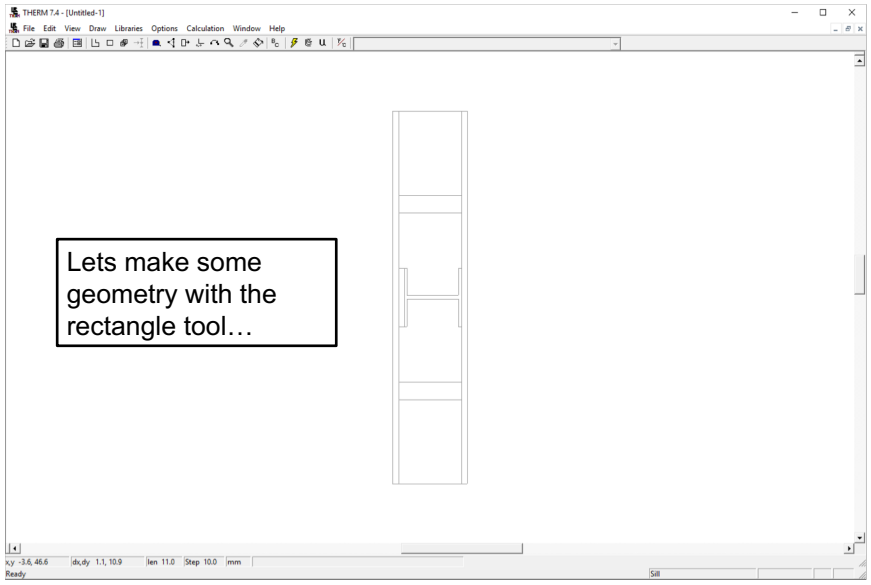
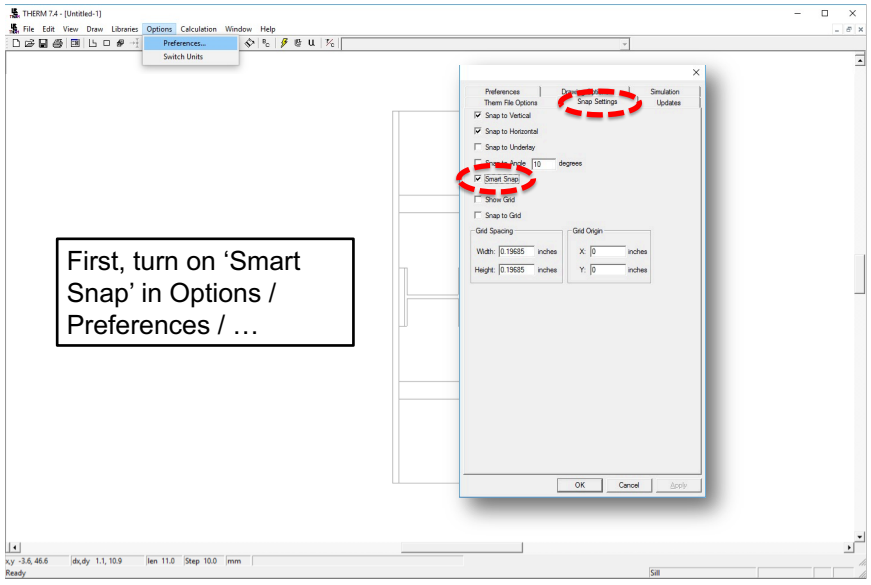
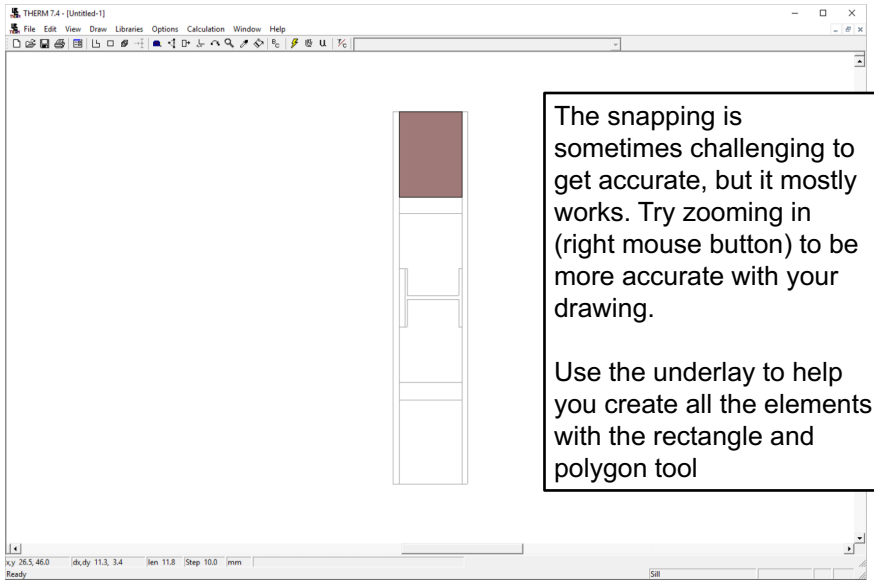


Lets make some geometry with the rectangle tool…



First, turn on ‘Smart Snap’ in Options / Preferences / …

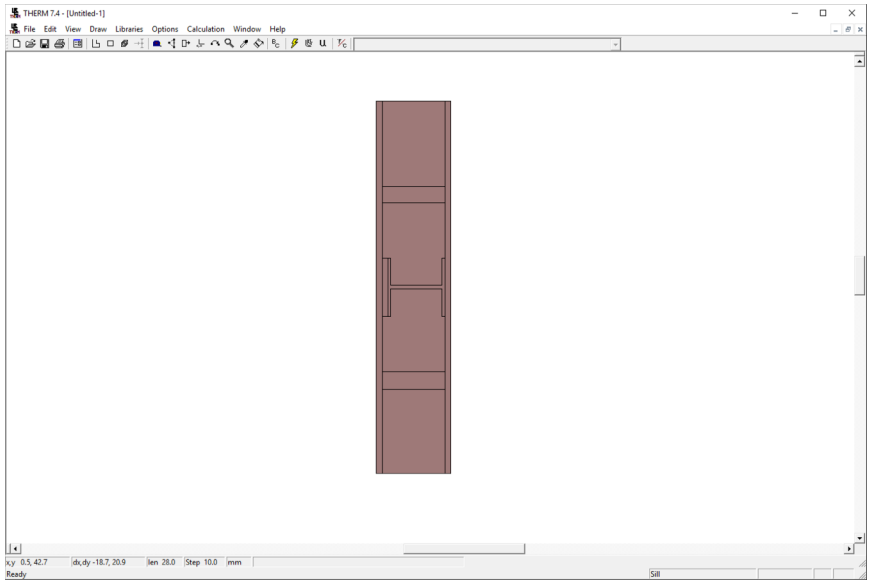


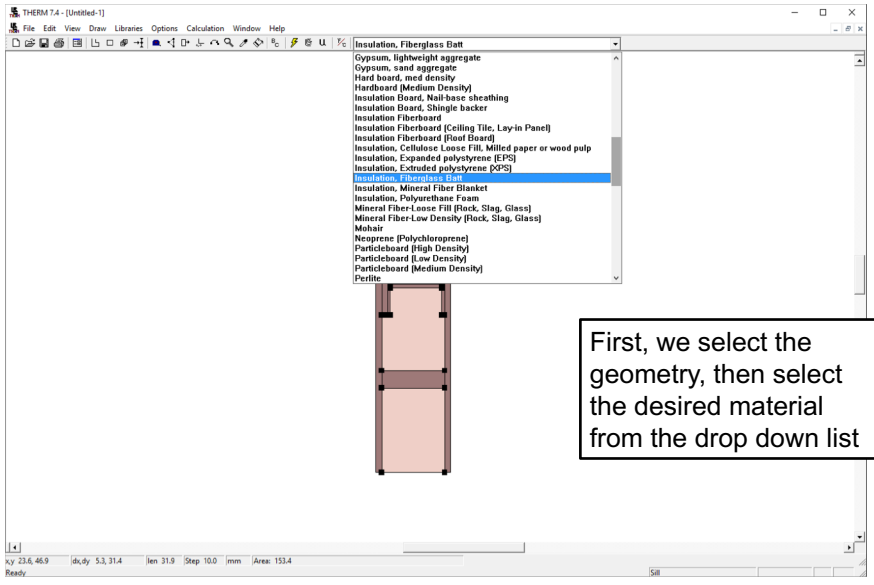
The snapping is sometimes challenging to get accurate, but it mostly works. Try zooming in (right mouse button) to be more accurate with your drawing.

Use the underlay to help you create all the elements with the rectangle and polygon tool

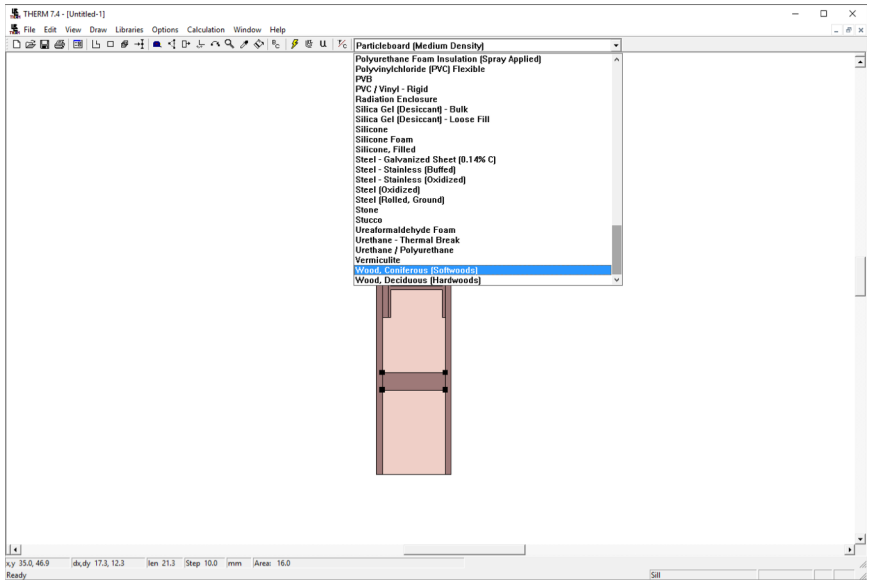
Assign Material Properties

.../Share/THM files/01 Beginner/Therm Example_2_Materials.THM





First, we select the geometry, then select the desired material from the drop down list



