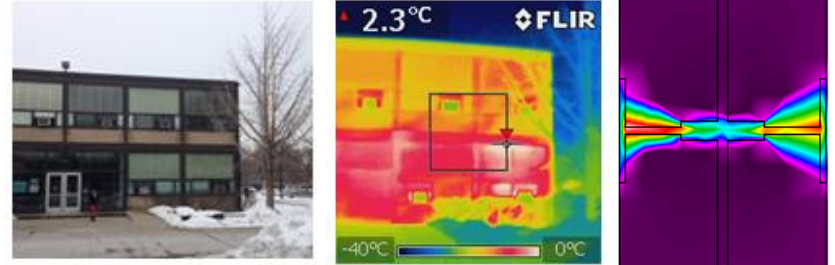


CAE 331/513

Building Science

Fall 2016



Week 13: November 17, 2016

Cooling load calculations

Built
Environment
Research

@ IIT



*Advancing energy, environmental, and
sustainability research within the built environment*

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Civil, Architectural and Environmental Engineering
Illinois Institute of Technology
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Course evaluations

- Open now, due Sunday December 4th
- Please login to myIIT, go to the Teaching portal, and submit your course and instructor evaluations!

Webinar next week

POWER DOWN



SPONSORED BY MINNESOTA DEPARTMENT OF COMMERCE, DIVISION OF ENERGY RESOURCES

Advancing the last frontier: reduction of commercial plug loads

Tuesday, November 22, 2016 · LIVE WEBINAR 1–2 pm Central

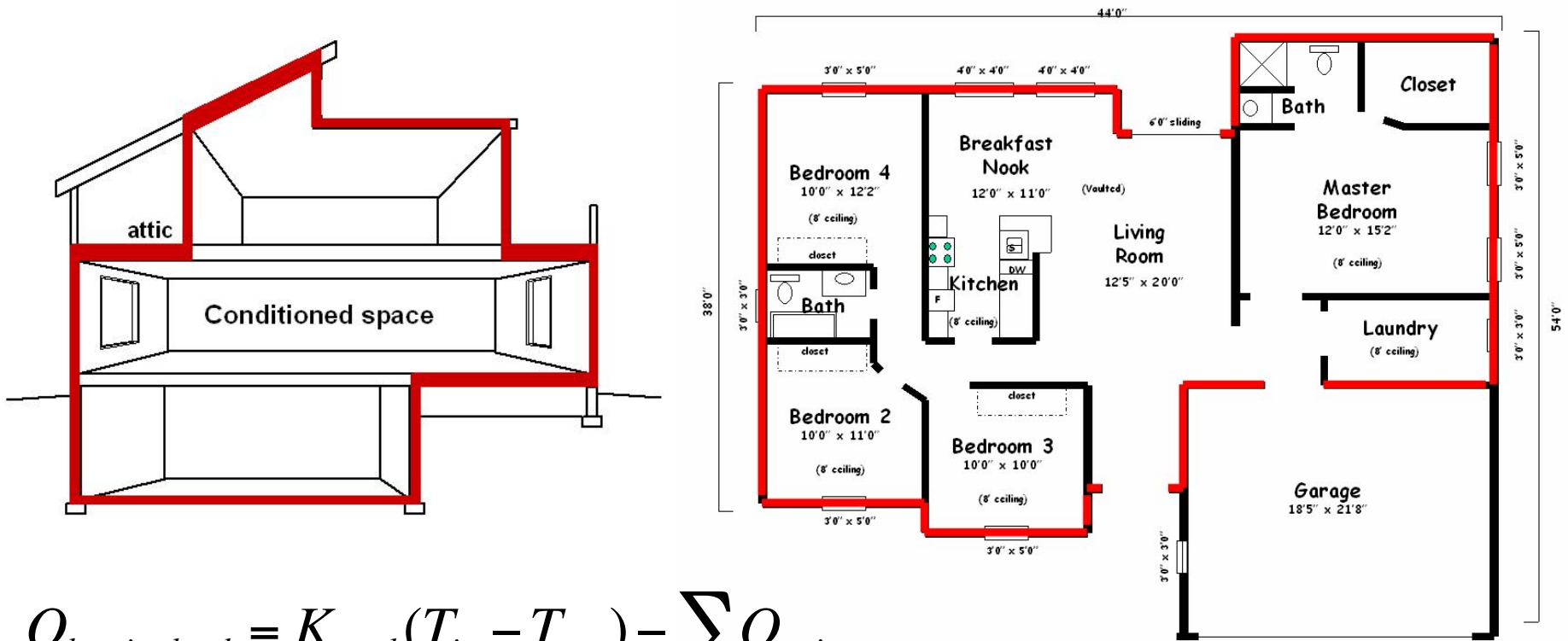
<http://www.seventhwave.org/education/webinars/commercial-plug-loads-webinar>

Last time

- Introduced the concept of heating and cooling load calculations
- Introduced environmental design conditions
- Introduced heating load calculation procedures
 - Relatively simple
 - Steady-state/instantaneous
 - Envelope + air exchange - internal gains

Heating load calculations

- Define the building envelope, calculate transmission losses and internal gains, find design conditions, and use the simple equations below

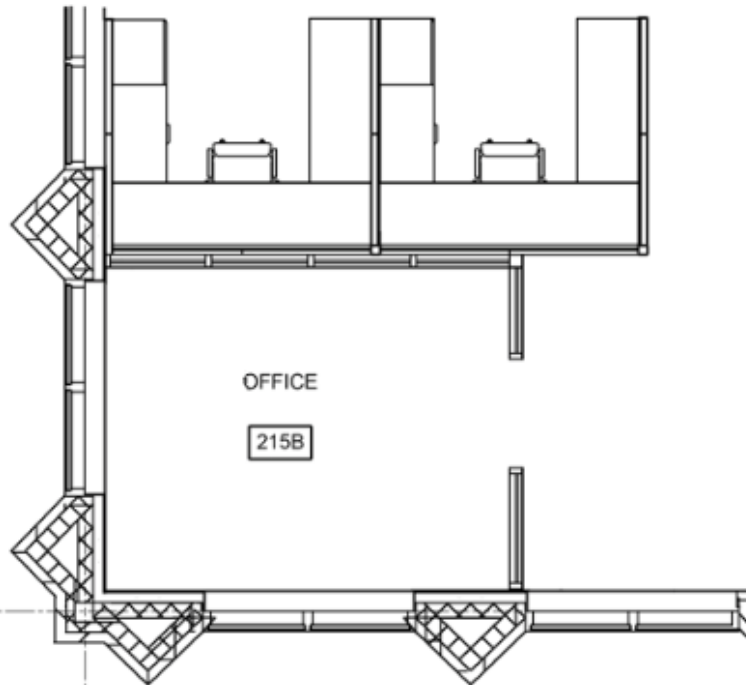


$$Q_{heatingload} = K_{total} (T_{in} - T_{out}) - \sum Q_{gains}$$

$$Q_{heatingload} = \left(\sum UA + \dot{V}_{OA} \rho_{OA} C_{p,air} \right) (T_{in} - T_{out}) - \sum Q_{gains}$$

