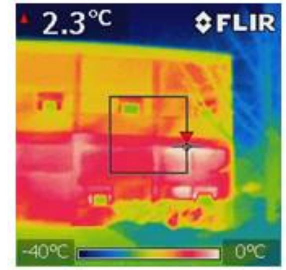
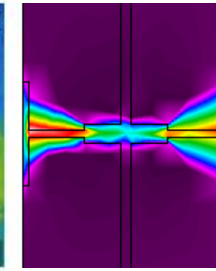
CAE 331/513
Building Science
Fall 2014



Week 11: November 6, 2014
Cooling loads (continued)

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Dr. Brent Stephens, Ph.D.
Civil, Architectural and Environmental Engineering
Illinois Institute of Technology
brent@iit.edu

Notes on HW 5

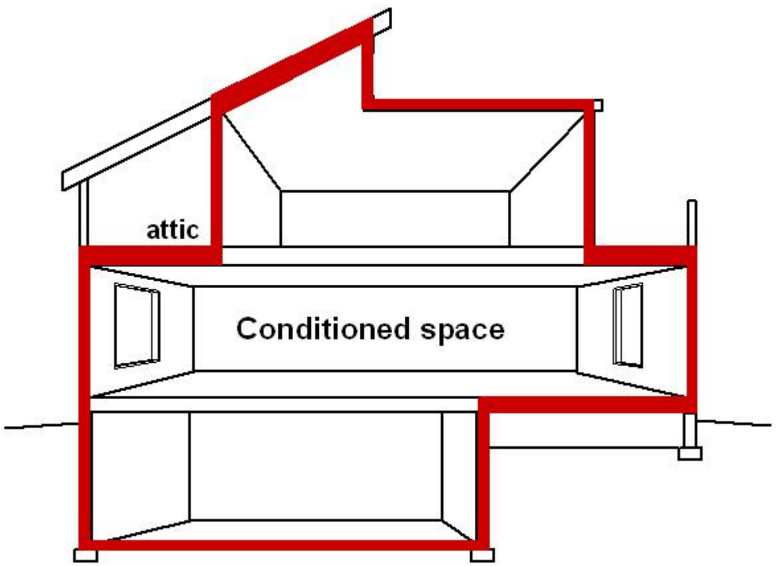
1. Find the design heat load for a building with a total heat loss coefficient K_{tot} = 5000 BTU/(hr·°F) [2640 W/K] if the indoor design temperature is 70°F (21.1°C) and outdoor design temperature is 0°F (-17.8°F) if there are 10 kW of heat gain from equipment that will be left on at all times. **(10 points)**

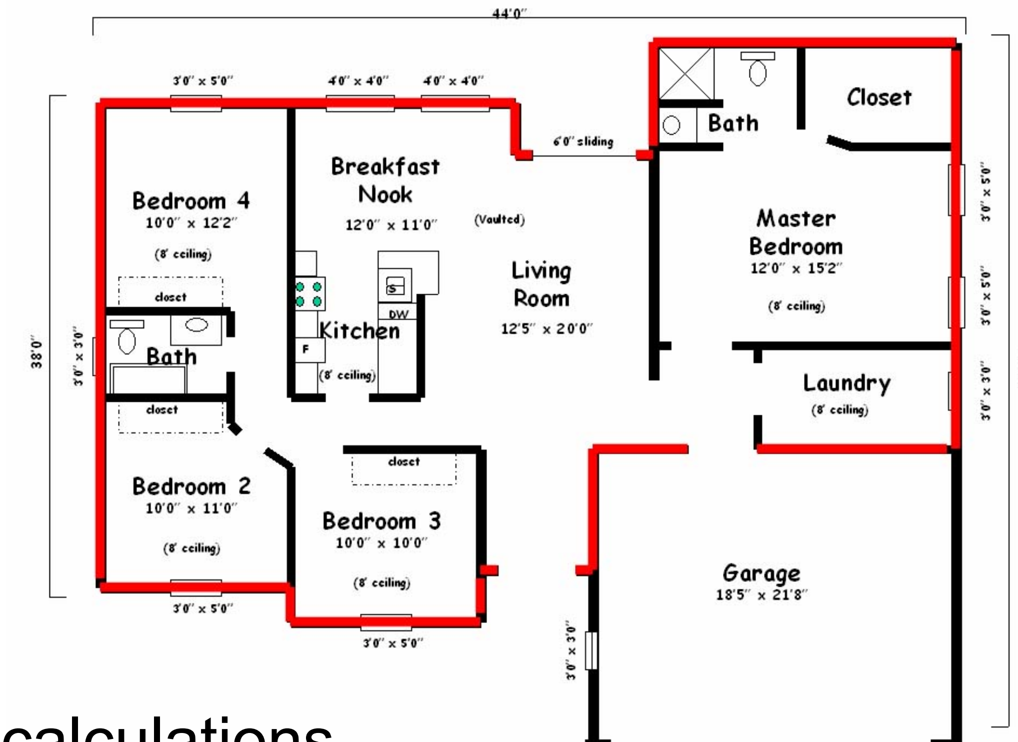
Should be 0°F (-17.8°C)

Last time

- Heating load calculations $$Q_{h,\max} = K_{total}(T_{in} - T_{out}) - Q_{gain}$$

A note on building **envelopes** or **enclosures**:



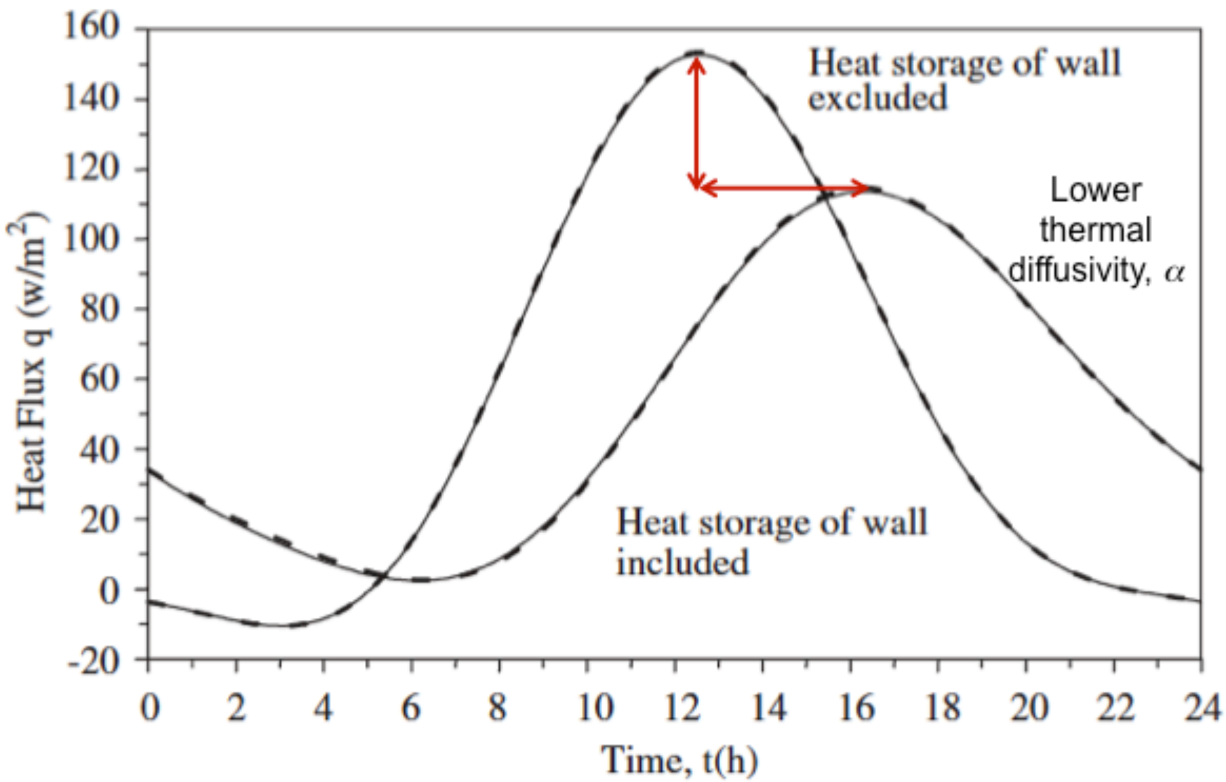


- Introduced cooling load calculations

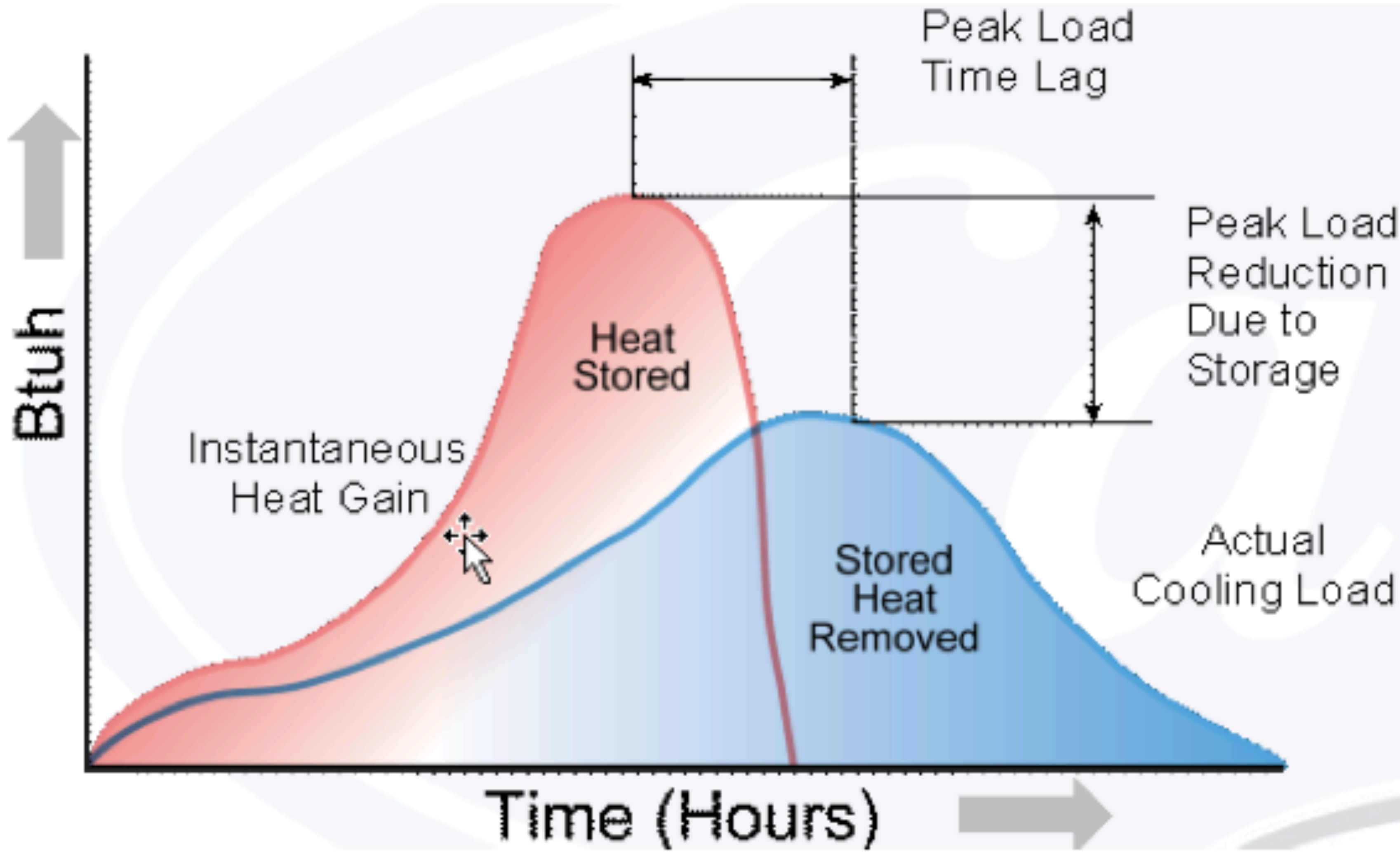
Cooling load calculations

- Must account for thermal mass
  - Thermal gains, storage, and release
  - Radiation versus convection/conduction

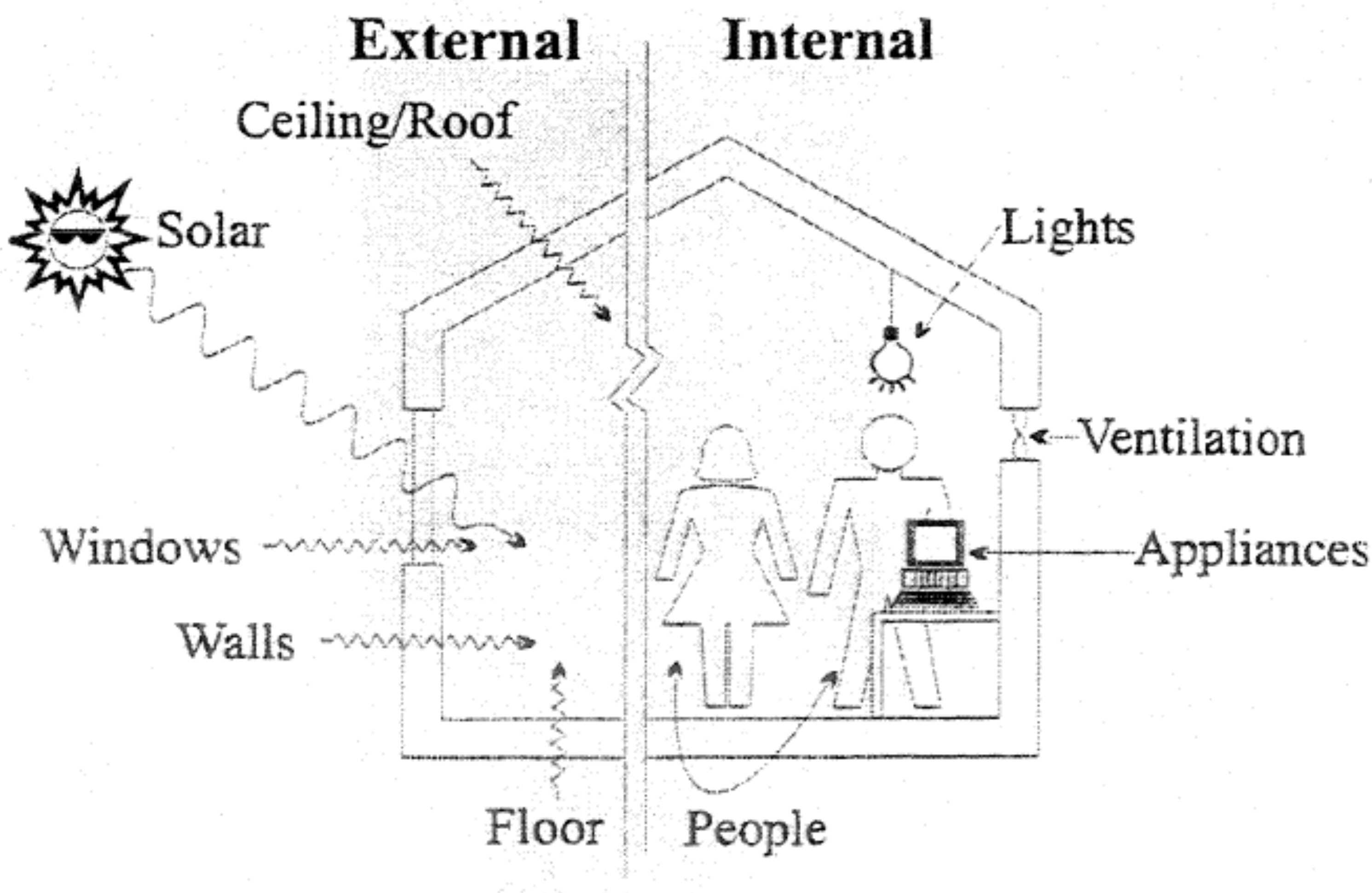
$$\alpha = \frac{k}{\rho C_p} \quad [\mathrm{m^2/s}]$$



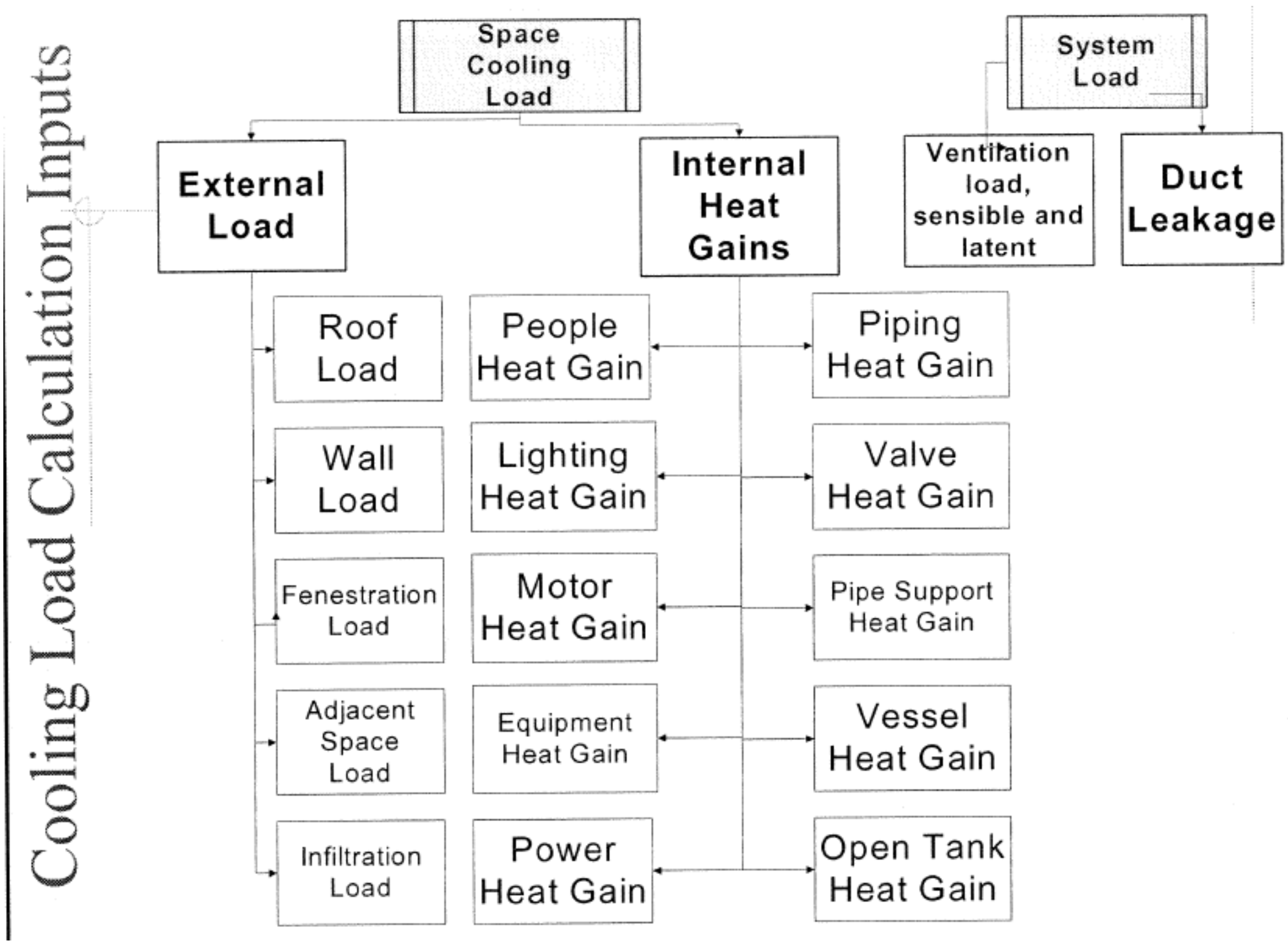
Cooling load calculations and thermal mass



Internal and external inputs for cooling load calculations



Inputs for all cooling load calculations

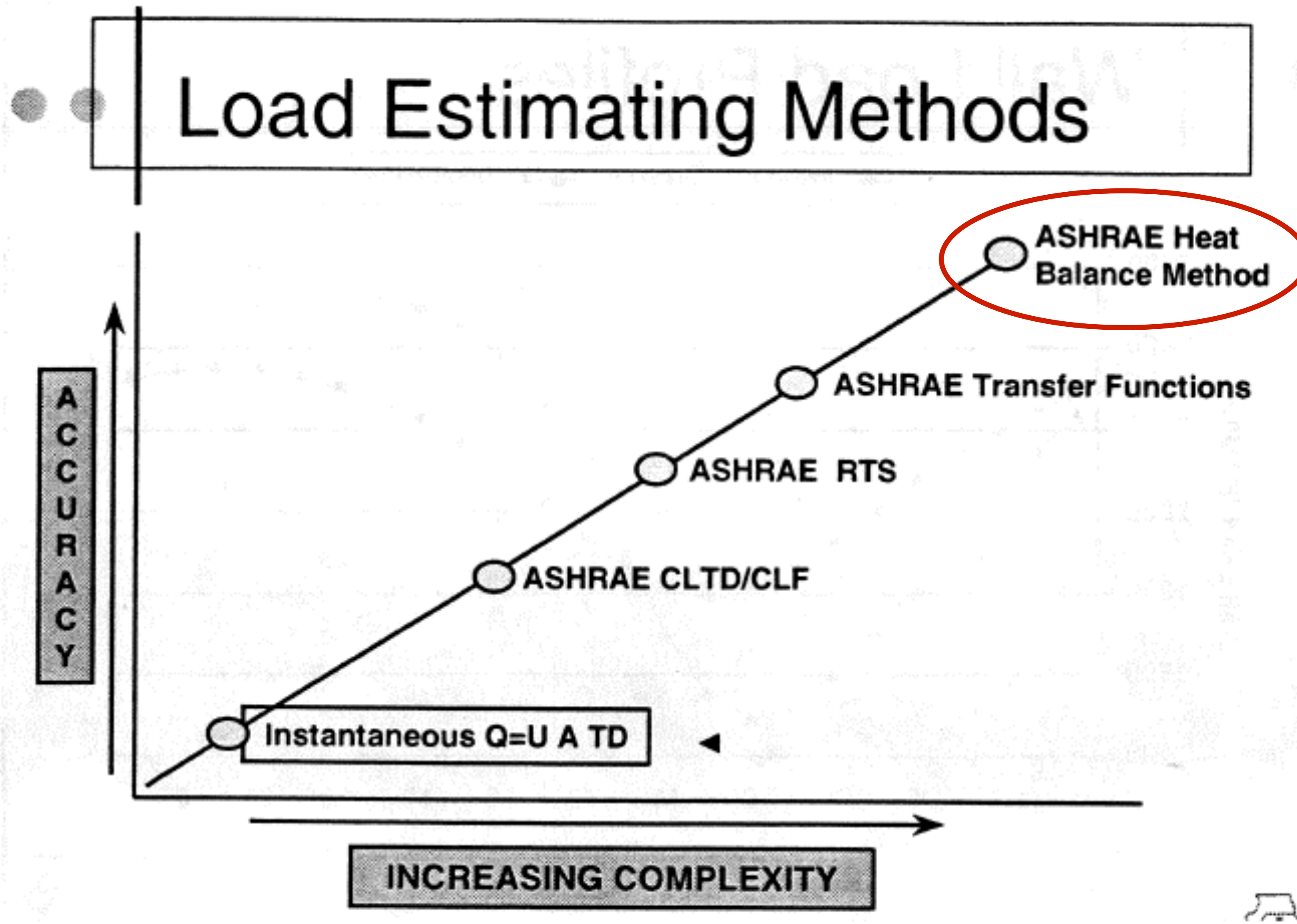


There are several cooling load calculation methods

- Transfer Function
- Total Equivalent Temperature Difference (TETD)
- Cooling Load Temperature Difference / Cooling Load Factor (CLTD/CLF)
- Heat Balance Method (HBM)
- Radiant Time-Series Method (RTSM)