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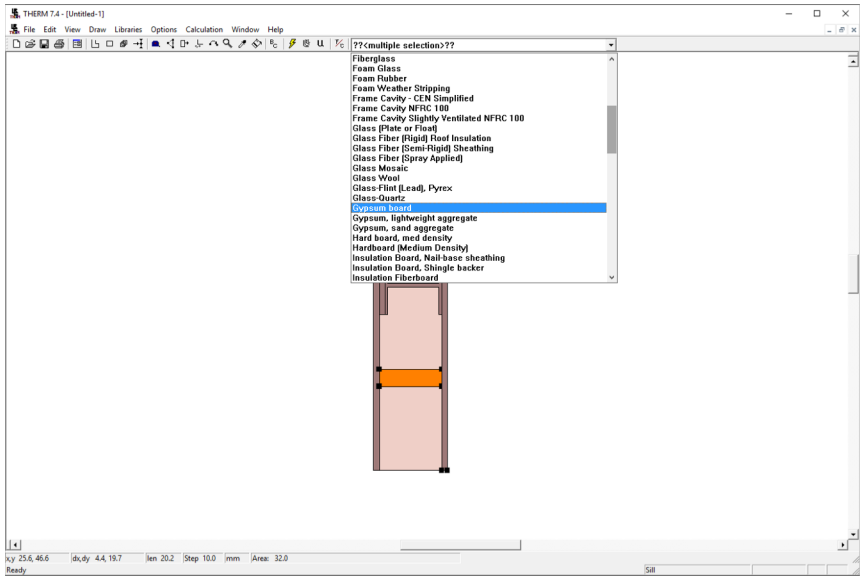

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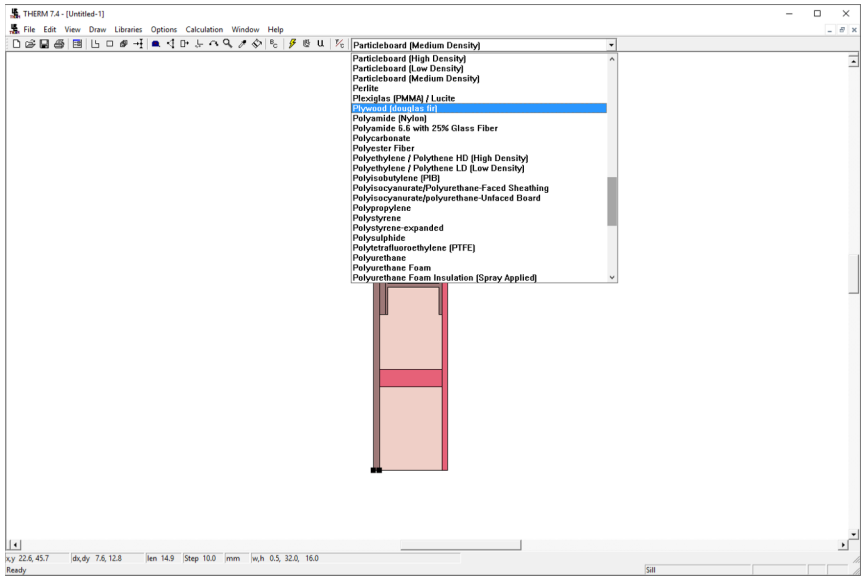

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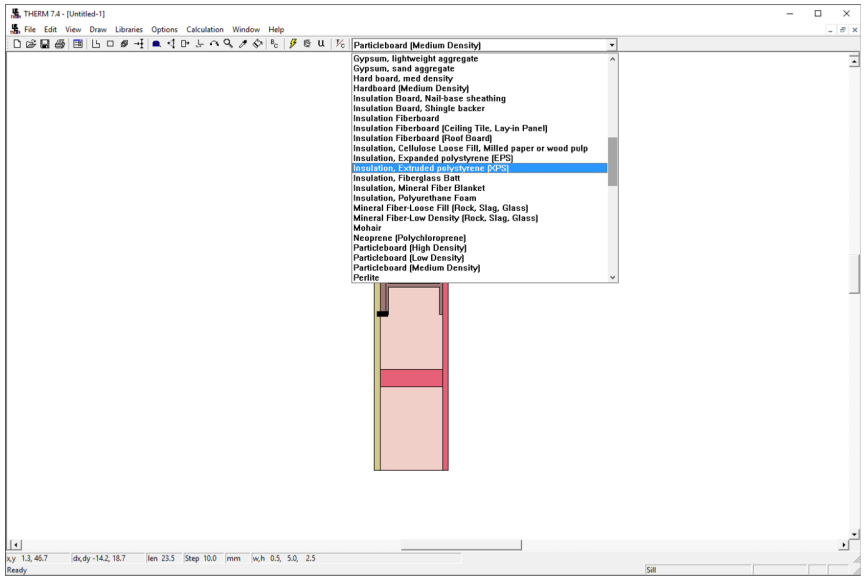

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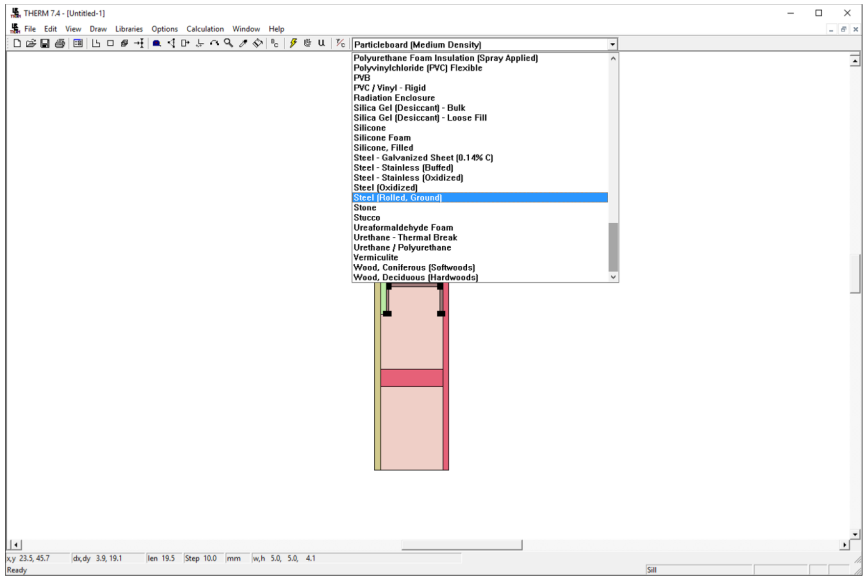
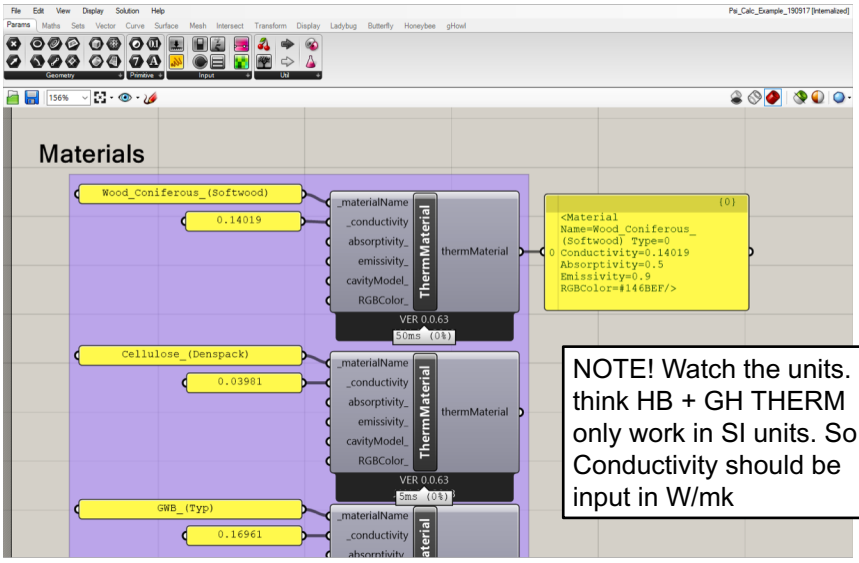
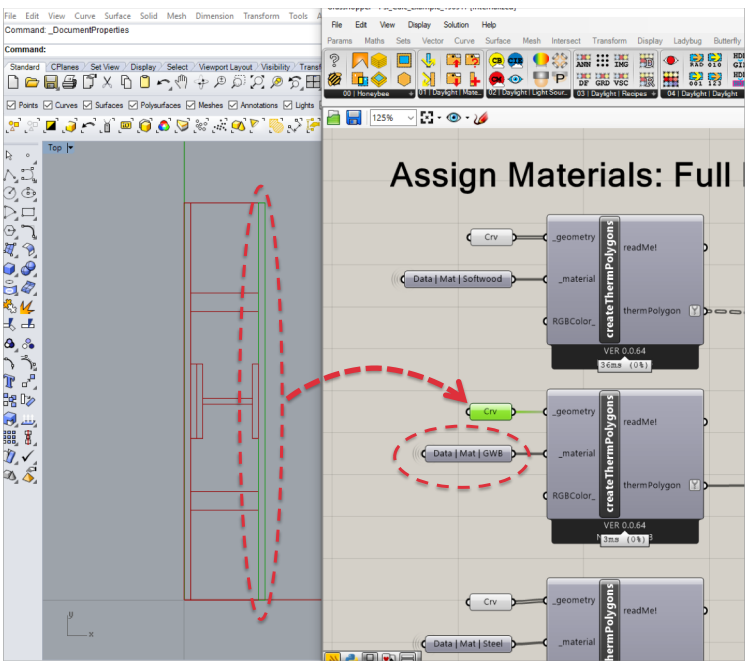


Materials in GH



NOTE! Watch the units. I think HB + GH THERM only work in SI units. So Conductivity should be input in W/mk



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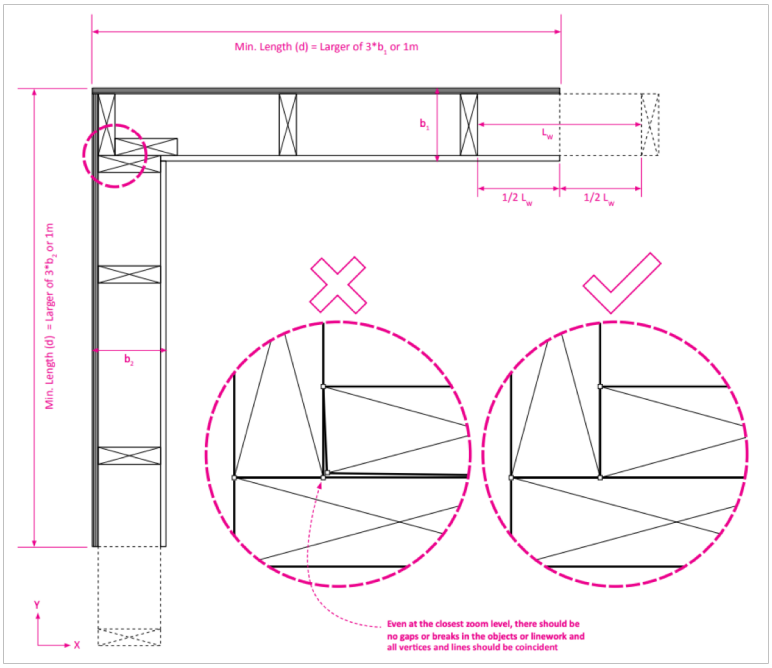