Heating load calculations (single zone – IP units)

Calculate the peak heating load for the office room shown here (at 99.6%):



<i>South exposure:</i>	Orientation	= 30° east of true south
	Window area	= 40 ft ²
	Spandrel wall area	= 60 ft ²
	Brick wall area	= 60 ft ²
<i>West exposure:</i>	Orientation	= 60° west of south
	Window area	= 40 ft ²
	Spandrel wall area	= 60 ft ²
	Brick wall area	= 40 ft ²

Location: Atlanta, GA, 2nd floor of a two-story building,
Enclosure: 2 vertical exterior exposures and a flat roof above

Area: 130 ft²

Ceiling height: 9 ft

Floor: Carpeted 5 inch concrete slab on metal deck above conditioned space

Roof: Flat metal deck with rigid closed cell polyisocyanurate foam insulation (R=30 hr-ft²-°F/BTU)

Spandrel wall: Bronze tinted glass, opaque, backed with air space and rigid fiberglass insulation. Total U-value of 0.077 BTU/hr-ft²-°F

Insulated brick wall: Brick with continuous exterior insulation and interior fiberglass batt insulation. Total U = 0.08 BTU/hr-ft²-°F).

Infiltration: 1 air change per hour during peak heating

Window U values: Double glazed ¼" bronze tinted with ½" air space. Total U = 0.56 BTU/hr-ft²-°F.

Occupancy: None during peak heating

Lighting: None during peak heating

Indoor design conditions: 72°F for heating

Heating load calculations (single zone – IP units)

2013 ASHRAE Handbook - Fundamentals (IP)

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ATLANTA MUNICIPAL, GA, USA

WMO#: 722190

Lat: 33.64N

Long: 84.43W

Elev: 1027

StdP: 14.16

Time Zone: -5 (NAE)

Period: 86-10

WBAN: 13874

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)
1	21.5	26.4	4.2	7.1	28.6	9.1	9.1	32.2	24.9	39.9	23.5	40.0	11.9	320

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)
7	17.0	93.9	74.2	91.7	73.9	89.8	73.5	77.3	88.5	76.4	86.7	75.4	85.0	8.7	300

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours 8 to 4 & 55/69
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)
74.3	133.1	81.3	73.3	128.7	80.2	72.6	125.5	79.6	41.4	88.5	40.4	86.7	39.5	85.6	800

Extreme Annual Design Conditions

Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)
21.5	19.0	17.1	82.4	14.1	96.7	4.4	3.3	10.9	99.1	8.3	101.0	5.8	102.9	2.6	105.3

Selecting heating equipment

- Once you know your design heating load, you can select heating equipment

$$Q_{h,\max} = 4406 \text{ BTU/hr} = 4.4 \text{ kBTU/hr}$$

MODEL	HEIGHT (IN.)	WIDTH (IN.)	DEPTH (IN.)	NOMINAL CAPACITY OUTPUT (BTUH)
TUE1A040A9241A	40	14.5	28	31,000
TUE1A060A9241A	40	14.5	28	47,000
TUE1A060A9361A	40	14.5	28	47,000
TUE1B060A9361A	40	17.5	28	47,000
TUE1B080A9361A	40	17.5	28	63,000



Estimating heating energy use with HDD

- Now that we know how to get HDD, we can calculate the heating energy, E , required to keep the building heated
- Using hourly values:

$$E_{heating} = \frac{K_{total}}{\eta} \int [T_{bal} - T_{out}(t)] dt \quad \text{when } T_{out} < T_{bal}$$

Where η = heating system efficiency (-)

- Using HDD:

$$E_{heating} = \frac{K_{total}}{\eta} HDD$$

*Convert HDD to proper units (degree-seconds or degree-hours)

Estimating heating energy use with HDD

- Find the annual heating bill for a house in Chicago under the following conditions:
 - $K_{total} = 400 \text{ BTU}/(\text{hr } ^\circ\text{F})$
 - $T_{bal} = 65^\circ\text{F}$
 - Natural gas heating system is 75% efficient
 - Natural gas fuel price is \$8/MMBTU
 - $HDD_{65F} = 6280 \text{ } ^\circ\text{F-days}$

$$E_{heating} = \frac{400 \frac{\text{BTU}}{\text{hr}^\circ\text{F}}}{0.75} (6280 \text{ } ^\circ\text{F-days}) \left(\frac{24 \text{ hours}}{1 \text{ day}} \right) = 6.03 \times 10^7 \text{ BTU} = 60.3 \text{ MMBTU}$$

$$Costs_{heating} = 60.3 \text{ MMBTU} \times \frac{\$8}{\text{MMBTU}} = \$482$$

Today's class

- Introduce cooling load calculations
 - Concepts and procedures

COOLING LOAD CALCULATIONS

The need for cooling load calculations

- You are designing a home and need to provide central air-conditioning. Which one of these air-conditioners do you select?
 - Selection from Trane:
<https://www.trane.com/residential/en/products/heating-and-cooling/air-conditioners.html>
- A contractor might tell you 1 ton for every 600 ft²
 - But that doesn't take the properties of the building into account

The need for cooling load calculations

XR16 CENTRAL AIR CONDITIONING SYSTEMS



MODEL	COOLING CAPACITY (BTUH)	NOMINAL TONS	HEIGHT (IN.)	WIDTH (IN.)	DEPTH (IN.)
4TTR6018B	18,000	1.5	29	33	30
4TTR6024B	24,000	2	29	33	30
4TTR6030B	30,000	2.5	33	37	34
4TTR6036B	36,000	3	37	37	34
4TTR6042B	42,000	3.5	41	37	34
4TTR6048B	48,000	4	45	37	34
4TTR6049B	48,000	4	45	37	34
4TTR6060B	60,000	5	45	37	34

Cooling loads

- Cooling load calculations are more complicated than heating load calculations
- Peak cooling loads will occur during the day when solar radiation is present
 - People and equipment can also be highly variable
- Radiation varies throughout the day and the building's **thermal mass** affects the time release of this heat energy
 - Calculations must be **dynamic** to account for **storage**

$$Q_{sensible\ load} = Q_{envelope\ transmission} + Q_{air\ exchange} - Q_{solar} - Q_{people} - Q_{equipment} - Q_{lights} \pm Q_{storage}$$

