Thermal Bridge Modeling for Architects

Friday, October 25, 2019. 1-5 PM

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Acknowledgements/Credits

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Ed May

- Partner, Building-Type, LLC
- Licensed Architect
- Certified Passive House Designer (PHI, PHIUS)
- LEED Green Associate
- Trainer with North American Passive House Network (NAPHN), Passive House Canada (PHC) & New York Passive House (NYPH)

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Course / Learning Objectives

- Build a foundation for understanding thermal bridging in buildings and how excess heat loss impacts building energy consumption, durability, and health.
- Learn how to use the free software LBNL THERM to execute typical architectural-envelope simulations on areas such as steel-stud assemblies, corner details, and balcony penetrations.
- Compare details and material thermal properties, learn how to examine details for common thermal bridges, and how to classify and calculate detail ‘PSI-Values’ for your own projects.
- Study effective thermal bridge mitigation techniques, and learn how to solve common design problems through iteration and simulation.

Outline

- Introduction to Thermal Bridges
- THERM Libraries, Underlays, Geometry
- THERM Materials & Boundary Conditions
- THERM Simulations
- Calculating Psi-Values:
  - Outside Corners
  - Parapets
  - Windows
  - Slab on Grade
  - Heated Basement

From ISO 10211

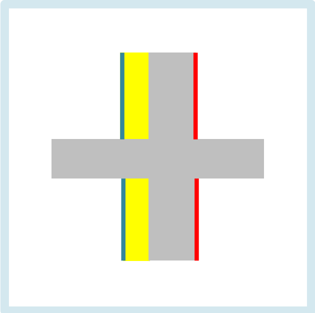
“***thermal bridge:*** *part of the building envelope where the otherwise uniform thermal resistance is significantly changed by full or partial penetration of the building envelope by materials with a different thermal conductivity, and/or a change in thickness of the fabric, and/or a difference between 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:

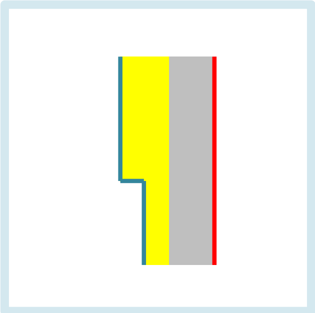
1. **a change in heat flow rate, and**
2. **a change in internal surface temperature.**

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:

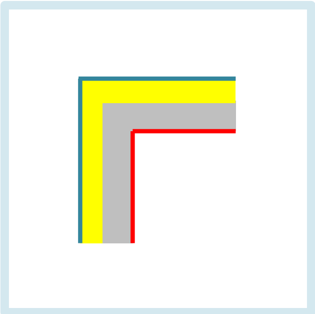


full or partial penetration of the insulating layers by materials with a different thermal conductivity



and/or

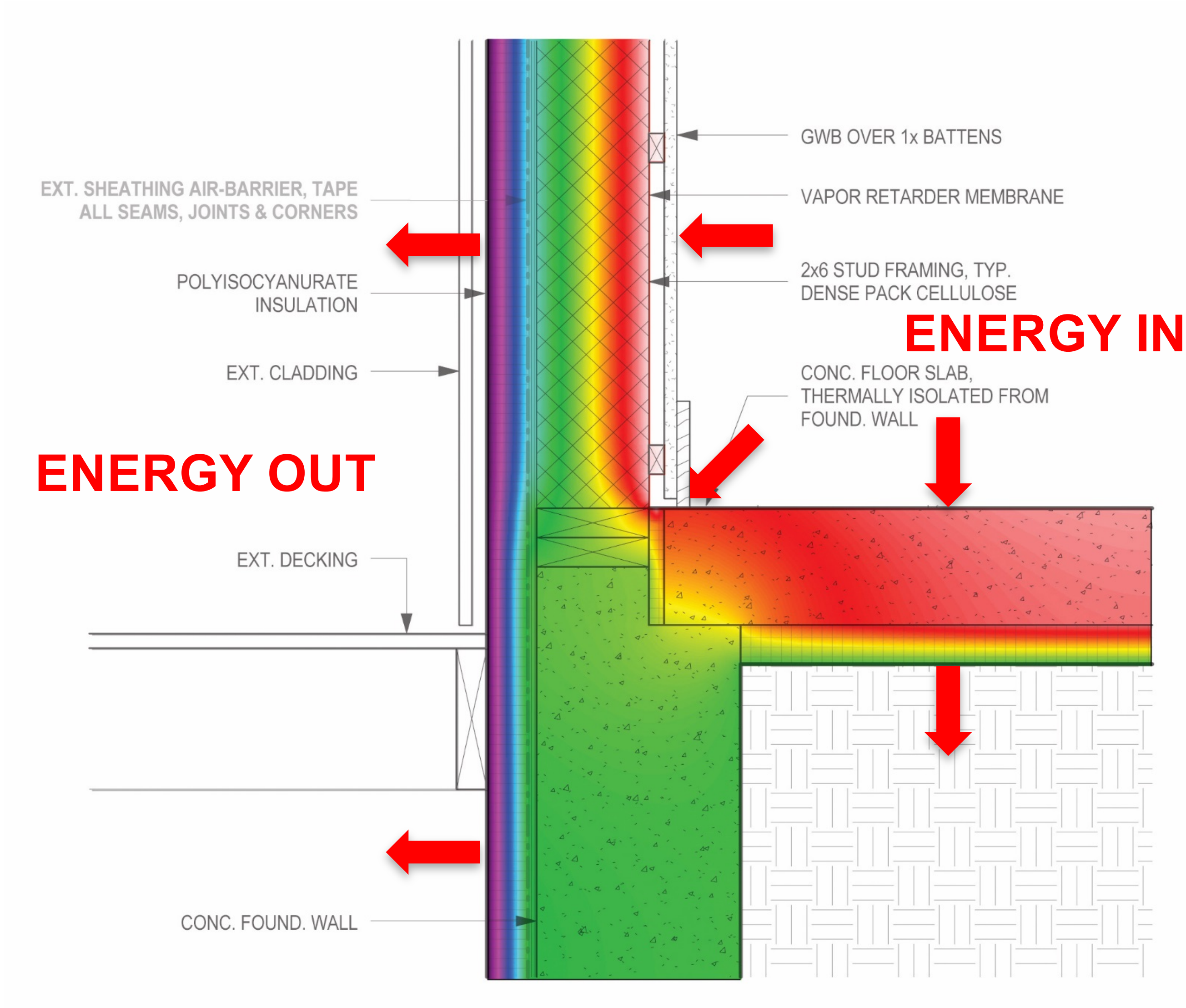
a change in thickness of the insulating layers



and/or

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

Simulating Thermal Bridges



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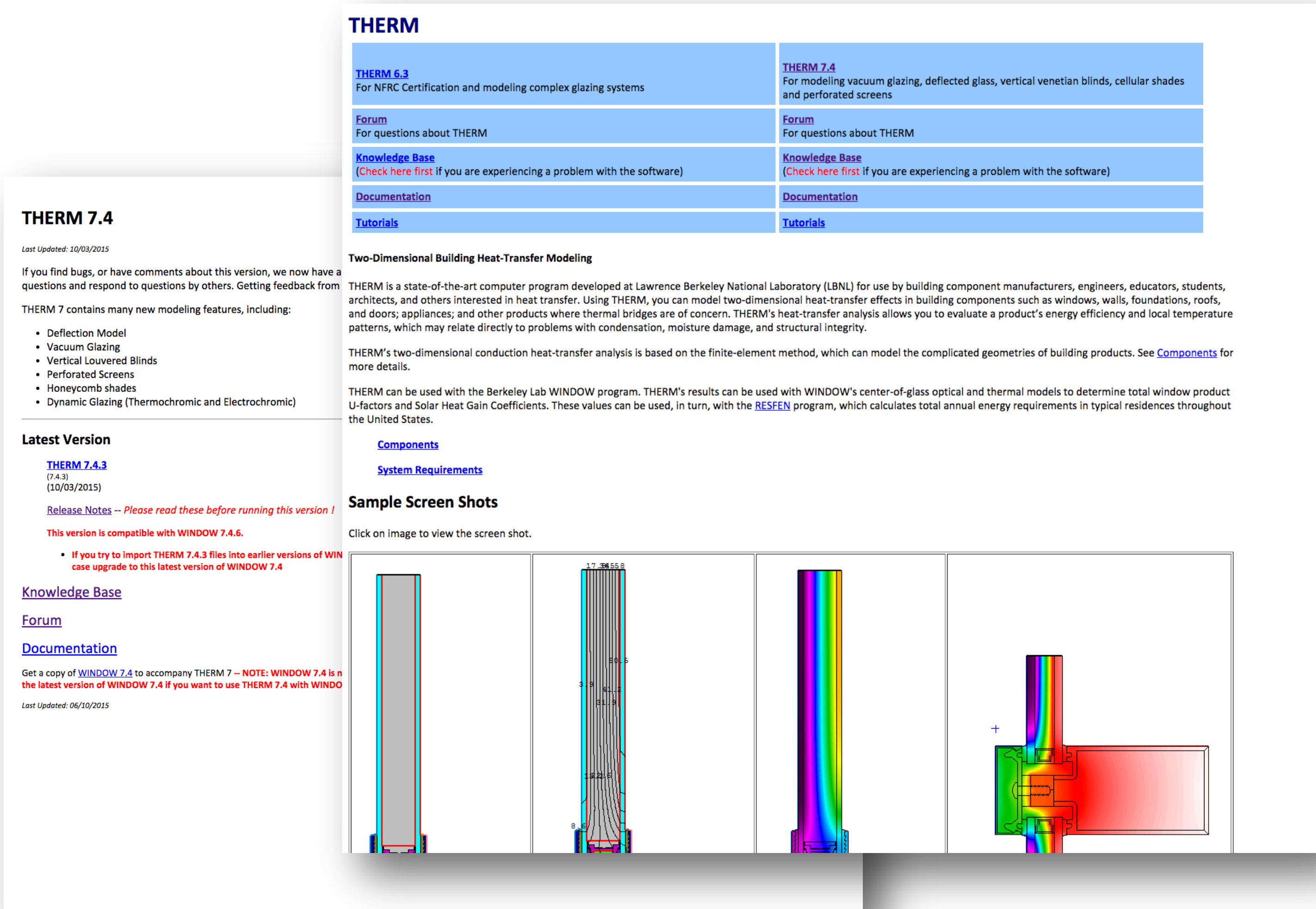
THERM (LBNL)

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



THERM

THERM 6.3 For NFRC Certification and modeling complex glazing systems	THERM 7.4 For modeling vacuum glazing, deflected glass, vertical venetian blinds, cellular shades and perforated screens
Forum For questions about THERM	Forum For questions about THERM
Knowledge Base (Check here first if you are experiencing a problem with the software)	Knowledge Base (Check here first if you are experiencing a problem with the software)
Documentation	Documentation
Tutorials	Tutorials

Two-Dimensional Building Heat-Transfer Modeling

THERM is a state-of-the-art computer program developed at Lawrence Berkeley National Laboratory (LBNL) for use by building component manufacturers, engineers, educators, students, architects, and others interested in heat transfer. Using THERM, you can model two-dimensional heat-transfer effects in building components such as windows, walls, foundations, roofs, and doors; appliances; and other products where thermal bridges are of concern. THERM's heat-transfer analysis allows you to evaluate a product's energy efficiency and local temperature patterns, which may relate directly to problems with condensation, moisture damage, and structural integrity.

THERM's two-dimensional conduction heat-transfer analysis is based on the finite-element method, which can model the complicated geometries of building products. See Components for more details.

THERM can be used with the Berkeley Lab WINDOW program. THERM's results can be used with WINDOW's center-of-glass optical and thermal models to determine total window product U-factors and Solar Heat Gain Coefficients. These values can be used, in turn, with the RESFEN program, which calculates total annual energy requirements in typical residences throughout the United States.

Components

System Requirements

Sample Screen Shots

Click on image to view the screen shot.

THERM 7.4

Last Updated: 10/03/2015

If you find bugs, or have comments about this version, we now have a
questions and respond to questions by others. Getting feedback from

THERM 7 contains many new modeling features, including:

- Deflection Model
- Vacuum Glazing
- Vertical Louvered Blinds
- Perforated Screens
- Honeycomb shades
- Dynamic Glazing (Thermochromic and Electrochromic)

Latest Version

THERM 7.4.3
(7.4.3)
(10/03/2015)

Release Notes -- *Please read these before running this version !*

This version is compatible with WINDOW 7.4.6.