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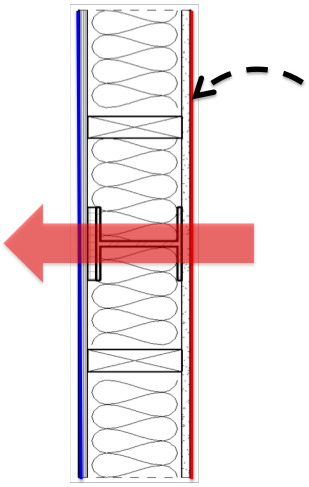
Assigning ‘Boundary Conditions’

…/Share/THM files/01 Beginner/Therm Example_3_BC.THM

BC + U-Factor ‘TAGS’

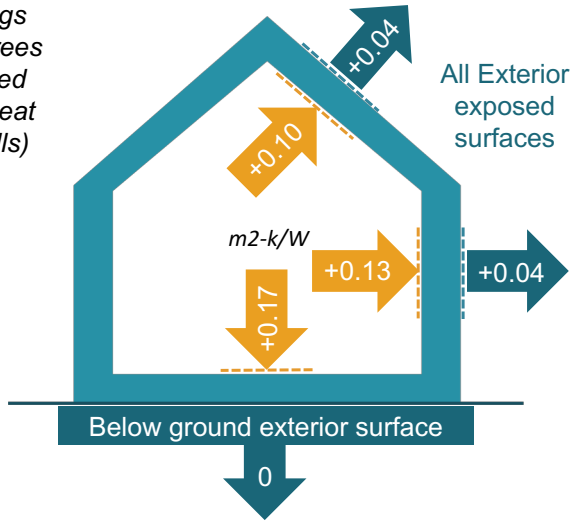
THERM needs us to specify the **surface temperature**, as well as **surface film-coefficient** information. We’ll also specify some custom **U-Factor Tags** which will allow us to measure the amount of heat flow later on.



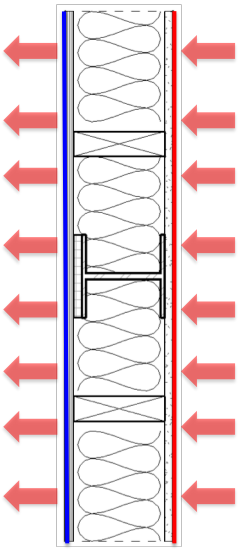
We’ll specify this edge as the interior ‘gate’ and set it as a U-Factor tag of ‘Inside’

Surface Film Resistances

**Note: Ceilings over 60 degrees are considered 'horizontal' heat flow (like walls)*

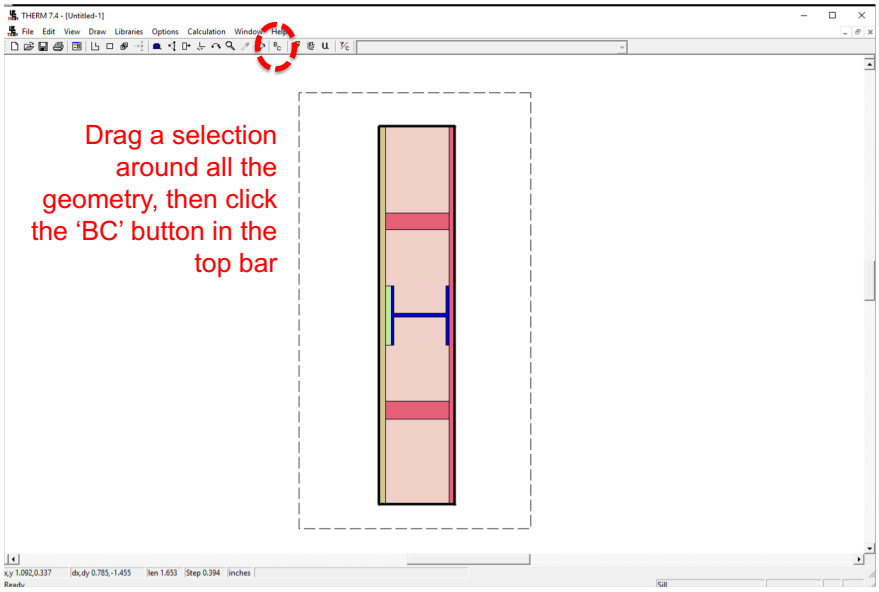


Boundary Conditions



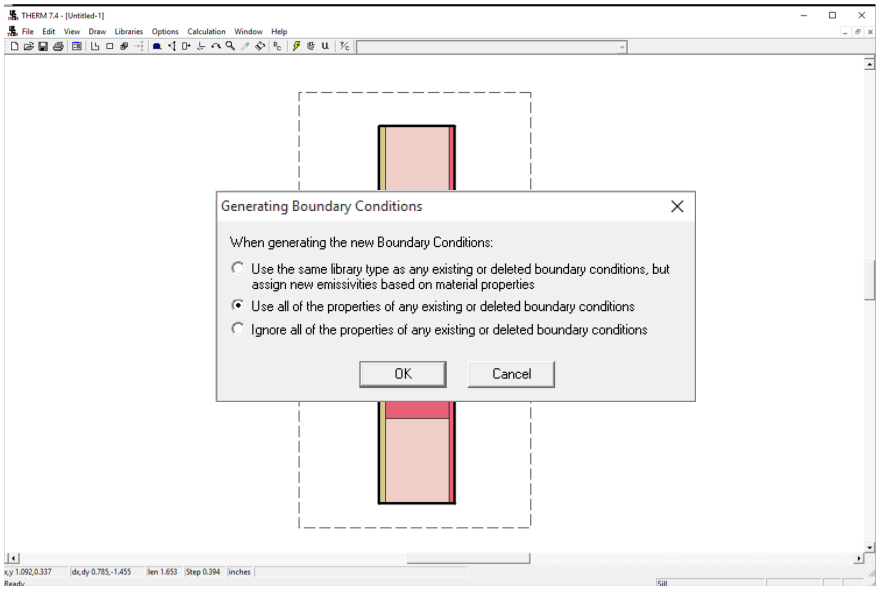
Exterior_Normal
T = -10°C
R_{SI} = 0.04 m^2-k/W