Remember:

Q is typically positive (+) when there is a heating load (cold outside)

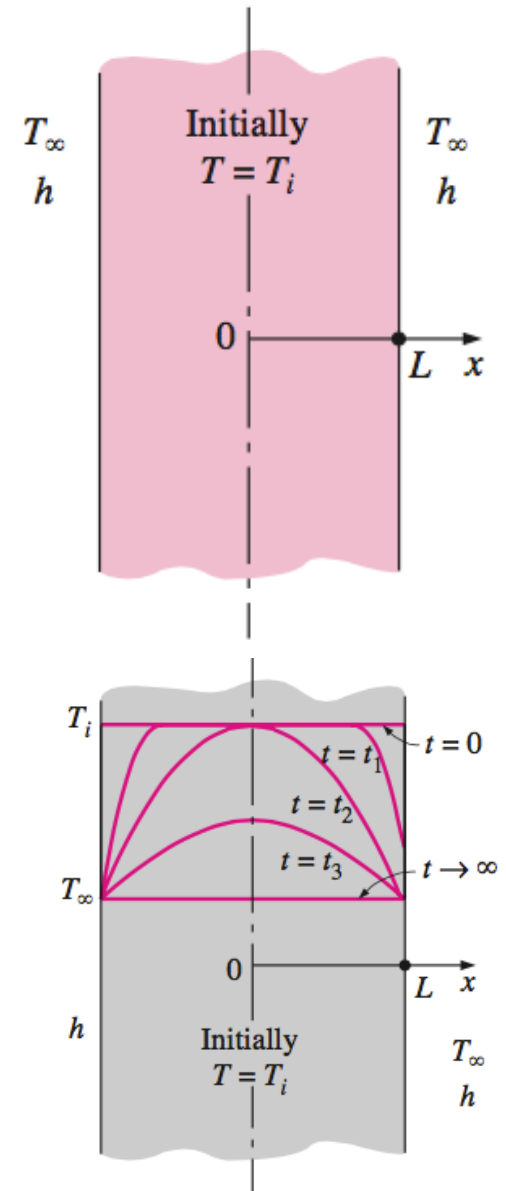
Q is typically negative (-) when there is a cooling load (hot outside)

Dynamic response for **cooling** loads

- Cooling load calculations differ because gains from **radiation** do not directly heat up the air in the space
 - Only **convection** from interior surfaces contributes to an immediate temperature rise in the air space
- Radiation through windows, from interior surfaces, and from internal sources (e.g., lights) will be absorbed by other interior surfaces, and then those surfaces will eventually transfer that heat energy to the air by convection
 - But the addition of radiative heat does not occur immediately
- Because radiative heating is not direct, **heat storage** through **thermal mass** can create a thermal lag, which can have a large effect on cooling loads

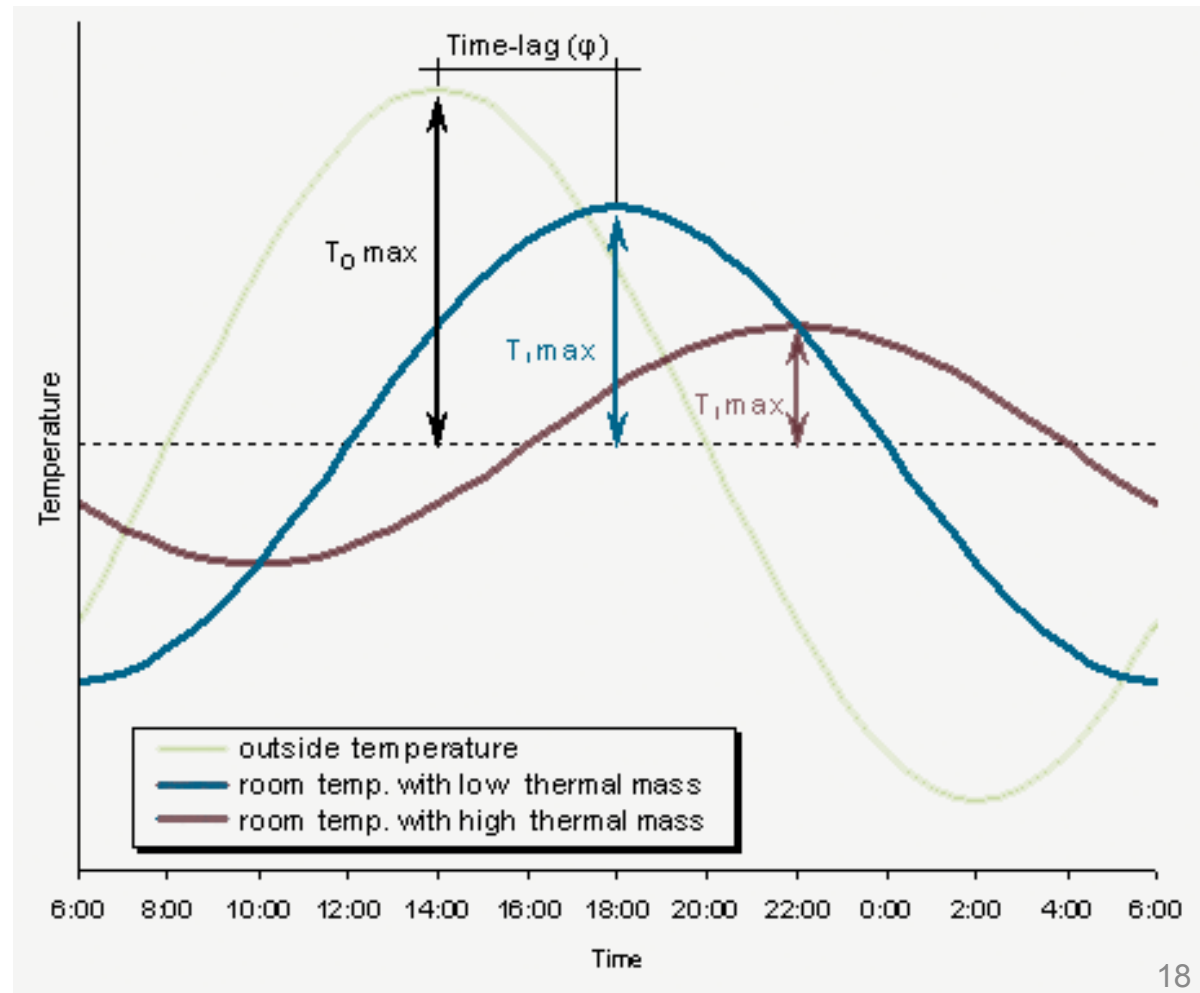
Transient heat conduction

- Very often, conductive heat transfer in buildings does not occur at “steady-state”
- Instead, temperatures change in time at different places within and outside of a building object, so “non steady-state” conduction actually occurs
- When temperature changes occur, the system changes in time toward a new equilibrium with the new conditions, but it takes time for that to happen