- **If you try to import THERM 7.4.3 files into earlier versions of WIN case upgrade to this latest version of WINDOW 7.4**

Knowledge Base

Forum

Documentation

Get a copy of WINDOW 7.4 to accompany THERM 7 -- **NOTE: WINDOW 7.4 is n the latest version of WINDOW 7.4 if you want to use THERM 7.4 with WINDO**

Last Updated: 06/10/2015

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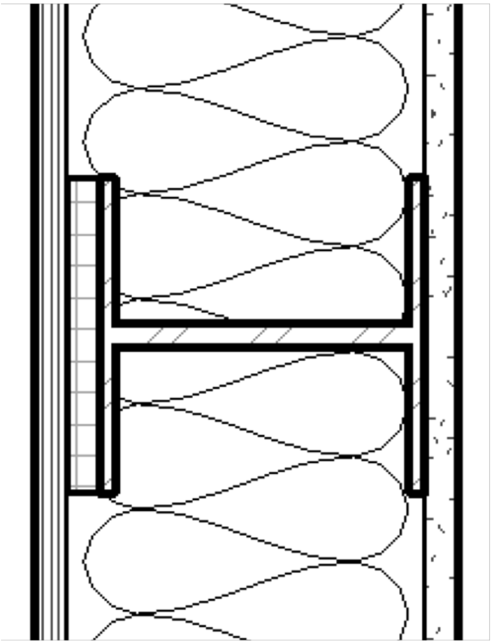
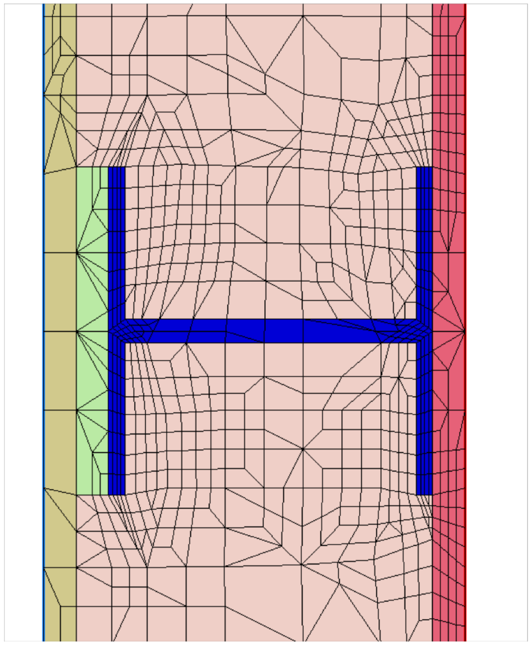
THERM Model

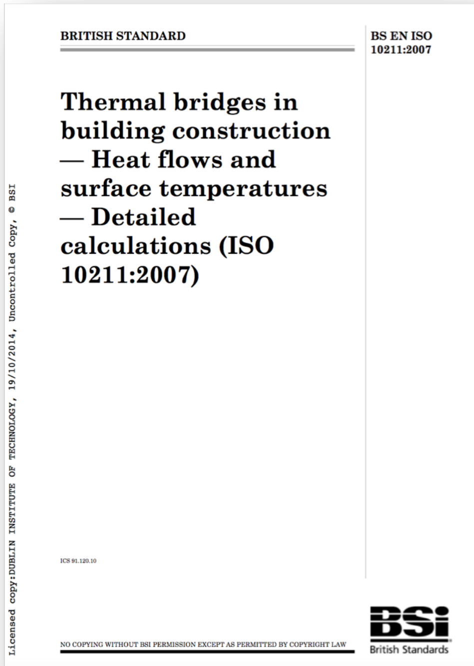
A model is made of the construction assembly and the conductivities / resistances are added for the relevant materials

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


BRITISH STANDARD

BS EN ISO 10211:2007

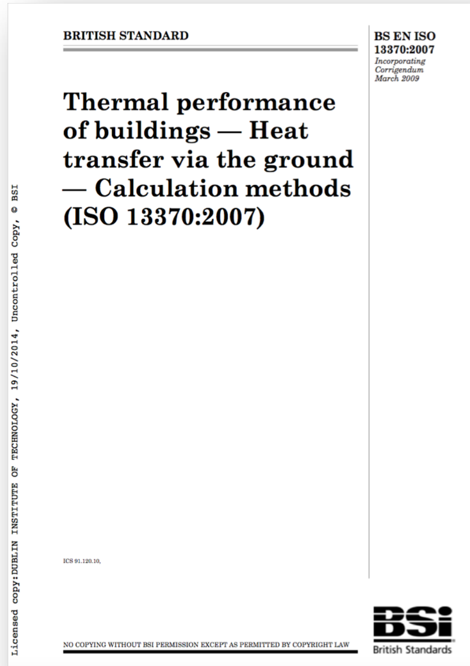
Thermal bridges in building construction — Heat flows and surface temperatures — Detailed calculations (ISO 10211:2007)

ICS 91.120.10

British Standards

ISO 10211

- Thermal bridges in building construction.


BRITISH STANDARD

BS EN ISO 13370:2007

Incorporating Corrigendum March 2009

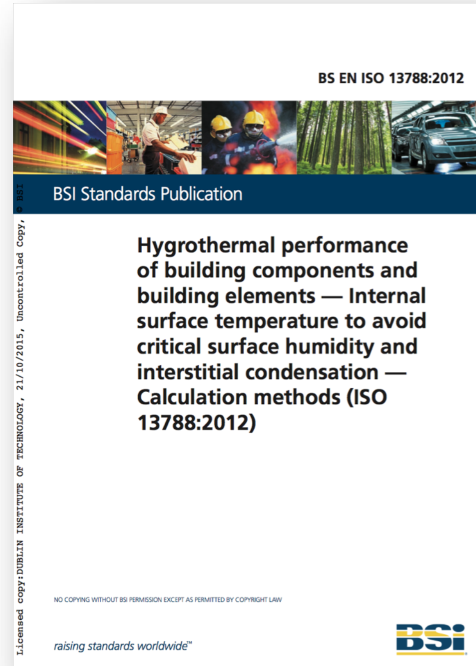
Thermal performance of buildings — Heat transfer via the ground — Calculation methods (ISO 13370:2007)

ICS 91.120.10,

British Standards

ISO 13370

- Heat transfer via the ground.


BS EN ISO 13788:2012

BSI Standards Publication

Hygrothermal performance of building components and building elements — Internal surface temperature to avoid critical surface humidity and interstitial condensation — Calculation methods (ISO 13788:2012)

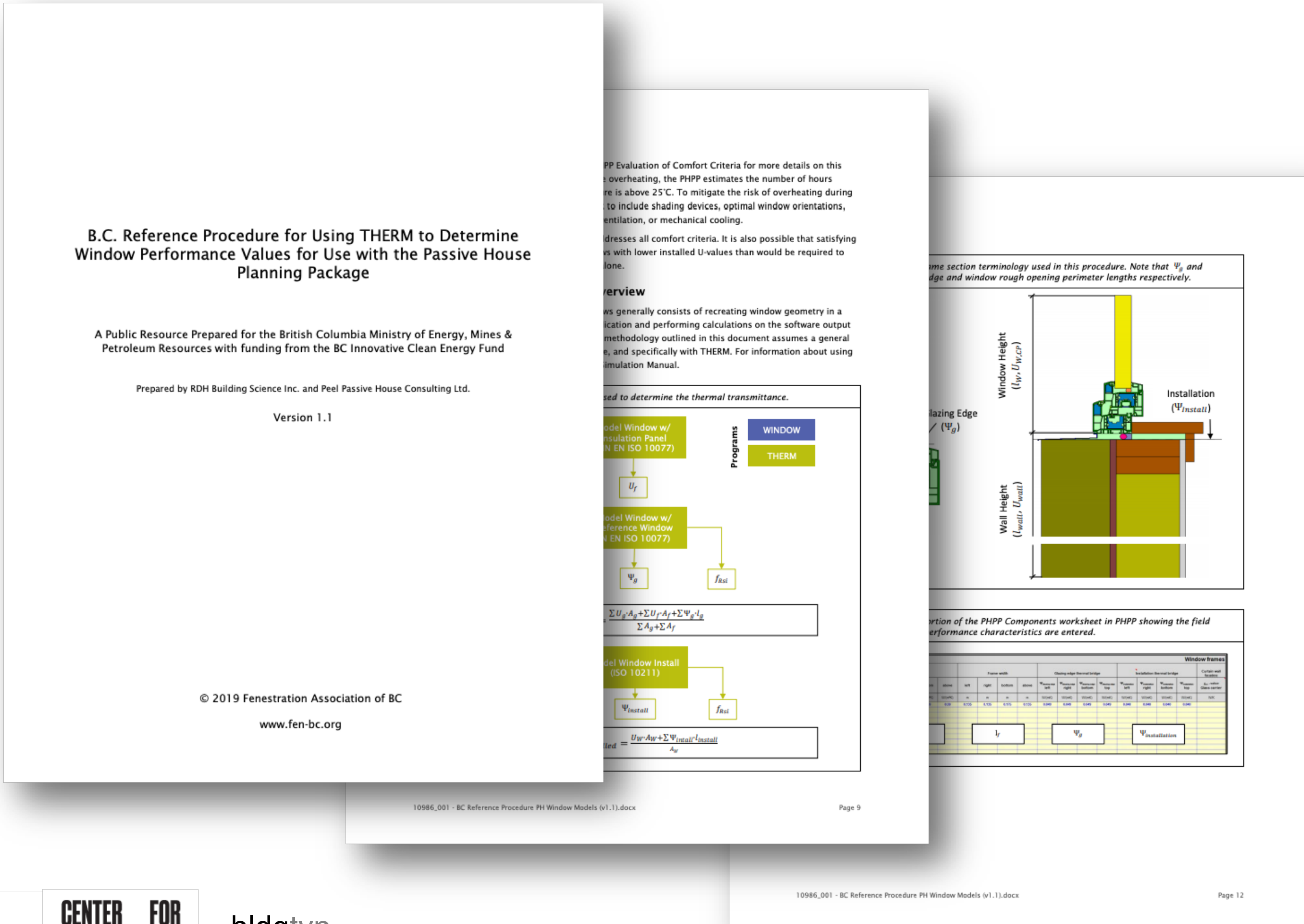
raising standards worldwide™

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



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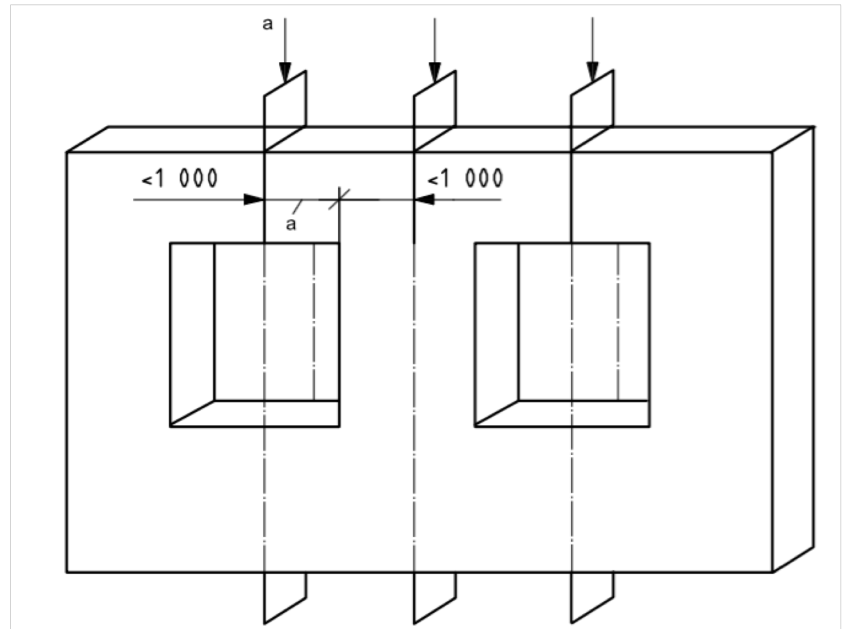
How much to model?

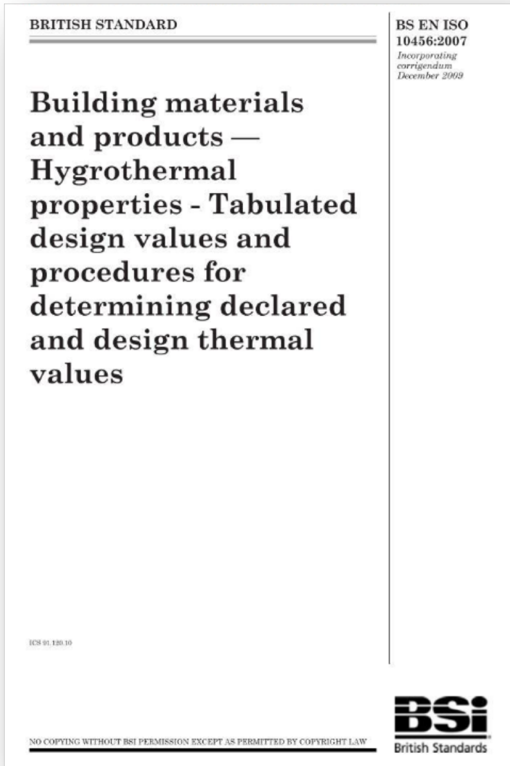
ISO 10211 Section 5.2.2 and 5.2.3 have detailed rules about how far to model, and where to 'cut' the model in order to ensure accurate simulation results.

- 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


BRITISH STANDARD

BS EN ISO 10456:2007

Incorporating corrigendum December 2009

Building materials and products — Hygrothermal properties - Tabulated design values and procedures for determining declared and design thermal values

ICS 91.120.10

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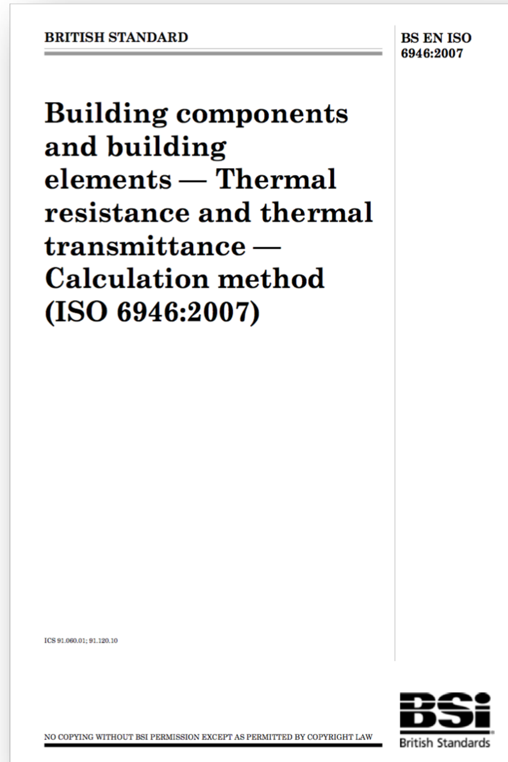
BSi British Standards


BRITISH STANDARD

BS EN ISO 6946:2007

Building components and building elements — Thermal resistance and thermal transmittance — Calculation method (ISO 6946:2007)

ICS 91.060.01; 91.120.10

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BSi British Standards

ISO 10456

- Building Materials and Products

ISO 6946

- Thermal resistance and thermal transmittance

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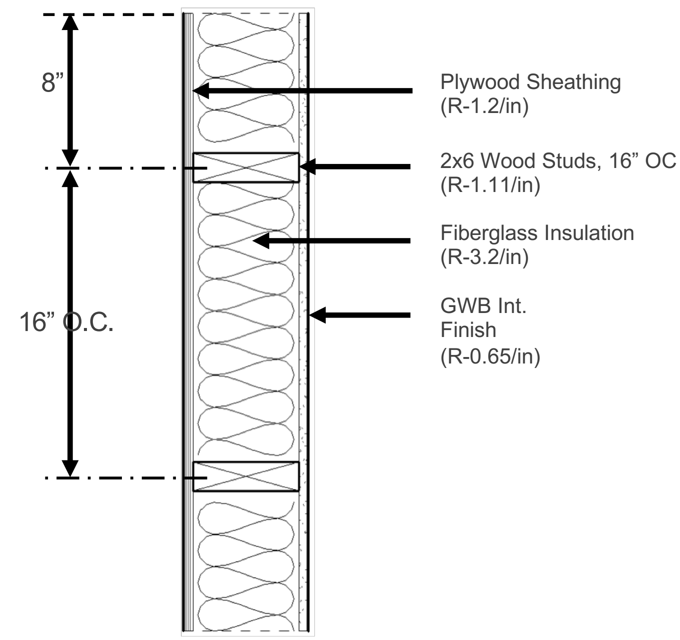
2x6 Stud Wall (Typ.)