Interior_Normal_Horizontal
T = 20°C
R_{SI} = 0.13 m^2-k/W



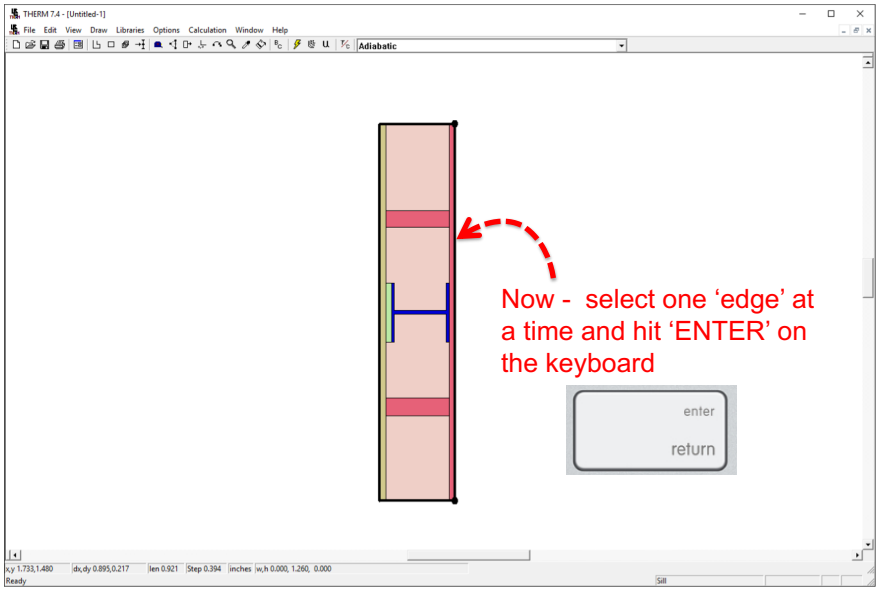
RENSSELAER | ARCHITECTURE

bldgtyp llc



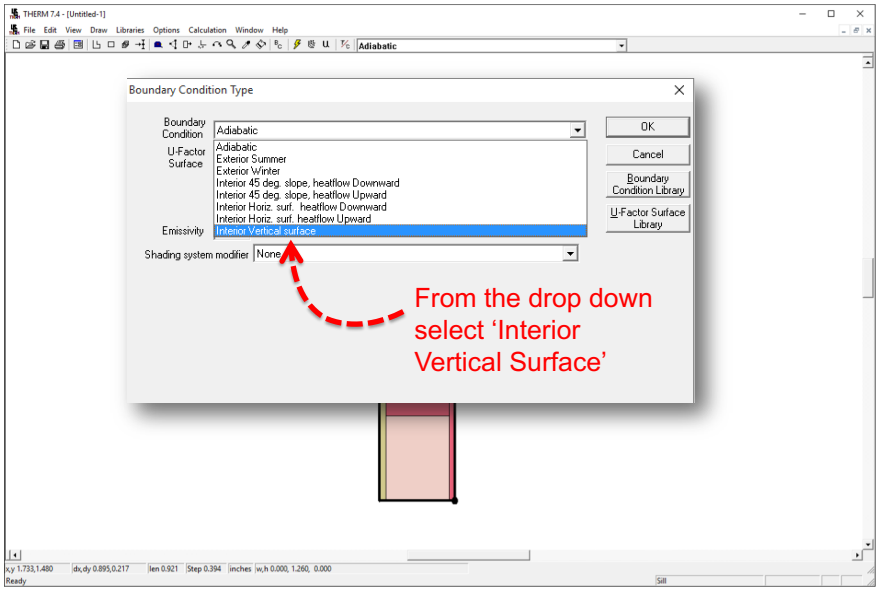
RENSSELAER | ARCHITECTURE

bldgtyp llc



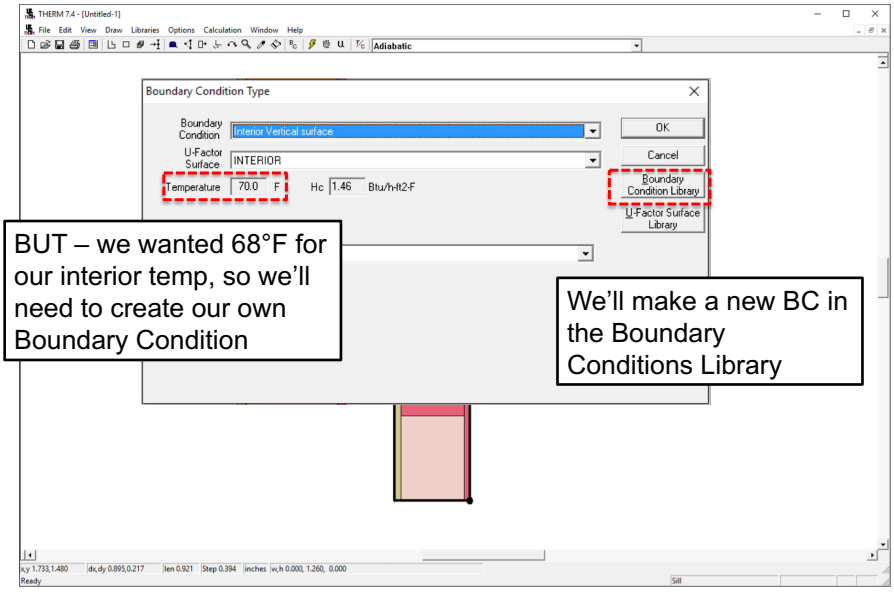
RENSSELAER | ARCHITECTURE

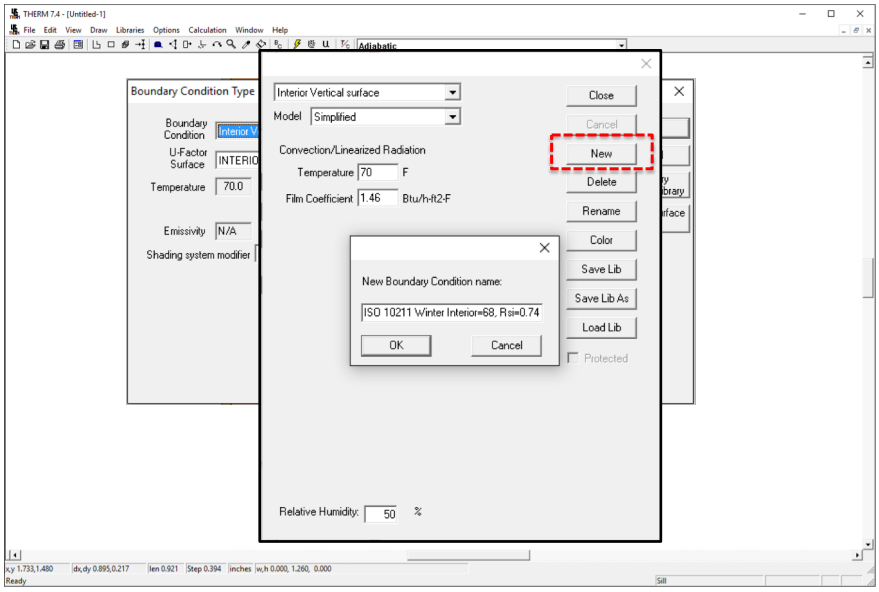
bldgtyp llc

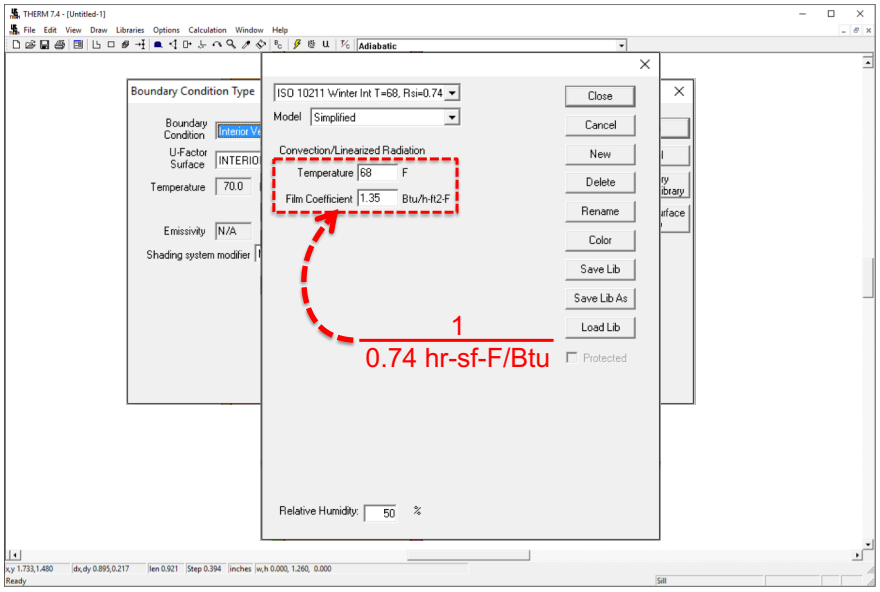


RENSSELAER | ARCHITECTURE

bldgtyp llc

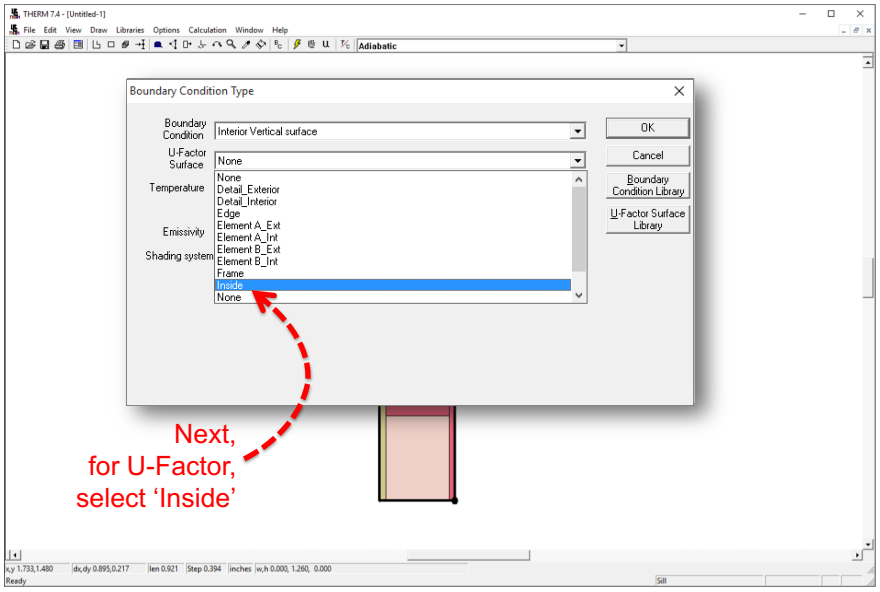

THERM 7.4 - [Untitled-1]
Boundary Condition Type
Boundary Condition
Interior Vertical surface
U-Factor Surface
INTERIOR
Temperature
70.0
F
Hc
1.46
Btu/h-ft2-F
OK
Cancel
Boundary Condition Library
U-Factor Surface Library
BUT – we wanted 68°F for our interior temp, so we'll need to create our own Boundary Condition
We'll make a new BC in the Boundary Conditions Library


THERM 7.4 - [Untitled-1]
Boundary Condition Type
Interior Vertical surface
Model
Simplified
Convection/Linearized Radiation
Temperature
70
F
Film Coefficient
1.46
Btu/h-ft2-F
Close
Cancel
New
Delete
Rename
Color
Save Lib
Save Lib As
Load Lib
Protected
New Boundary Condition name:
ISO 10211 Winter Interior=68, Rsi=0.74
OK
Cancel
Relative Humidity:
50
%



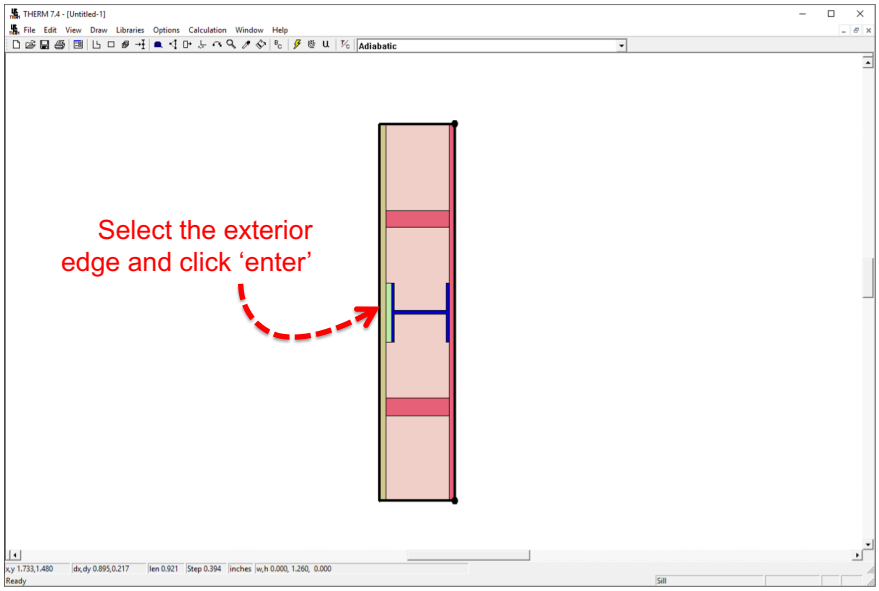
RENSSELAER | ARCHITECTURE

bldgtyp llc



RENSSELAER | ARCHITECTURE

bldgtyp llc



Exterior Boundary Temp?