Transient heat conduction: Accounting for heat capacity

- All materials have at least capacity to store thermal energy for extended periods of time
- This is often referred to as “thermal mass”
- Thermal mass absorbs heat gains and release them at a later time



Heat capacity, HC

- The **heat capacity** (HC) of a material is a measure of the ability of a material to store energy under a temperature diff.
 - HC is the product of the **density** of the material and its **specific heat capacity**, with different thickness/area/volume formulations:

$HC = \rho L C_p$	$HCA = \rho L A C_p = \rho V C_p$
[J/m ² K]	[J/K]

- ρ = density [kg/m³]
 - C_p = specific heat capacity [J/kgK]
 - L = thickness of material [m]
 - A = projected surface area of material [m²]
 - V = volume of material [m³]
- Heat capacity is important to thermal mass, but needs to be compared with thermal conductivity to get the whole story

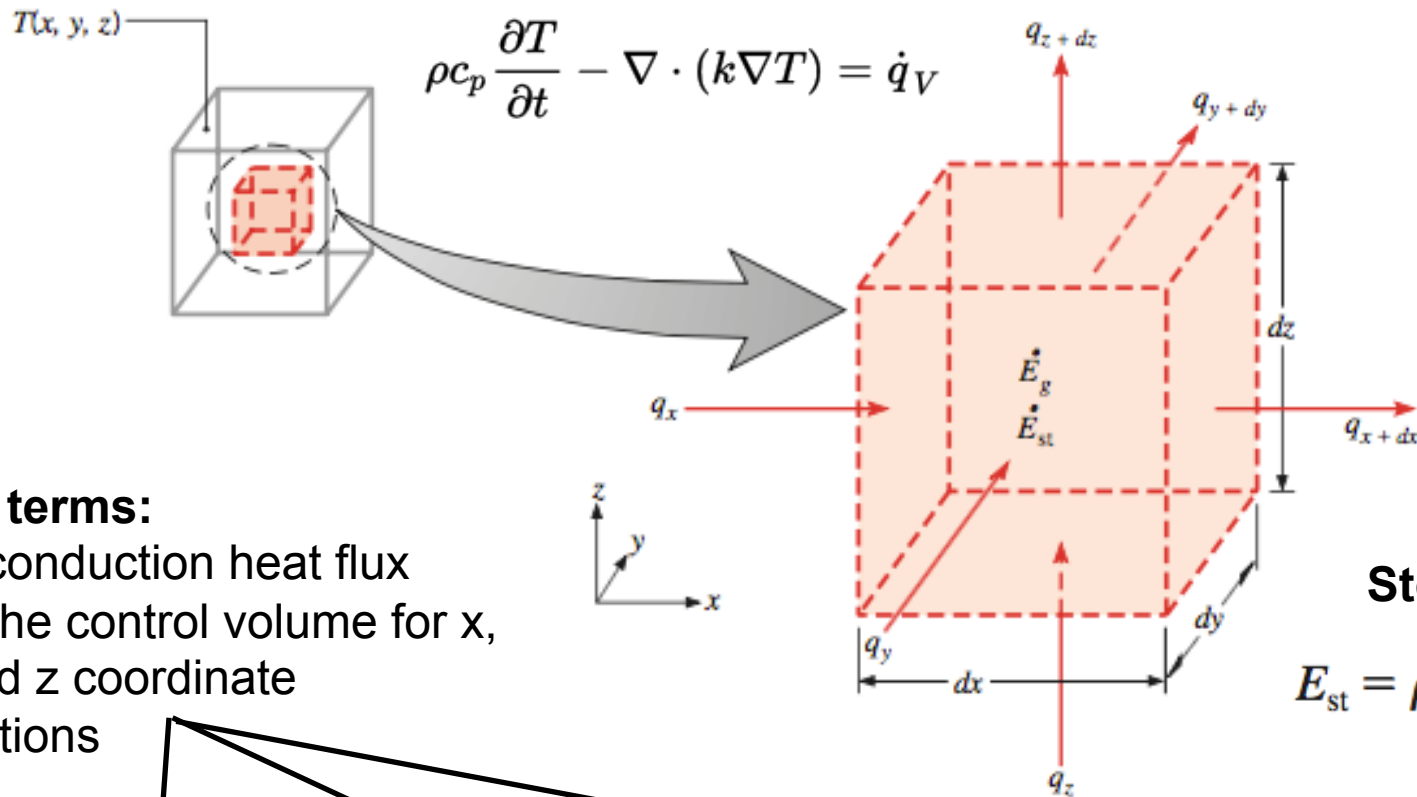
Thermal diffusivity, α

- Thermal diffusivity, α , is the measure of how fast heat can travel through an object
- α is proportional to conductivity but inversely proportional to density and specific heat capacity:

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

- The lower the α , the better the material is as a thermal mass (low conductivity relative to storage ability)
 - The time lag between peak internal and external temperature is related to the diffusivity of the walls
 - Steel has a high ρC_p but also a high k so it is not as good a thermal mass as concrete or brick

The transient heat conduction equation



$$\rho c_p \frac{\partial T}{\partial t} - \nabla \cdot (k \nabla T) = \dot{q}_V$$

Flux terms:

Net conduction heat flux into the control volume for x, y, and z coordinate directions