- They all rely on spreadsheets and/or computer programs

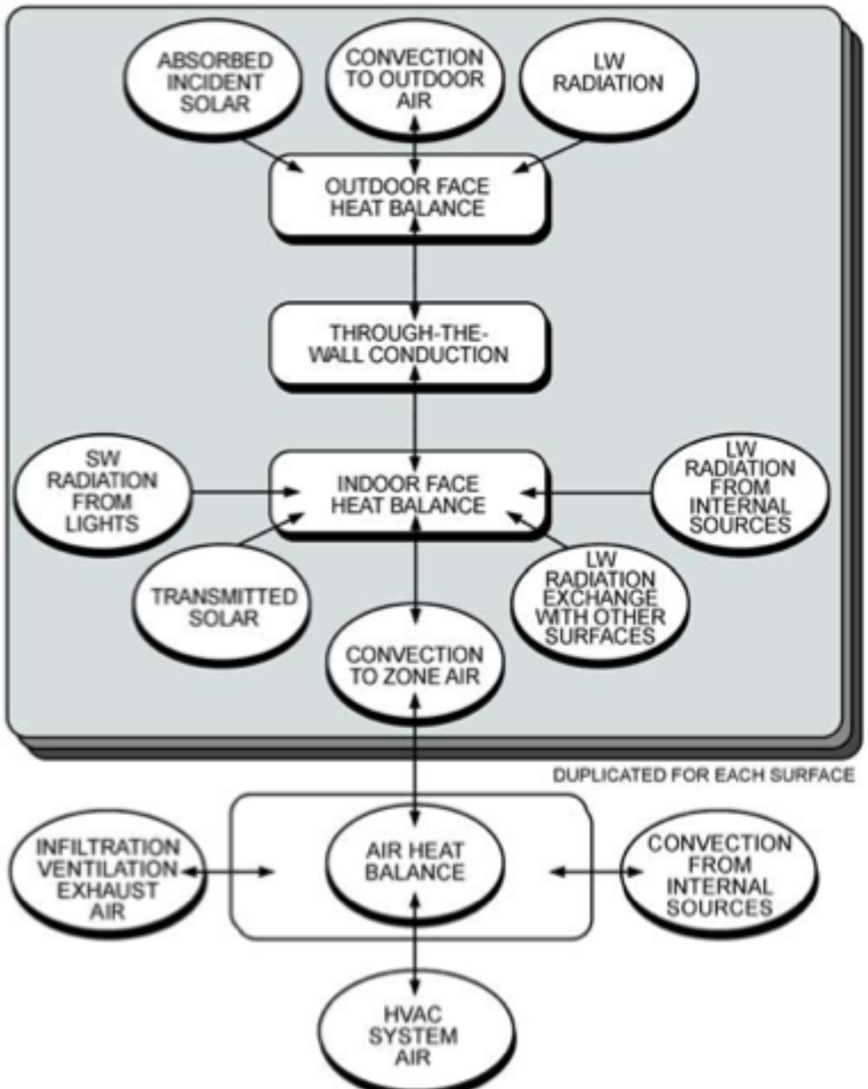
Accuracy of methods



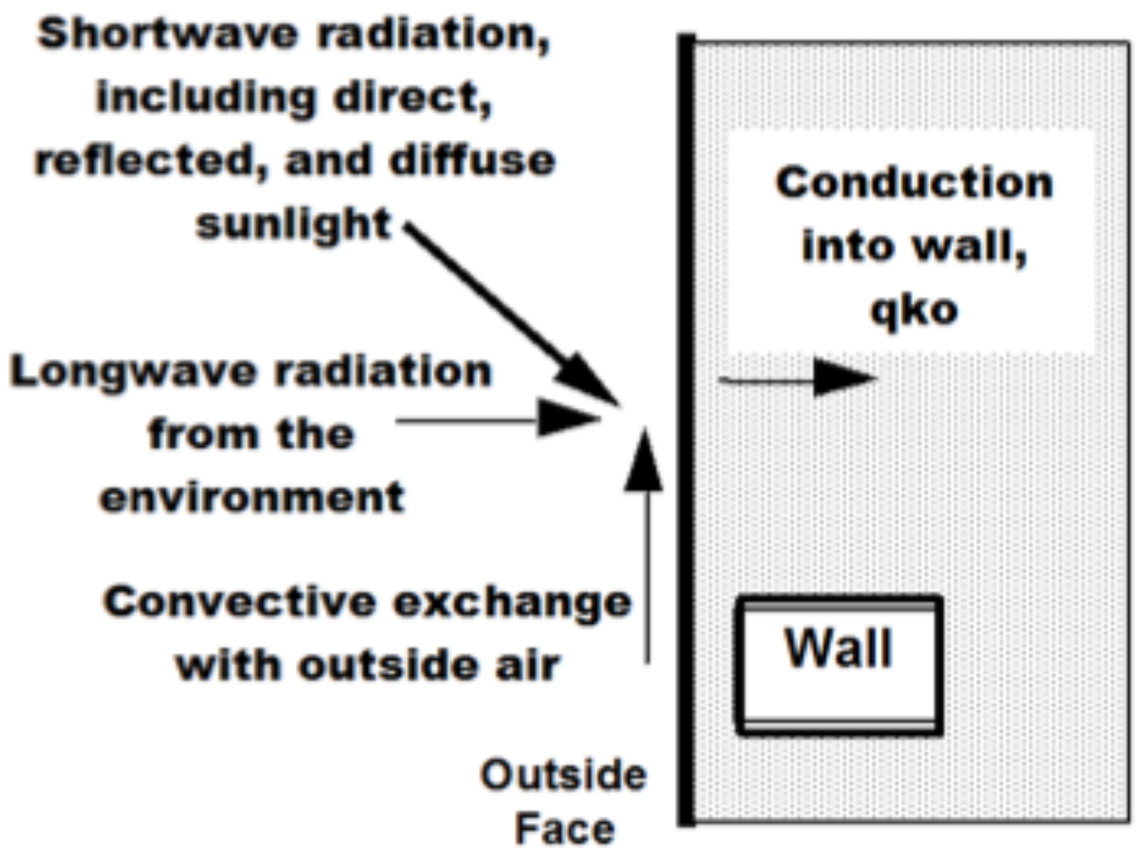
Heat balance method (HBM)

- HBM is based on the law of conservation of energy
  - A set of energy balance equations for an enclosed space is solved simultaneously for unknown surface and air temperatures
- Consists of three important energy balance equations:
  - Outside surfaces heat balance
  - Inside surfaces heat balance
  - Indoor air heat balance
    - The energy balance is based on the fundamental heat transfer equations we already know
- Calculations are initiated by hourly outdoor weather data
  - Design day meteorological data (or full year)
- It is more fundamentally linked than other approaches
  - Makes fewer assumptions than the other methods
    - But is more complex to solve
  - Provides basis for modern energy simulation programs

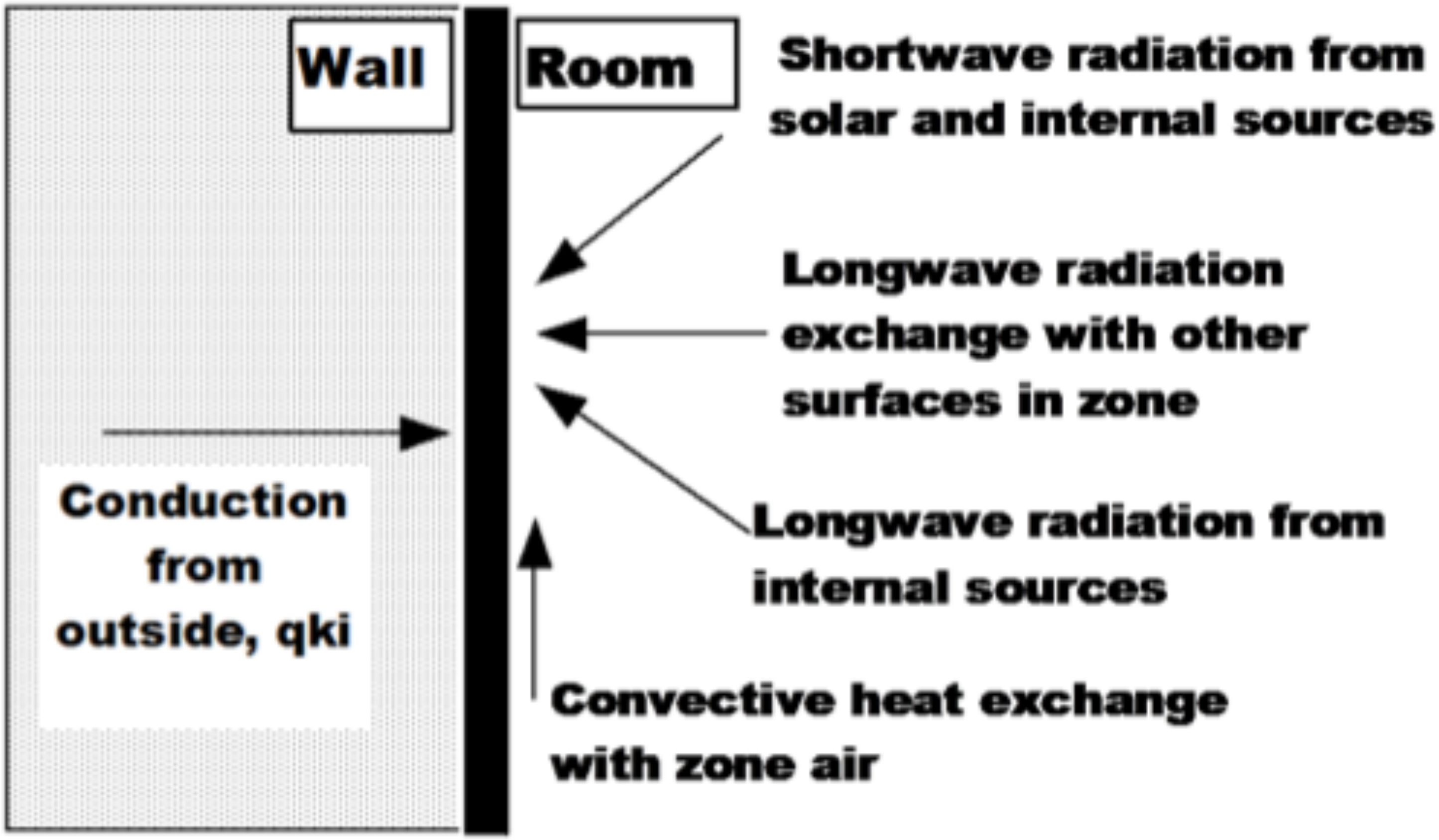
Heat balance method (HBM)



Heat balance method (HBM): Outside surface heat balance

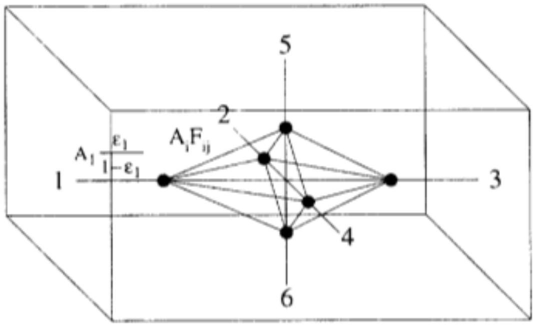


Heat balance method (HBM): Inside surface heat balance



Heat balance method (HBM): Indoor air heat balance

$$C_z \frac{dT_z}{dt} = \sum_{i=1}^{N_{sl}} \dot{Q}_i + \sum_{i=1}^{N_{surfaces}} h_i A_i \left(T_{si} - T_z\right) + \sum_{i=1}^{N_{zones}} \dot{m}_i C_p \left(T_{zi} - T_z\right) + \dot{m}_{\inf} C_p \left(T_\infty - T_z\right) + \dot{Q}_{sys}$$



where:

$\sum_{i=1}^{N_{sl}} \dot{Q}_i$ = sum of the convective internal loads

$\sum_{i=1}^{N_{surfaces}} h_i A_i \left(T_{si} - T_z\right)$ = convective heat transfer from the zone surfaces

$\dot{m}_{\inf} C_p \left(T_\infty - T_z\right)$ = heat transfer due to infiltration of outside air

$\sum_{i=1}^{N_{zones}} \dot{m}_i C_p \left(T_{zi} - T_z\right)$ = heat transfer due to interzone air mixing

$\dot{Q}_{sys}$ = air systems output

$C_z \frac{dT_z}{dt}$ = energy stored in zone air

$C_z = \rho_{air} C_p$

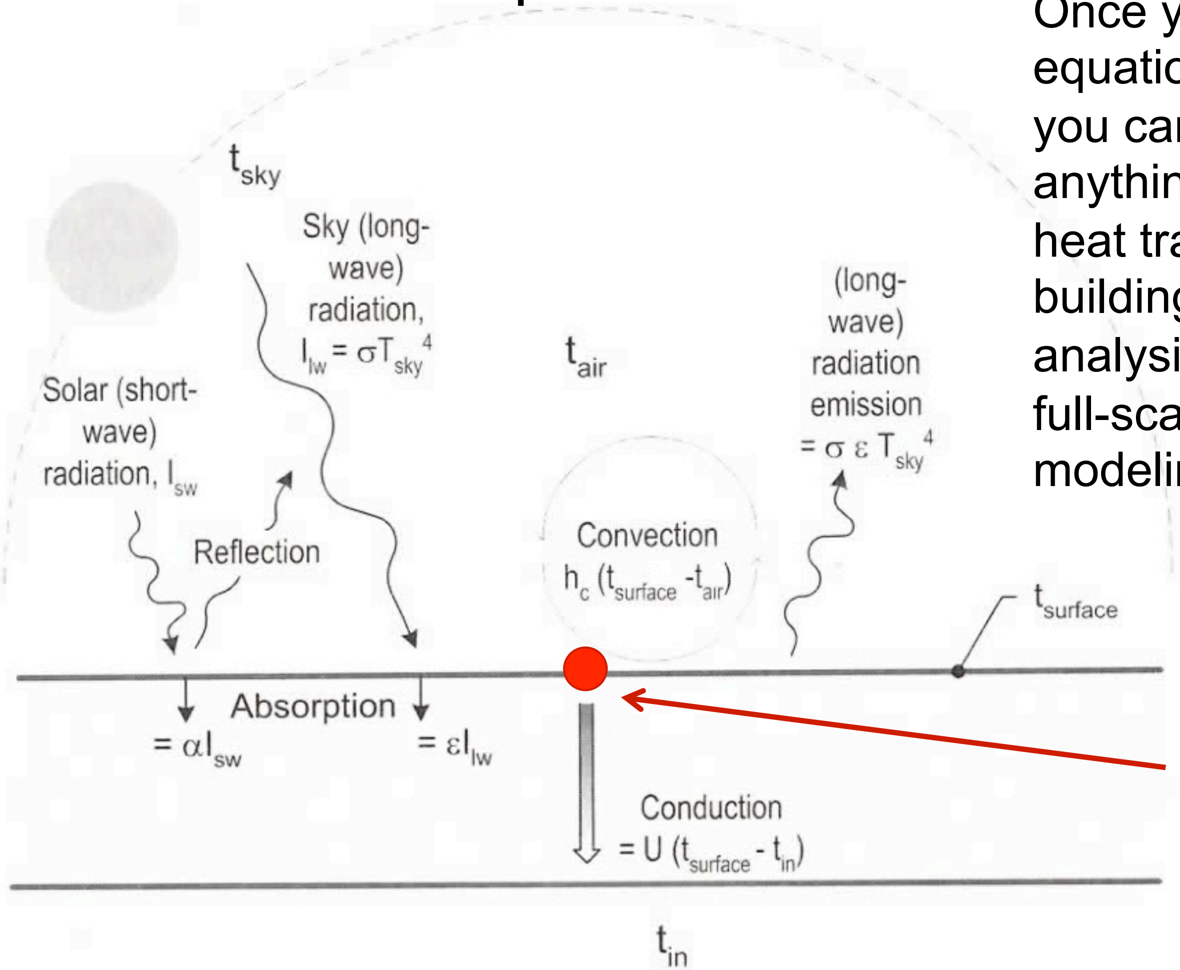
ρ_{air} = zone air density

C_p = zone air specific heat

$$-\dot{Q}_{sys} = \sum_{i=1}^{N_{sl}} \dot{Q}_i + \sum_{i=1}^{N_{surfaces}} h_i A_i \left(T_{si} - T_z\right) + \sum_{i=1}^{N_{zones}} \dot{m}_i C_p \left(T_{zi} - T_z\right) + \dot{m}_{\inf} C_p \left(T_\infty - T_z\right)$$

HBM: Surface energy balance

- Exterior surface example: roof



Once you have this equation described, you can do just about anything regarding heat transfer in building enclosure analysis, leading into full-scale energy modeling

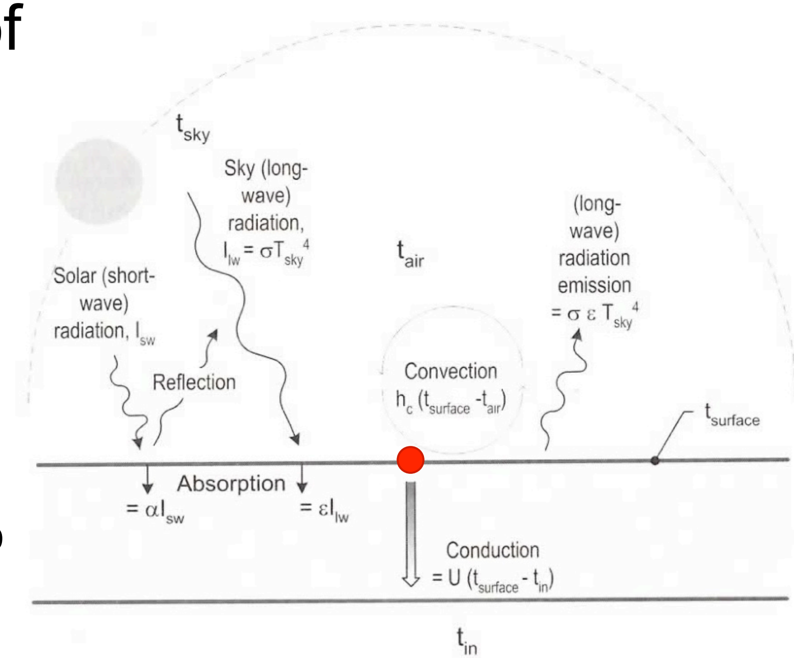
Steady-state energy balance at this exterior surface:
What enters must also leave (no storage)

$$\boxed{q_{solar} + q_{longwaveradiation} + q_{convection} - q_{conduction} = 0}$$

HBM: Surface energy balance

- Exterior surface example: roof

$$\boxed{\sum q = 0}$$



We can use this equation to estimate indoor and outdoor surface temperatures

At steady state, net energy balance is zero

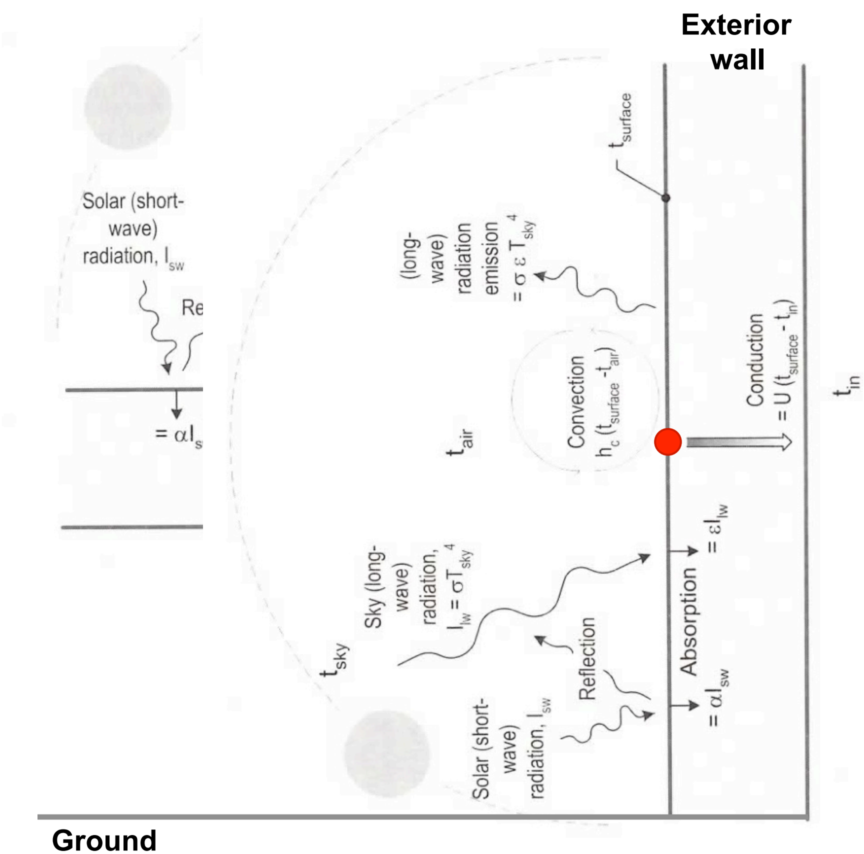
- Because of T^4 term, often requires iteration

Solar gain	αI_{solar}	$q_{sw,solar}$
Surface-sky radiation	$+\varepsilon_{surface}\sigma F_{sky}(T_{sky}^4 - T_{surf}^4)$	$+q_{lw,surface-sky}$
Convection on external wall	$+h_{conv}(T_{air} - T_{surface})$	$+q_{convection}$
Conduction through wall	$-U(T_{surface} - T_{surface,interior}) = 0$	$-q_{conduction} = 0$

HBM: Surface energy balance

- Similarly, for a vertical surface:

$$q_{solar} + q_{lwr} + q_{conv} - q_{cond} = 0$$



$$\alpha I_{solar}$$

$$+\varepsilon_{surface} \sigma F_{sky} (T_{sky}^4 - T_{surface,ext}^4)$$

$$+\varepsilon_{surface} \sigma F_{ground} (T_{ground}^4 - T_{surface,ext}^4)$$

$$+h_{conv} (T_{air} - T_{surface,ext})$$

$$-U (T_{surface,ext} - T_{surface,int}) = 0$$

HBM: Combining surface energy balances

- For an example room like this, you would setup a system of equations where the temperature at each node (either a surface or within a material) is unknown
  - 12 material nodes + 1 indoor air node