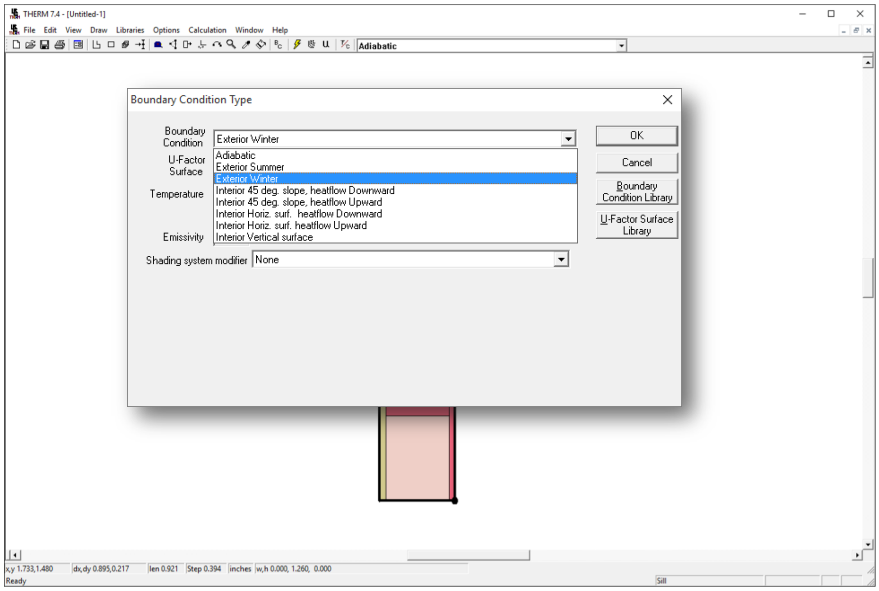
- ISO 10211 gives no useful guidance
- PHI says to use 20°C int. and -10°C ext.
- If using the model to evaluate RH or condensation risk, follow ISO 13788:

4.2 External boundary conditions

4.2.1 Location

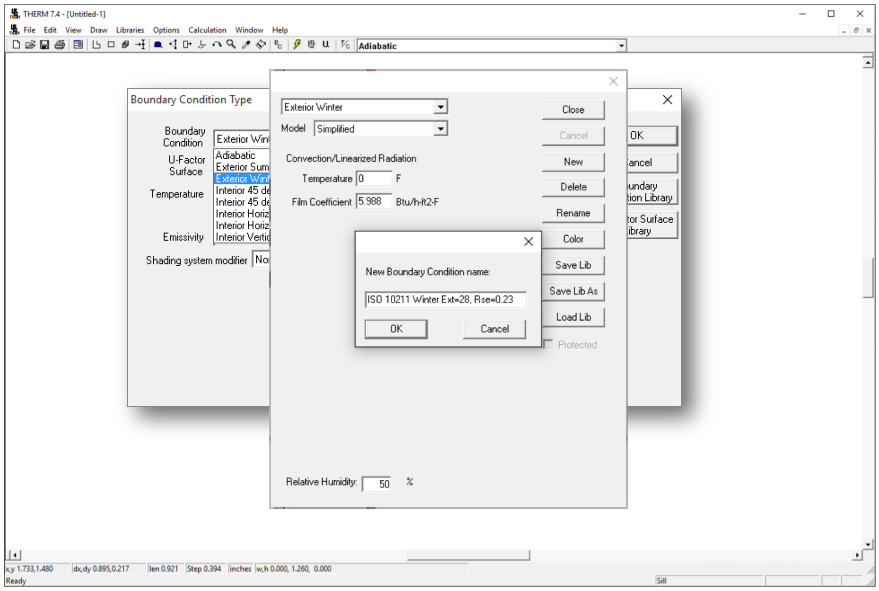
Unless otherwise specified, the external conditions used shall be representative of the location of the building, taking account of altitude where appropriate.

NOTE Unless other information is available (for example in national standards), it can be assumed that temperature falls by 1 K for every 200 m increase in altitude.



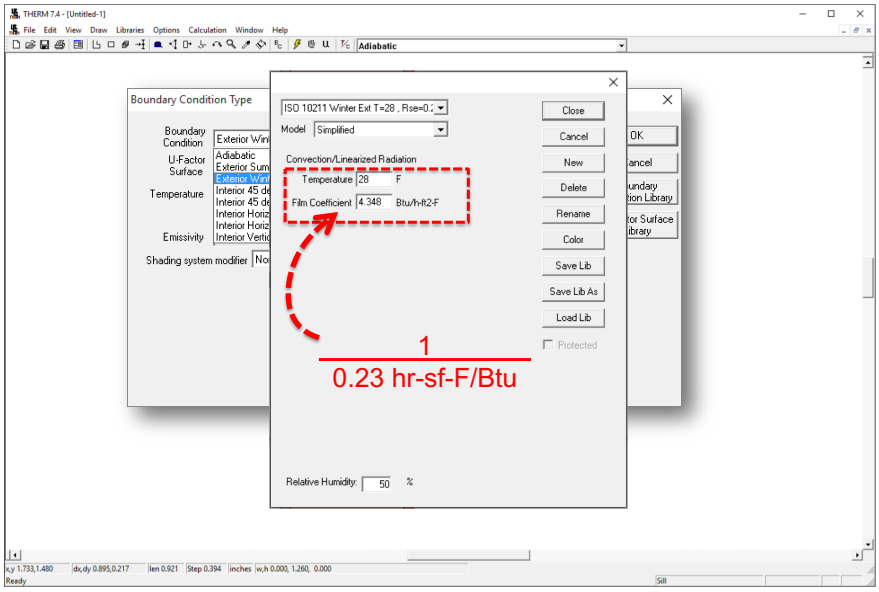
RENSSELAER | ARCHITECTURE

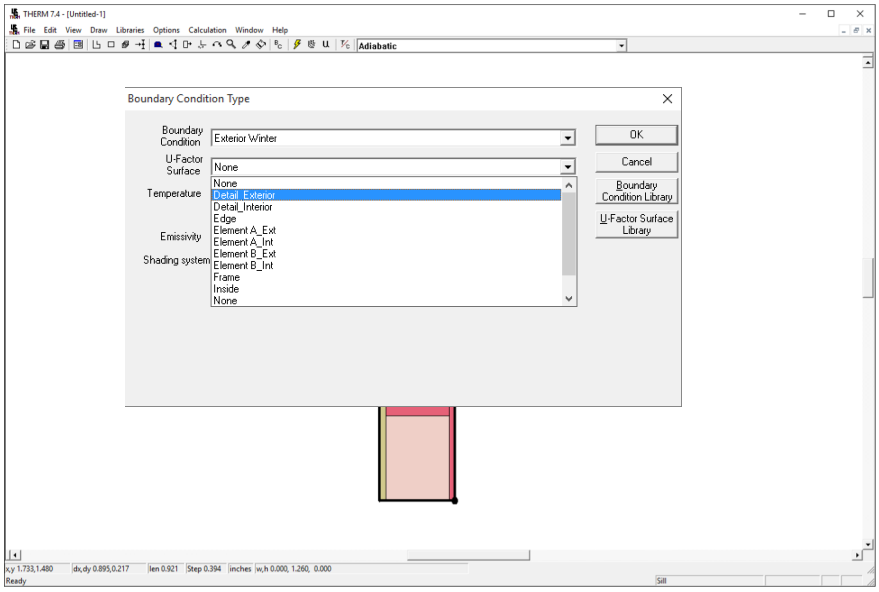
bldgtyp llc

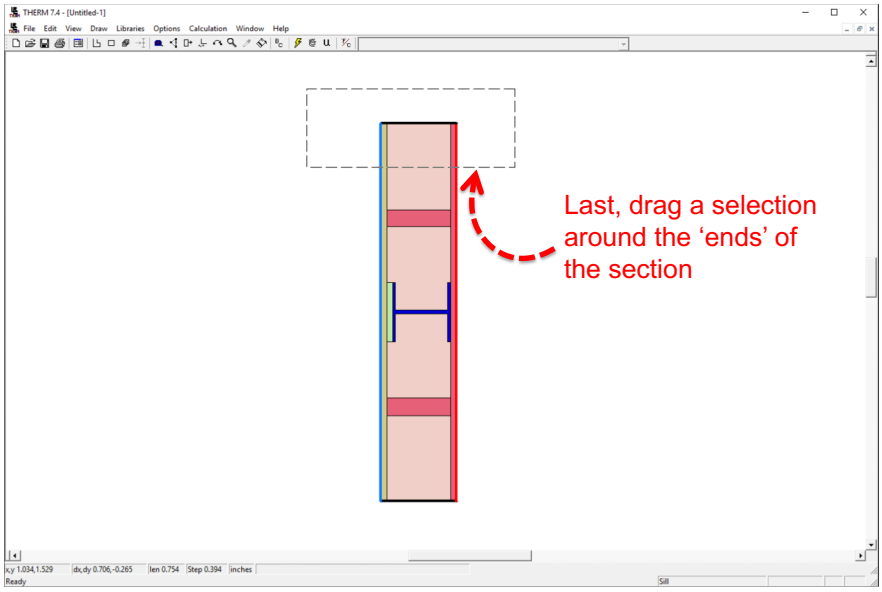


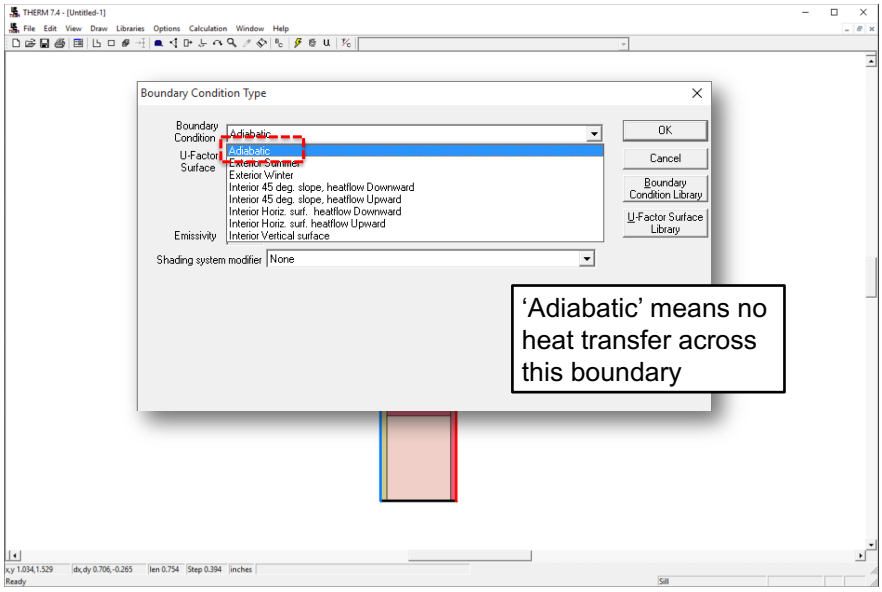
RENSSELAER | ARCHITECTURE

bldgtyp llc

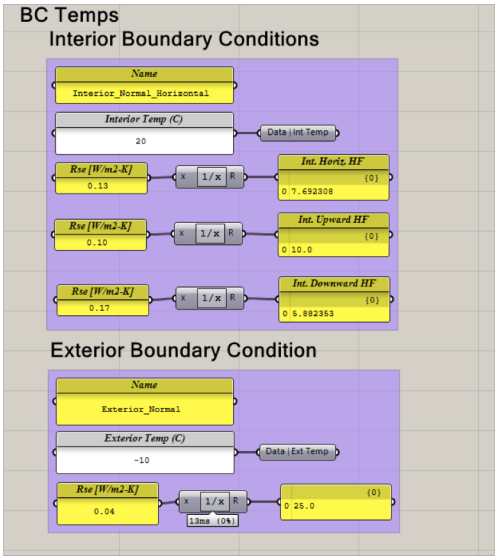

THERM 7.4 - [Untitled-1]
Boundary Condition Type
ISO 10211 Winter Ext T=28 , Rse=0.
Model Simplified
Convection/Linearized Radiation
Temperature 28 F
Film Coefficient 4.348 Btu/h-ft2-F
Close
Cancel
New
Delete
Rename
Color
Save Lib
Save Lib As
Load Lib
Protected
1
0.23 hr-sf-F/Btu
Relative Humidity: 50 %