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.

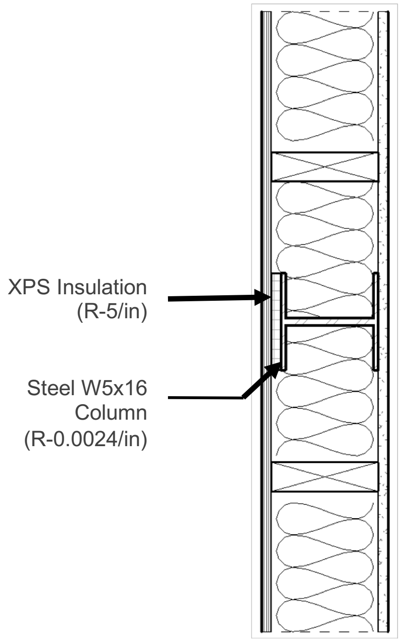


U-Factor = 0.0570 (Btu / hr·ft²·F)

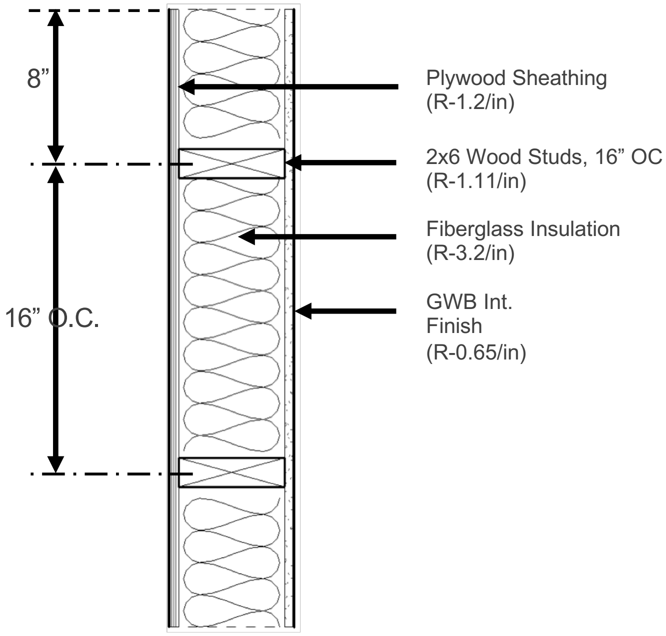
Structural Steel Thermal Bridge

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



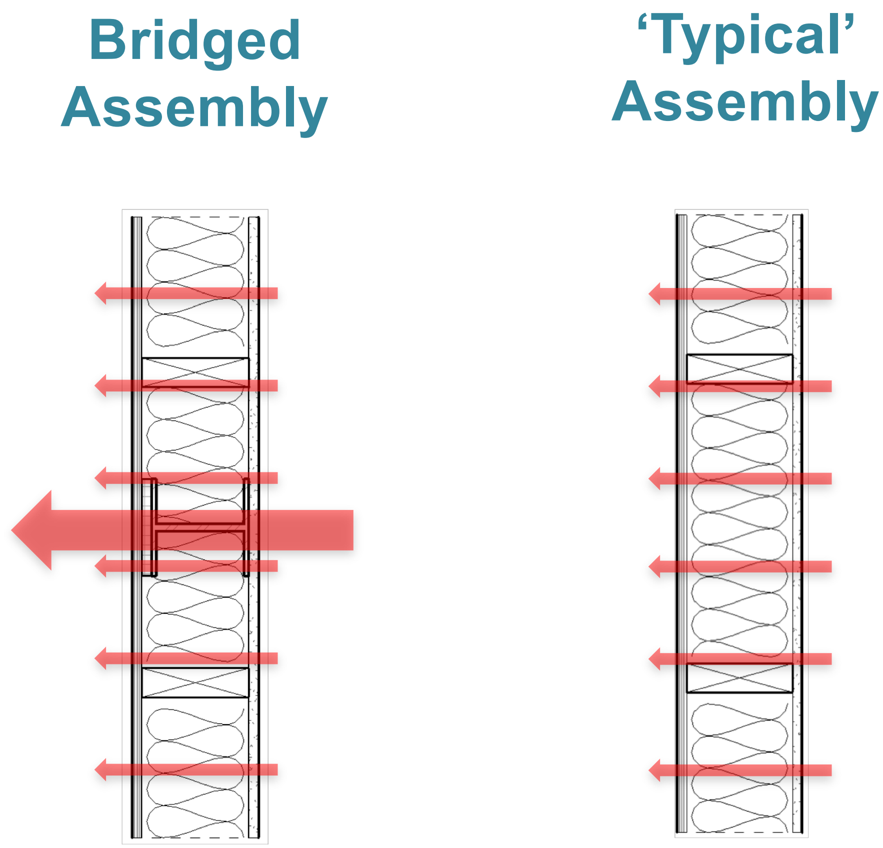
'Typical' Assembly



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

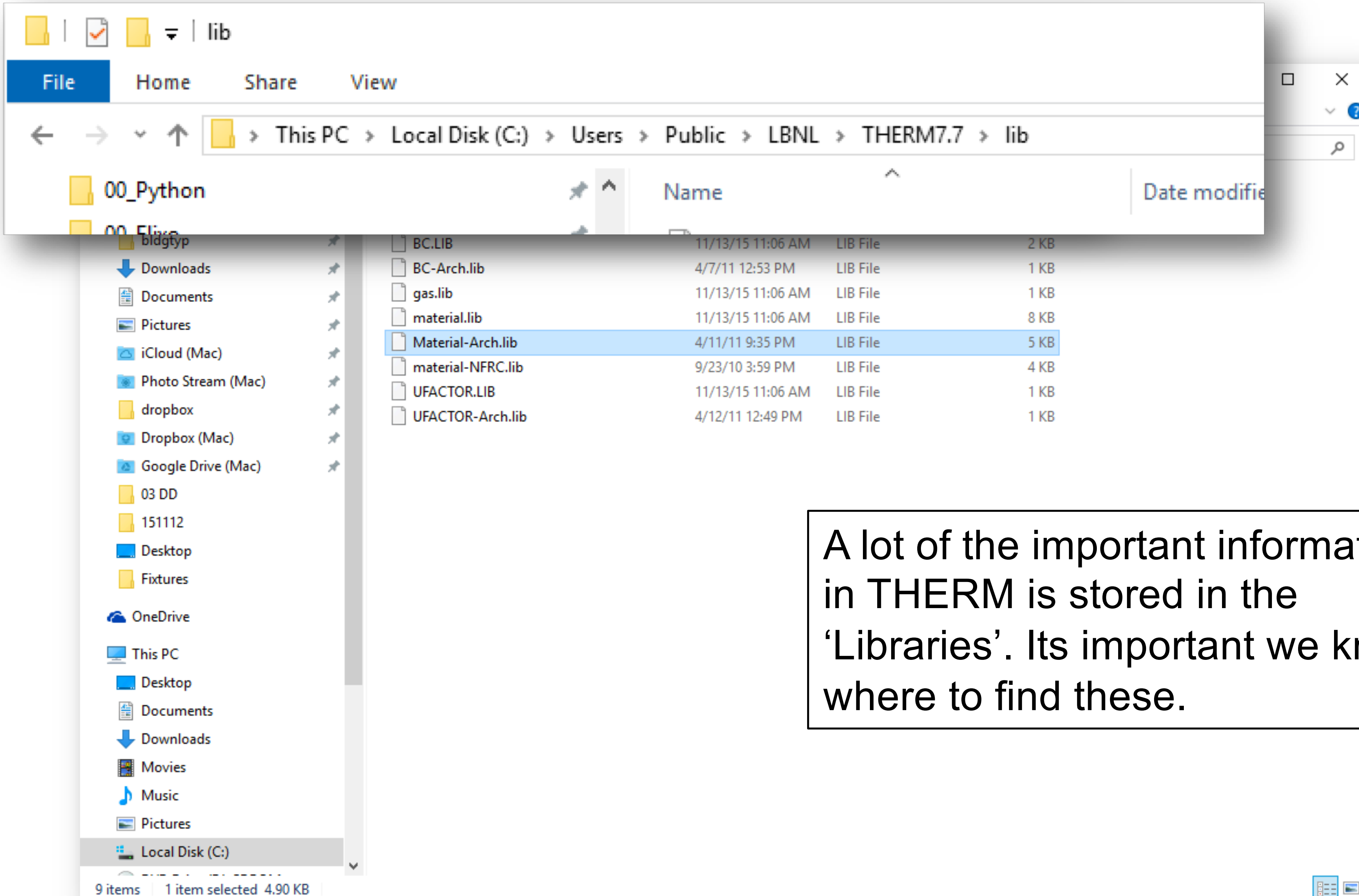
The steel columns' disruption to this 'typical' construction will mean additional heat loss at this area



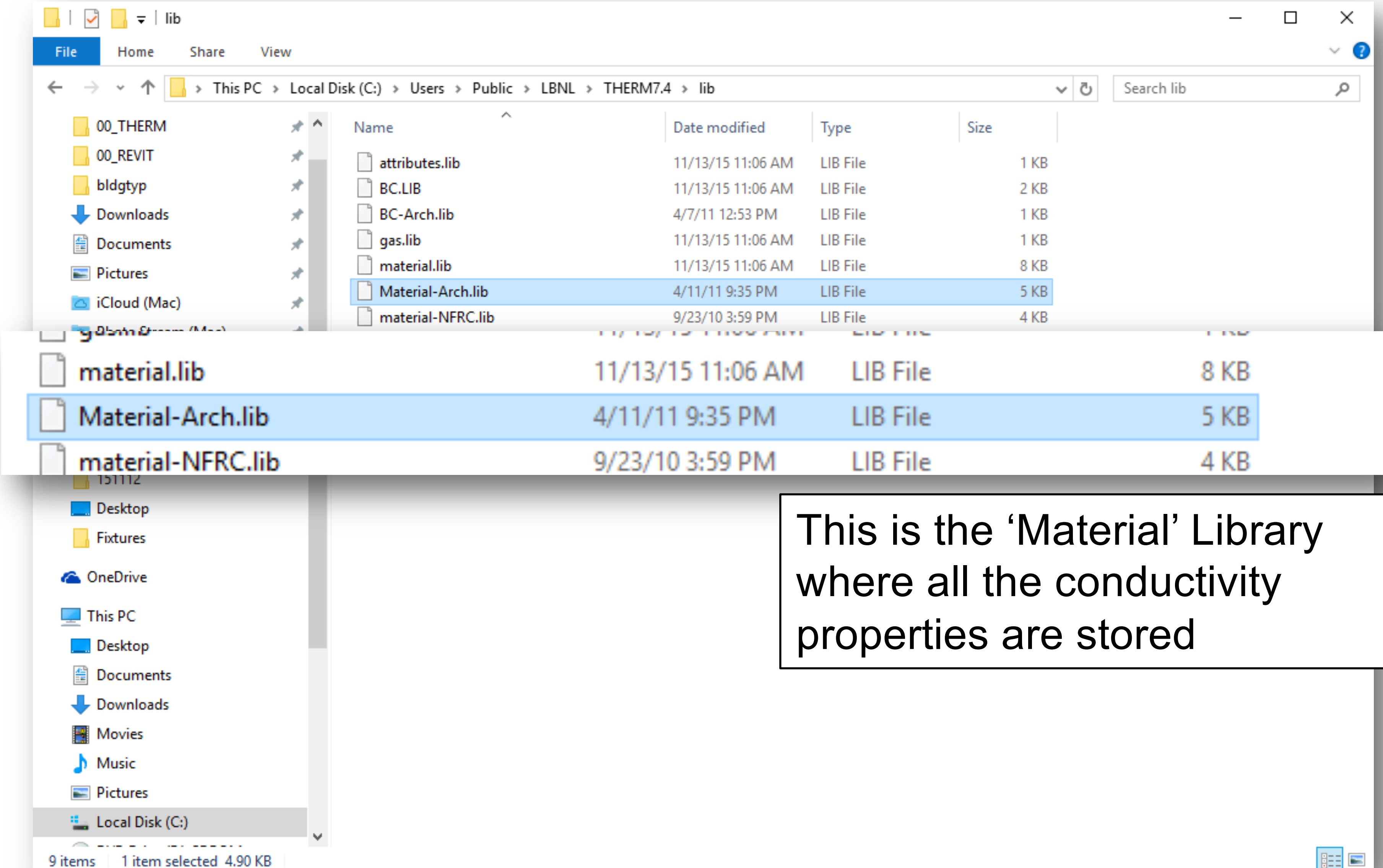
Actual Heat Loss – 'Typical' Heat Loss = Psi-Value