Heat Xfer @ external surfaces:
Radiation and convection

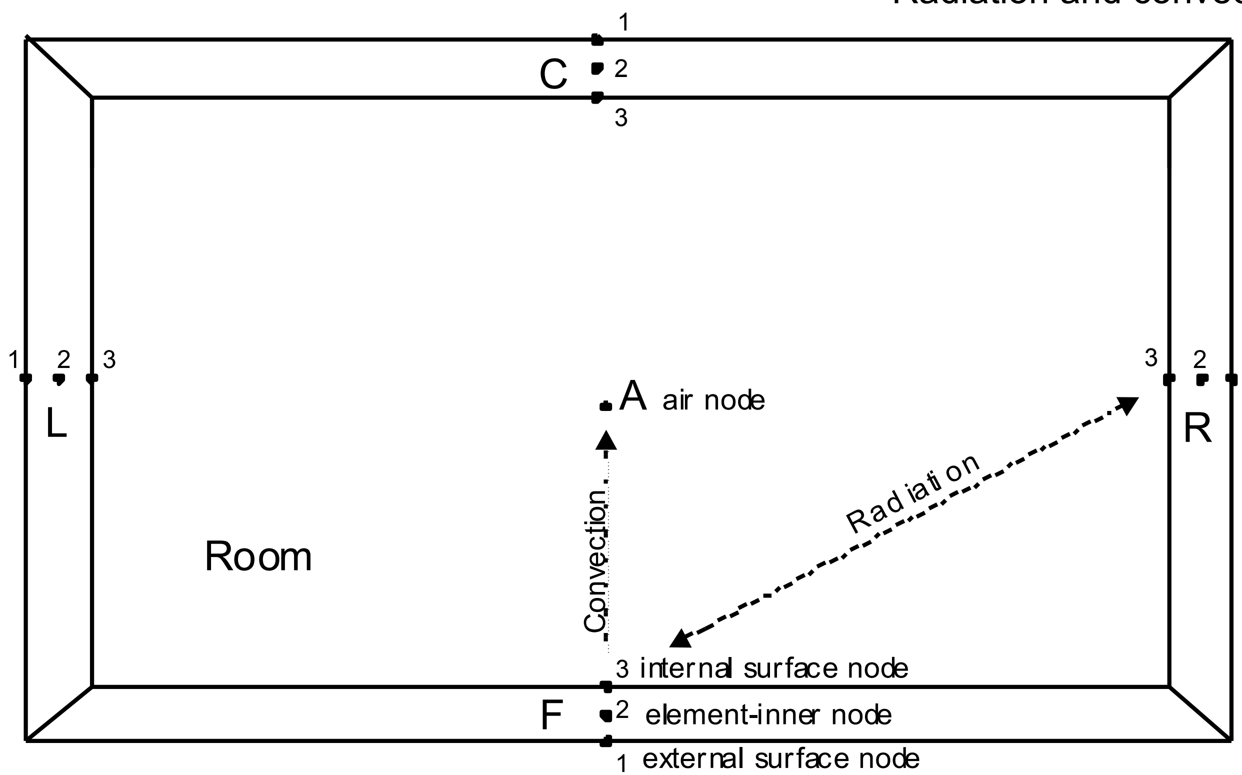
At surface nodes:

$$\sum q = 0$$

At nodes inside materials:

$$mc_p \frac{dT}{dt} = \sum q_{at\ boundaries}$$

Based on density and heat capacity of material…



Modeling thermal mass: Unsteady conduction

- Conduction and thermal mass together can be modeled using a **lumped capacitance** approach in 1-dimension:

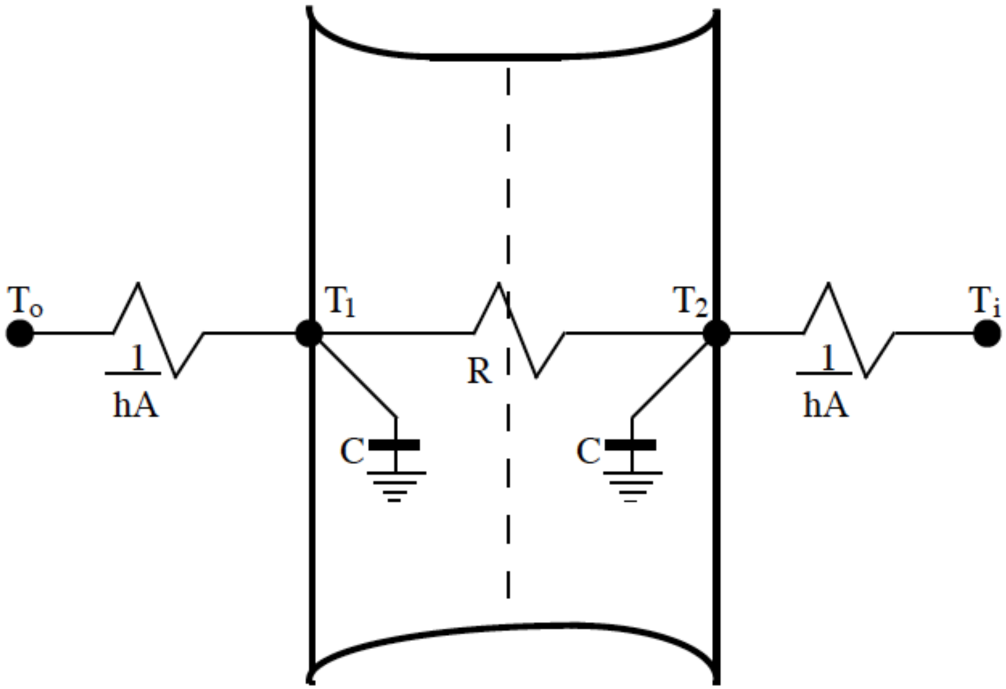


Figure 9. Two Node State Space Example.

$$C\frac{dT_1}{dt} = hA\left(T_o - T_1\right) + \frac{T_2 - T_1}{R}$$

$$C\frac{dT_2}{dt} = hA\left(T_i - T_2\right) + \frac{T_1 - T_2}{R}$$

where:

$$R = \frac{\ell}{kA},$$

$$C = \frac{\rho c_p \ell A}{2}$$

Lumped capacitance model

- Wall example: Exterior surface balance at T_1 changes

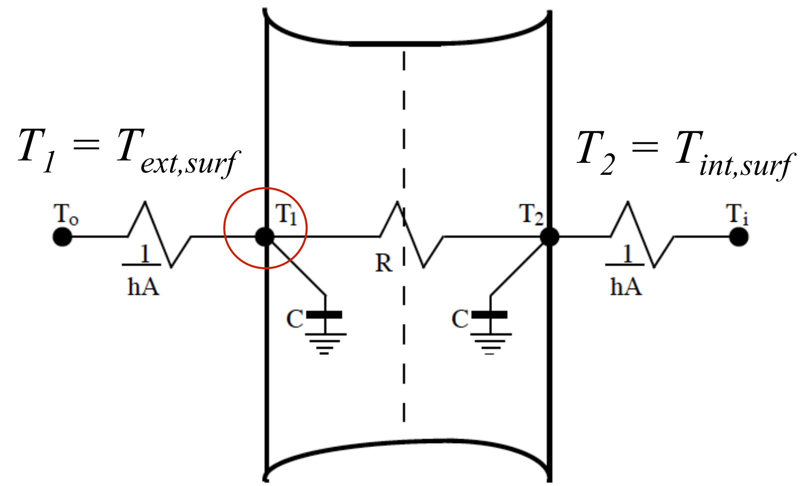


Figure 9. Two Node State Space Example.

From:

$$q_{sw,solar} + q_{lw,surface-sky} + q_{lw,surface-ground} + q_{convection} - q_{conduction} = 0$$

To:

$$q_{sw,solar} + q_{lw,surface-sky} + q_{lw,surface-ground} + q_{convection} - q_{conduction} = \rho C_p \frac{L}{2} \frac{dT}{dt}$$

Lumped capacitance model

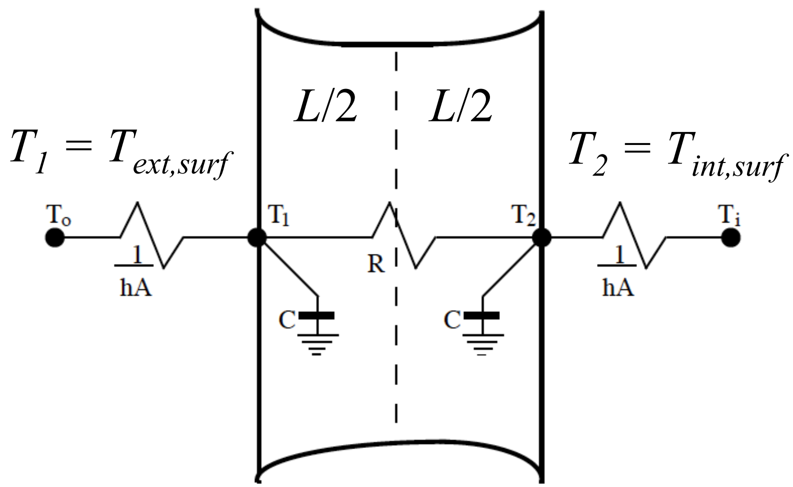


Figure 9. Two Node State Space Example.

Steady state surface energy balance…

$$\alpha I_{solar} + \varepsilon_1 \sigma F_{sky}(T_{sky}^4 - T_1^4) + \varepsilon_1 \sigma F_{ground}(T_{ground}^4 - T_1^4) + h_{conv}(T_{air} - T_1) - U(T_1 - T_2) = 0$$

…becomes a time-varying surface energy balance:

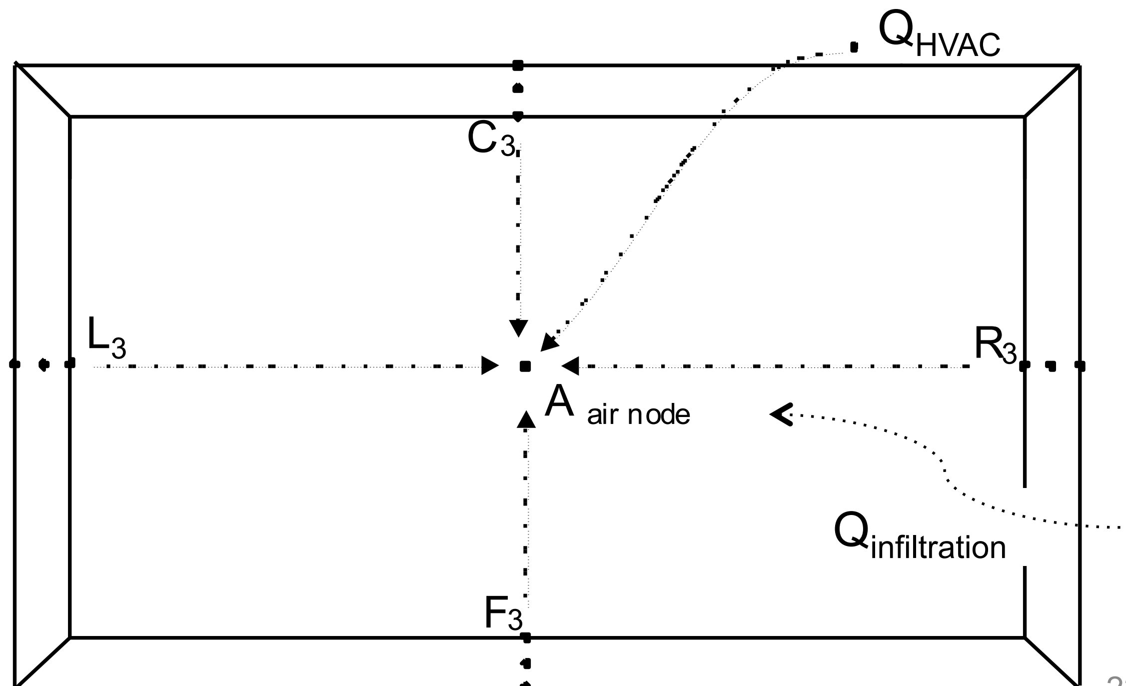
$$\alpha I_{solar} + \varepsilon_1 \sigma F_{sky}(T_{sky}^4 - T_1^4) + \varepsilon_1 \sigma F_{ground}(T_{ground}^4 - T_1^4) + h_{conv}(T_{air} - T_1) - U(T_1 - T_2) = \frac{\rho C_p}{\Delta t}\frac{L}{2}(T_1^n - T_1^{n-1})$$

HBM: Air energy balance

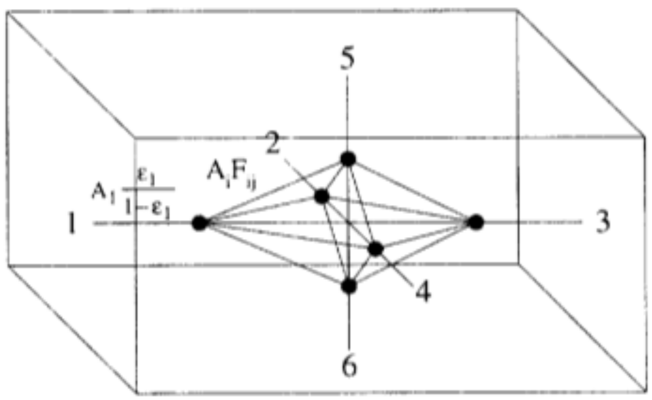
- To get the impact on indoor air temperature (and close the system of equations)
  - Write an energy balance on the indoor air node
  - Air impacted directly only by convection (bulk and/or surface)

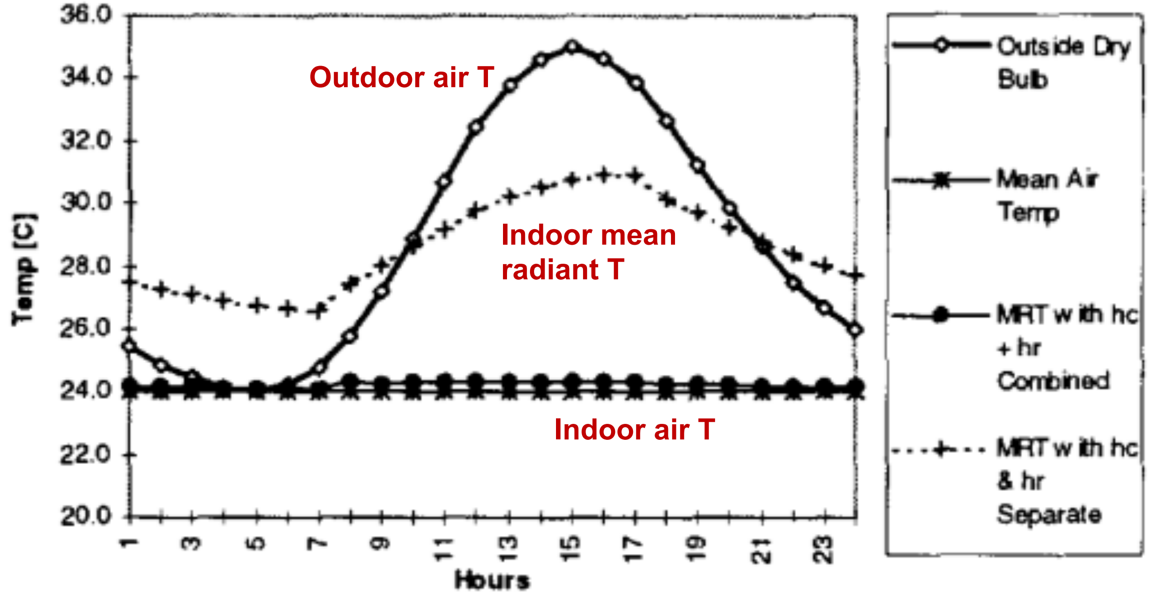
$$(V_{room}\rho_{air}c_{p,air})\frac{dT_{air,in}}{dt} = \sum_{i=1}^{n} h_i A_i \left(T_{i,surf} - T_{air,in}\right) + \dot{m}c_p\left(T_{out} - T_{air,in}\right) + Q_{HVAC}$$

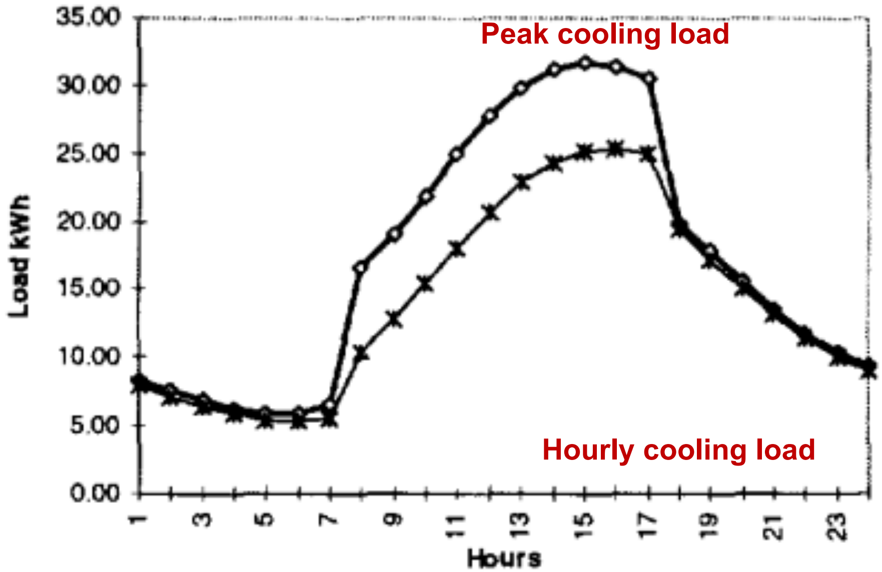
In plain English:
The change in indoor air temperature is equal to the sum of convection from each interior surface plus outdoor air delivery (by infiltration or dedicated outdoor air supply), plus the bulk convective heat transfer delivered by the HVAC system