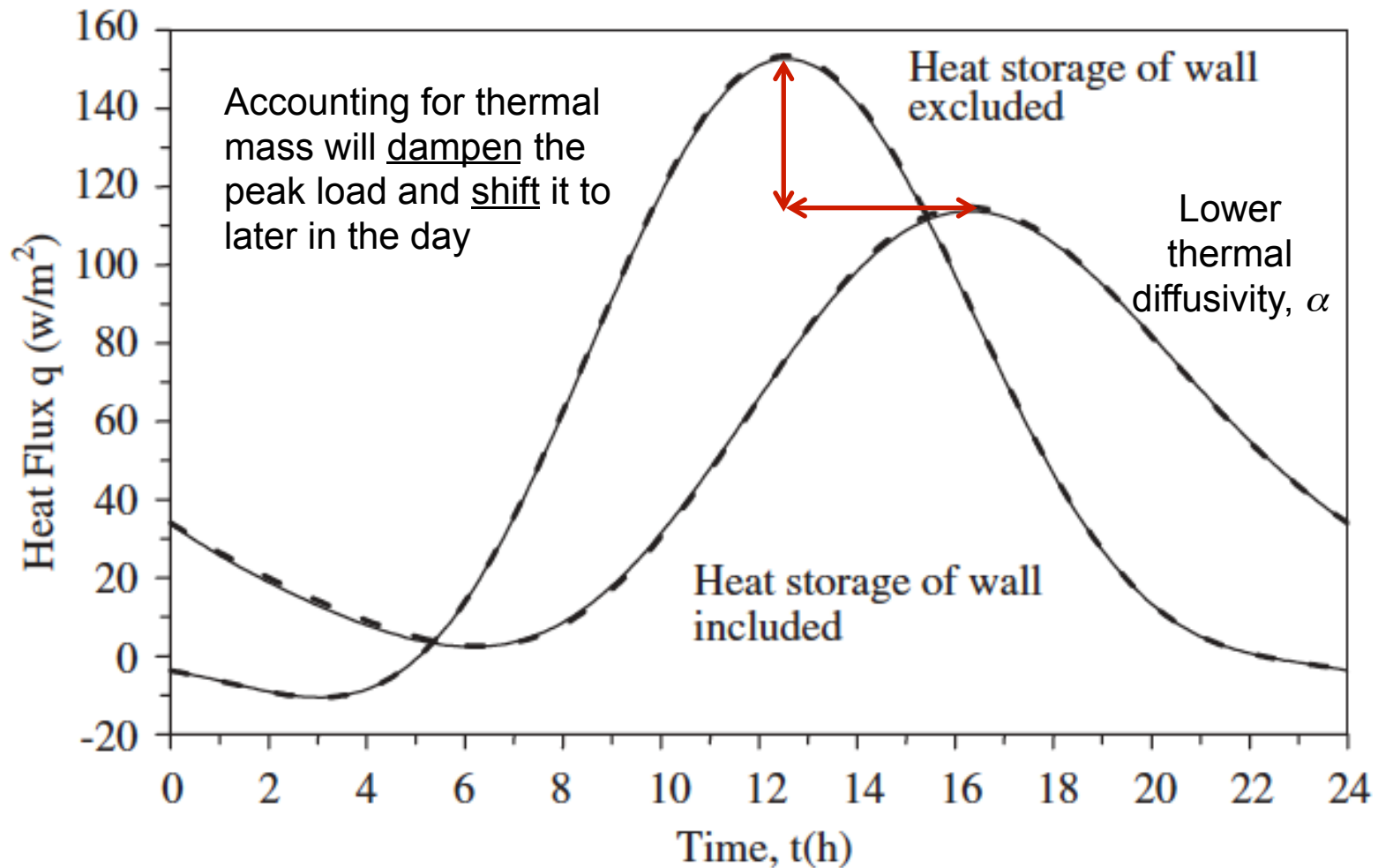
Storage term:

$$E_{st} = \rho c_p \frac{\partial T}{\partial t} dx dy dz$$

$$\frac{\partial}{\partial x} \left(k \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left(k \frac{\partial T}{\partial y} \right) + \frac{\partial}{\partial z} \left(k \frac{\partial T}{\partial z} \right) + q = \rho c_p \frac{\partial T}{\partial t}$$

Heat energy source term:
Usually ignored

Accounting for thermal mass impacts



Accounting for thermal mass is necessary for other types of loads as well

- Need to account for heat capacity of building materials and the fraction of radiative versus convective heat given off by systems and equipment

	Radiative, percent	Convective, percent
Fluorescent lights	50	50
People	33	67
External walls and roofs	60	40
Appliance and machines	20–80	80–20

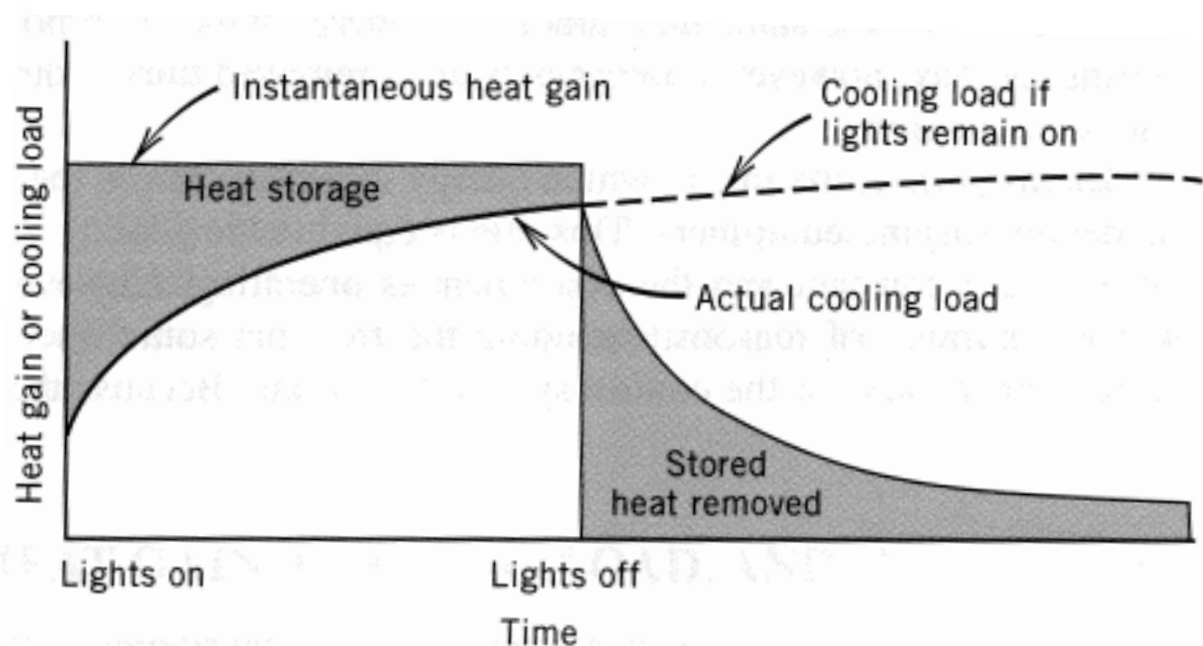


Figure 8-3 Actual cooling load from fluorescent lights.