Setting Up THERM Libraries

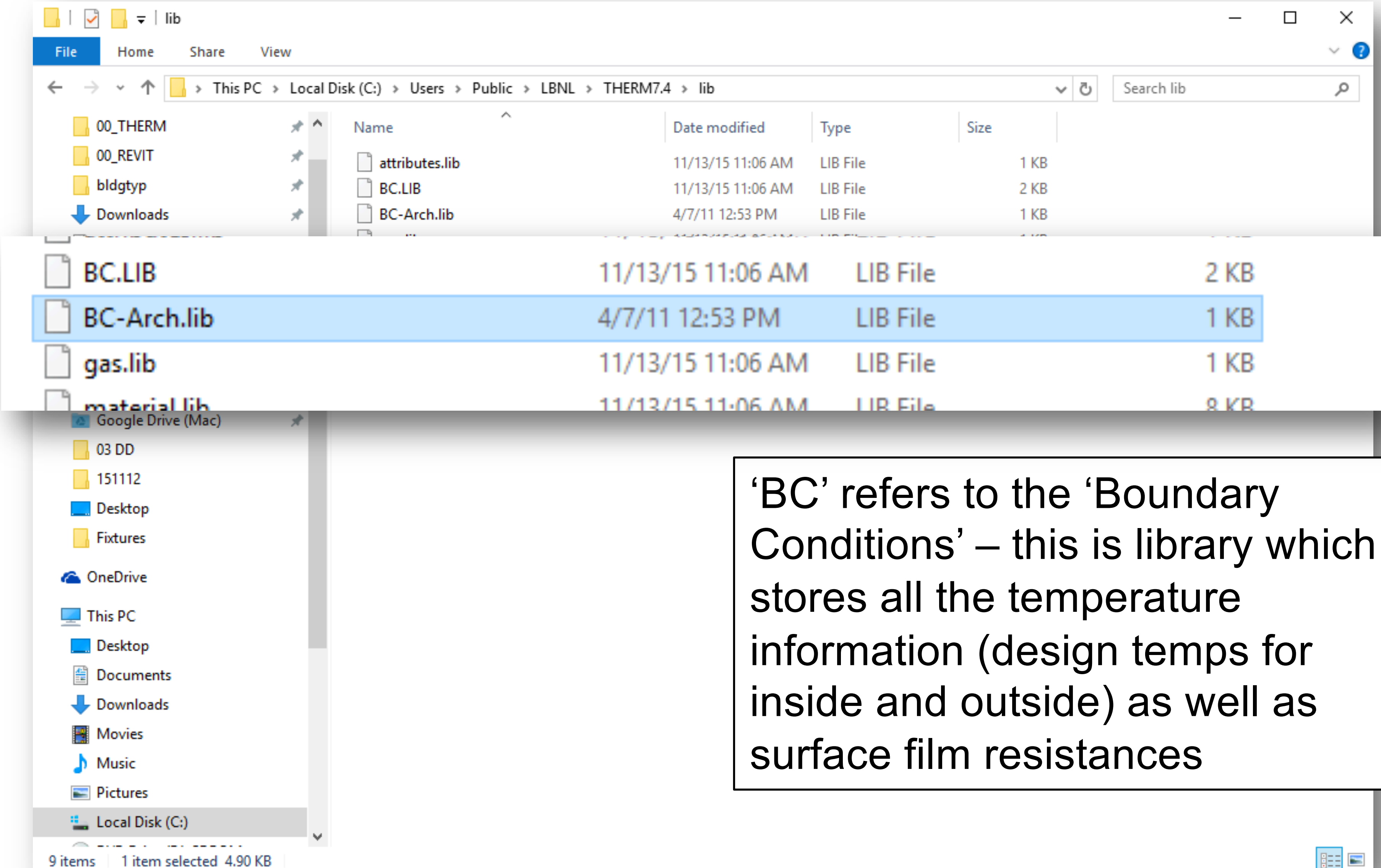
…/Users/Public/LBNL/Therm7.7/lib/…



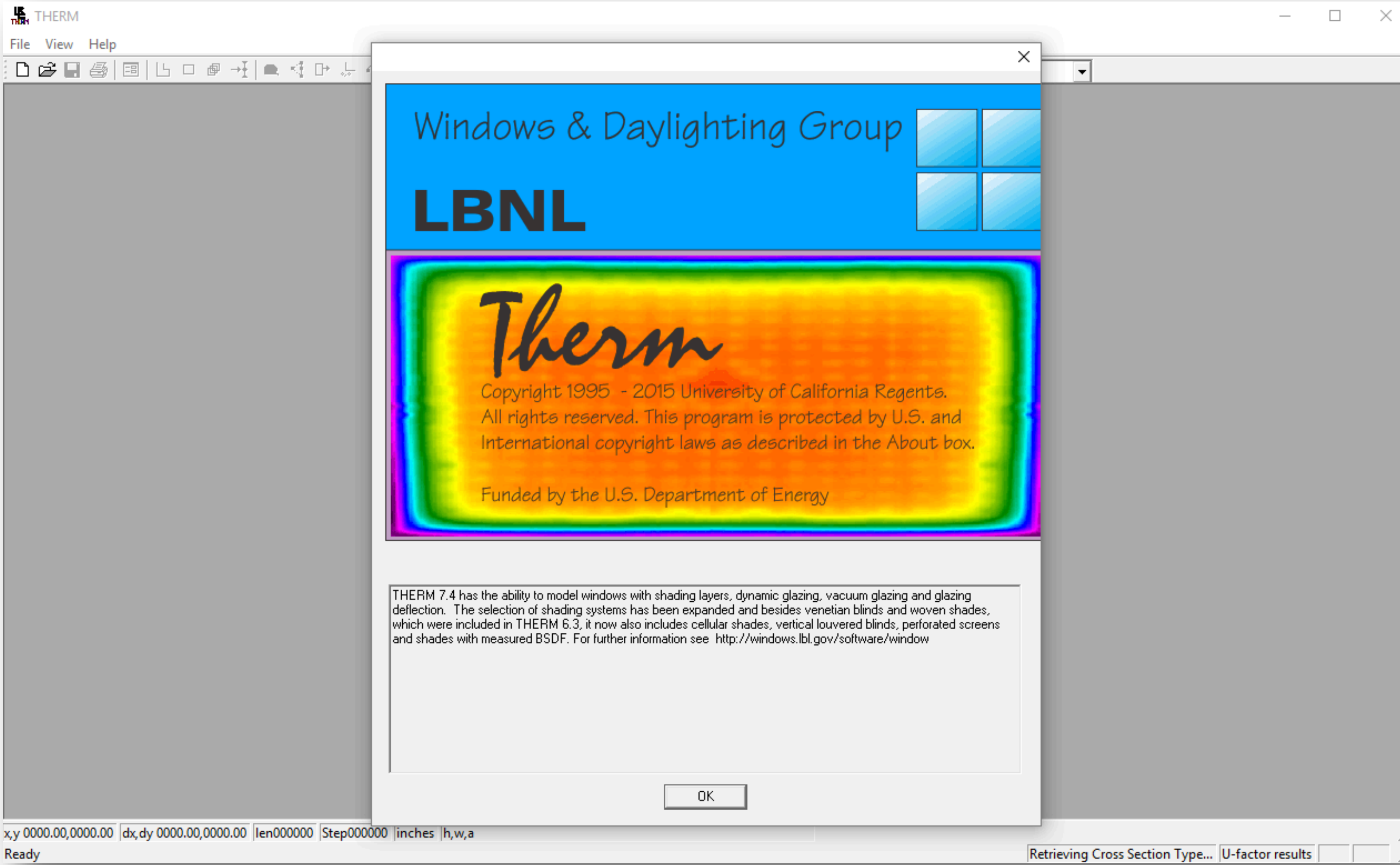
A lot of the important information in THERM is stored in the ‘Libraries’. Its important we know where to find these.



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



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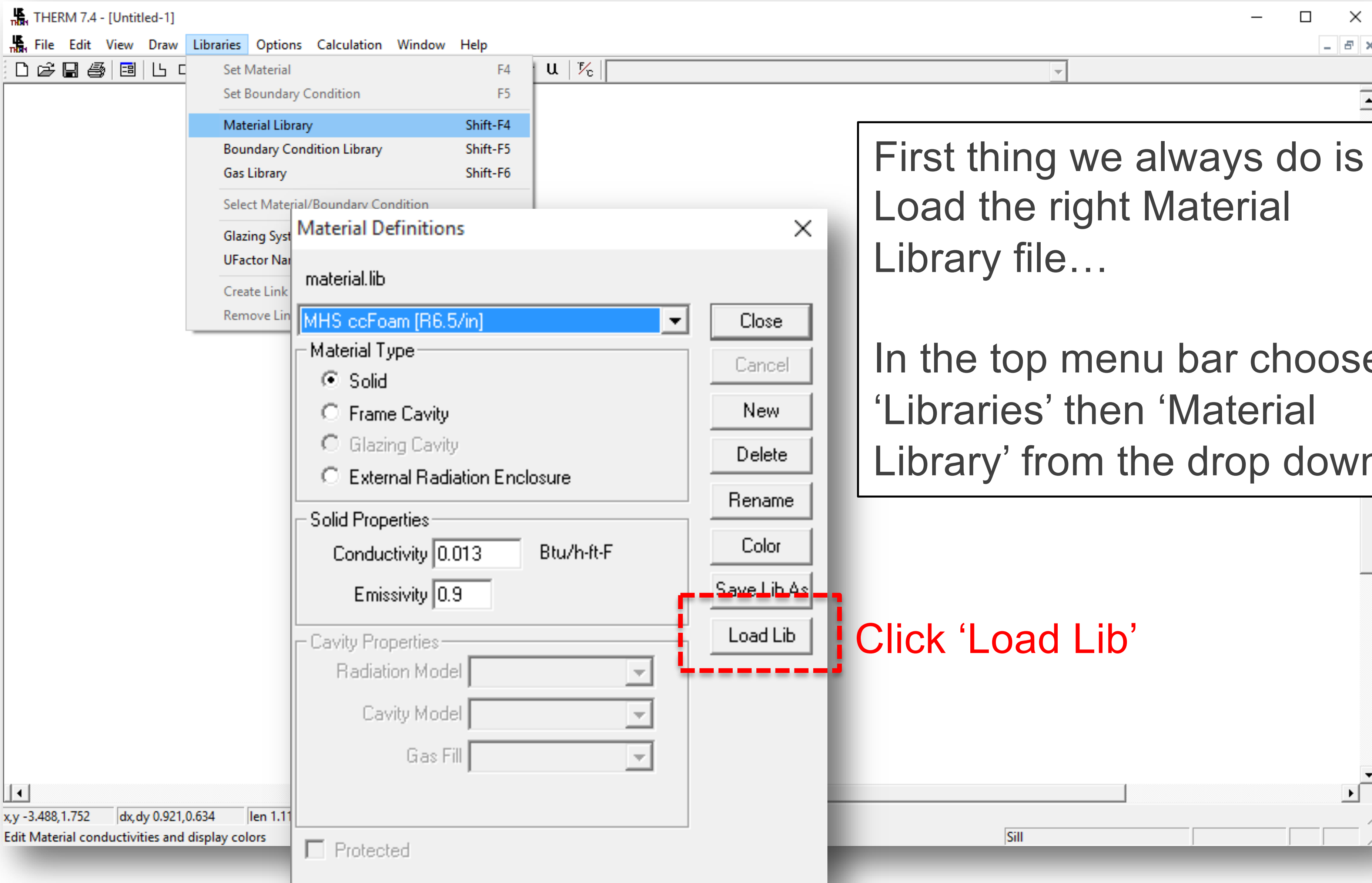
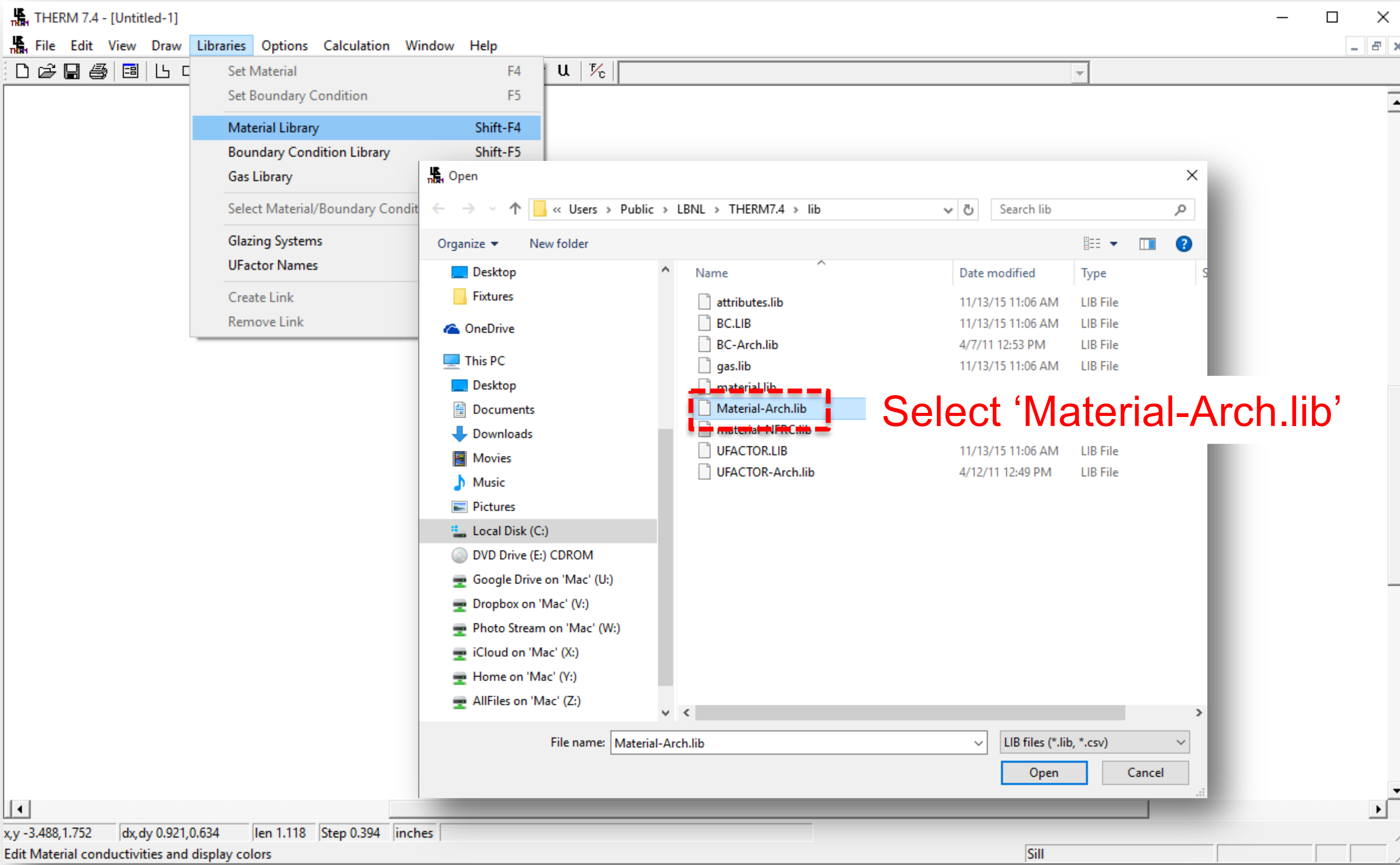
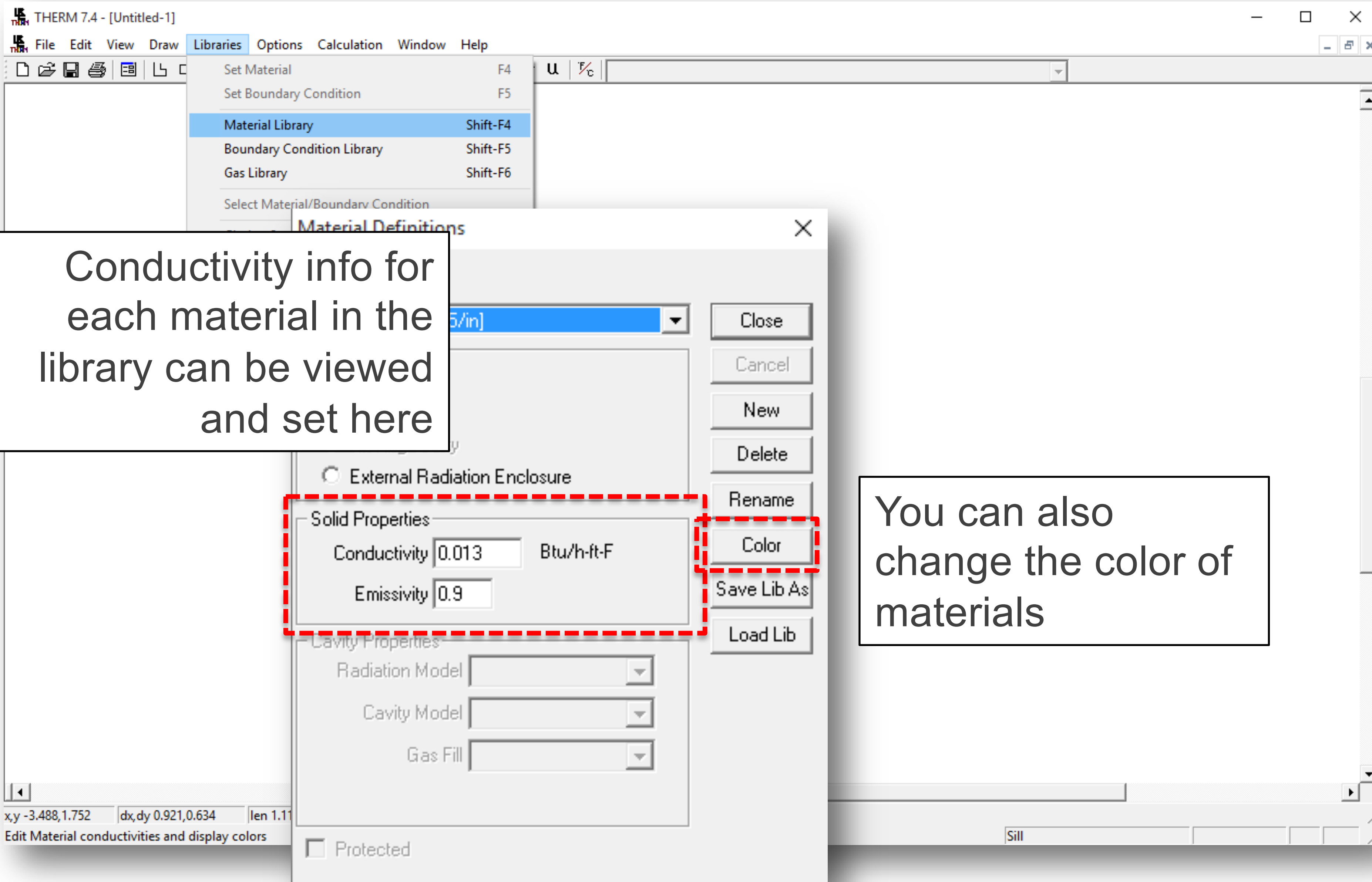