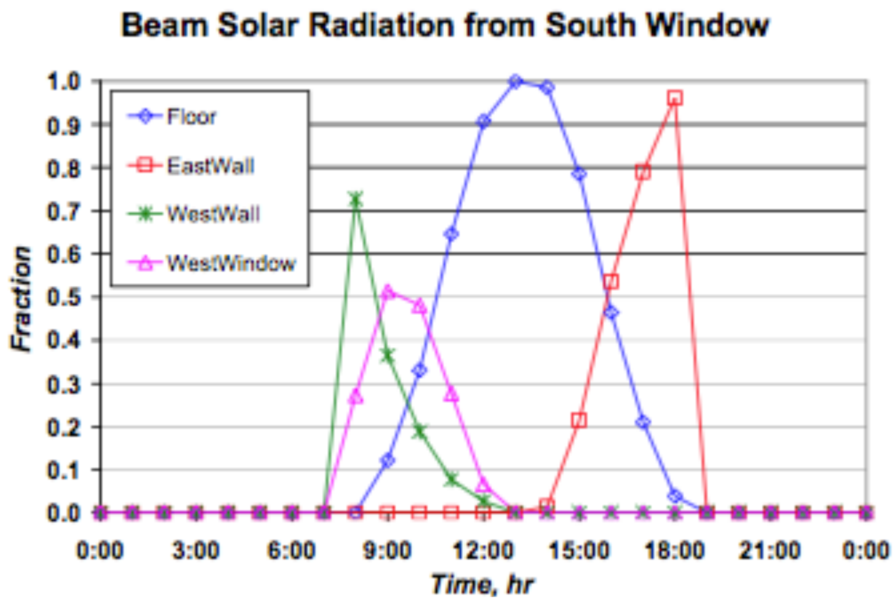
Using HBM to calculate peak loads

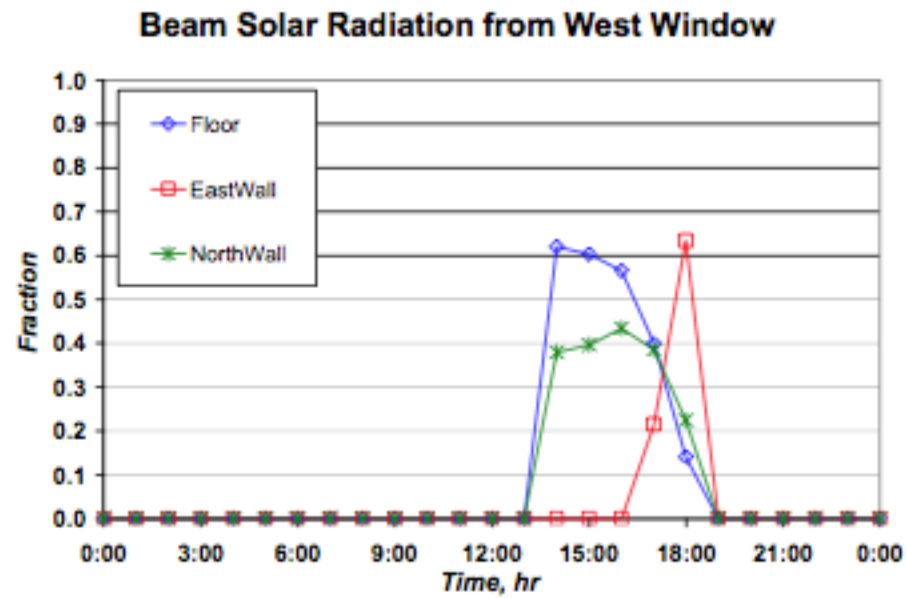


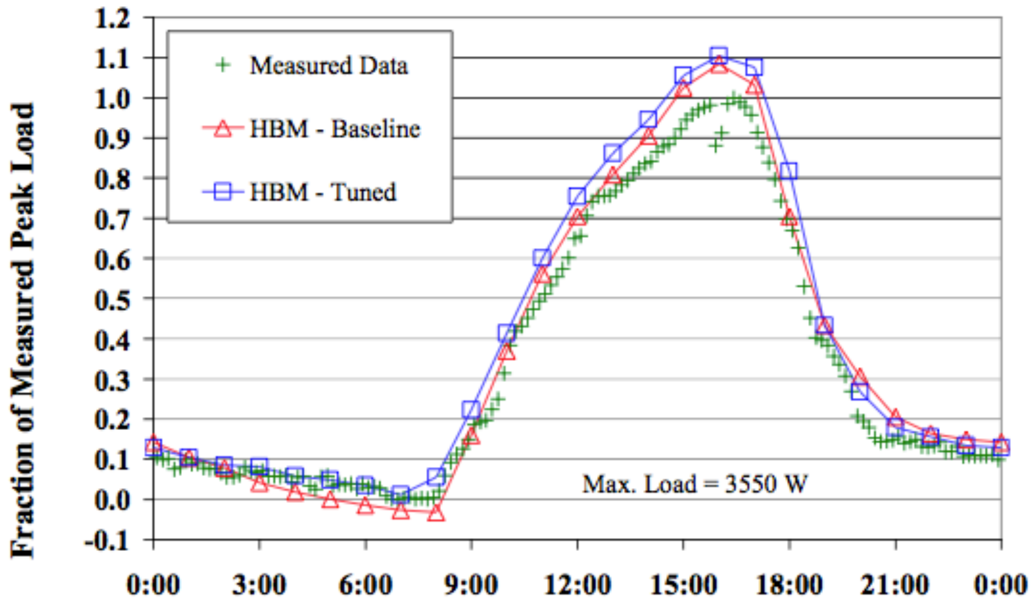




Using HBM to calculate peak loads



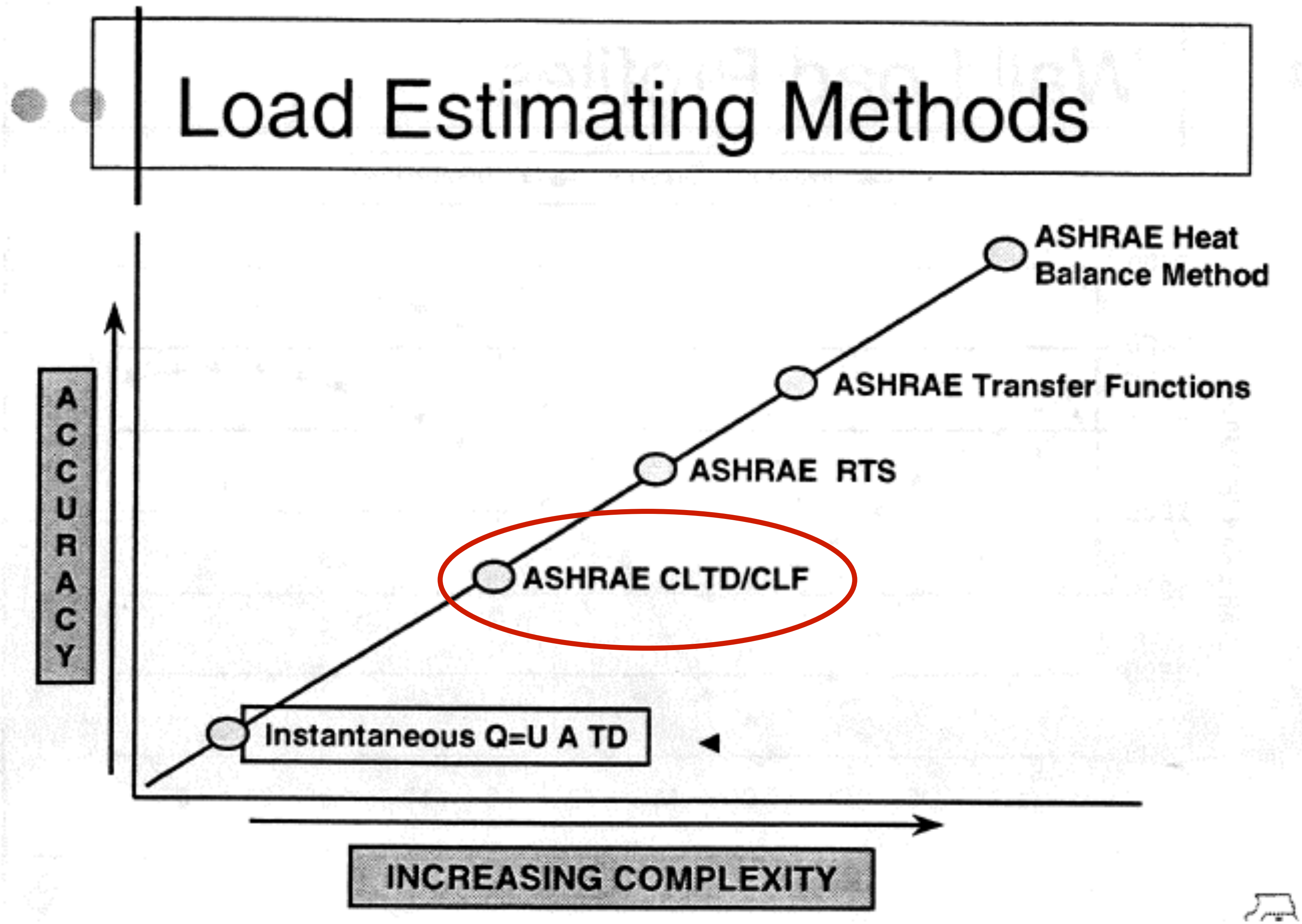




Software tools for load calculations

- These are not done by hand, sometimes by spreadsheet
  - Many use ACCA Manual J
- Most use computer programs
- Big list of programs:
  - http://apps1.eere.energy.gov/buildings/tools_directory/subjects.cfm/pagename=subjects/pagename_menu=whole_building_analysis/pagename_submenu=load_calculation

Accuracy of methods



ASHRAE CLTD/CLF method

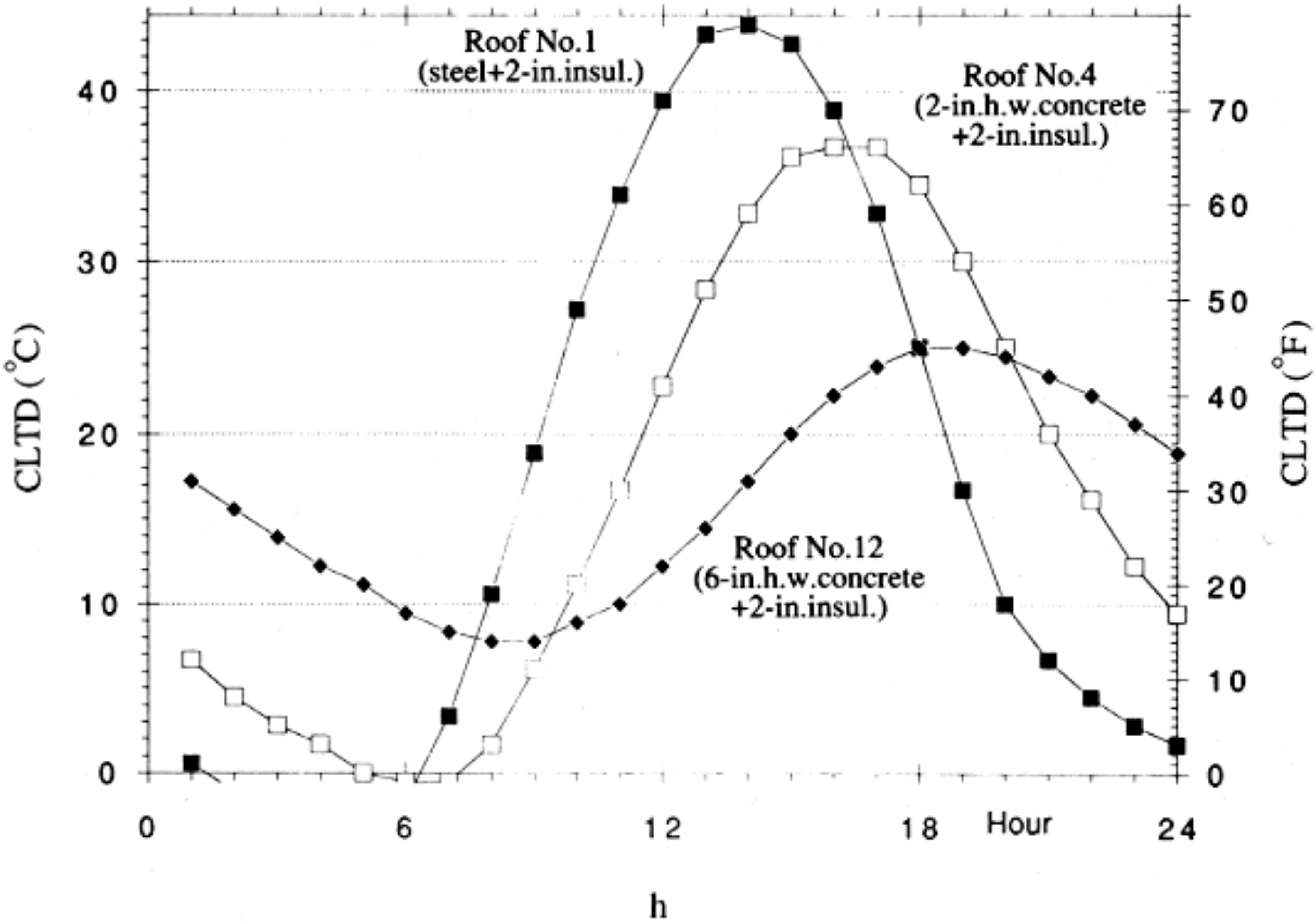
- One method of accounting for periodic responses for conduction and radiation (simpler than others)

- CLTD = cooling load temperature difference [K]
  - The temperature difference that gives the same cooling load when multiplied by UA for a given assembly
  - Calculate these ΔT values for typical constructions and typical temperature patterns
    - Then adjust the conductive load accordingly

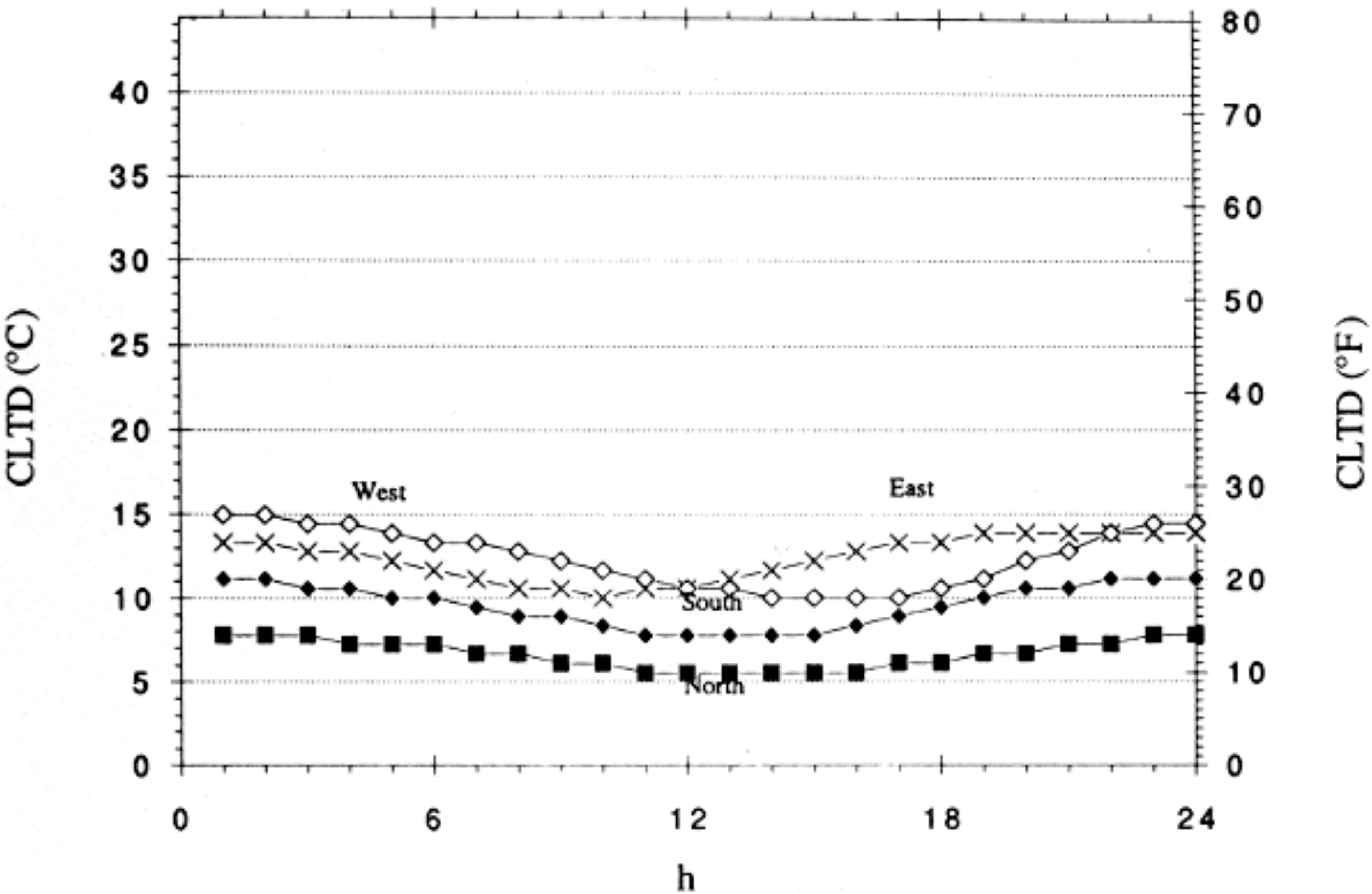
Instead of: $$Q_{cooling,conduction} = UA(T_{out} - T_{in})$$

You use: $$Q_{cooling,conduction} = UA(CLTD_t)$$ at hour t

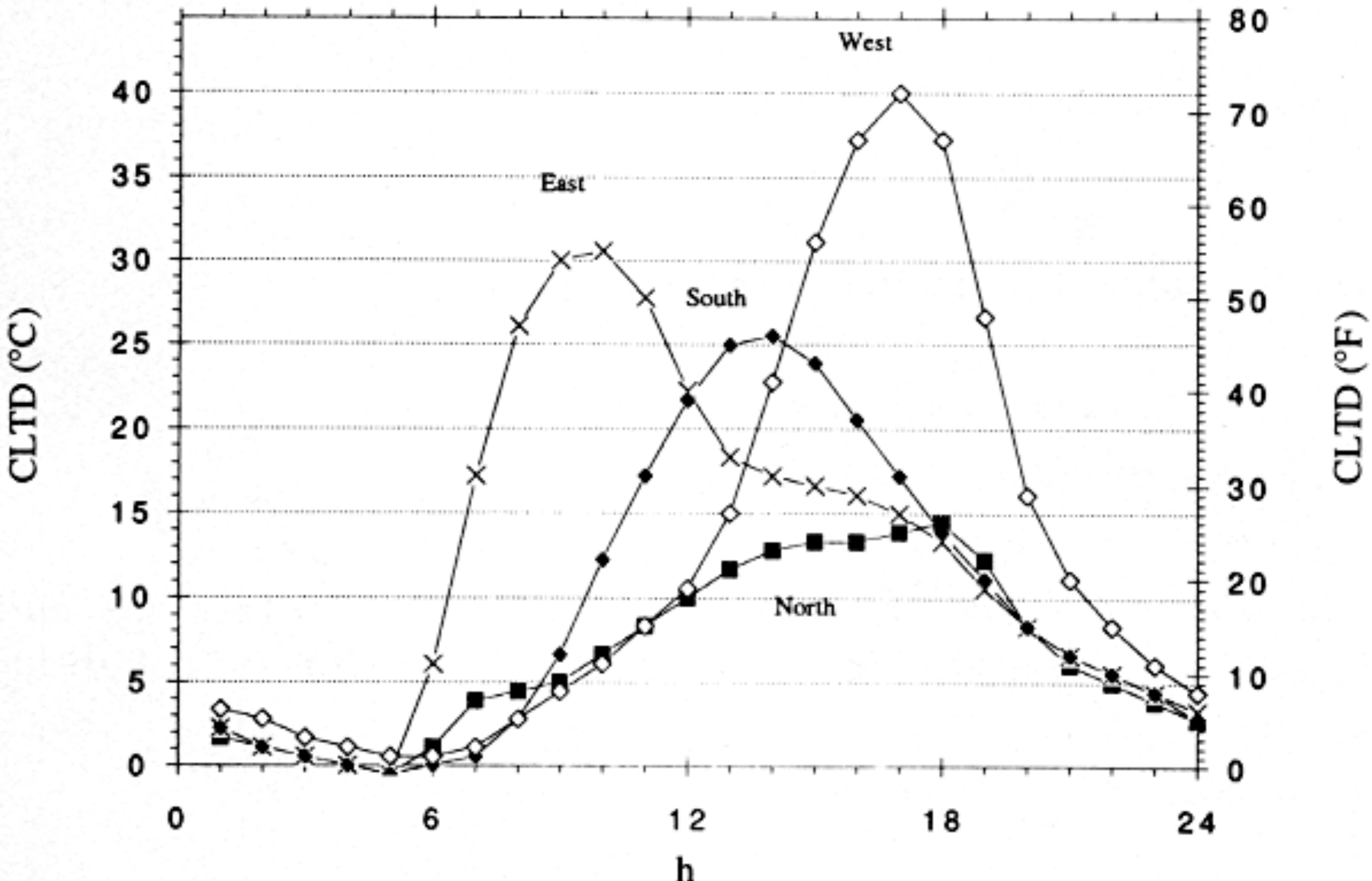
CLTD for roof materials



CLTD for "heavy" or "massive" walls

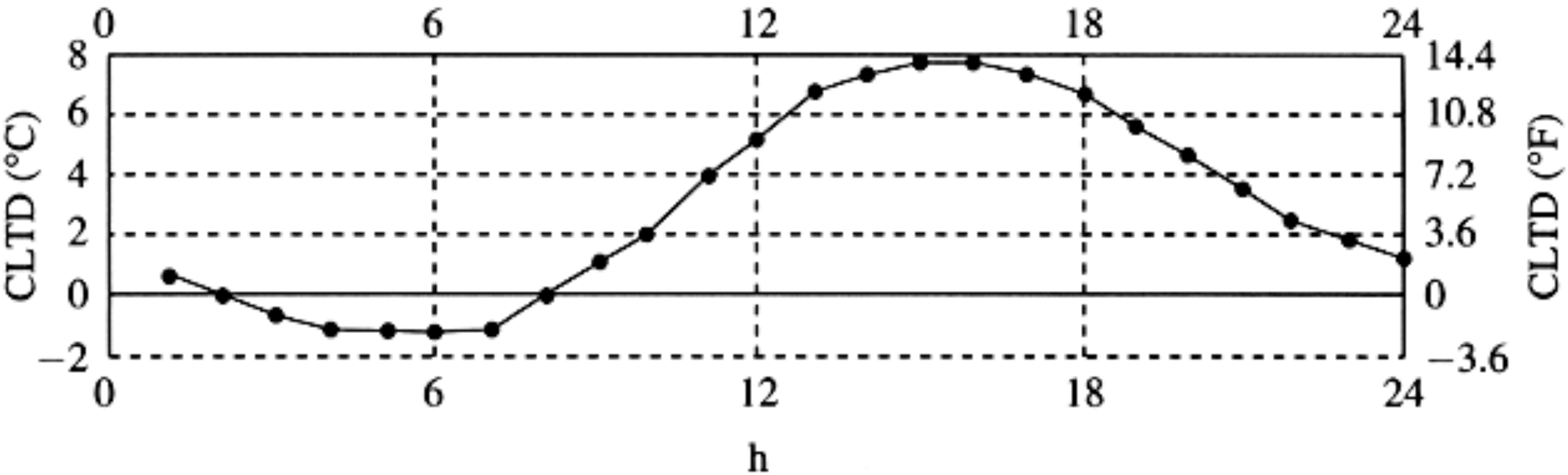


CLTD for “lightweight” walls



Lightweight walls

CLTD for glass



ASHRAE CLTD/CLF method

- CLF = cooling load factor [dimensionless]
  - Yields the cooling load at hour *t* as a function of maximum daily load
    - Also calculated for common construction materials
    - Just look values up in tables

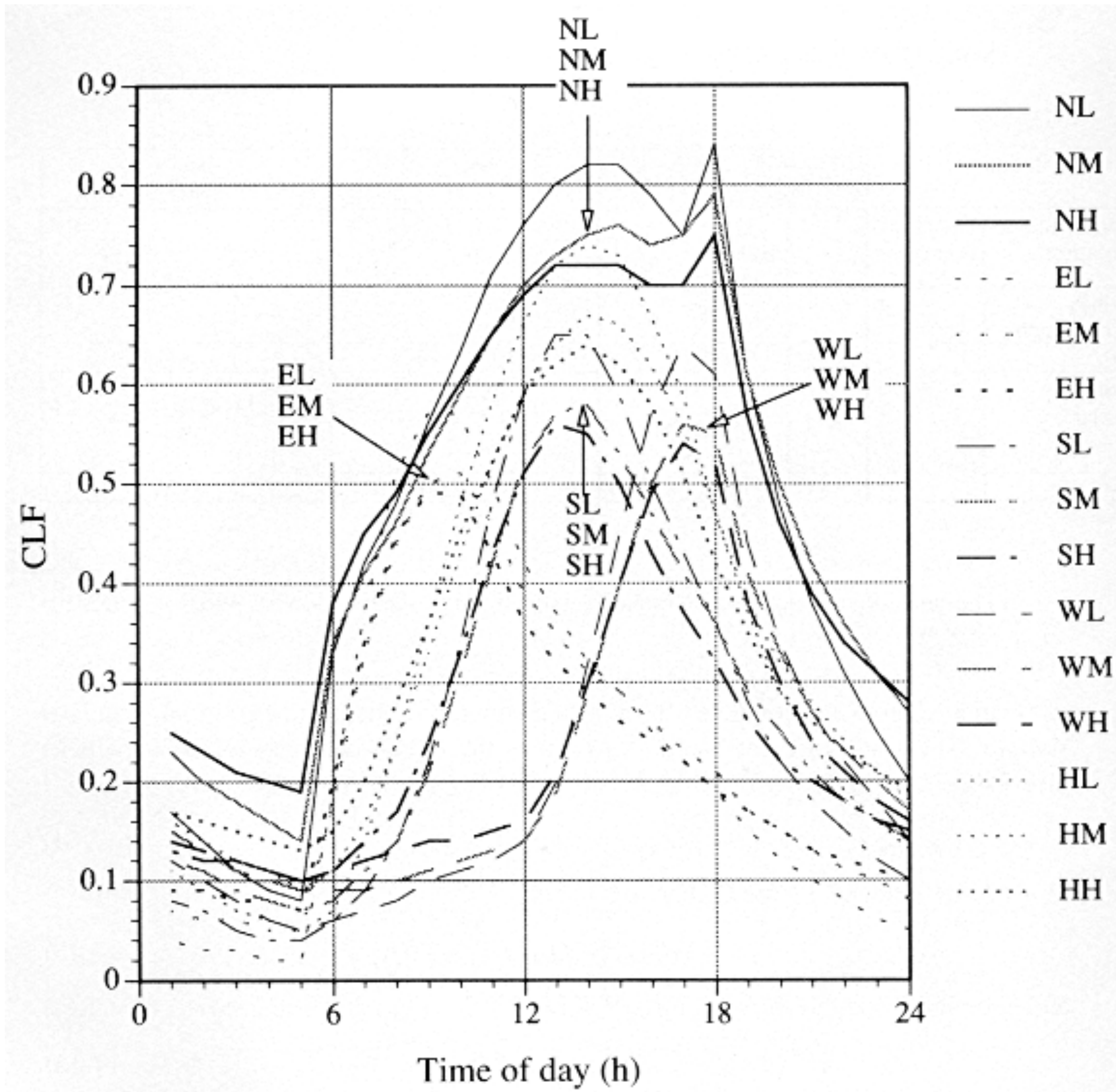
Instead of: $Q_{solar} = \alpha I_{solar} A$