COOLING LOAD CALCULATION METHODS

Cooling load calculation methods

- Dynamic responses and thermal mass makes cooling load calculations much more complex than heating load calculations
- There are many methods of estimating peak cooling loads
 - They vary in complexity, accuracy, computational time, and requirements for input details
- Common cooling load calculation methods:
 - Transfer Function (TF)
 - Total Equivalent Temperature Difference (TETD)
 - Cooling Load Temperature Difference / Cooling Load Factor (CLTD/CLF)
 - Radiant Time-Series Method (RTSM)
 - Heat Balance Method (HBM)
- They all rely on spreadsheets and/or computer programs

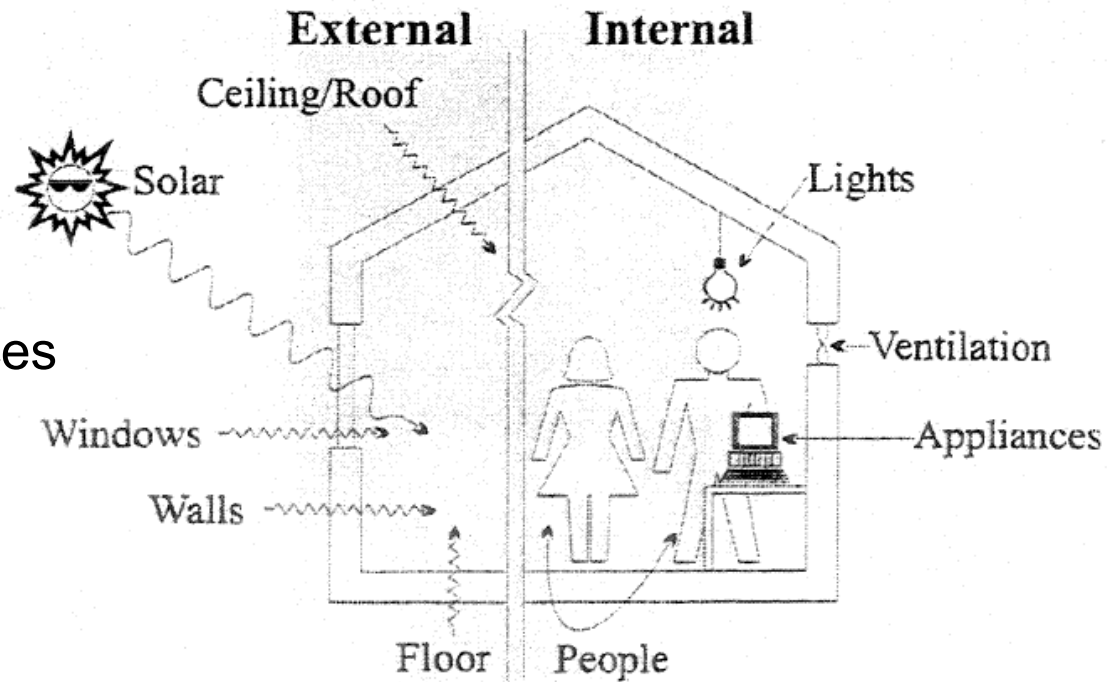
Components of cooling loads

- External loads

- Heat gain from exterior roofs, walls, floors,
- Solar heat gain transmitted through fenestration
- Conductive heat gain through fenestration
- Ventilation/infiltration of outdoor air