First thing we always do is Load the right Material Library file…

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

Click 'Load Lib'


THERM 7.4 - [Untitled-1]
File Edit View Draw Libraries Options Calculation Window Help
Set Material F4
Set Boundary Condition F5
Material Library Shift-F4
Boundary Condition Library Shift-F5
Gas Library
Select Material/Boundary Condit
Glazing Systems
UFactor Names
Create Link
Remove Link
Open
« Users › Public › LBNL › THERM7.4 › lib
Search lib
Organize New folder
Desktop
Fixtures
OneDrive
This PC
Desktop
Documents
Downloads
Movies
Music
Pictures
Local Disk (C:)
DVD Drive (E:) CDROM
Google Drive on 'Mac' (U:)
Dropbox on 'Mac' (V:)
Photo Stream on 'Mac' (W:)
iCloud on 'Mac' (X:)
Home on 'Mac' (Y:)
AllFiles on 'Mac' (Z:)
Name Date modified Type
attributes.lib 11/13/15 11:06 AM LIB File
BC.LIB 11/13/15 11:06 AM LIB File
BC-Arch.lib 4/7/11 12:53 PM LIB File
gas.lib 11/13/15 11:06 AM LIB File
material.lib
Material-Arch.lib
UFACTOR.LIB 11/13/15 11:06 AM LIB File
UFACTOR-Arch.lib 4/12/11 12:49 PM LIB File
Select 'Material-Arch.lib'
File name: Material-Arch.lib
LIB files (*.lib, *.csv)
Open
Cancel
x,y -3.488,1.752
dx,dy 0.921,0.634
len 1.118
Step 0.394
inches
Edit Material conductivities and display colors
Sill



Conductivity info for each material in the library can be viewed and set here

You can also change the color of materials

Conductivity?

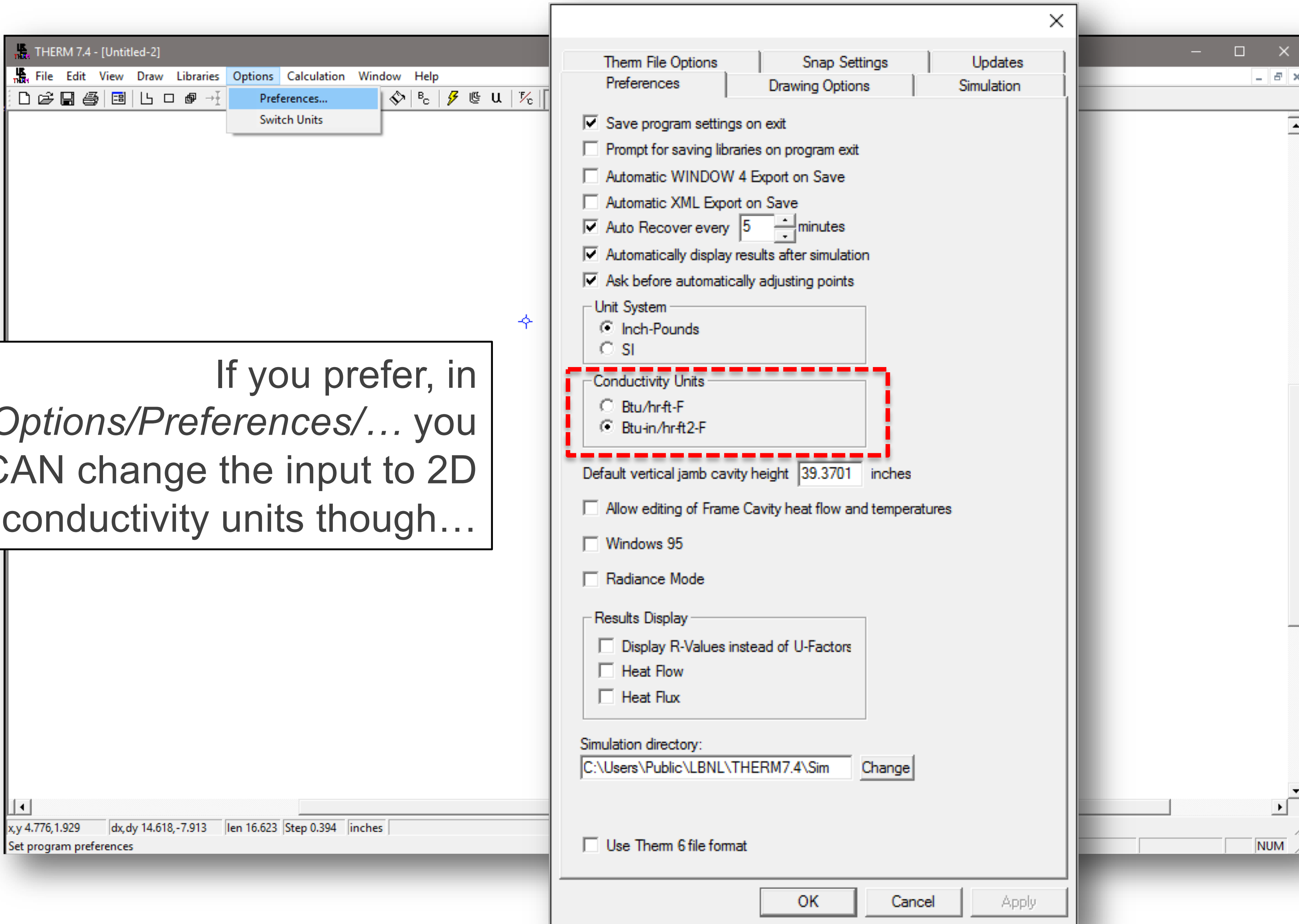
Note: Conductivity (k) is a measure of the material properties measured over 1 inch of thickness, measured in Btu-in/hr-ft^2-F

By default Therm uses 1D Conductivity values, rather than the 2D Transmittance values (k) we are probably 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*

If you prefer, in *Options/Preferences/…* you CAN change the input to 2D conductivity units though…