THERM 7.4 - [Untitled-1]
Boundary Condition Type
Boundary Condition
Exterior Winter
U-Factor Surface
None
Temperature
Emissivity
Shading system
None
Detail_Exterior
Detail_Interior
Edge
Element A_Ext
Element A_Int
Element B_Ext
Element B_Int
Frame
Inside
None
OK
Cancel
Boundary Condition Library
U-Factor Surface Library

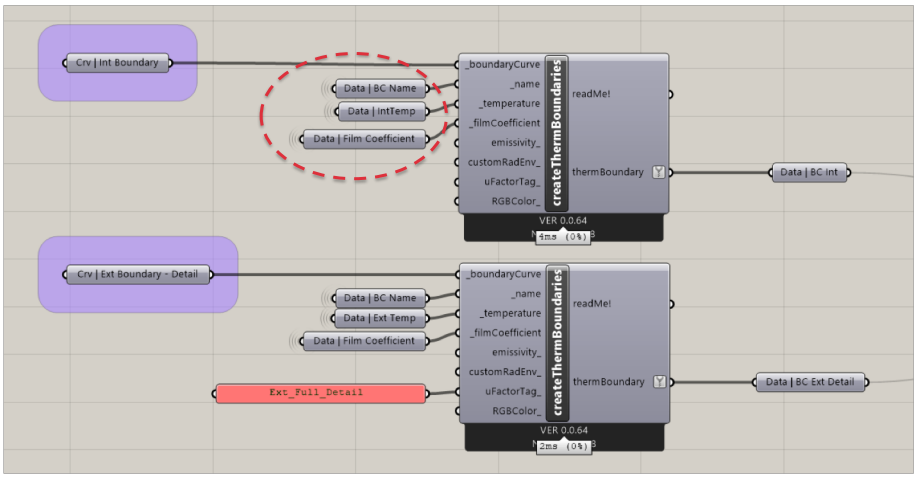

Last, drag a selection around the 'ends' of the section


Boundary Condition Type
Boundary Condition
Adiabatic
U-Factor Surface
Emissivity
Exterior Winter
Interior 45 deg. slope, heatflow Downward
Interior 45 deg. slope, heatflow Upward
Interior Horiz. surf. heatflow Downward
Interior Horiz. surf. heatflow Upward
Interior Vertical surface
Shading system modifier
None
OK
Cancel
Boundary Condition Library
U-Factor Surface Library
'Adiabatic' means no heat transfer across this boundary

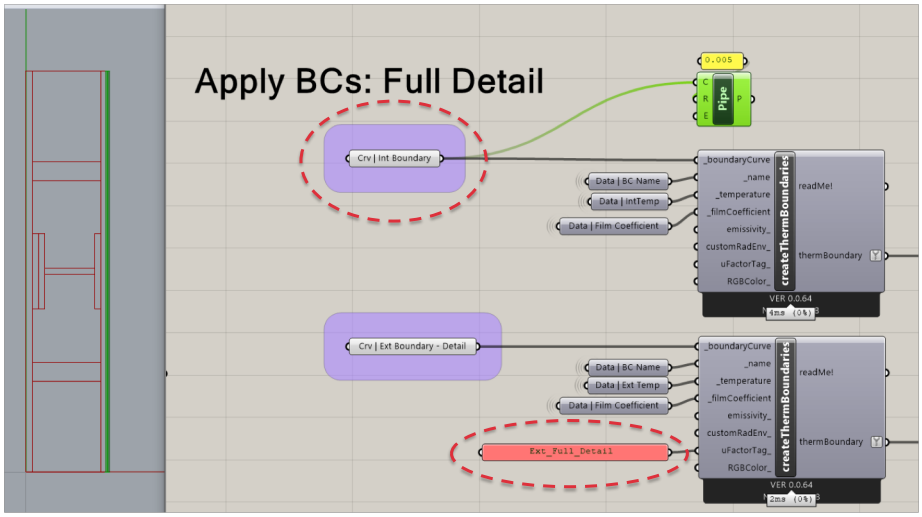
BC's in GH



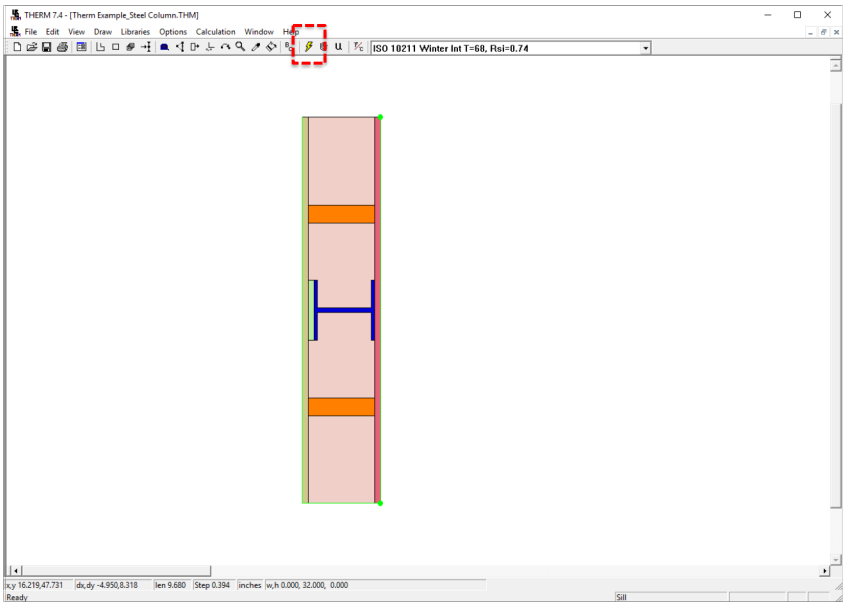
BC's in GH

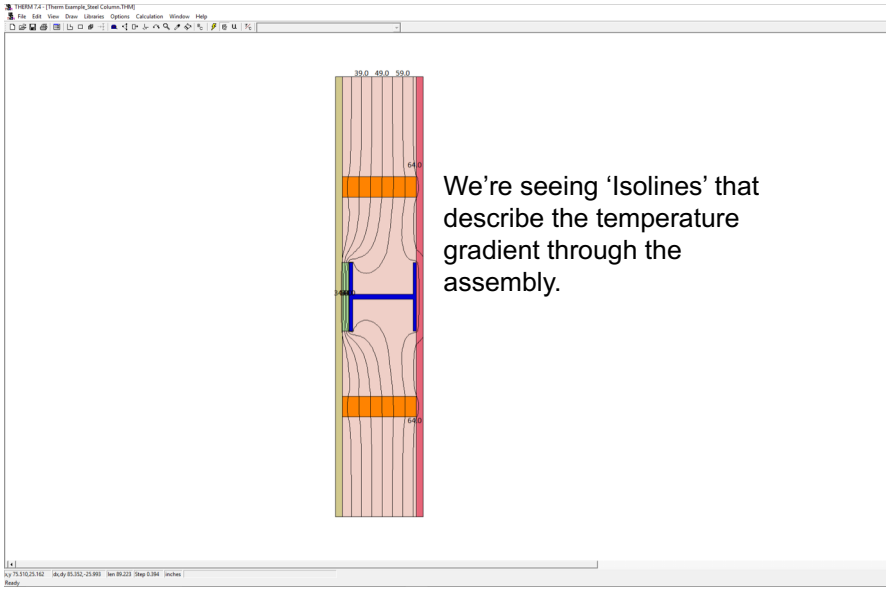


BC's in GH

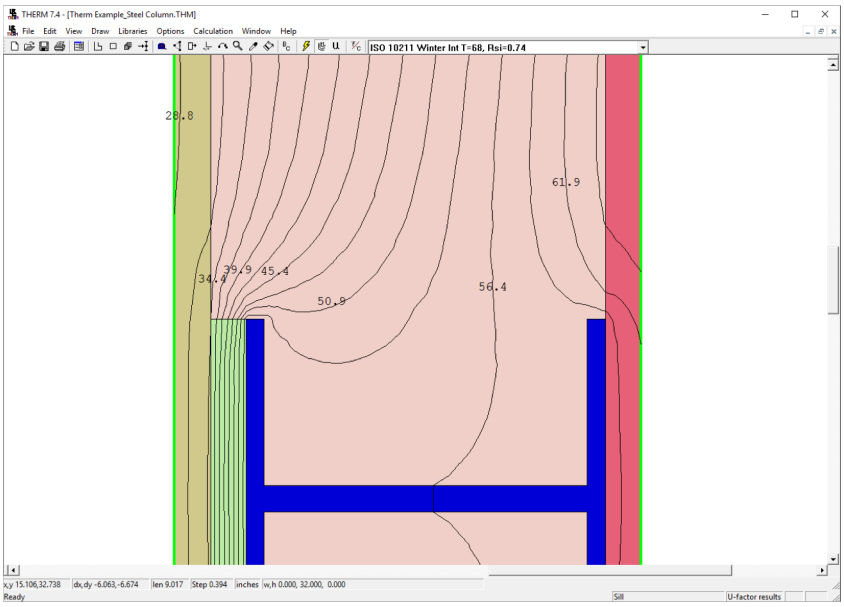


Running the Simulation



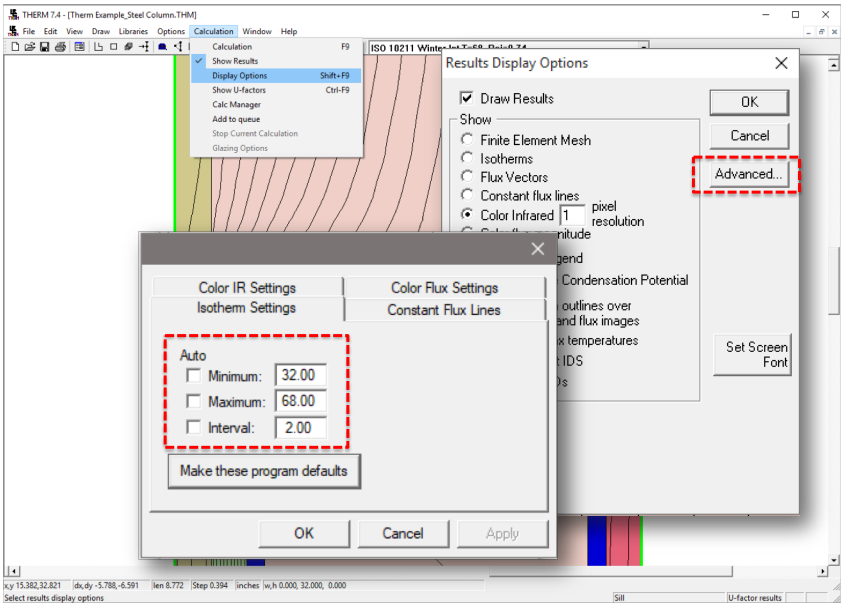


We're seeing 'Isolines' that describe the temperature gradient through the assembly.