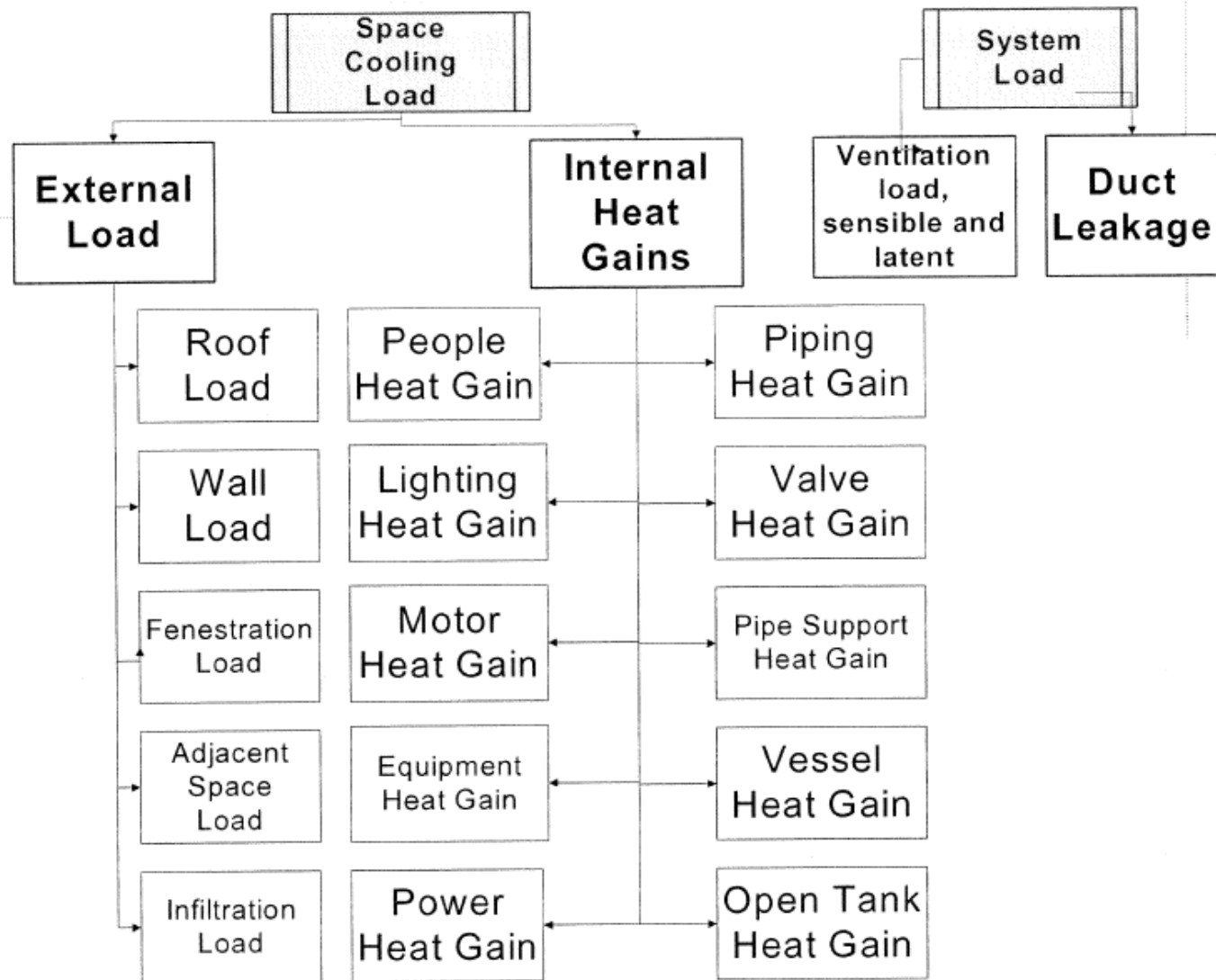
- Internal loads

- People
- Electric lights
- Equipment and appliances



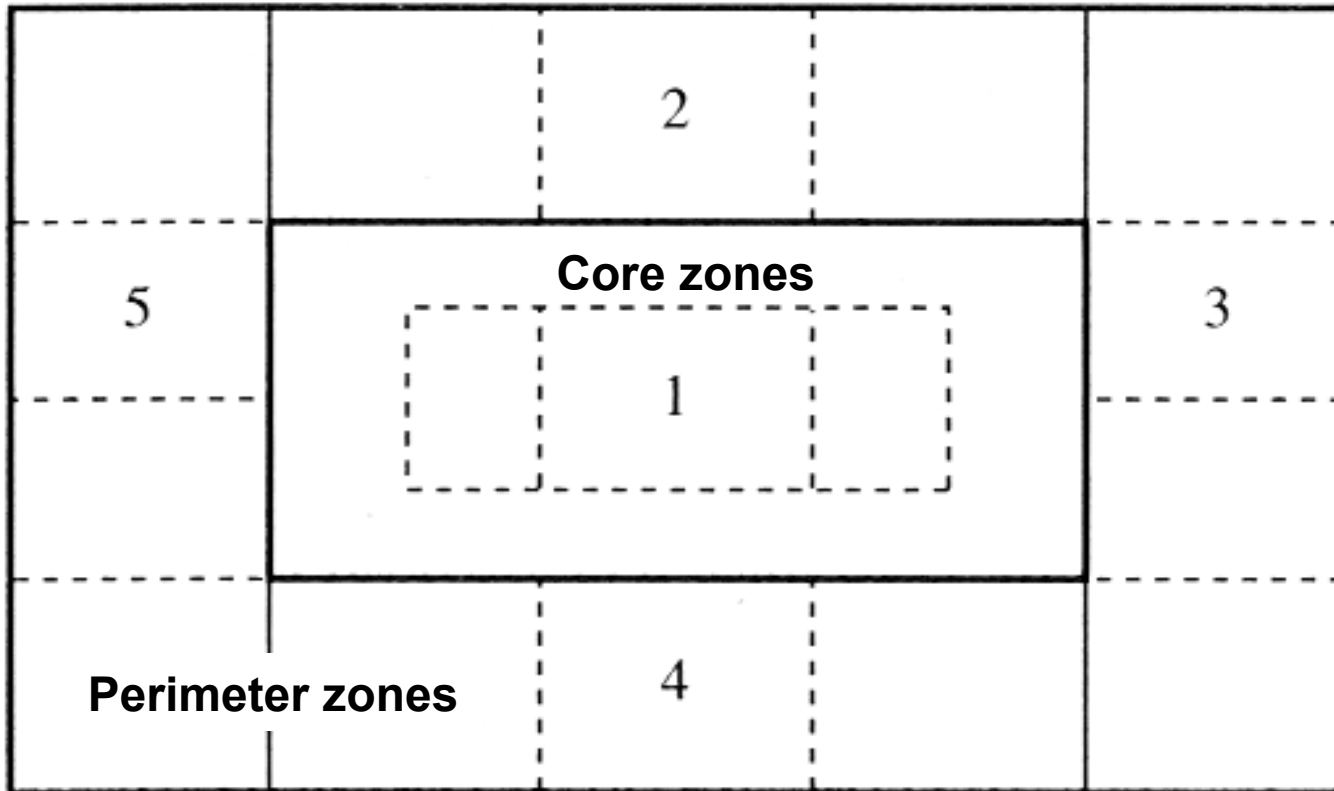
Inputs for all cooling load calculations

Cooling Load Calculation Inputs



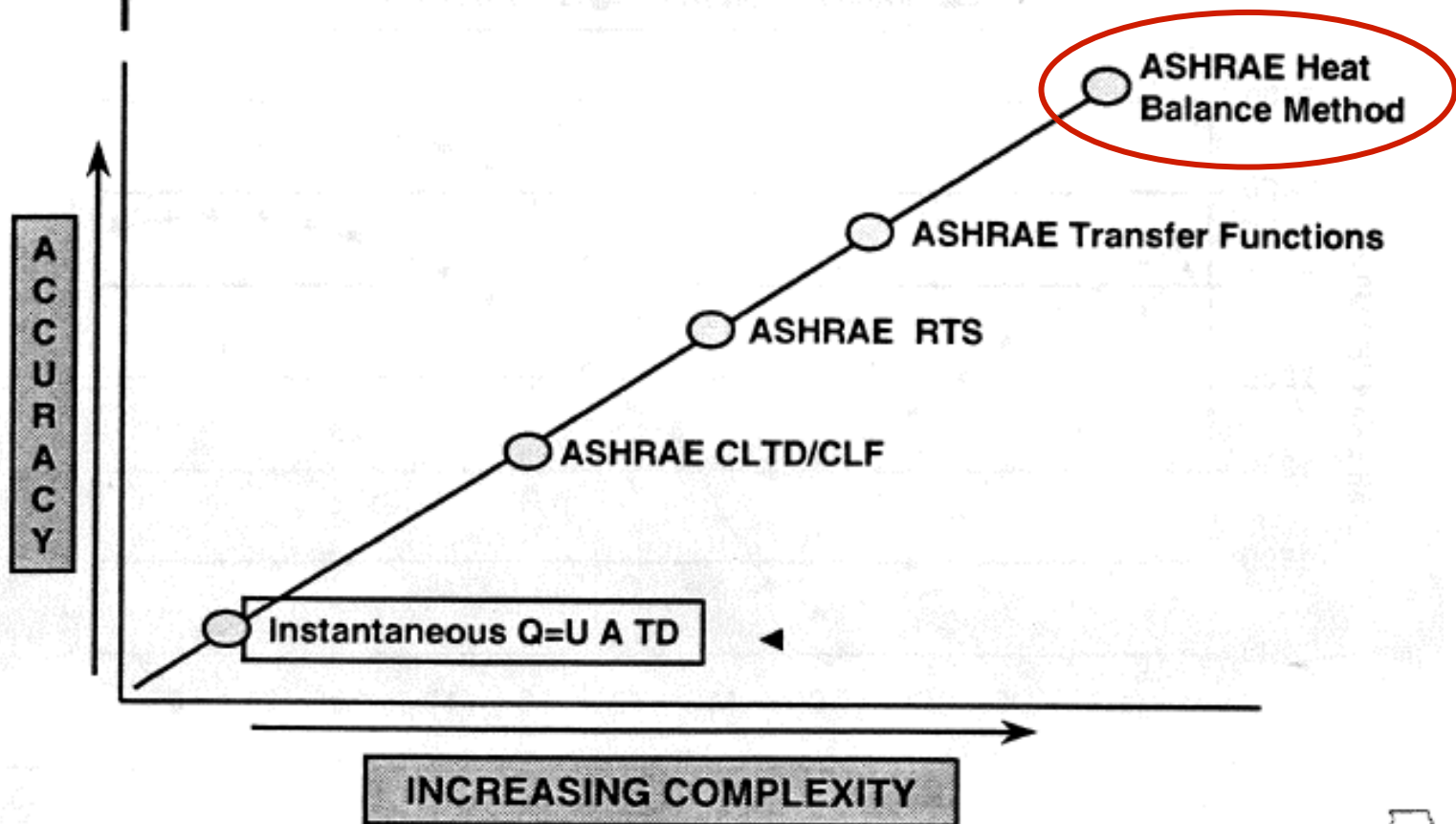
Zoning

Cooling load calculations (and heating load calculations) can be done room-by-room or zone-by-zone, and summed up for the whole building