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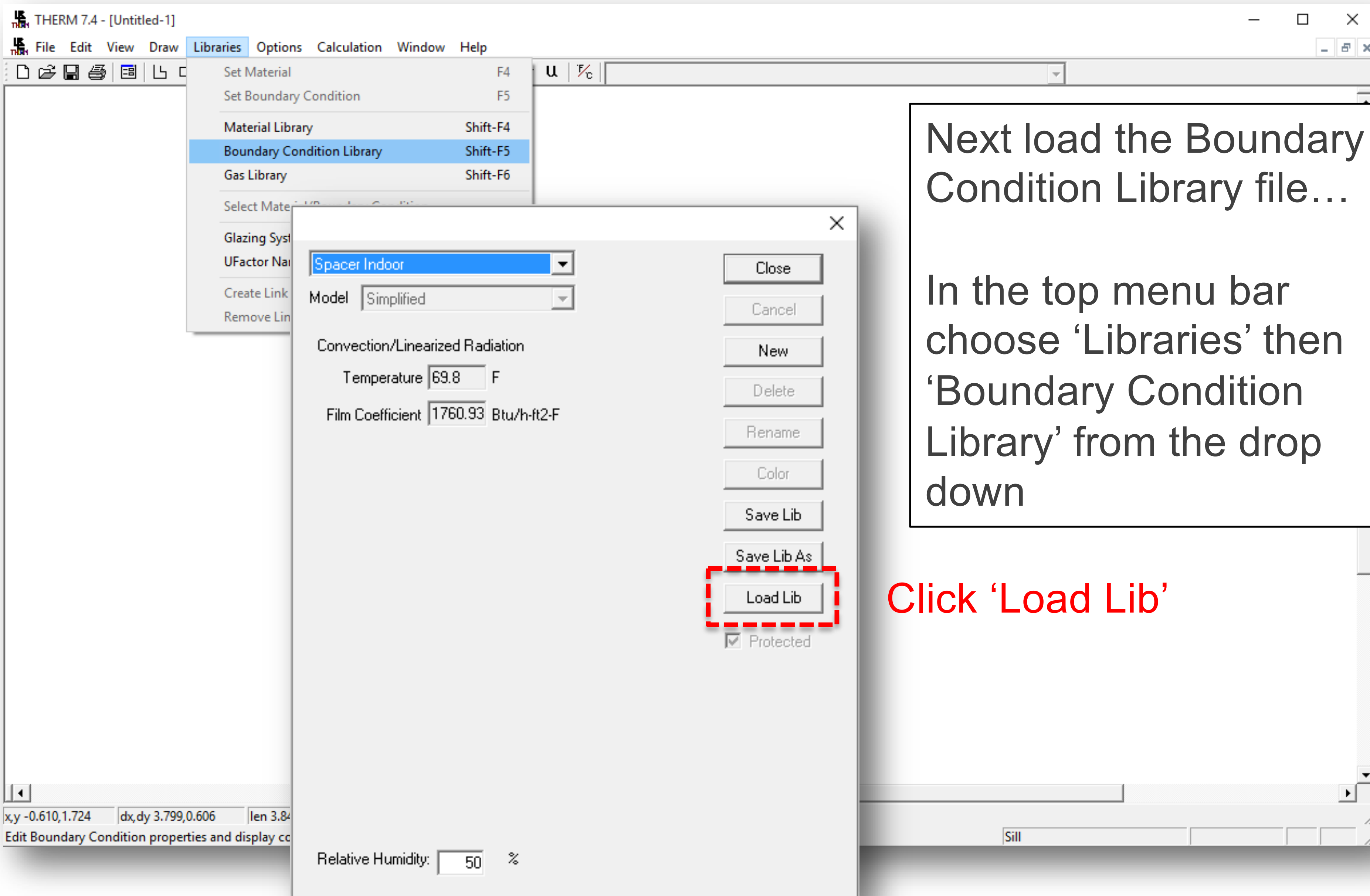
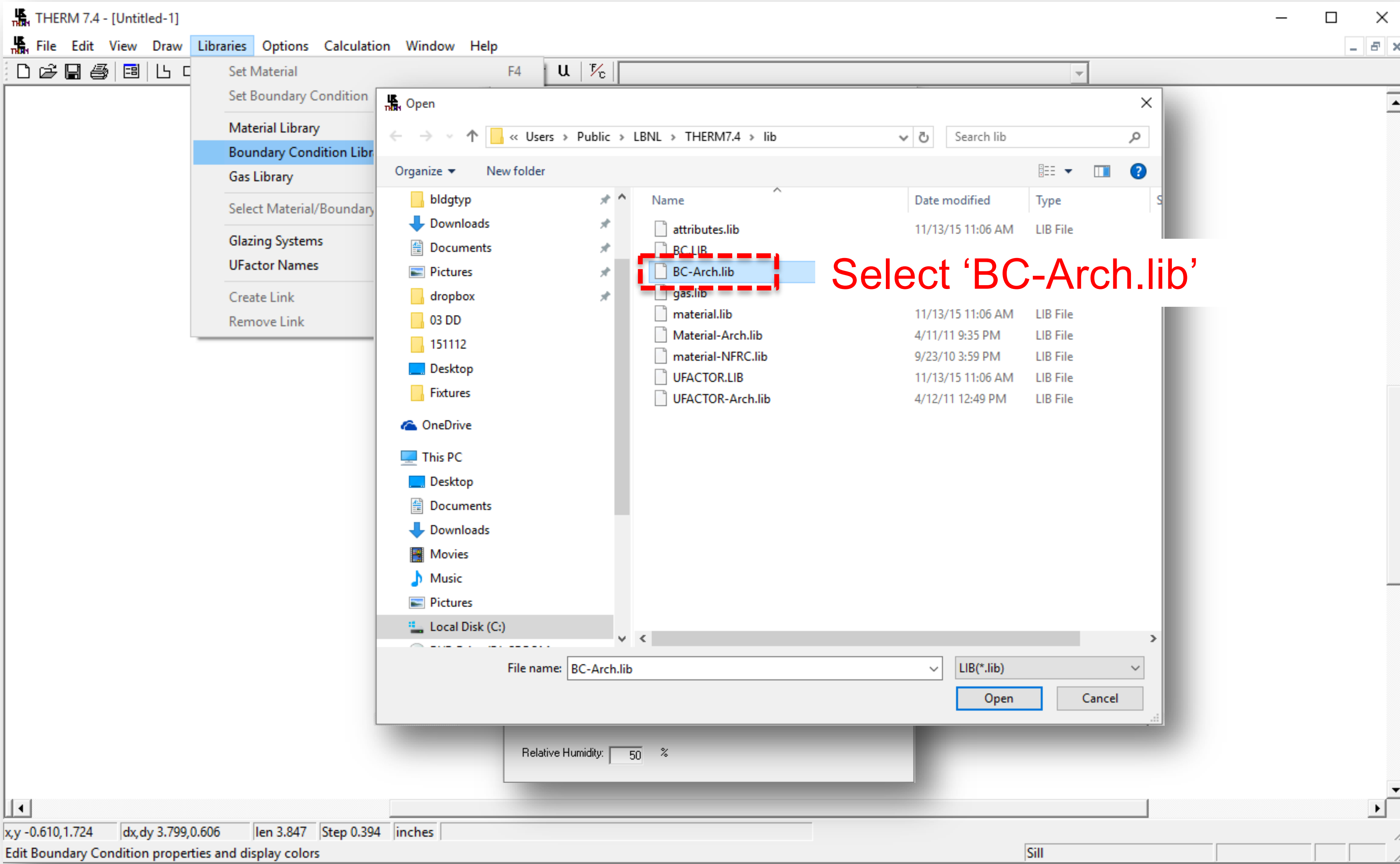


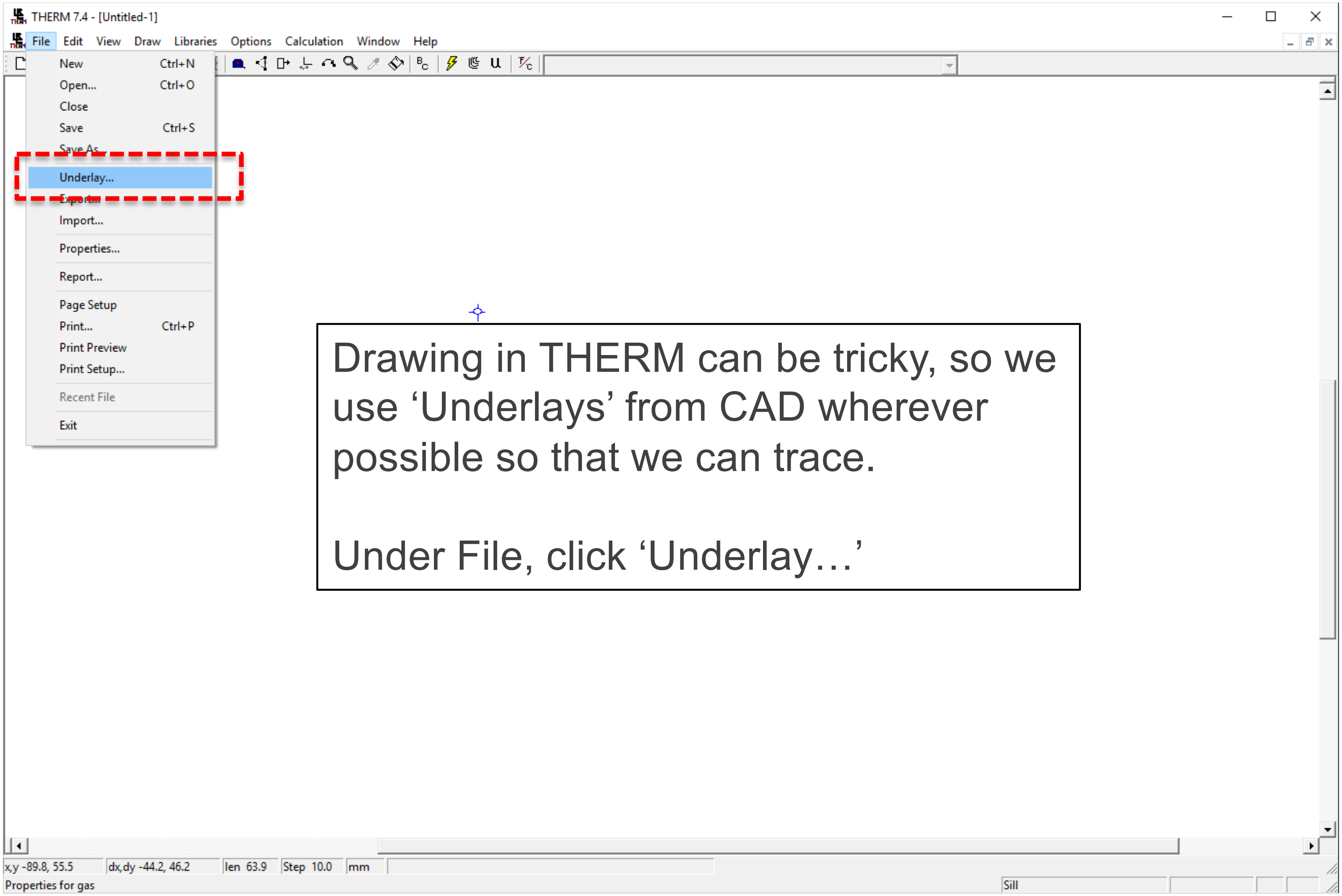
Next load the Boundary Condition Library file…

In the top menu bar choose 'Libraries' then 'Boundary Condition Library' from the drop down

Click 'Load Lib'

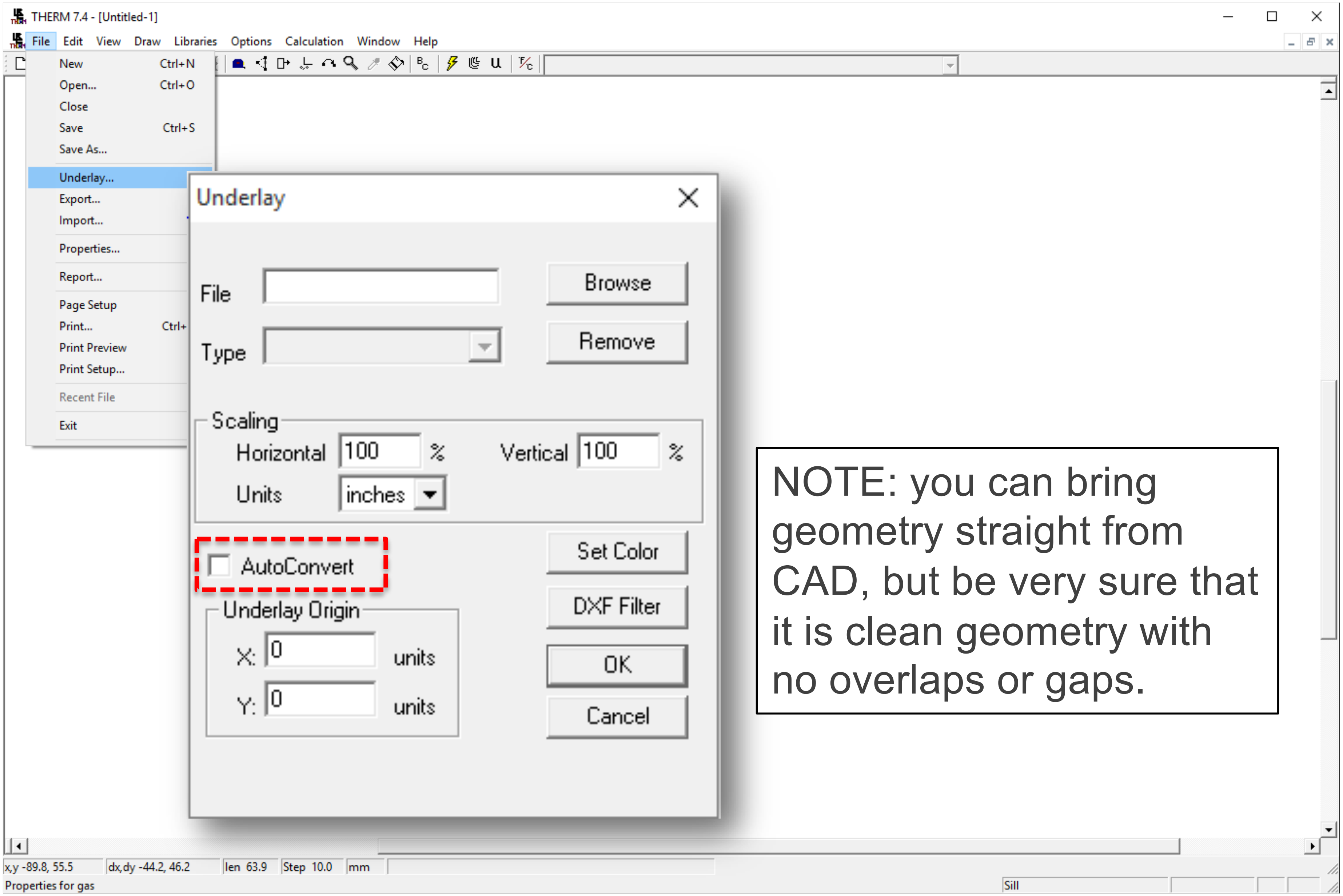

THERM 7.4 - [Untitled-1]
File Edit View Draw Libraries Options Calculation Window Help
Set Material F4
Set Boundary Condition
Material Library
Boundary Condition Libr
Gas Library
Select Material/Boundary
Glazing Systems
UFactor Names
Create Link
Remove Link
Open
Users > Public > LBNL > THERM7.4 > lib
Search lib
Organize New folder
bldgtyp
Downloads
Documents
Pictures
dropbox
03 DD
151112
Desktop
Fixtures
OneDrive
This PC
Desktop
Documents
Downloads
Movies
Music
Pictures
Local Disk (C:)
Name Date modified Type
attributes.lib 11/13/15 11:06 AM LIB File
BC.LIB
BC-Arch.lib
gas.lib
material.lib 11/13/15 11:06 AM LIB File
Material-Arch.lib 4/11/11 9:35 PM LIB File
material-NFRC.lib 9/23/10 3:59 PM LIB File
UFACTOR.LIB 11/13/15 11:06 AM LIB File
UFACTOR-Arch.lib 4/12/11 12:49 PM LIB File
Select 'BC-Arch.lib'
File name: BC-Arch.lib
LIB(*.lib)
Open
Cancel
Relative Humidity: 50 %
x,y -0.610,1.724
dx,dy 3.799,0.606
len 3.847
Step 0.394
inches
Edit Boundary Condition properties and display colors
Sill