You use: $Q_{cooling,radiation,t} = Q_{\max}(CLF_t)$ at hour t

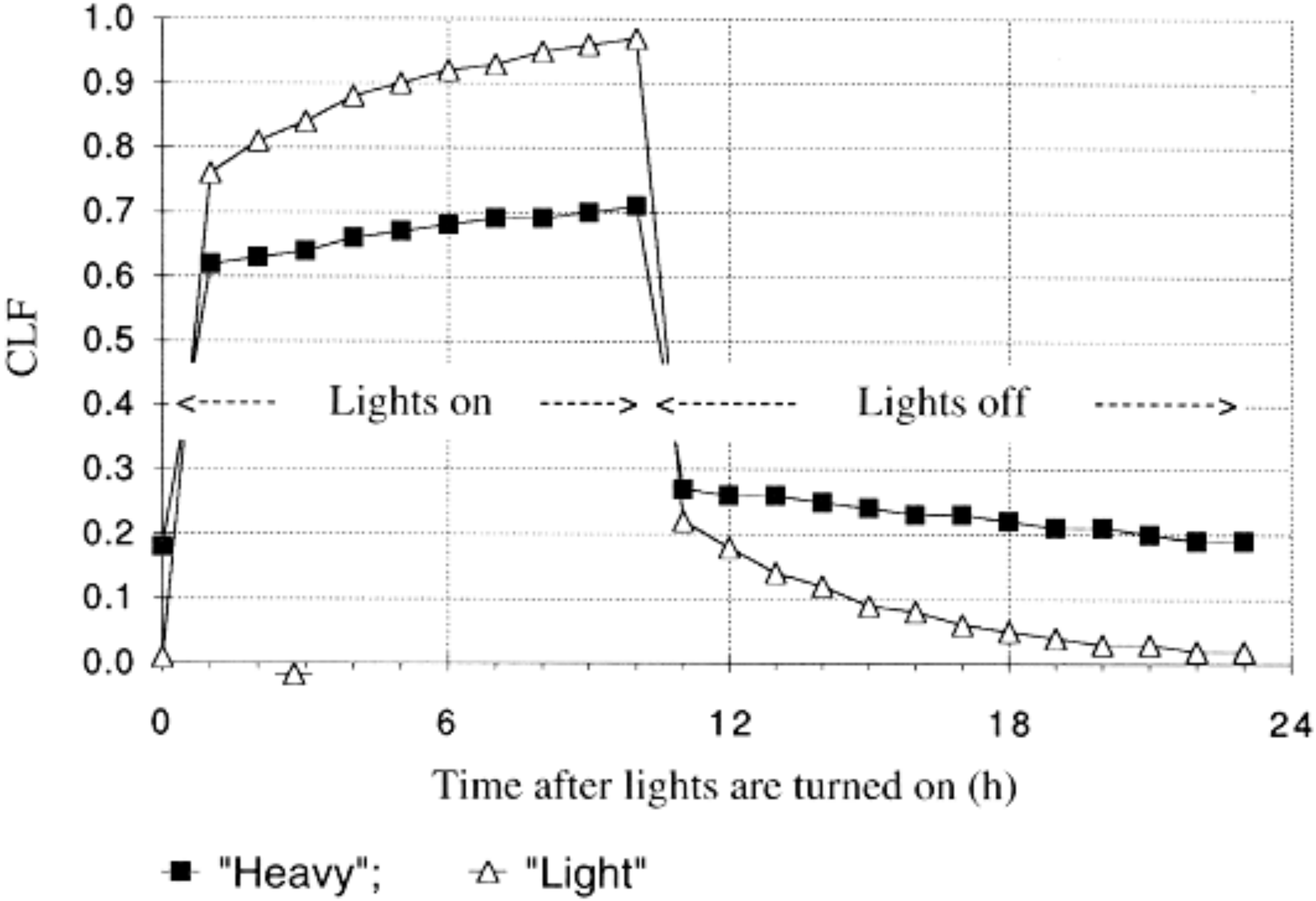
CLF for glass

L = light
M = medium
H = heavy

N = north
E = east
W = west
S = south



CLF for internal gains



Finding peak cooling load with CLTD/CLF method

- To find the peak cooling load you would need to take into account the magnitude of all individual loads around a peak time period
- Typically late afternoon or early evening
- Use a spreadsheet tool

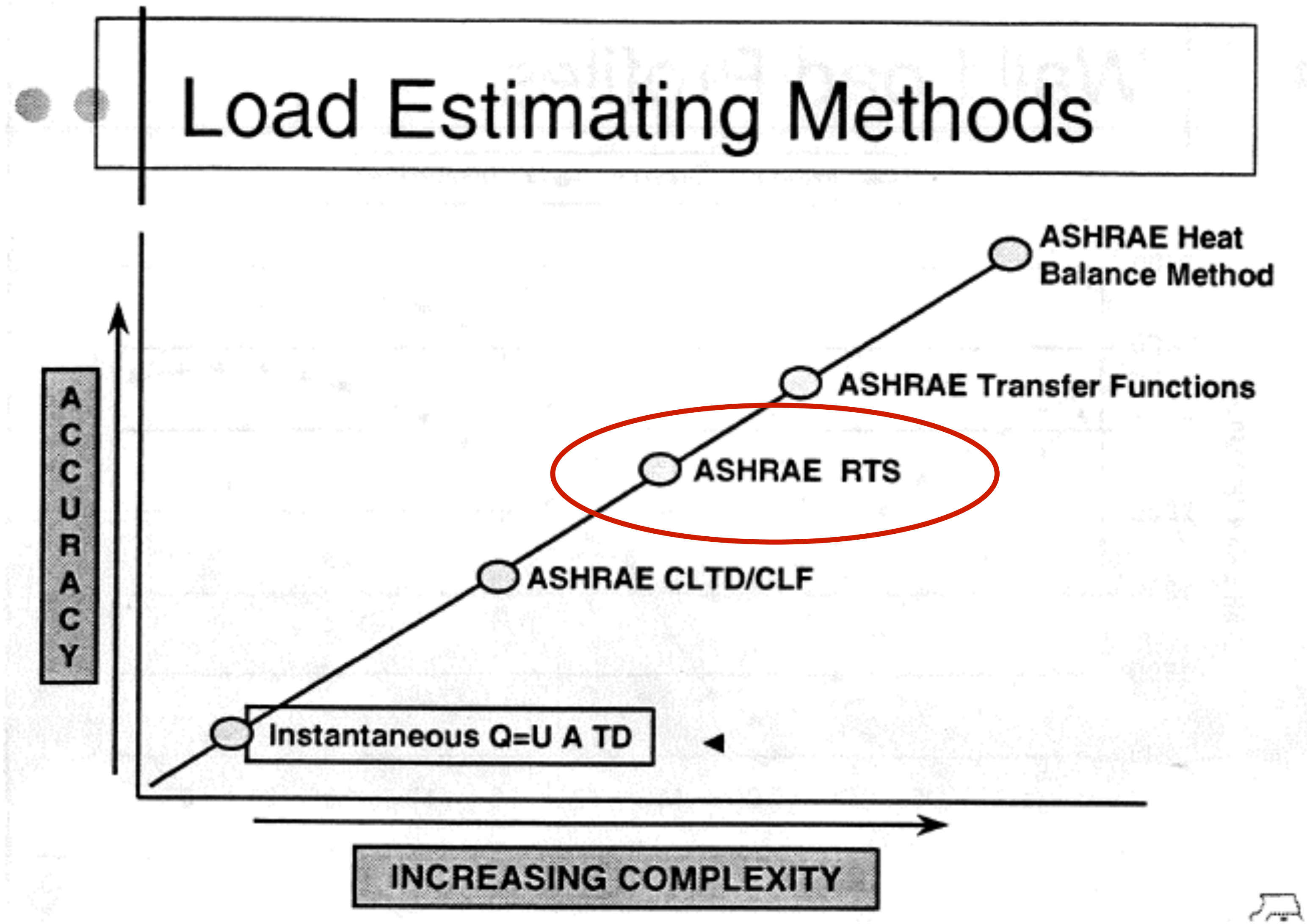
ASHRAE CLTD/CLF method

Sensible loads					hour t	hour t
Component and orientation	Construction type		U	A	$CLTD_t$	$\dot{Q}_t=U\times A\times CLTD_t$
Walls						
Roof						
Glazing conduction						
Glazing solar		A	SC	$SHGF_{max}$	CLF_t	$\dot{Q}_t=A\times SC\times SHGF_{max}\times CLF_t$
Air exchange		V	$\dot{V}$	T_i	T_o	$\dot{Q}=\rho\times c_p\times\dot{V}\times(T_o-T_i)$ (instantaneous)
Internal partitions			U	A	ΔT across partition	$\dot{Q}=U\times A\times\Delta T$ (instantaneous)
Ceiling						
Floor						
Sides						
Ducts						
Internal gains		number	gain /unit	$\dot{Q}$	CLF_t	$\dot{Q}_t=\dot{Q}\times CLF_t$
Appliances						
Fans						
Lights						
Motors						
People						
TOTAL SENSIBLE						

Our book (Kreider) has a Heating and Cooling for Buildings (HCB) tool on CD-ROM

- Demo

Accuracy of methods



Radiant time-series method (RTS)

- The Radiant Time-Series method (RTS) is a simplified version of the more complete heat balance version that can be implemented in a spreadsheet or similar software

- RTSM attempts to include dynamic elements like outdoor air temperatures, solar radiation, and enclosure heat transfer
  - Outdoor air temps and solar radiation are cyclic with 24 hour periods
  - Enclosure heat capacity will absorb and release heat with a time delay
  - This is like time delays (phase shifts) of electrical networks

RTS simplifying assumptions

- The combined effects of convective and radiative heat transfer to/from exterior can be modeled by convection to/from an equivalent exterior air temperature called the sol-air temp, $T_{sol\text{-}air}$
  - This means a single combined radiation-convection heat transfer coefficient independent of wind speed, surface temps and sky temps, must be used for all surfaces

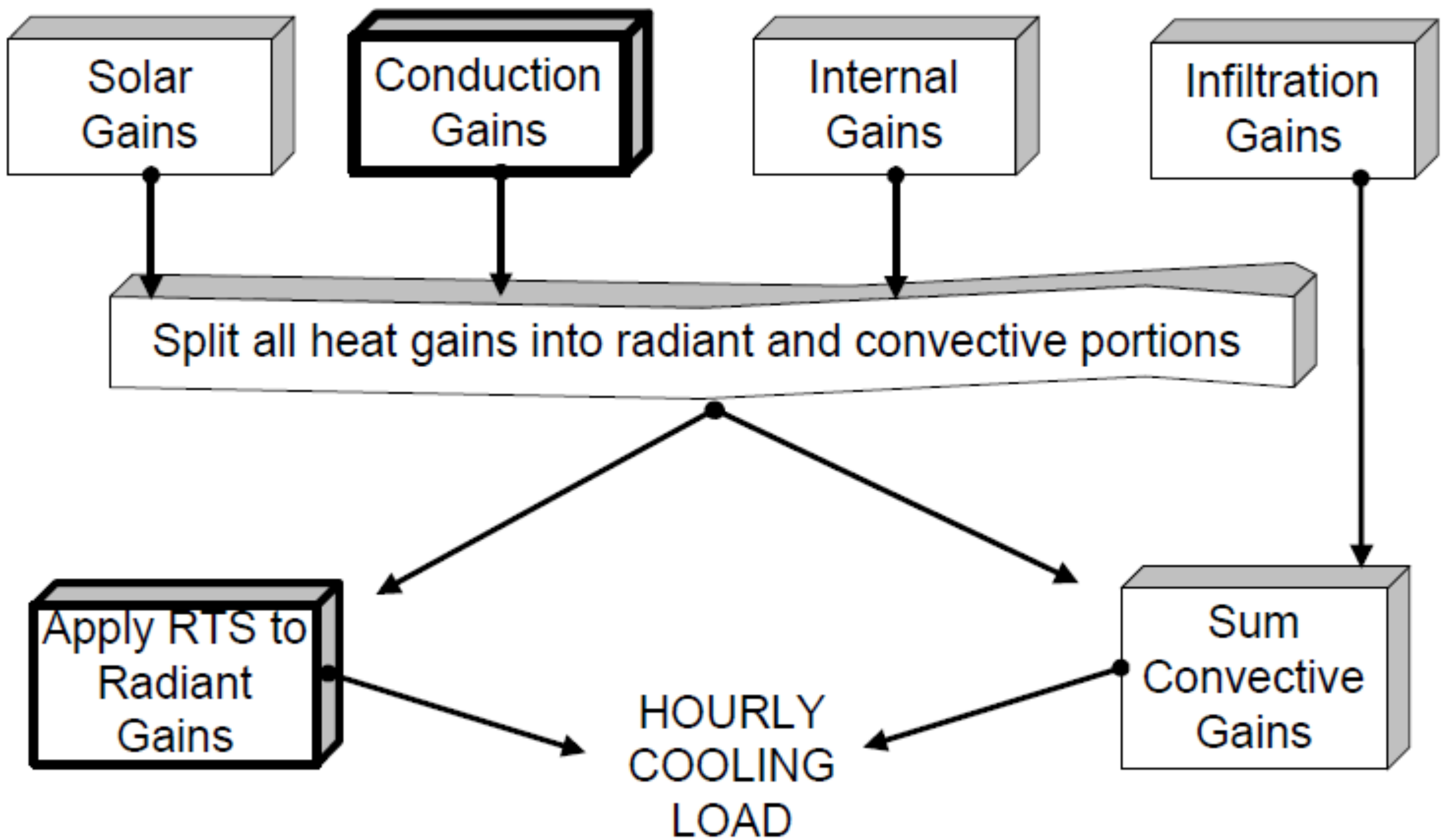
- All interior surface temperatures are nearly the same so all radiation between elements in the interior can be ignored

RTS main idea

The idea behind the radiant time series is this:

- The current heat transfer to/from the interior is equal to:
  - \+ Part of the current convective heat transfer to the outside of the enclosure
  - \+ Current solar heat gain through fenestration
  - \+ Part of the earlier convective and radiative heat transfer to the outside of the enclosure

RTS algorithm



RTS procedure

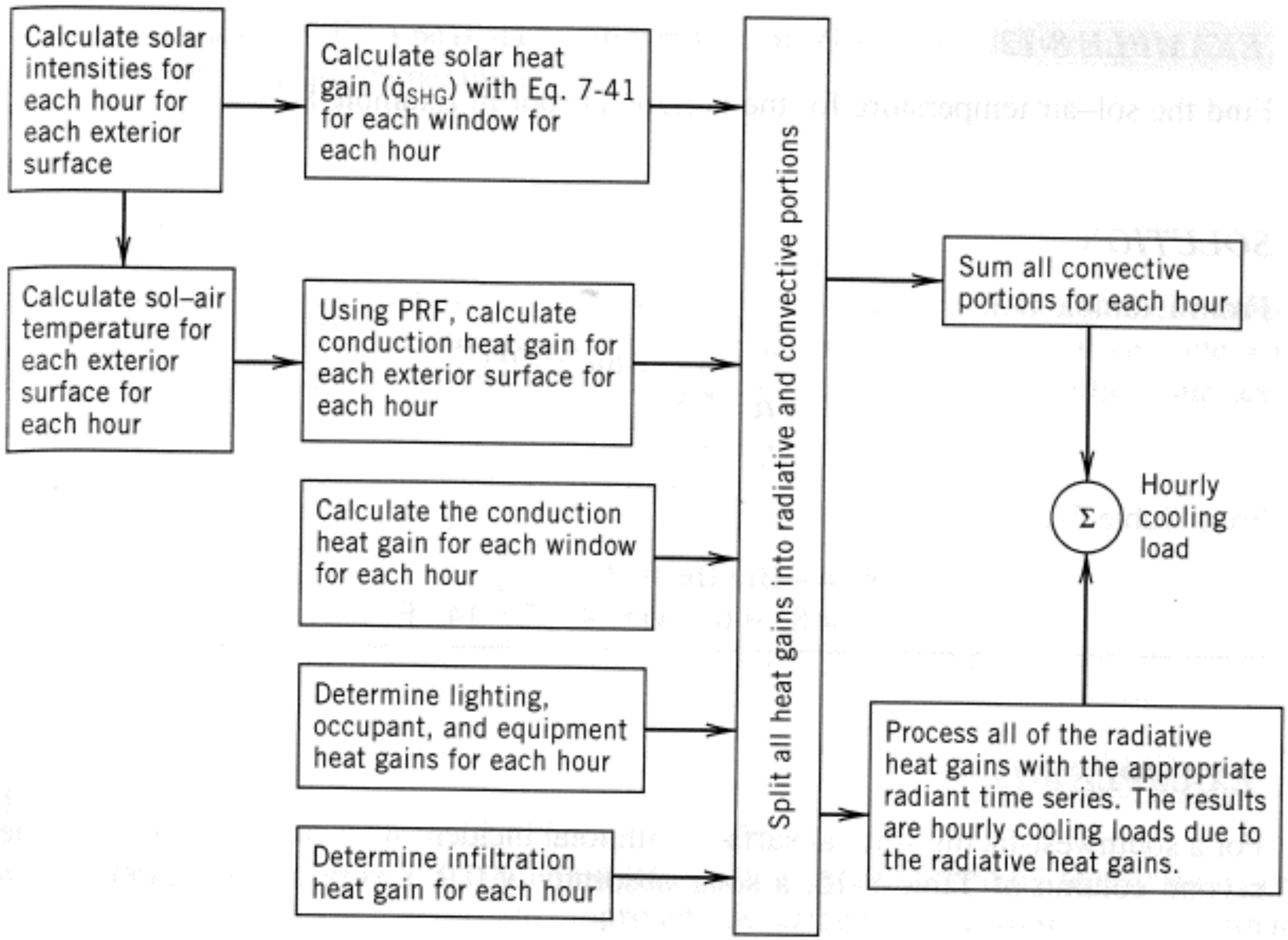


Figure 8-8 Radiant time series method.

RTS procedure

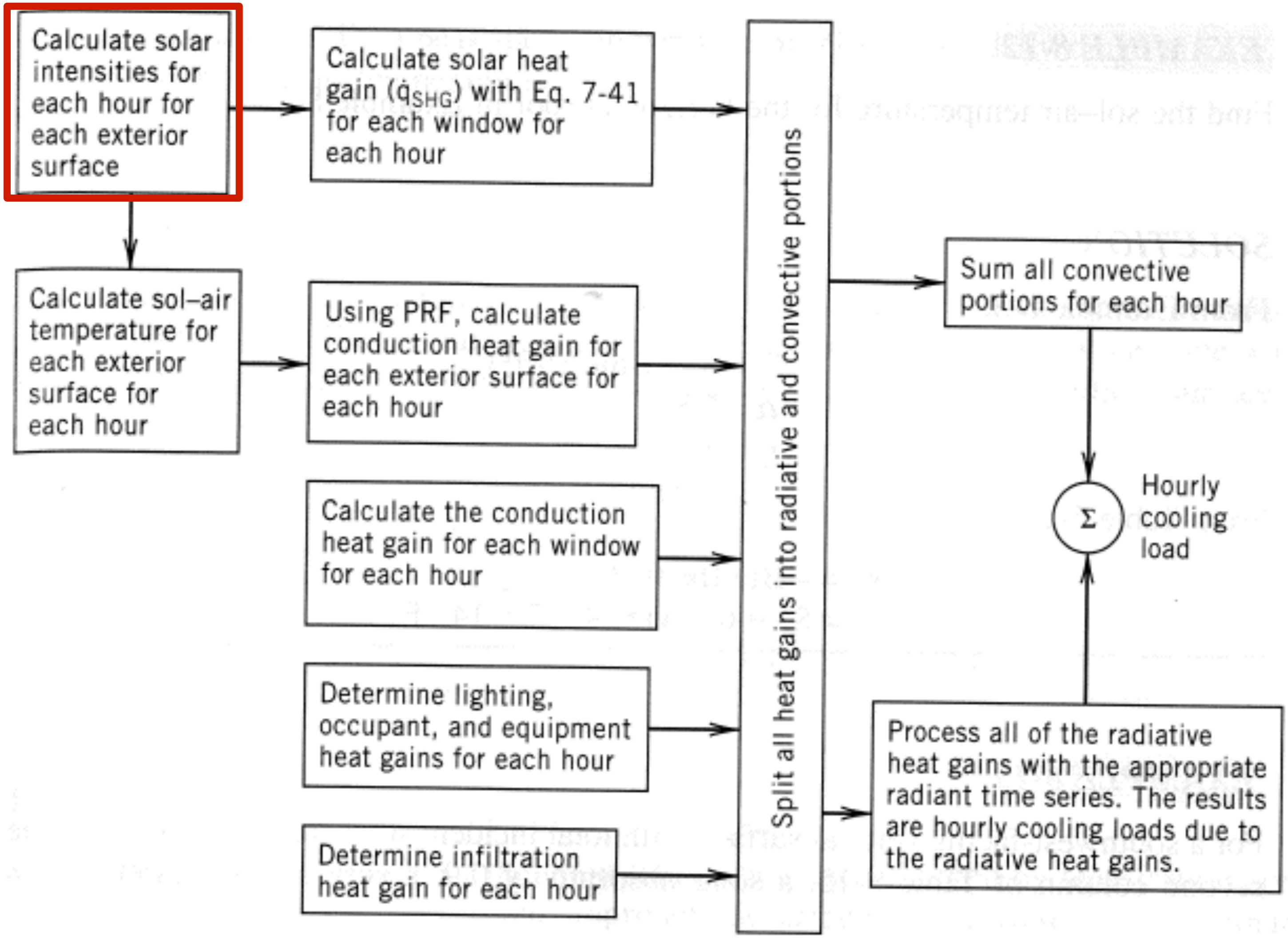


Figure 8-8 Radiant time series method.