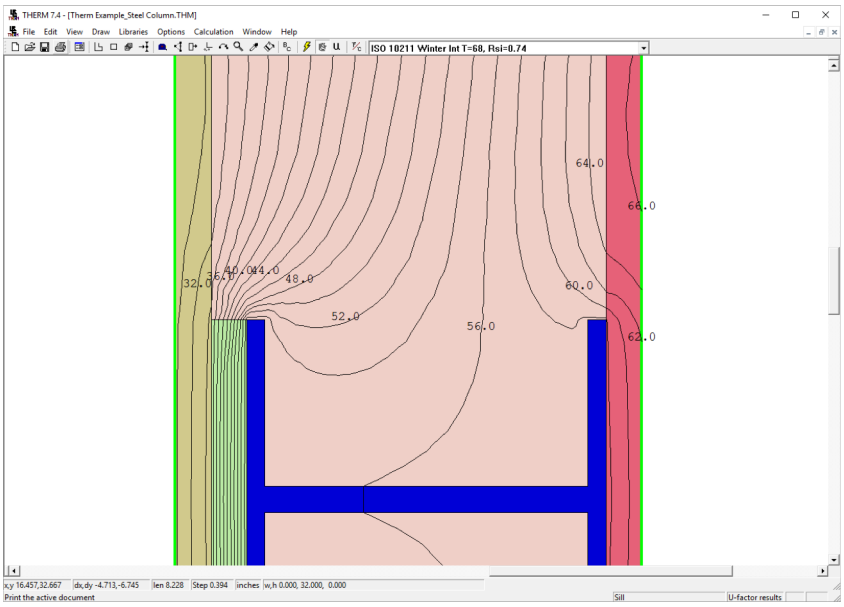
RENSSELAER | ARCHITECTURE

bldgtyp llc



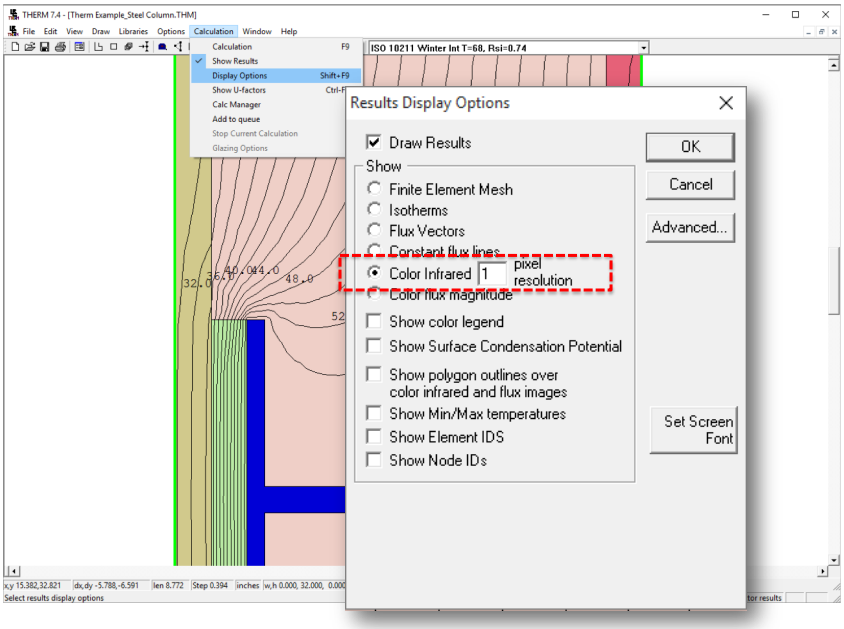
RENSSELAER | ARCHITECTURE

bldgtyp llc



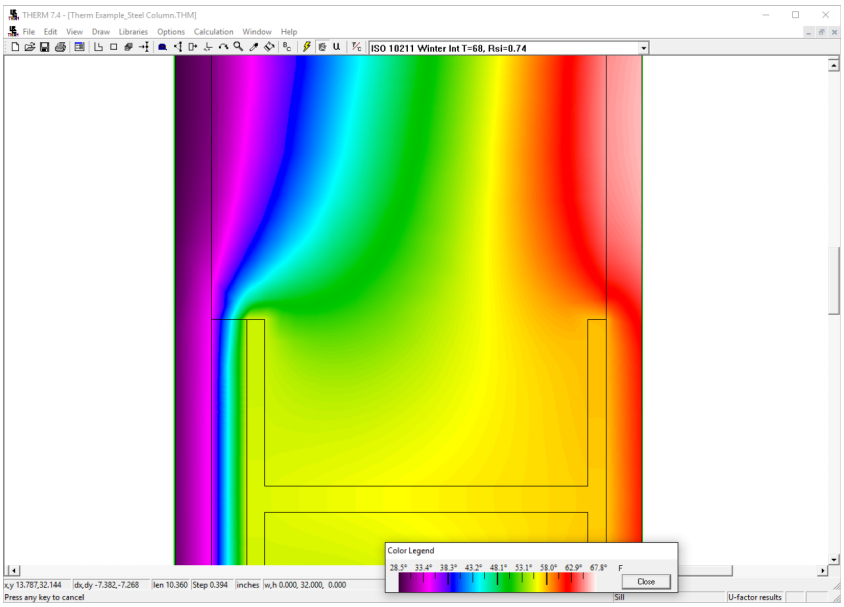
RENSSELAER | ARCHITECTURE

bldgtyp llc



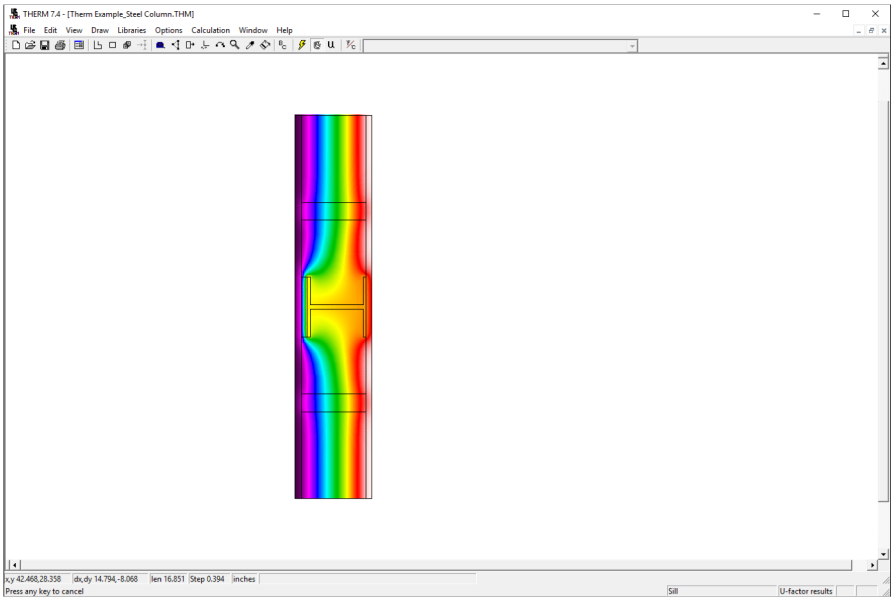
RENSSELAER | ARCHITECTURE

bldgtyp llc



RENSSELAER | ARCHITECTURE

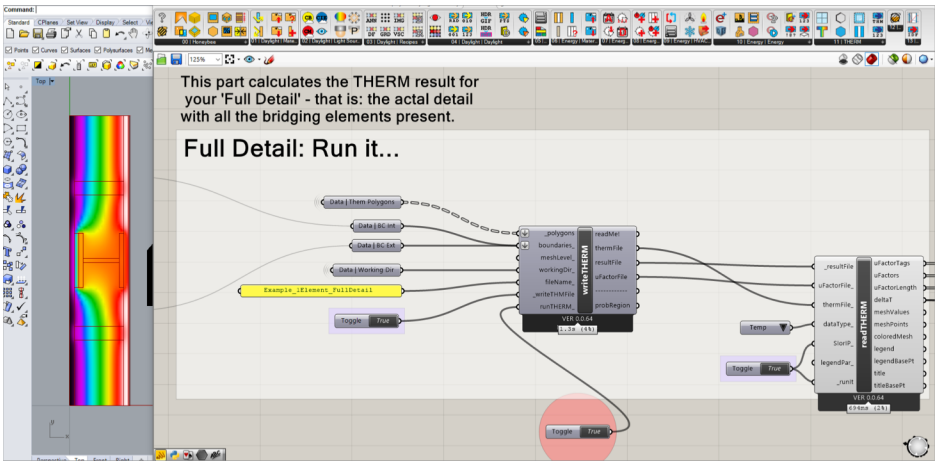
bldgtyp llc



RENSSELAER | ARCHITECTURE

bldgtyp llc

Running the Sim in GH



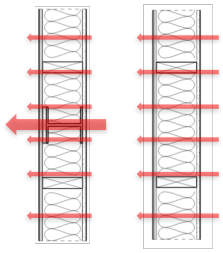
Calculating PSI Values (Ψ)

Calculating PSI Values (Ψ)

Total losses from 'typical' assembly

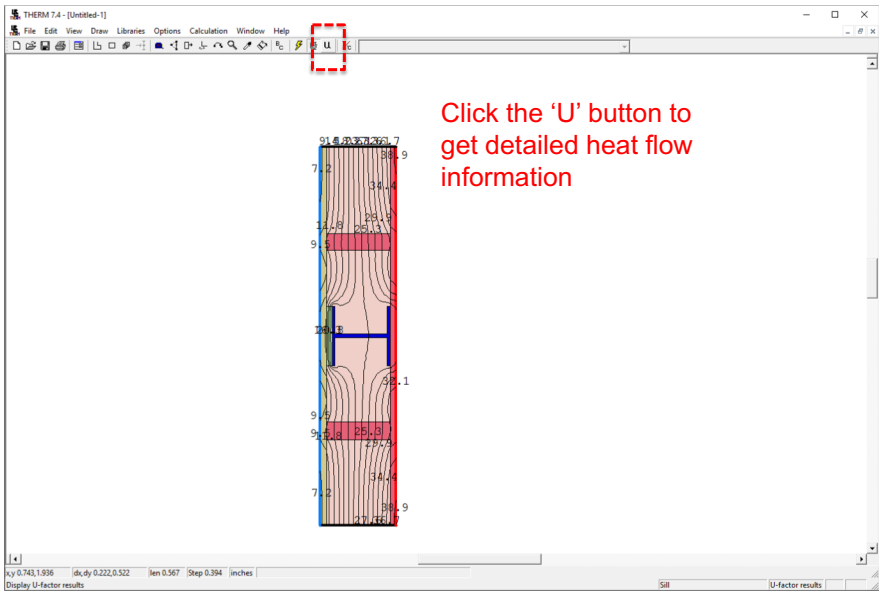
$$\text{Psi Value } (\Psi) = \frac{\text{Losses}_{2D} - \text{Losses}_{1D}}{\Delta T}$$