Importing Underlays

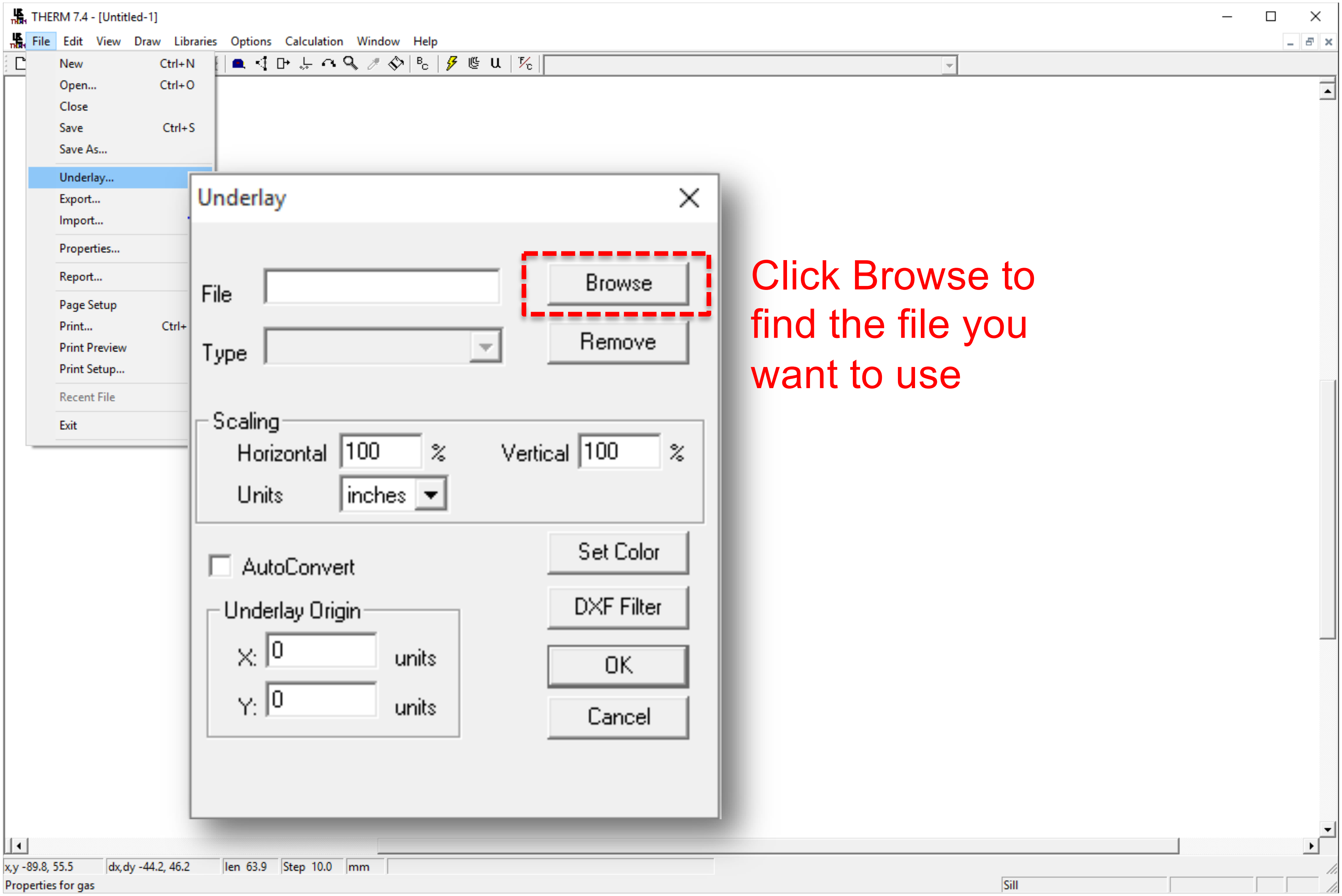


Drawing in THERM can be tricky, so we use ‘Underlays’ from CAD wherever possible so that we can trace.

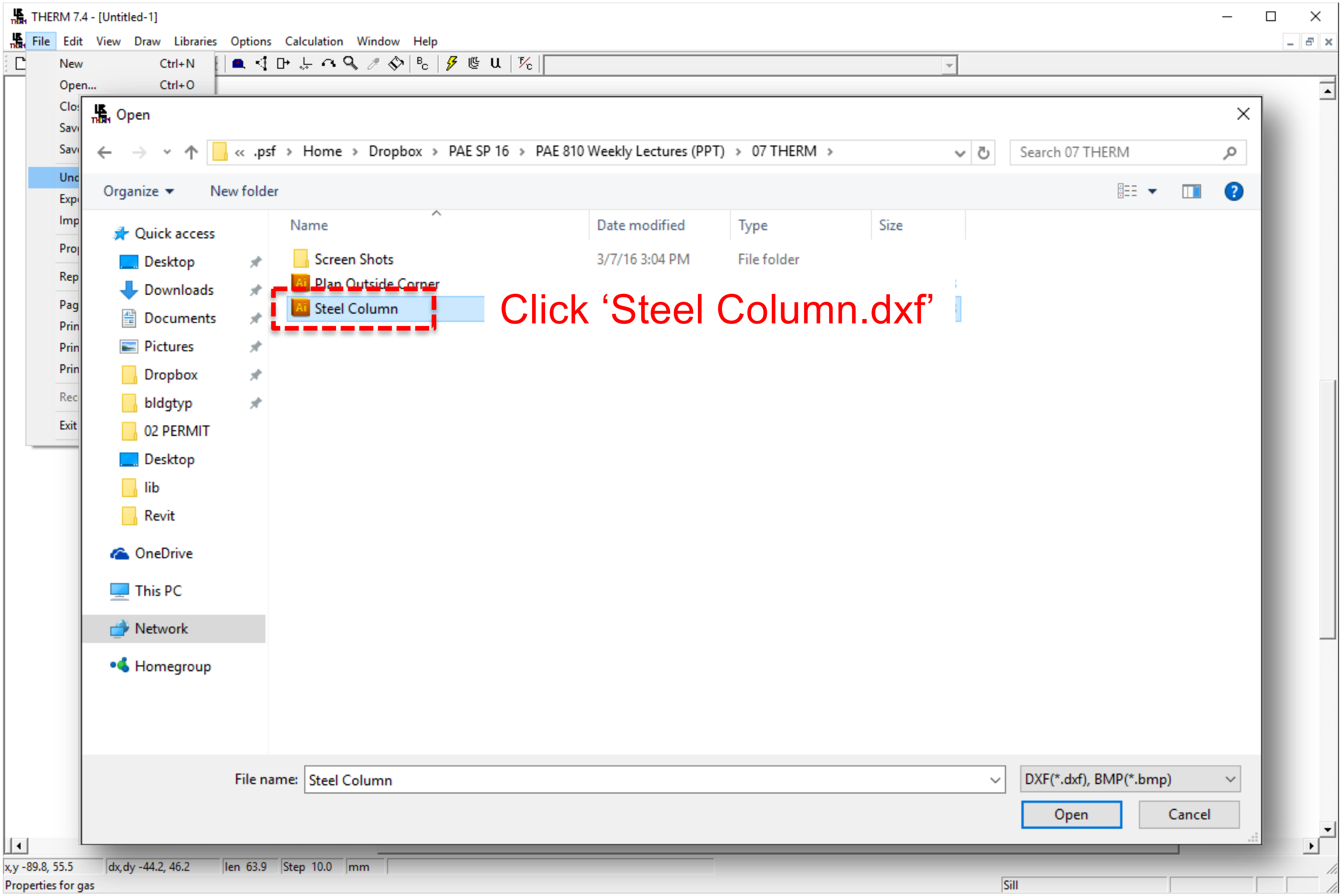
Under File, click ‘Underlay…’

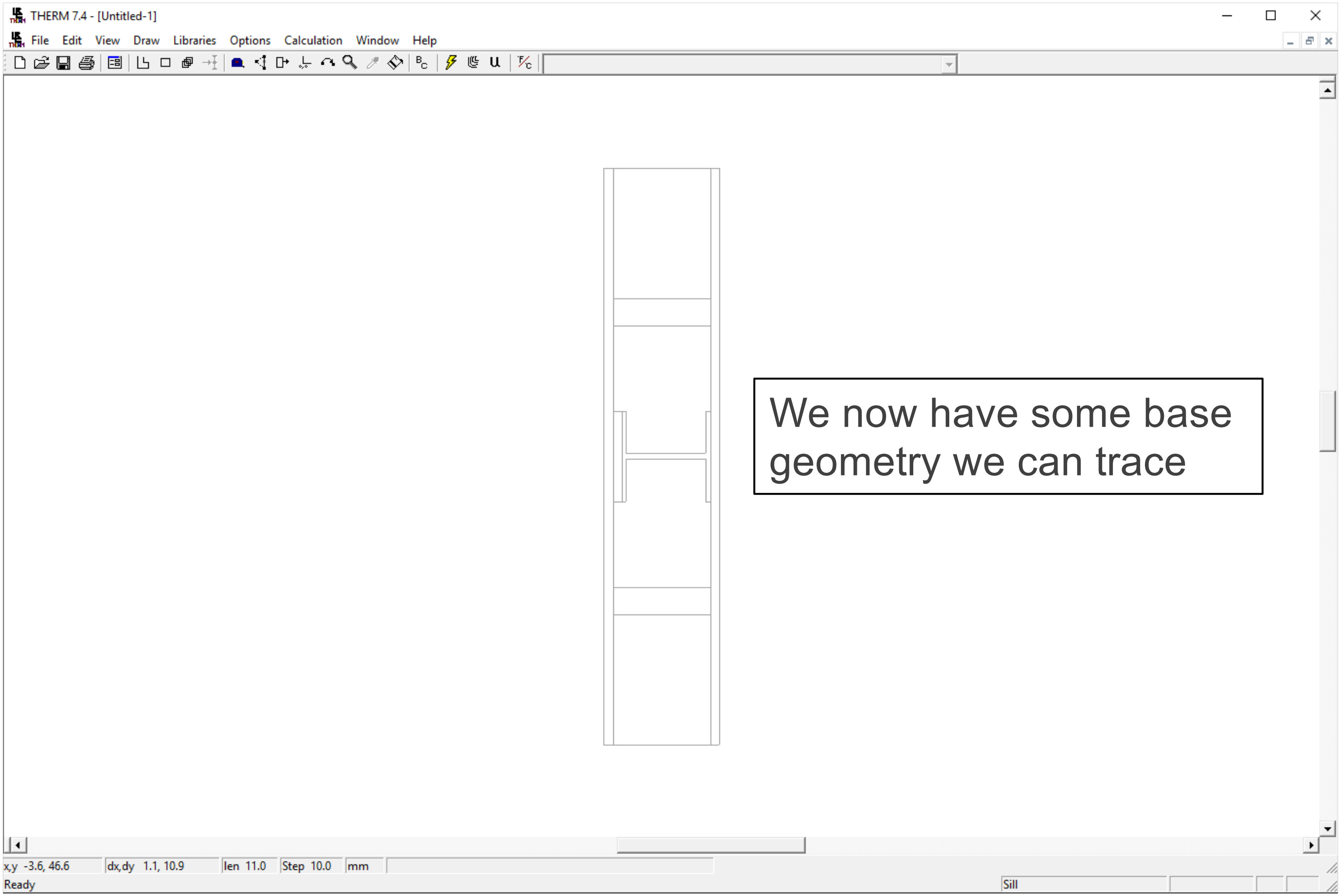


NOTE: you can bring geometry straight from CAD, but be very sure that it is clean geometry with no overlaps or gaps.