Solar intensities

- We can calculate hourly solar intensities based on solar geometry
- Or download data from the internet
  - http://rredc.nrel.gov/solar/old_data/nsrdb/
- This is often given to us

RTS procedure

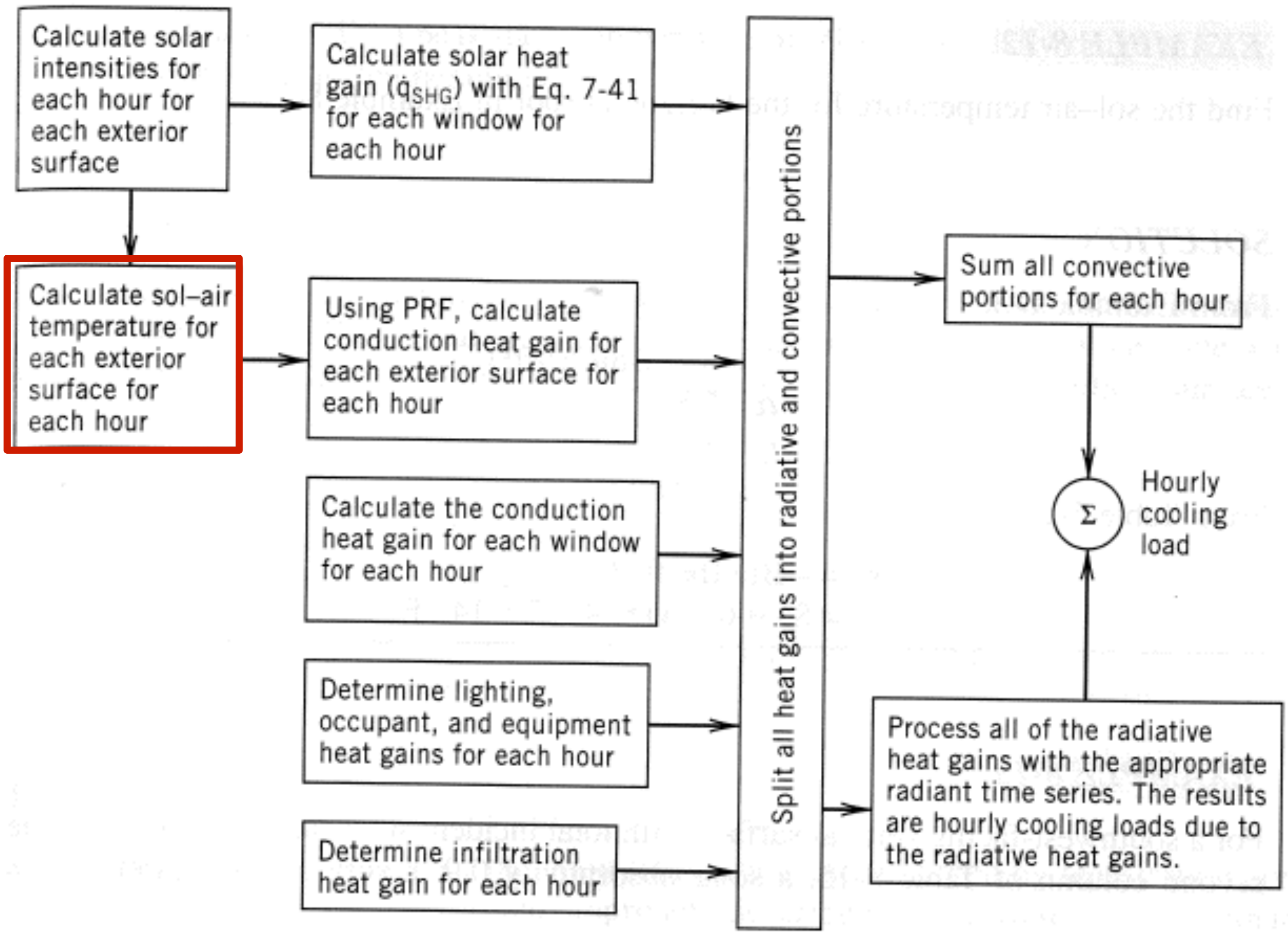


Figure 8-8 Radiant time series method.

Calculate sol-air temperature

- For each surface, for each hour

$$T_{sol-air} = T_{air,out} + \alpha \frac{I_{solar}}{h_{ext,conv+rad}} - \varepsilon \frac{\delta R}{h_{ext,conv+rad}}$$

$\varepsilon \delta R \approx 7$°F for horizontal surfaces

$\varepsilon \delta R \approx 0$°F for vertical surfaces

RTS procedure

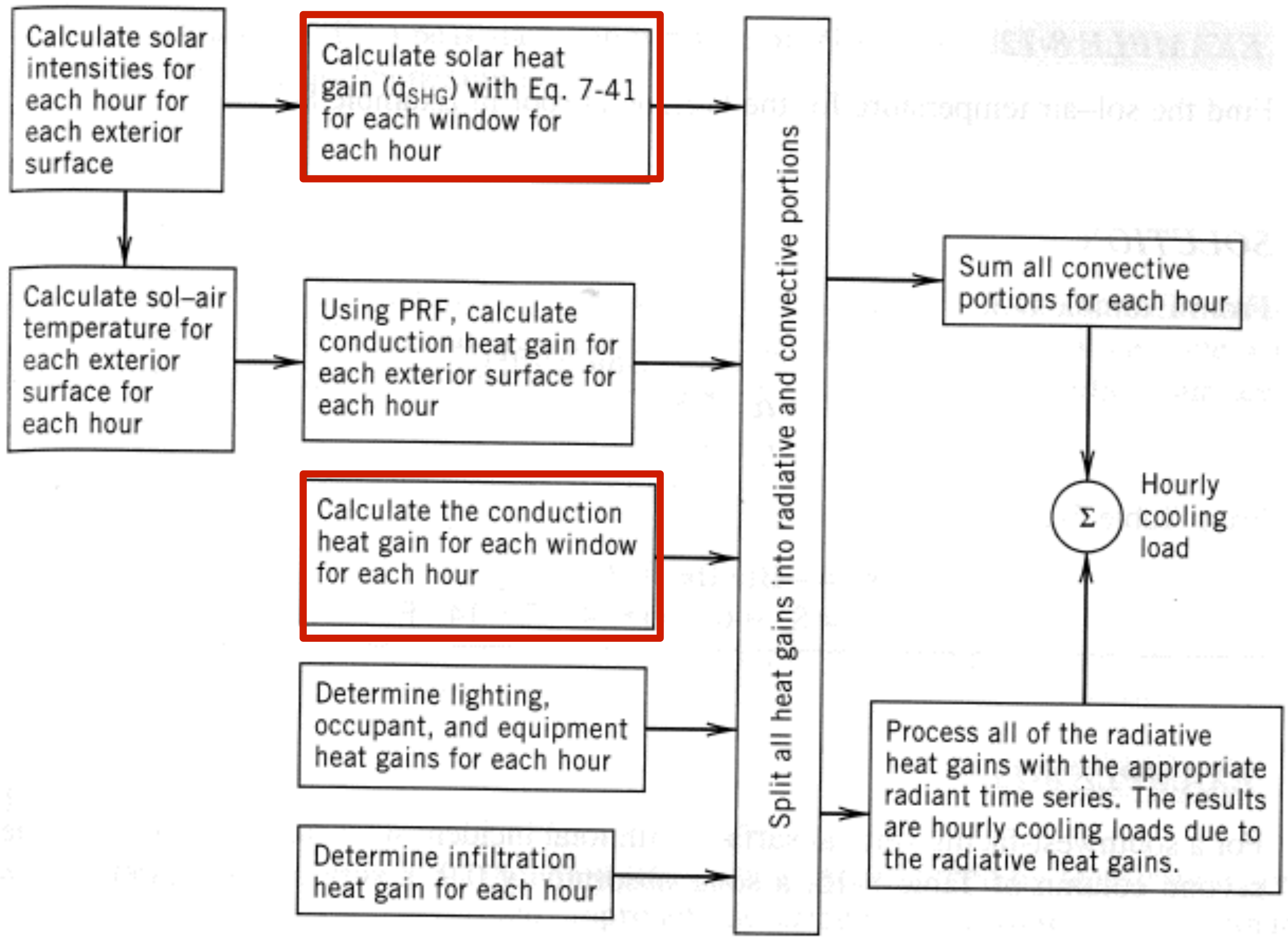


Figure 8-8 Radiant time series method.

Solar heat gain through windows

- Each window, each hour

$$q_{window} = U_{pf}\left(T_{out} - T_{in}\right) + I_{solar} SHGC(IAC)$$

- We've done this before

RTS procedure

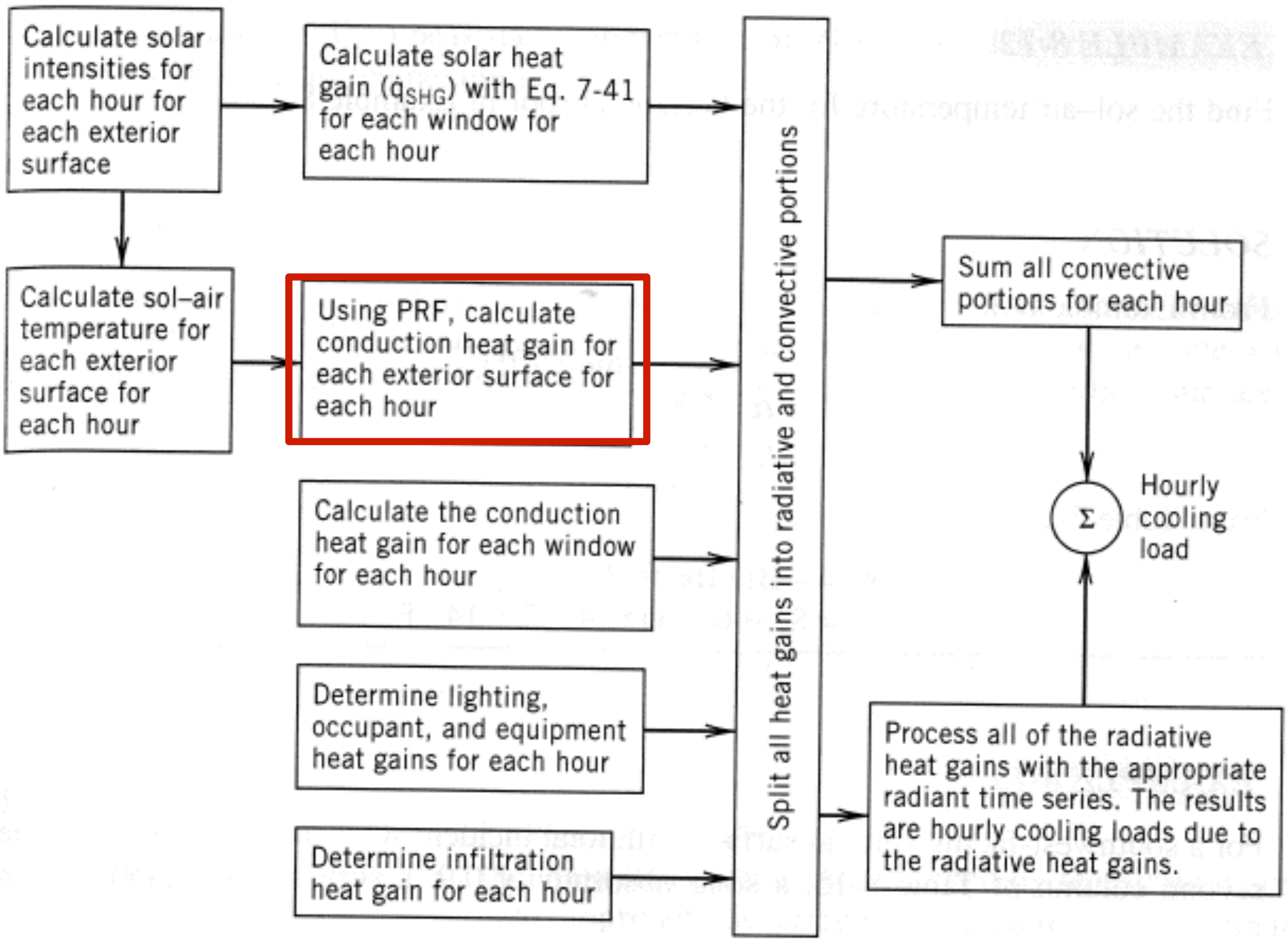


Figure 8-8 Radiant time series method.

Conduction heat gains and “PRF”

- Heat gains to the interior from conduction will be a sum of conduction going on right now + part of the heat transferred to the enclosure from earlier times
- For example:

$$q(n)=C_0U(T_e(n) - T_i(n)) + C_1U(T_e(n\text{-}1) - T_i(n\text{-}1)) + \ldots + C_{23}U(T_e(n\text{-}23) - T_i(n\text{-}23))$$

where $T_e = T_{sol\text{-}air}$

- We call C_n the **conduction time series**
- $Y_{pn} = C_n U$ is the periodic response factor (PRF) in [W/m^{2}K]

Conduction heat gains and “PRF”

- Once we have Y_{pn} we can write the heat conduction into the room at the current time

$$q_{conduction,in,t} = \sum_{n=0}^{23} Y_{pn}\left(T_{e,q-n} - T_{rc}\right) \text{ [Btu/(h}\cdot\text{ft}^2\text{) or W/m}^2\text{]}$$

where

$T_{e,q-n}$ =the sol-air temp n hours ago

T_{rc} = constant interior room temp

Y_{pn} = periodic response function

Using Y_{pn}

- To use the previous equation we need to know the sol-air temp for the previous 24 hours
- The calculation for 8 am would look like this:

$$q_{conduction,in,8am} = Y_{p0}\left(T_{e,8am} - T_{rc}\right) + Y_{p1}\left(T_{e,7am} - T_{rc}\right) + Y_{p2}\left(T_{e,6am} - T_{rc}\right) +$$
$$Y_{p3}\left(T_{e,5am} - T_{rc}\right) + Y_{p4}\left(T_{e,4am} - T_{rc}\right) + Y_{p5}\left(T_{e,3am} - T_{rc}\right) + \cdots$$
$$+ Y_{p22}\left(\underline{T_{e,11am}} - T_{rc}\right) + Y_{p23}\left(\underline{T_{e,10am}} - T_{rc}\right) + Y_{p24}\left(\underline{T_{e,9am}} - T_{rc}\right)$$

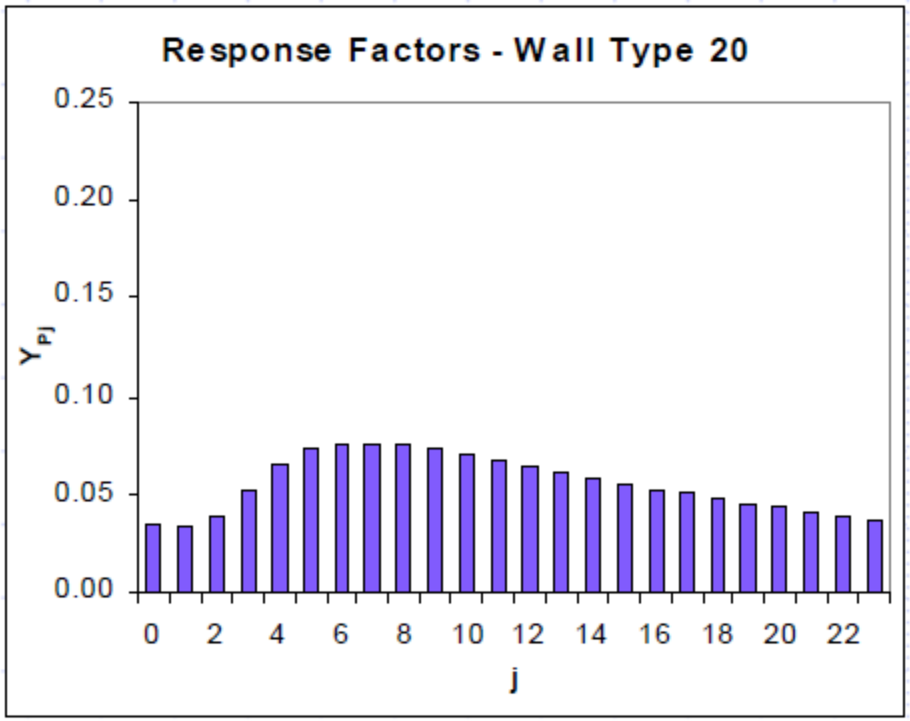
The underlined times are from the day before!

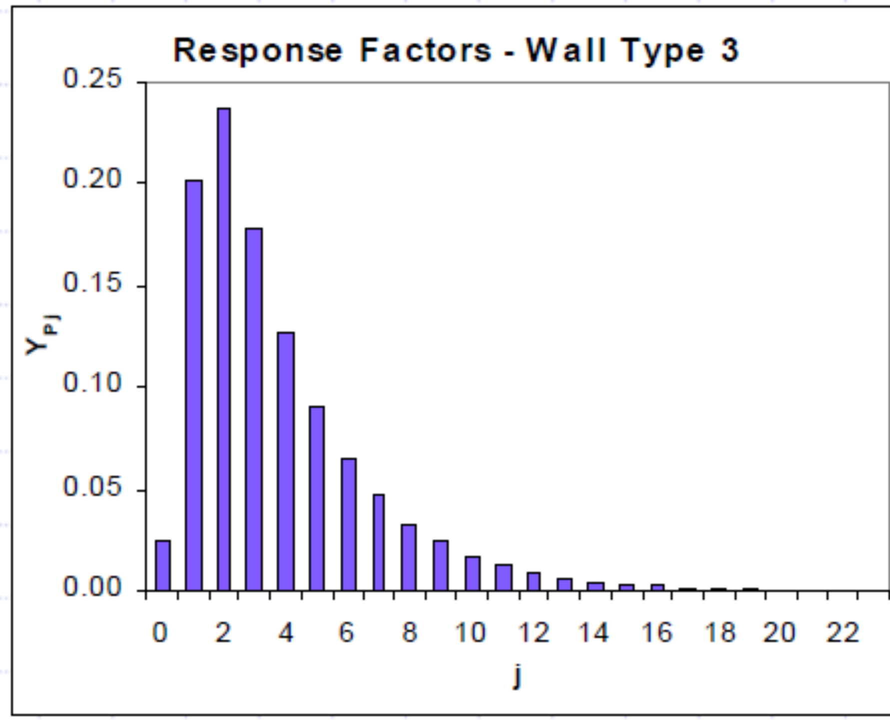
Finding Y_{pn} and C_n

- Y_{pn} depends highly on the exact details of the enclosure construction (wall or ceiling)
  - Overall insulation, mass, heat capacity and the insulation location both are important
  - The ASHRAE handbook has a table of U and C_n values for 20 common constructions

Example Y_{pn}

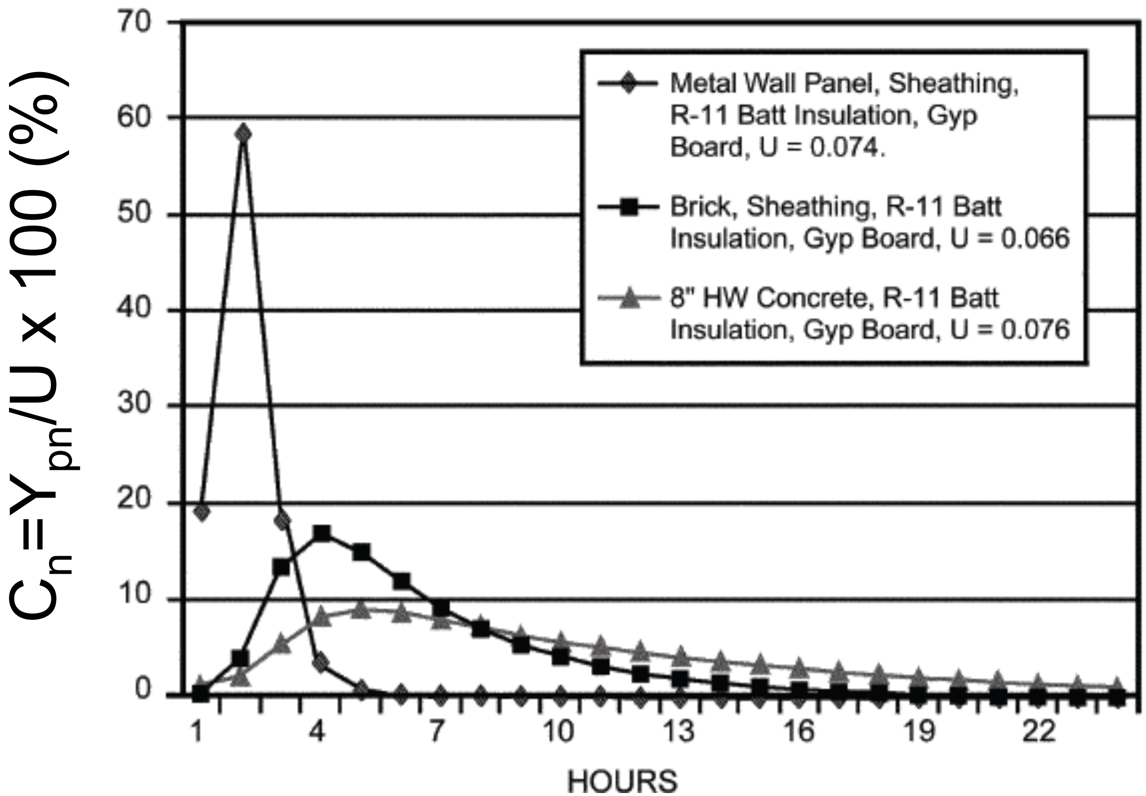
- Type 20: Brick + 8” concrete + R11 insulation + gypsum board
- Type 3: 1” stone + R10 insulation + gypsum board





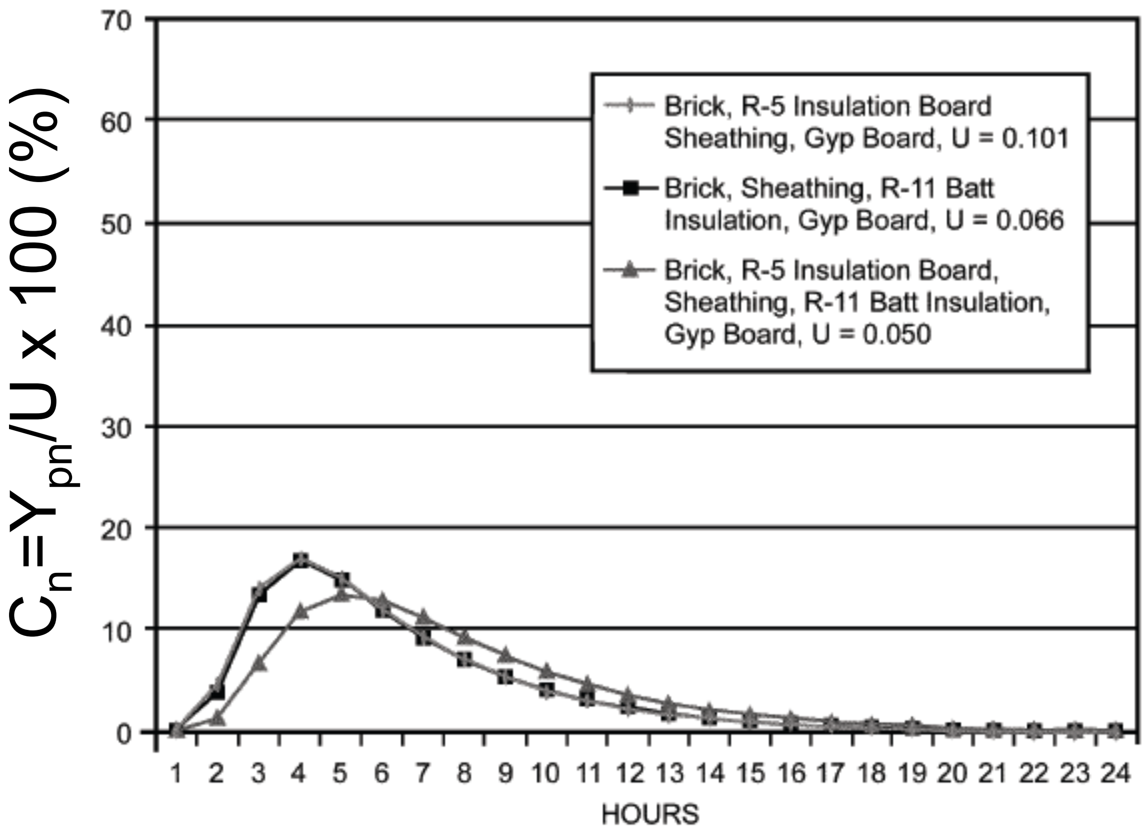
Y_{pn} for varying mass

- Increasing mass (heat capacity) increases delay in heat transmission



Y_{pn} for varying insulation

- Increasing Interior insulation increases delay but increasing exterior insulation does not