Total losses from 'actual' assembly



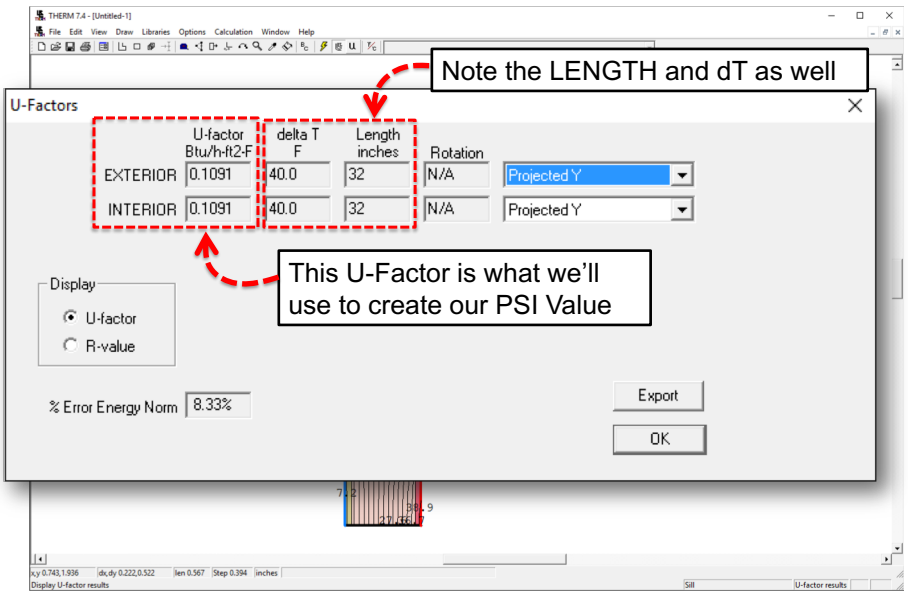
$\text{Losses}_{2D} = \text{U-factor}_{2D} \times \text{Length}_{2D} \times \Delta T$

$\text{Losses}_{1D} = \text{U-factor}_{1D} \times \text{Length}_{1D} \times \Delta T$

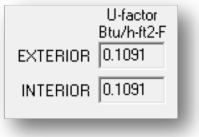


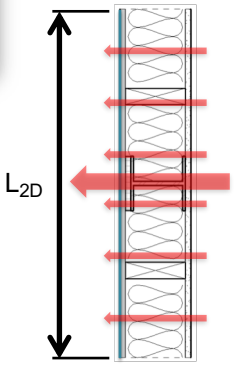
RENSSELAER | ARCHITECTURE

bldgtyp llc



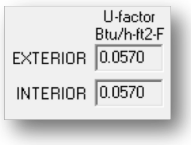
Calculate Losses$_{2D}$

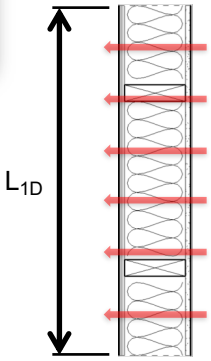




THERM's U-Factor takes into account all the particulars of the actual detail and combines it into one value which represents heat flow over the entire area

Calculate Losses$_{1D}$





We also need to model the typical 'clear field' assembly without the disrupting element in a separate THERM file to calculate its U-Factor.

Calculating Psi (Ψ)

$$\Psi = (Losses_{2D} - Losses_{1D}) \div \Delta T$$

$$Losses_{2D} = U\text{-}factor_{2D} \times L_{2D} \times \Delta T$$
$$Losses_{1D} = U\text{-}factor_{1D} \times L_{1D} \times \Delta T$$

INPUTS		
U-factor$_{2D}$ (Actual)	=	0.1091 Btu/hr-ft^2-F
U-factor$_{1D}$ (Typical)	=	0.0570 Btu/hr-ft^2-F
L_{2D}	=	2.66' (32")
L_{1D}	=	2.66' (32")
ΔT	=	40°F

$Losses_{2D}$ = Total losses from 'actual' assembly
$Losses_{1D}$ = Total losses from 'typical' assembly

Calculating Psi (Ψ)

$\mathbf{Losses_{2D}}$	$\mathbf{Losses_{1D}}$
U-factor$_{2D}$ × L_{2D} × ΔT	U-factor$_{1D}$ × L_{1D} × ΔT
0.1091 × 2.66' × 40°F	0.0570 × 2.66' × 40°F
= 11.64 BTU/hr·ft	**= 6.06 BTU/hr·ft**

$$\Psi = (Losses_{2D} - Losses_{1D}) \div \Delta T$$

$$\Psi = (\ 11.64\ Btu/hr{\cdot}ft\ -\ 6.06\ Btu/hr{\cdot}ft\ ) \div 40°F$$

$$\Psi = 0.139\ BTU/hr{\cdot}ft{\cdot}°F$$

Calculating Losses via Linear Thermal Bridges

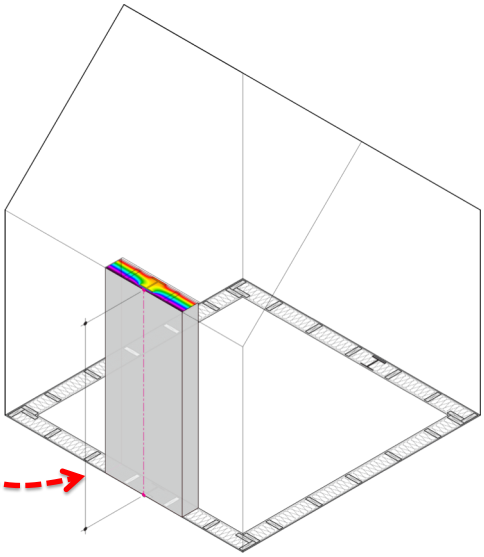
$$\mathbf{Q_{T\text{-}tb} = L \times \Psi \times f_t \times G_t}$$

$$kBtu/yr = ft \times \frac{Btu}{(hr - ft\text{-}^{\circ}F)} \times unitless \times \frac{(k^{\circ}F\text{-}hr)}{yr}$$

(Transmission Losses) $Q_{T\text{-}tb}$ =
Length of the Thermal Bridge (ft)
×
PSI-Value (Btu/hr-ft-˚F)
×
Temp. Correction Factor (if needed)
×
Yearly Heating Degree Hours (k˚F-hr/yr)
=kBtu/yr

Thermal Bridge Length?

The length of the thermal bridge is needed in order to calculate the actual yearly heat loss



Calculating Losses via Linear Thermal Bridges

$$Q_{T\text{-}tb} = L \times \Psi \times f_t \times G_t$$

EXAMPLE:

NYC, G_t = 117 kFh/yr

Ψ = 0.139 BTU/hr-ft-F

Length = 2 columns @ 10' long each

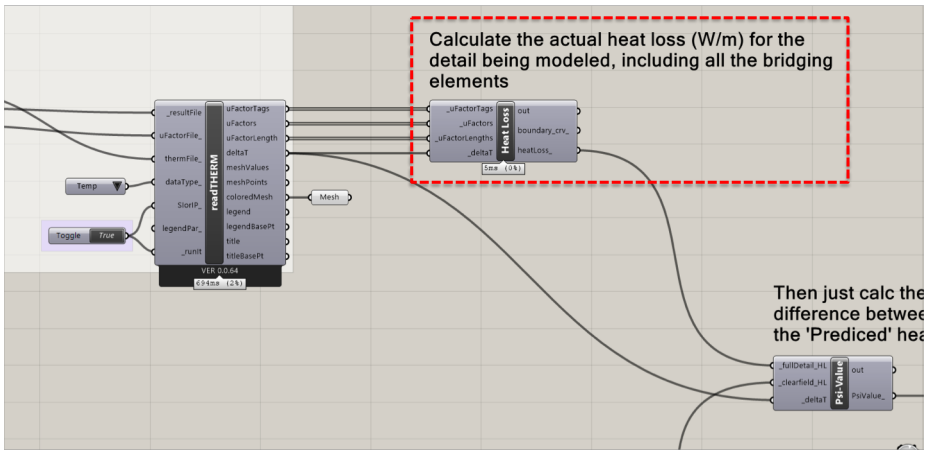
$Q_{T\text{-}tb}$= (2 × 10') × 0.139 Btu/hr-ft-F × 1.0 × 117 kFh/yr

$Q_{T\text{-}tb}$= 20 ft × 0.139 Btu/hr-ft-F × 1.0 × 117 kFh/yr

$Q_{T\text{-}tb}$= 325.26 kBtu/yr

We have to ADD an additional 325 kBtu/yr of losses to our energy model due to the steel columns

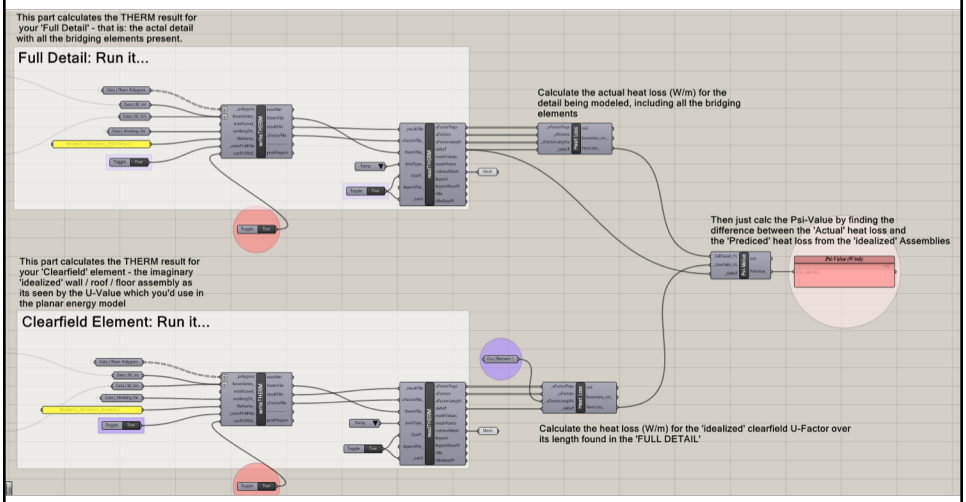
NEW: Heat Loss Component



RENSSELAER | ARCHITECTURE

bldgtyp llc

Psi-Value in GH



RENSSELAER | ARCHITECTURE

bldgtyp llc

https://discourse.ladybug.tools/t/using-honeybee-therm-to-calculate-psi-values/3328/19