Click Browse to find the file you want to use

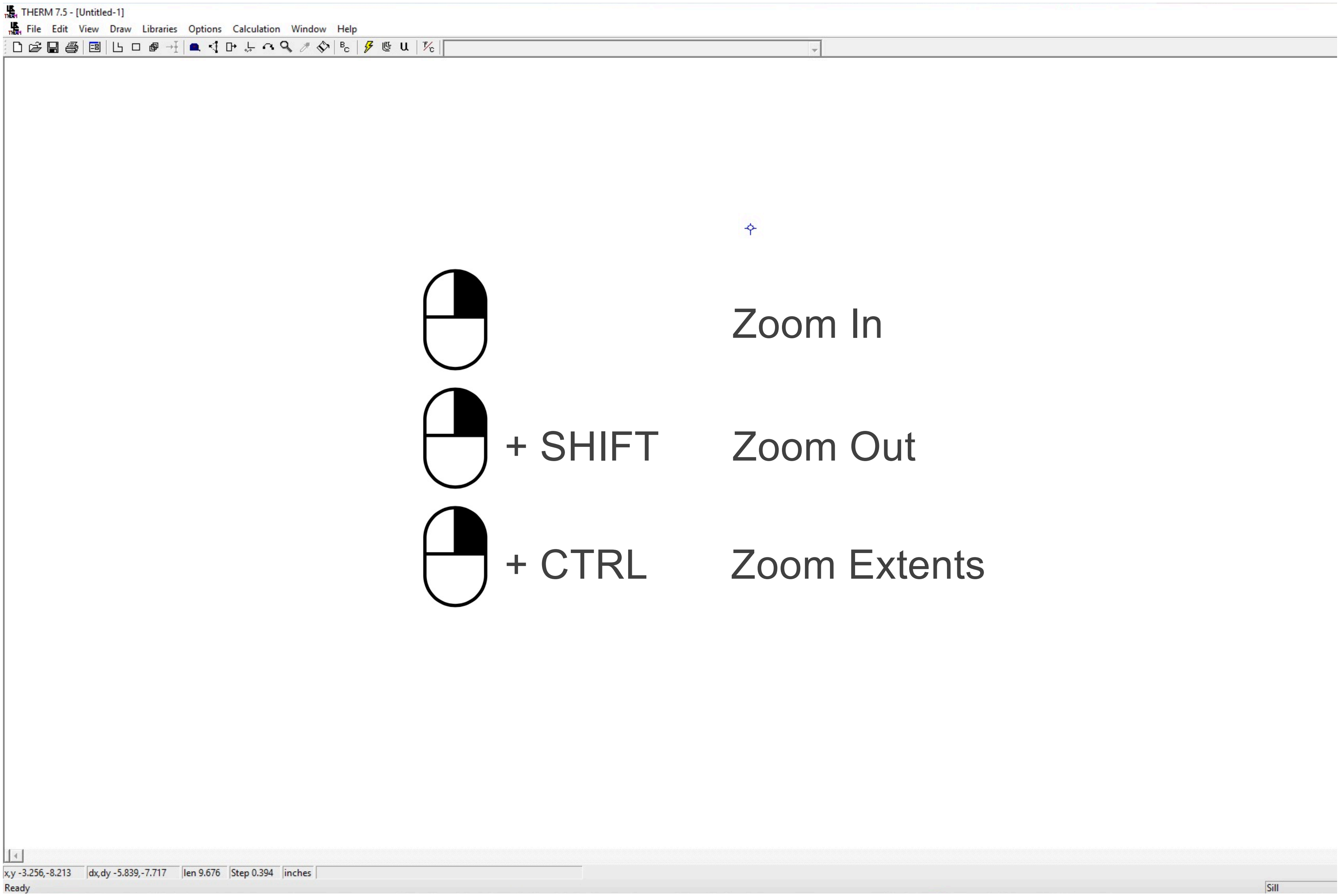

THERM 7.4 - [Untitled-1]
File
Edit
View
Draw
Libraries
Options
Calculation
Window
Help
New Ctrl+N
Open... Ctrl+O
Open
« .psf › Home › Dropbox › PAE SP 16 › PAE 810 Weekly Lectures (PPT) › 07 THERM ›
Search 07 THERM
Organize
New folder
Quick access
Desktop
Downloads
Documents
Pictures
Dropbox
bldgtyp
02 PERMIT
Desktop
lib
Revit
OneDrive
This PC
Network
Homegroup
Name
Date modified
Type
Size
Screen Shots
3/7/16 3:04 PM
File folder
Plan Outside Corner
Steel Column
Click 'Steel Column.dxf'
File name:
Steel Column
DXF(*.dxf), BMP(*.bmp)
Open
Cancel
x,y -89.8, 55.5
dx,dy -44.2, 46.2
len 63.9
Step 10.0
mm
Properties for gas
Sill

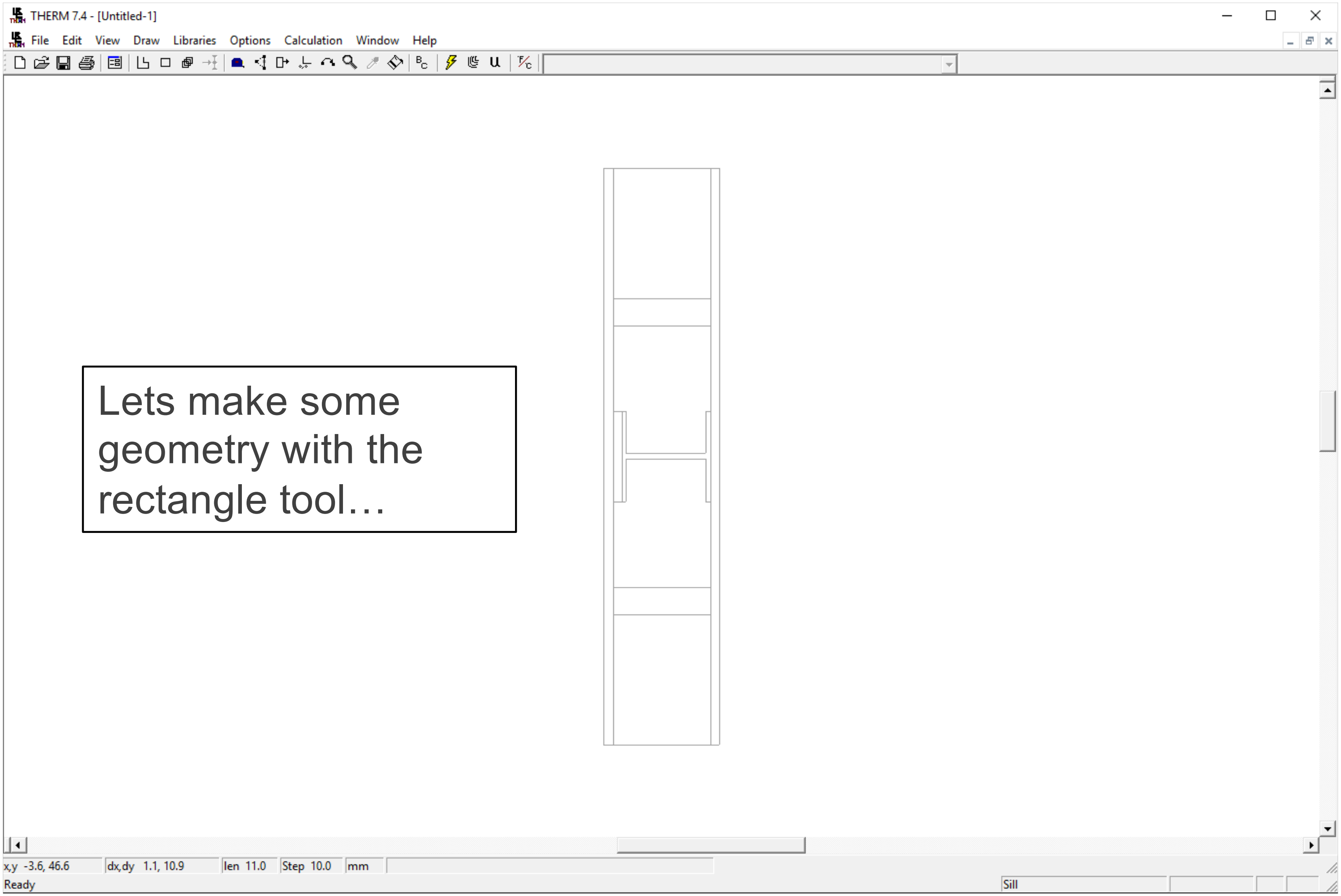


We now have some base geometry we can trace

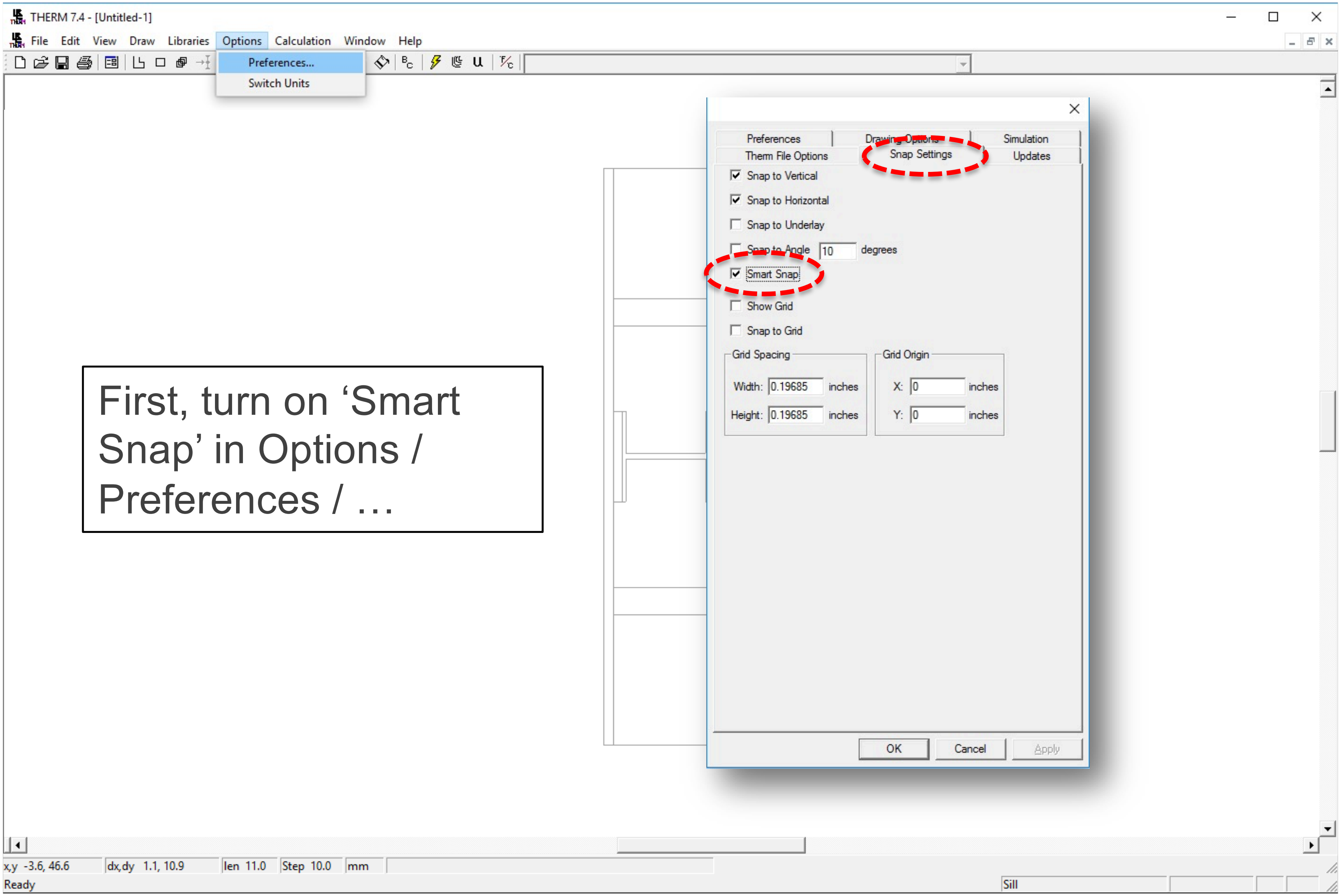
Creating Geometry

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

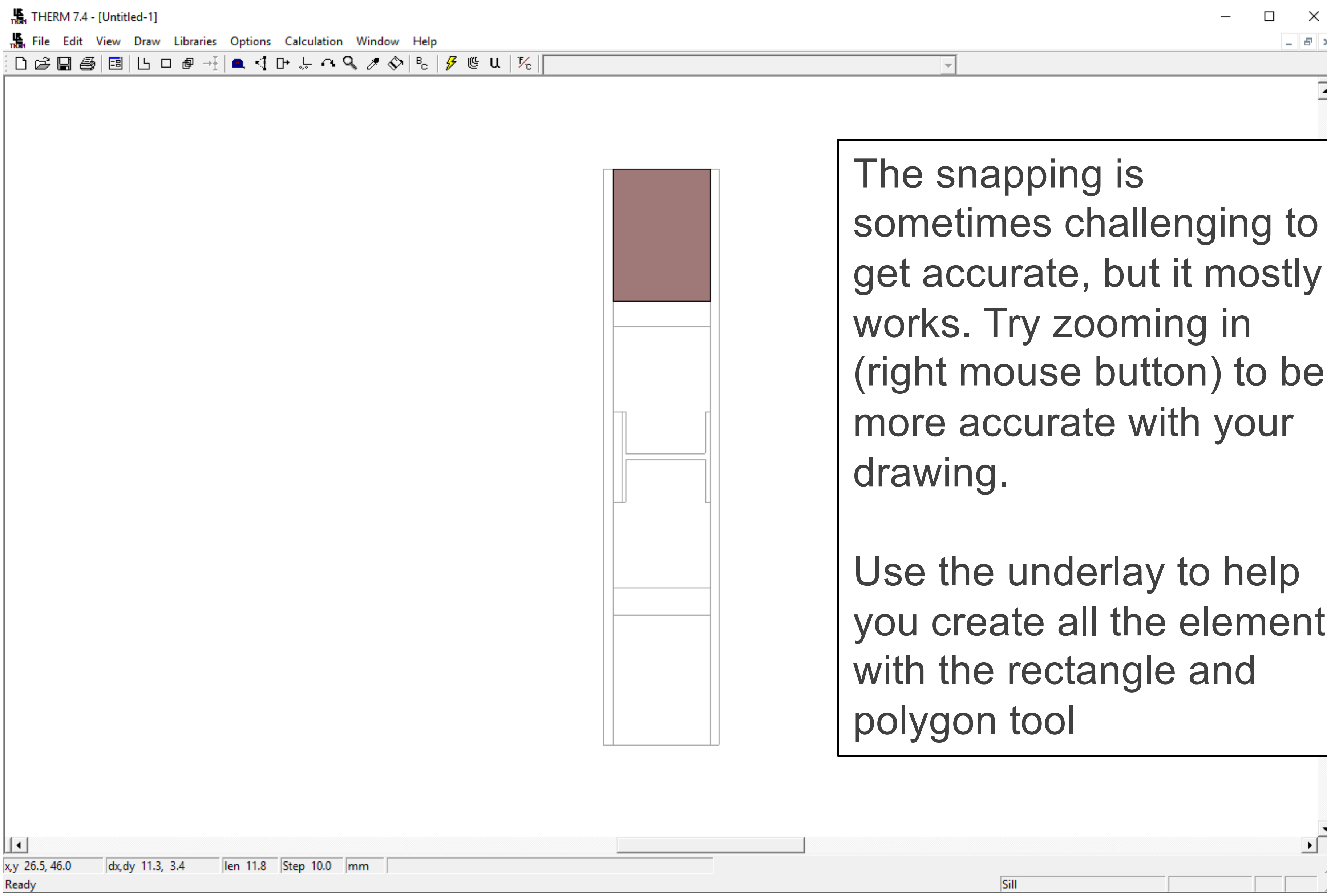

THERM 7.5 - [Untitled-1]
File Edit View Draw Libraries Options Calculation Window Help
Zoom In
+ SHIFT
Zoom Out
+ CTRL
Zoom Extents
x,y -3.256,-8.213
dx,dy -5.839,-7.717
len 9.676
Step 0.394
inches
Ready
Sill



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