RTS procedure

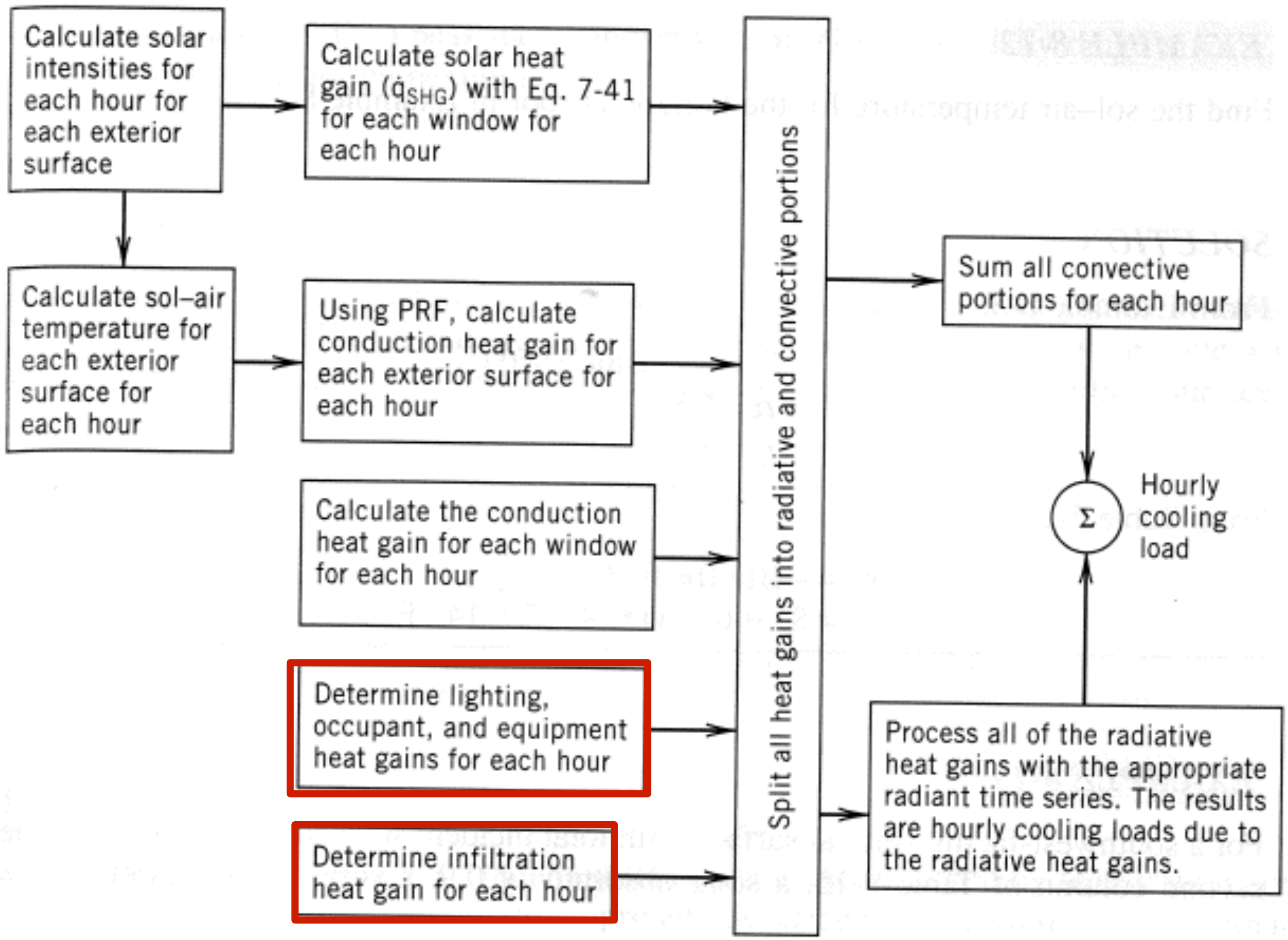


Figure 8-8 Radiant time series method.

Infiltration and internal gains

- We treat infiltration gains as instantaneous gains
  - We've already done this
  - We calculate these separately for each hour of the day because the exterior air temperature changes each hour

- We calculate internal gains using methods discussed earlier
  - We calculate these each hour too because the internal loads will change from hour to hour
  - Also need to keep track of the radiative + convective parts

Splitting gains into radiative and convective portions

- At each hour, each heat gain must be split into radiative parts + convective parts
  - "Delayed" versus "instantaneous"

Table 14 Recommended Radiative/Convective Splits f

Heat Gain Type	Recommended Radiative Fraction	Recommended Convective Fraction
Occupants, typical office conditions	0.6	0.4
Equipment	0.1 to 0.8	0.9 to 0.2
Office, with fan	0.10	0.9
Without fan	0.3	0.7
Lighting		
Conduction heat gain		
Through walls and floors	0.46	0.54
Through roof	0.60	0.40
Through windows	0.33 (SHGC > 0.5) 0.46 (SHGC < 0.5)	0.67 (SHGC > 0.5) 0.54 (SHGC < 0.5)
Solar heat gain through fenestration		
Without interior shading	1.0	0.0
With interior shading		
Infiltration	0.0	1.0

Application of the RTS

- Convection is considered instantaneous
- Radiation estimates cooling load due to the radiative portion of each heat gain by applying a **radiant time series**
  - This is analogous to the periodic response factors (PRF) for conduction based on current and past values of sol-air temperatures
- Radiant energy is absorbed + reradiated + absorbed + reradiated + absorbed + …
  - We must add up portions of radiation from previous hours to find the total radiant contribution now (kind of like we did with conduction)

Total radiant contribution

$$Q_{cooling,t} = \sum_{n=0}^{23} r_n Q_{t-n\delta} \quad \text{[Btu/h] or [W]}$$

where

$Q_{cooling,t}$ = radiative cooling load at current hour, Btu/hr or W

$Q_{t-n\delta}$ = radiative heat gain n hours ago, Btu/hr or W

$r_n = n^{th}$ radiant time factor (RTF)

- RTF depends upon the wavelength (LW vs SW or solar), the mass of the enclosure and the surface coverings
  - There is a different RTF for transmitted solar light than all the other radiated energy
  - ASHRAE has RTF tables for a number of different constructions with varying amounts of glass and carpet
  - Heavy construction with no carpet has the most contribution by older radiation

Example RTFs

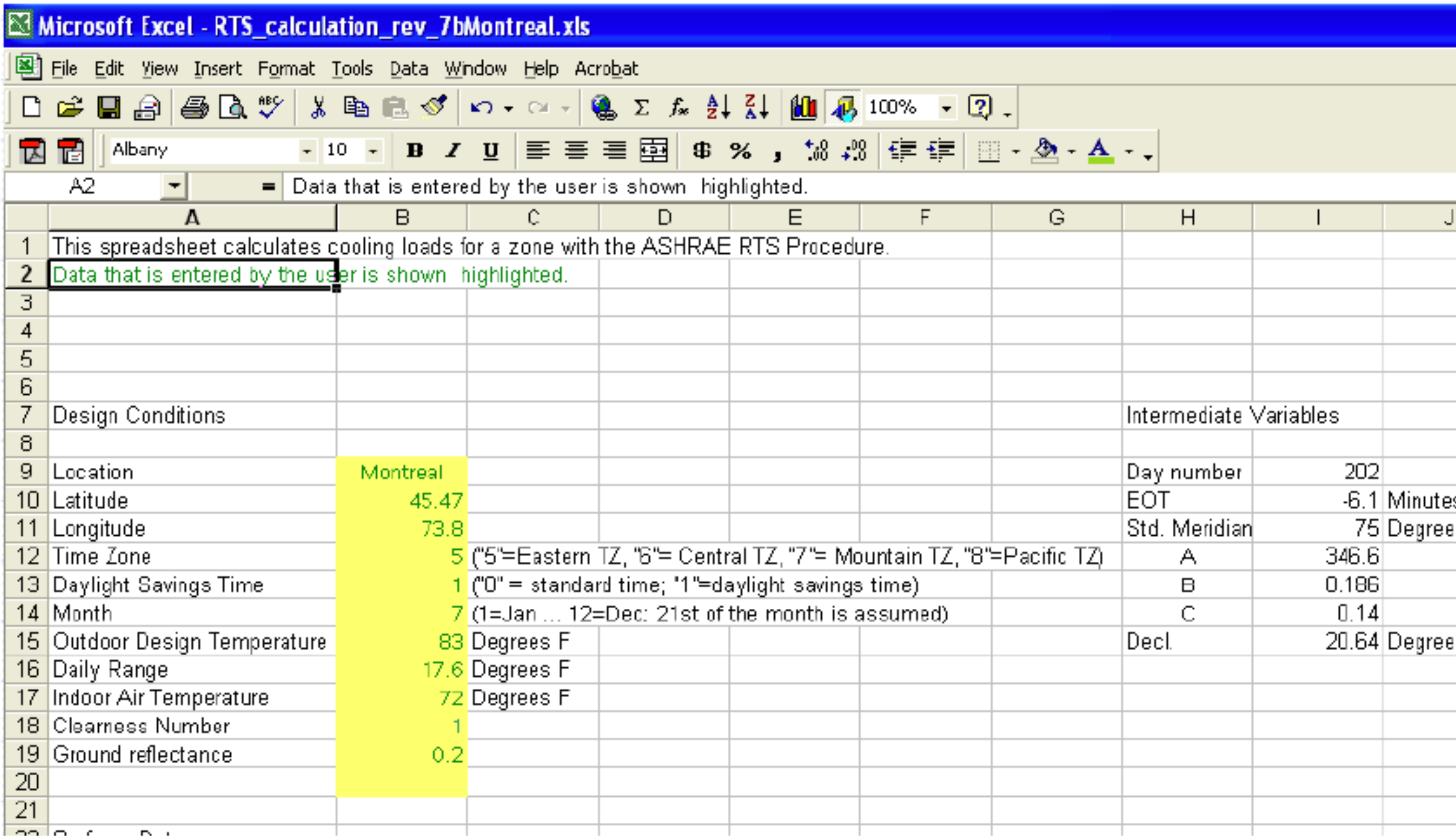
Table 19 Representative Nonsolar RTS Values for Light to Heavy Construc

	Light						Medium						Heavy					
	With Carpet			No Carpet			With Carpet			No Carpet			With Carpet			No Carpet		
% Glass	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%
Hour	Radiant Time Factor, %																	
0	47	50	53	41	43	46	46	49	52	31	33	35	34	38	42	22	25	28
1	19	18	17	20	19	19	18	17	16	17	16	15	9	9	9	10	9	9
2	11	10	9	12	11	11	10	9	8	11	10	10	6	6	5	6	6	6
3	6	6	5	8	7	7	6	5	5	8	7	7	4	4	4	5	5	5
4	4	4	3	5	5	5	4	3	3	6	5	5	4	4	4	5	5	4
5	3	3	2	4	3	3	2	2	2	4	4	4	4	3	3	4	4	4
6	2	2	2	3	3	2	2	2	2	4	3	3	3	3	3	4	4	4
7	2	1	1	2	2	2	1	1	1	3	3	3	3	3	3	4	4	4
8	1	1	1	1	1	1	1	1	1	3	2	2	3	3	3	4	3	3
9	1	1	1	1	1	1	1	1	1	2	2	2	3	3	2	3	3	3
10	1	1	1	1	1	1	1	1	1	2	2	2	3	2	2	3	3	3

RTS example

- Outdoor conditions
  - Montreal
  - July 21
  - 83F dry bulb
    - 17.6F daily range
  - Ground reflectivity = 0.2
- Indoor conditions
  - Air temperature = 72°F
- Assume only S wall and roof are exposed to outside
  - Wall is 280 ft^2, α=0.9
  - Roof is 900 ft^2, α=0.9
  - Y_{pn} as shown in the spreadsheet
- Other heat gains
  - 10 occupants
  - 1 W/ft^2 equipment gain 8AM to 5 PM
    - 0.2 W/ft^2 5P-8A
  - 1.5 W/ft^2 lighting gain 8AM to 5 PM
    - 0.3 W/ft^2 5P-8A
  - Ignore infiltration
- 80 ft^2 of window on S wall
  - No shading
  - SHGC=0.76, U=0.55

You would create a spreadsheet

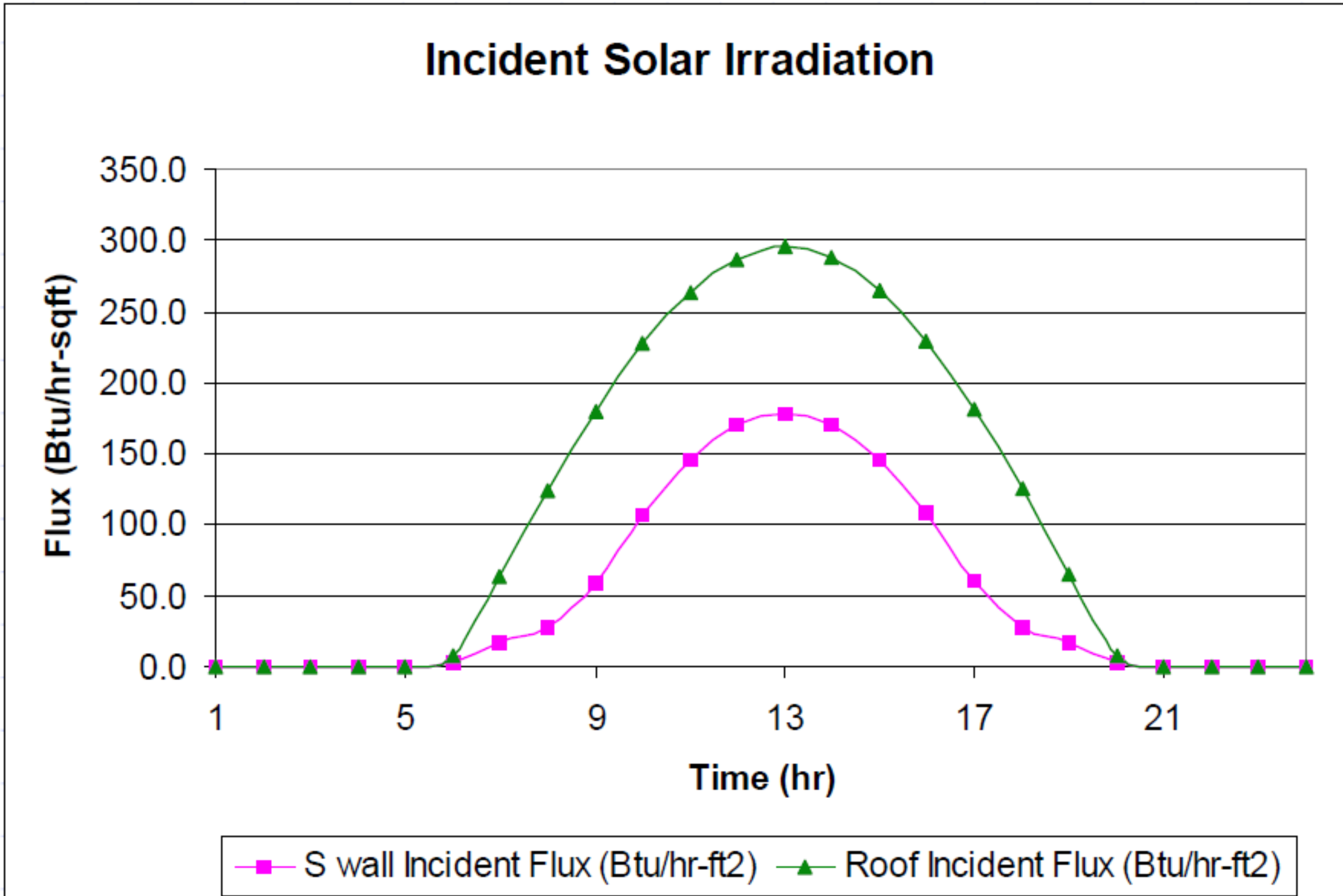

Microsoft Excel - RTS_calculation_rev_7bMontreal.xls

File Edit View Insert Format Tools Data Window Help Acrobat

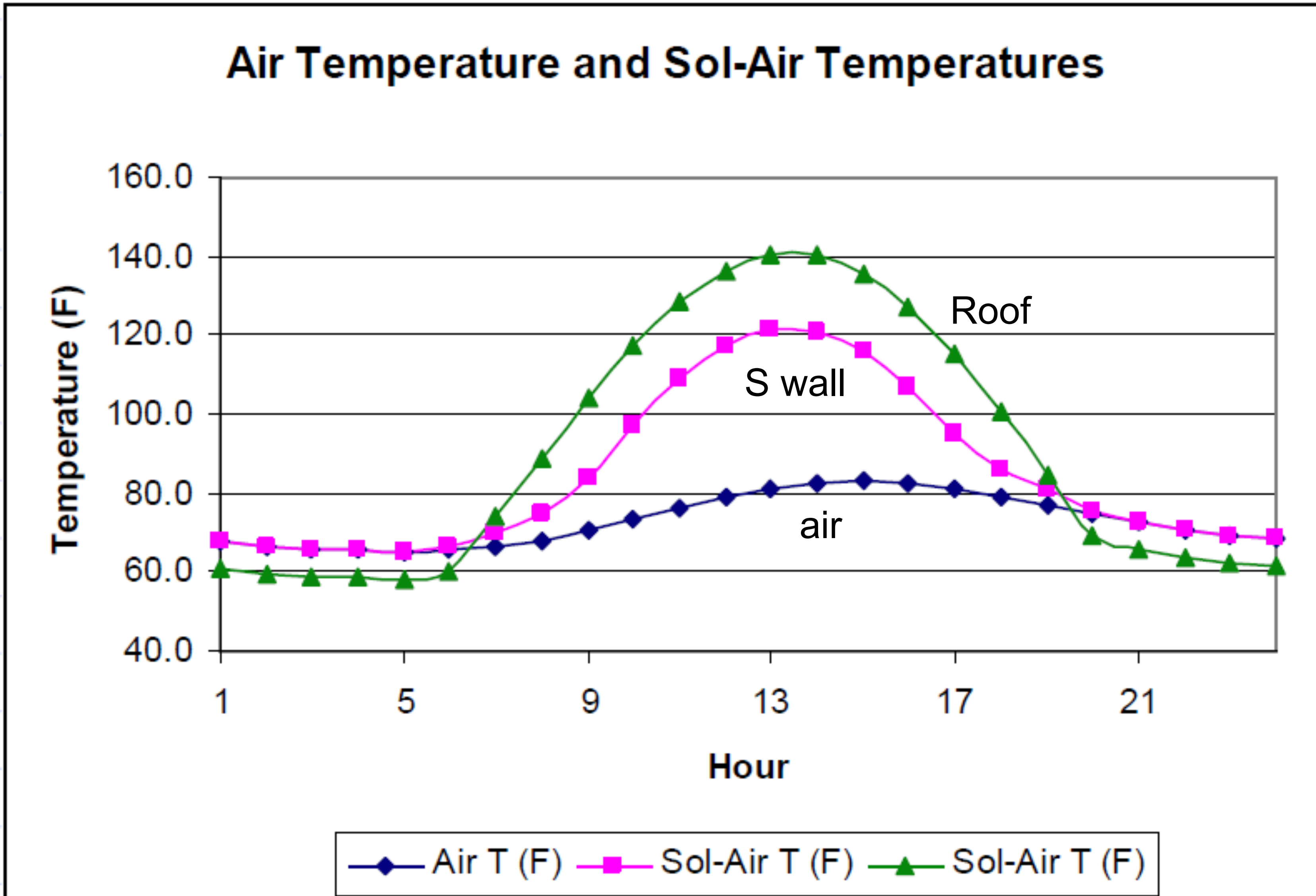
A2 = Data that is entered by the user is shown highlighted.

	A	B	C	H	I	J
1	This spreadsheet calculates cooling loads for a zone with the ASHRAE RTS Procedure.					
2	Data that is entered by the user is shown highlighted.					
3						
4						
5						
6						
7	Design Conditions			Intermediate Variables		
8						
9	Location	Montreal		Day number	202	
10	Latitude	45.47		EOT	-6.1	Minutes
11	Longitude	73.8		Std. Meridian	75	Degrees
12	Time Zone	5	("5"=Eastern TZ, "6"= Central TZ, "7"= Mountain TZ, "8"=Pacific TZ)	A	346.6	
13	Daylight Savings Time	1	("0" = standard time; "1"=daylight savings time)	B	0.186	
14	Month	7	(1=Jan ... 12=Dec: 21st of the month is assumed)	C	0.14	
15	Outdoor Design Temperature	83	Degrees F	Decl.	20.64	Degrees
16	Daily Range	17.6	Degrees F			
17	Indoor Air Temperature	72	Degrees F			
18	Clearness Number	1				
19	Ground reflectance	0.2				
20						
21						

Find incident solar radiation



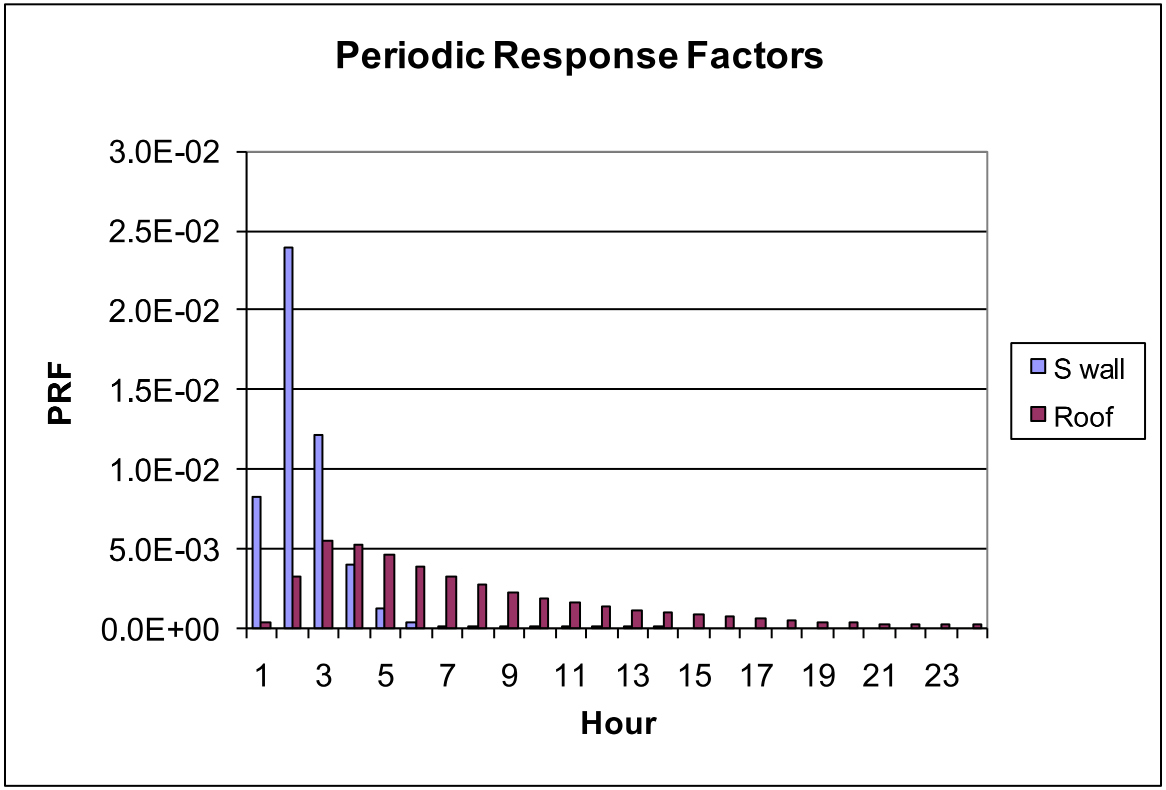
Find sol-air temperatures



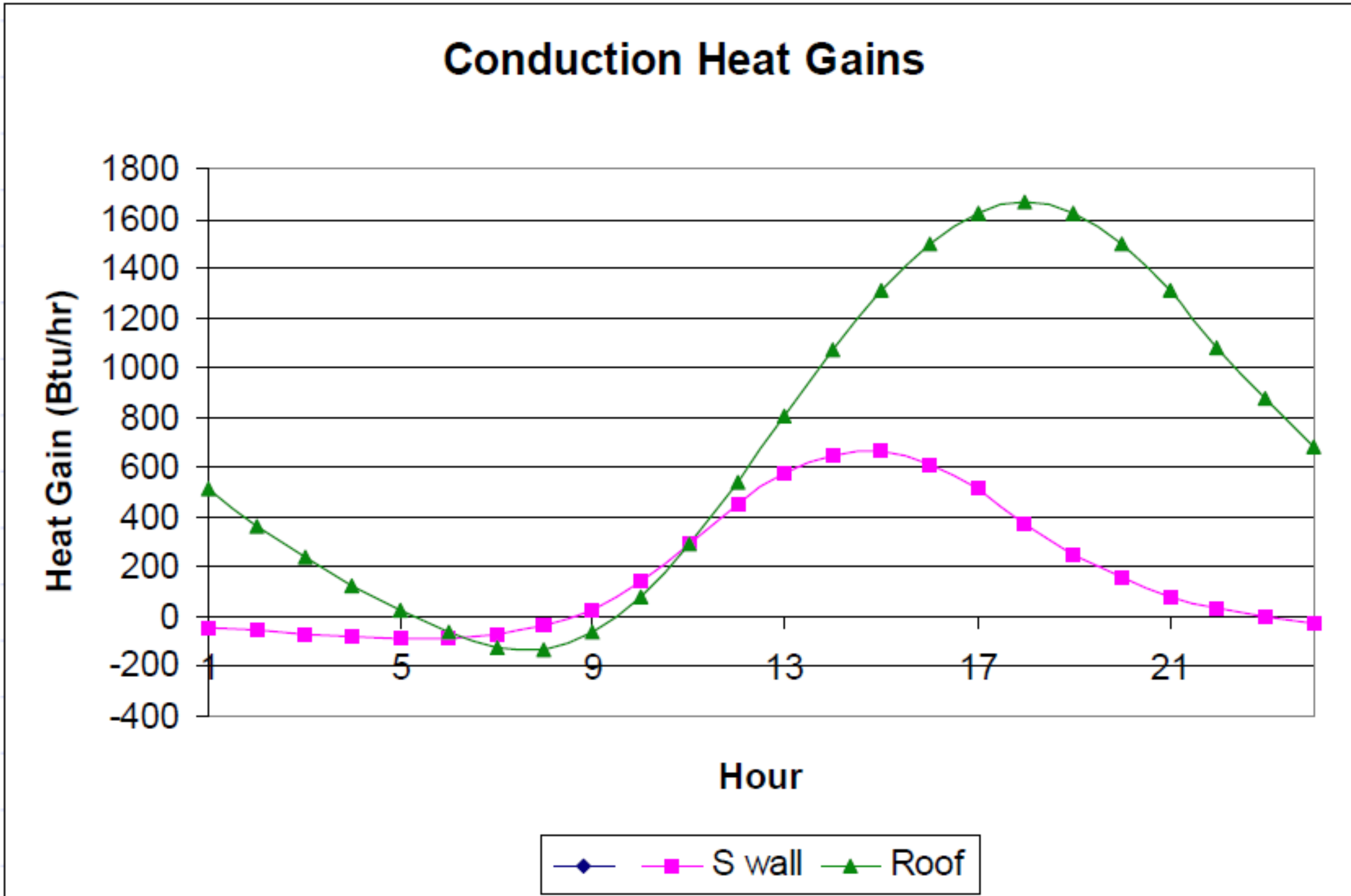
Find periodic response factors for conduction

Ypn		S wall	Roof
1		8.2148E-03	3.5460E-04
2		2.3910E-02	3.2232E-03
3		1.2148E-02	5.5313E-03
4		4.0220E-03	5.3005E-03
5		1.1786E-03	4.5555E-03
6		3.2876E-04	3.8405E-03
7		8.9655E-05	3.2265E-03
8		2.4185E-05	2.7090E-03
9		6.4892E-06	2.2743E-03
10		1.7365E-06	1.9092E-03
11		4.6405E-07	1.6028E-03
12		1.2393E-07	1.3455E-03
13		3.3084E-08	1.1296E-03
14		8.8307E-09	9.4828E-04
15		2.3569E-09	7.9608E-04
16		6.2900E-10	6.6831E-04
17		1.6786E-10	5.6104E-04
18		4.4798E-11	4.7099E-04
19		1.1955E-11	3.9540E-04
20		3.1905E-12	3.3194E-04
21		8.5145E-13	2.7866E-04
22		2.2723E-13	2.3393E-04
23		6.0640E-14	1.9639E-04
24		1.6183E-14	1.6487E-04

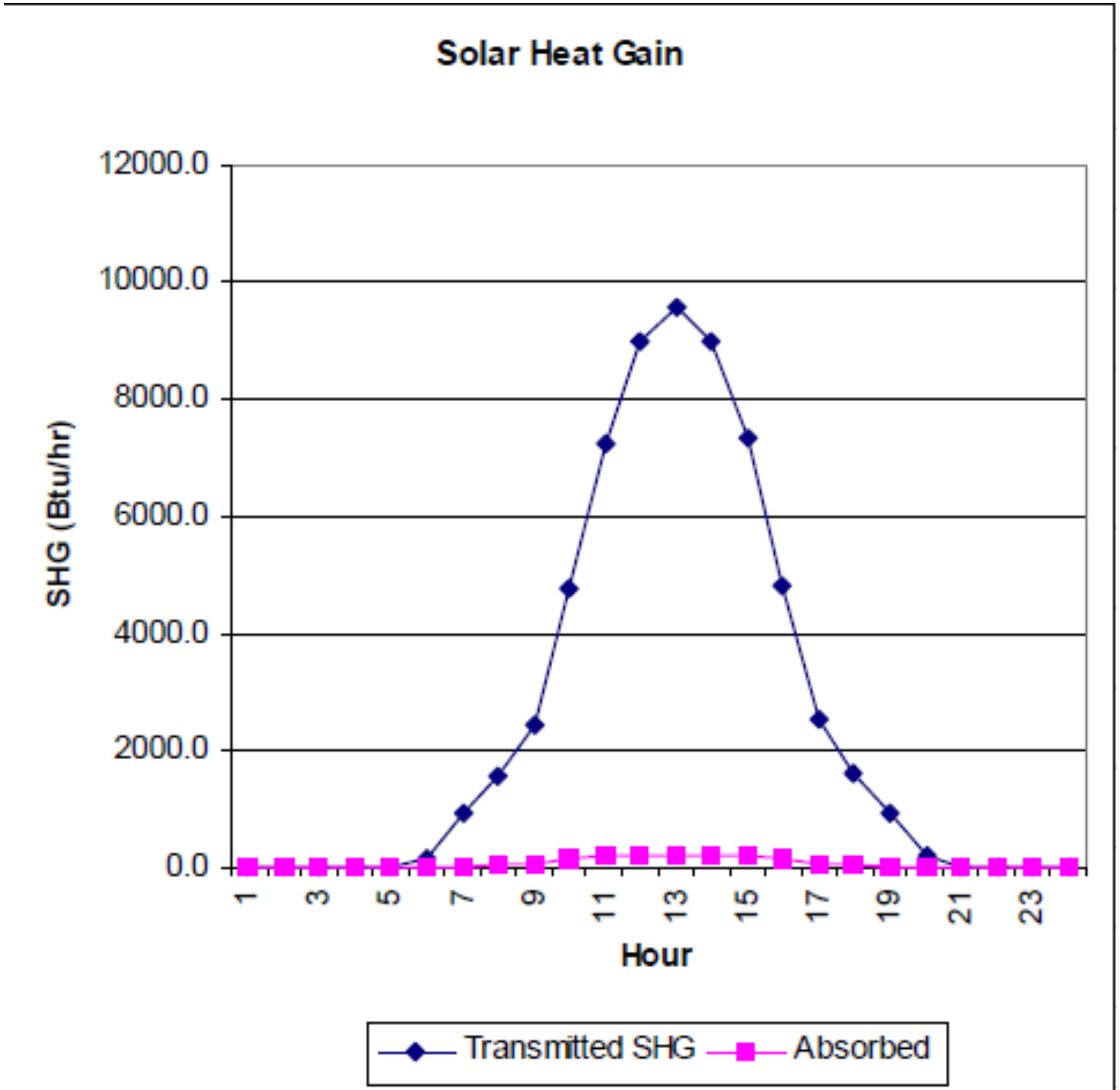
Y_{pn}



Estimate hourly conductive heat gains



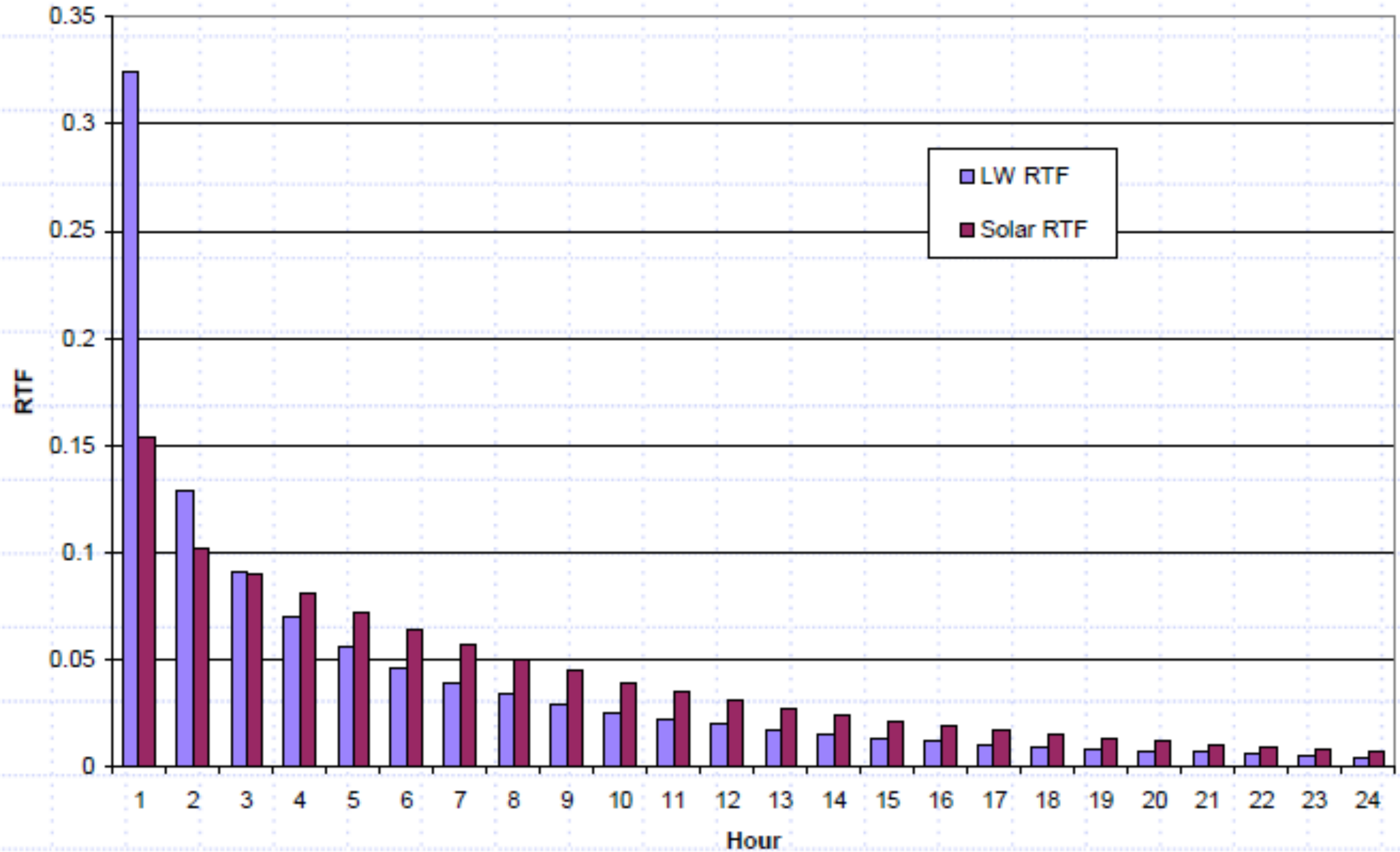
Find solar heat gains



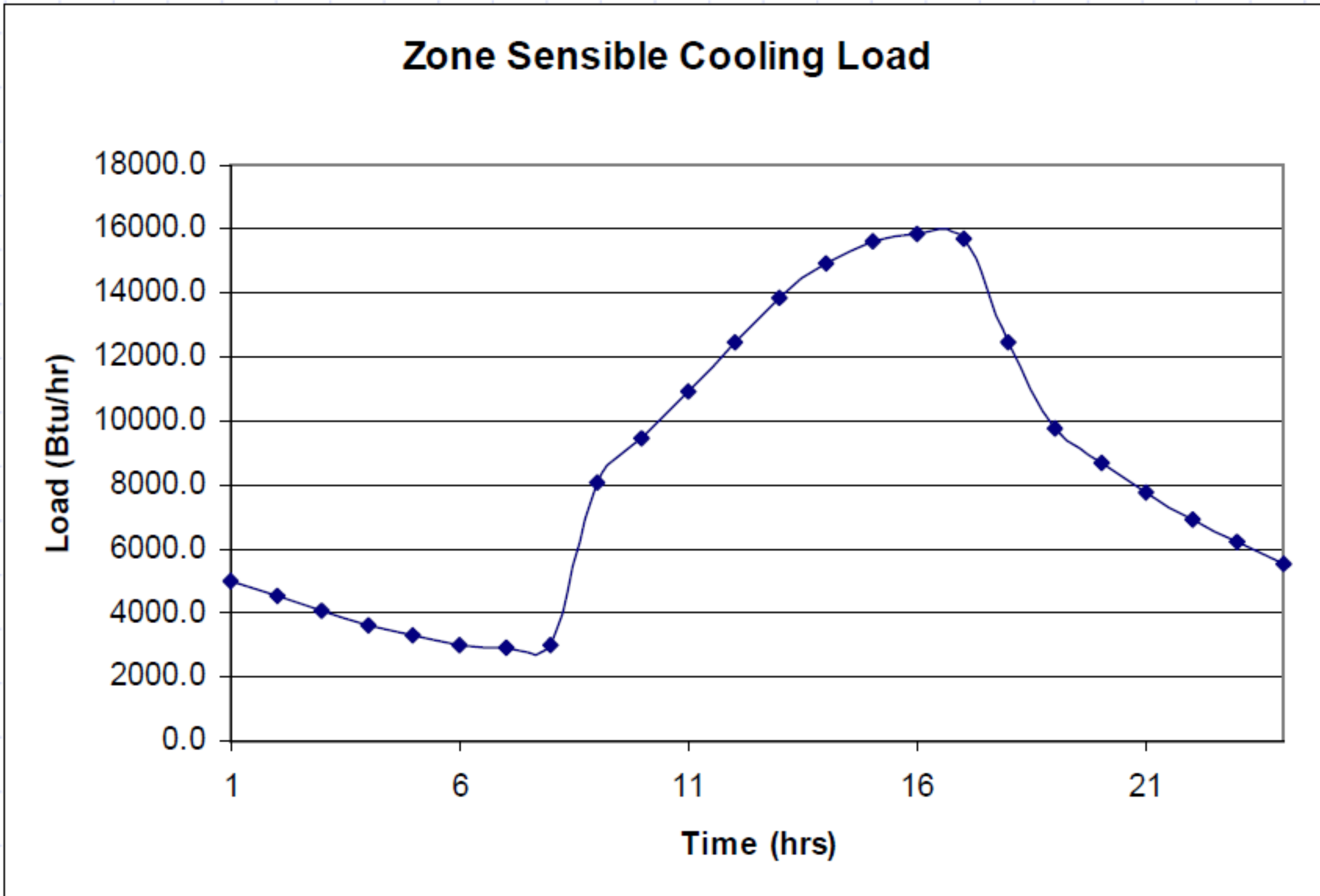
Radiative vs. convective split gains

Heat Gain	% radiative	% convective
Wall, window conduction	63	37
Roof conduction	84	16
People	70	30
Lighting	67	33
Equipment	20	80
Transmitted solar heat gain	100	0
Absorbed solar heat gain	63	37
Infiltration	0	100

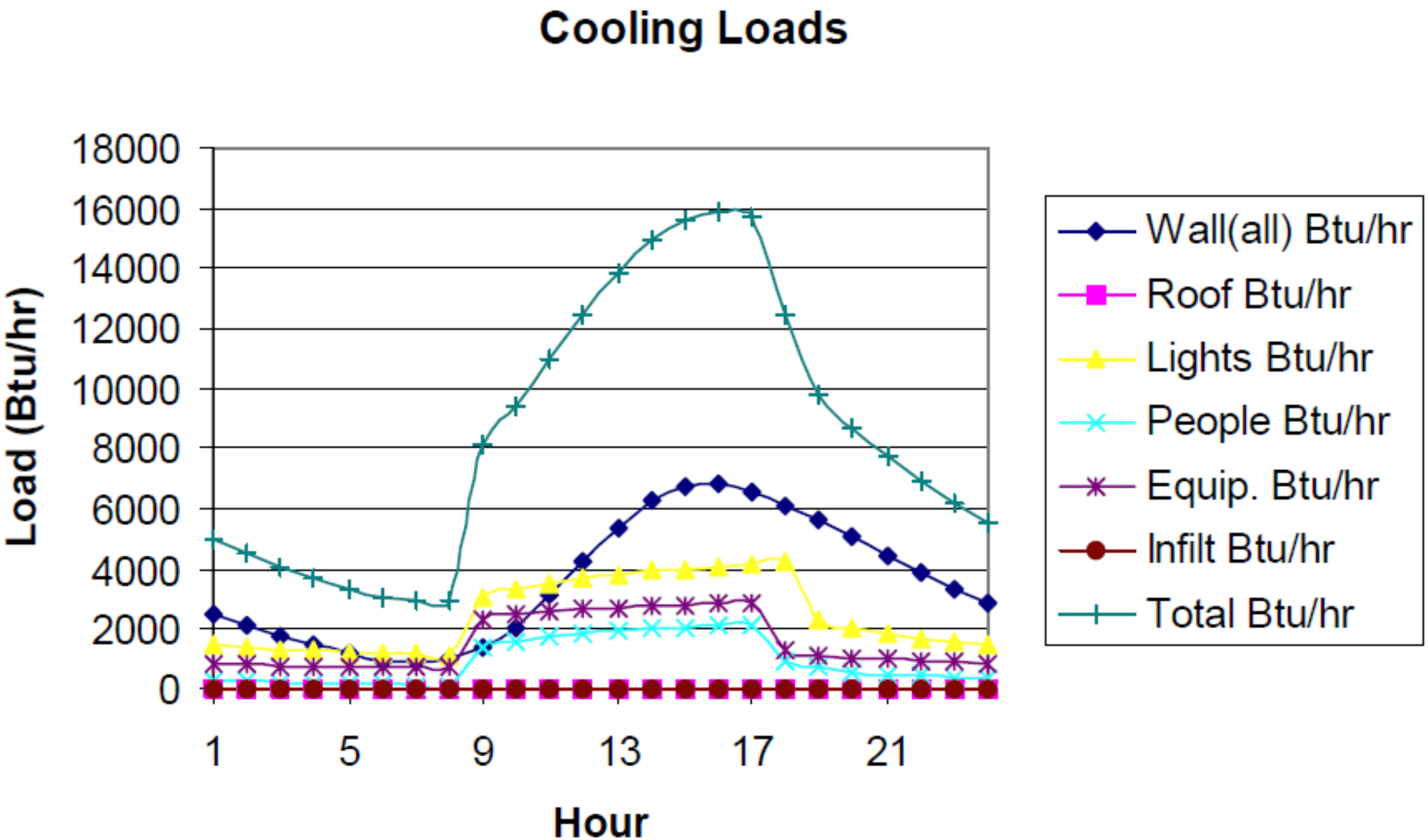
Enter RTFs from ASHRAE



Sum all to get total hourly cooling loads



Component hourly cooling loads



OTHER THOUGHTS ON HEATING AND COOLING LOADS

Estimating cooling loads

- Frequently a cooling load must be calculated before every parameter in the conditioned space can be properly or completely defined
  - An example is a cooling load estimate for a new building with many floors of un-leased spaces where detailed partition requirements, furnishings, lighting selection and layout cannot be predefined
  - Potential tenant modifications once the building is occupied also must be considered

- The total load estimating process requires proper engineering judgment that includes a thorough understanding of heat balance fundamentals

Issues with oversizing

- Since getting an accurate cooling load estimate can be difficult (or even impossible at an early design stage) some engineers design conservatively and deliberately oversize systems

- Oversizing a system is problematic because
  - Oversized systems are less efficient, harder to control, and noisier than properly sized systems
  - Oversized systems tend to duty cycle (turn on and off) which reduces reliability and increases maintenance costs
  - Oversized systems take up more space and cost more

Basic design steps for cooling equipment specification

- Determine building envelope and owner's criteria
- Determine outside/inside design conditions
- Calculate loads
  - Building loads, heat gains/losses
  - System loads, ventilation load, duct leakage
- Select equipment
- Prepare drawings and specifications

A note on “zoning”