Cooling load calculation methods

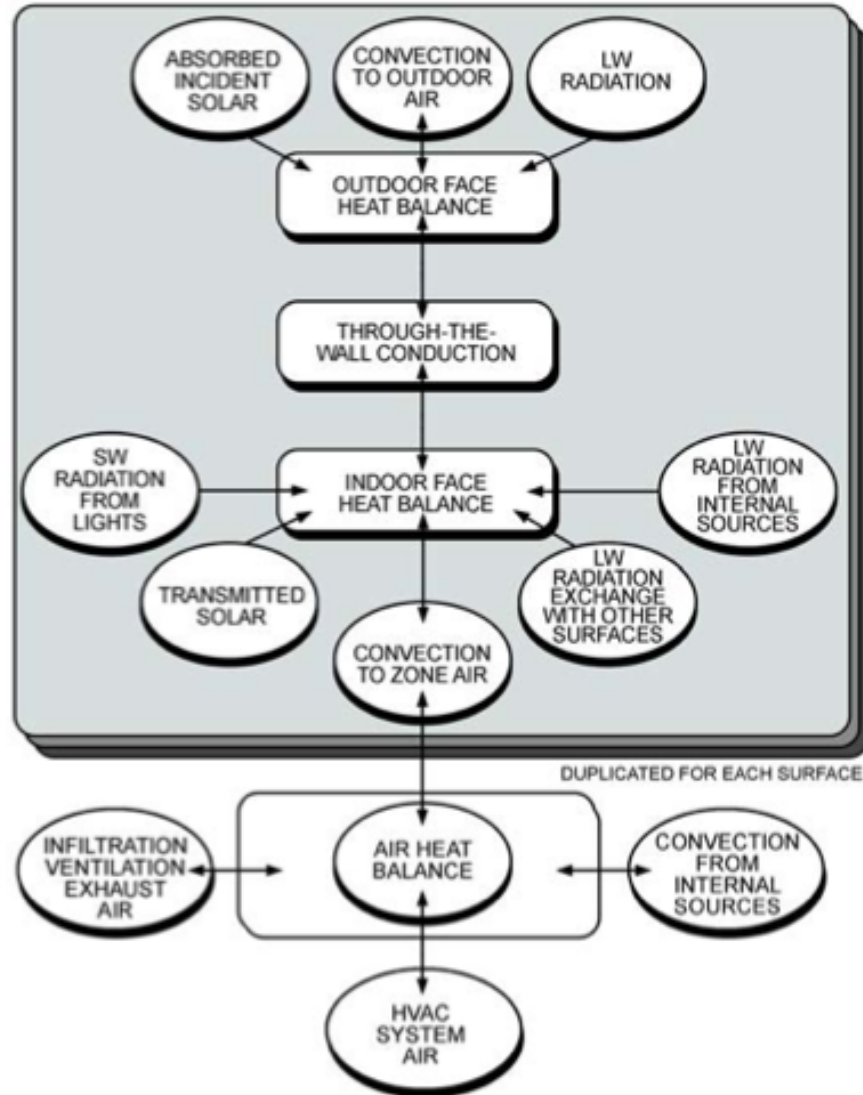
Load Estimating Methods



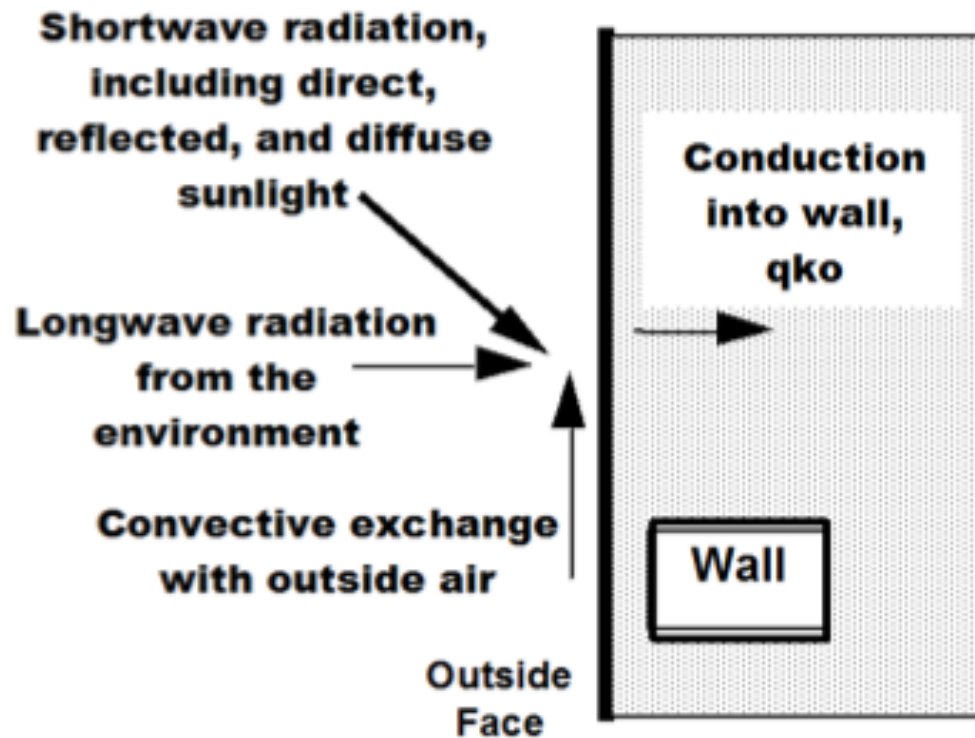
Heat balance method (HBM)

- 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:
 - Heat balance on exterior surfaces
 - Heat balance on interior surfaces
 - Heat balance on indoor air
 - 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, e.g., TMY3)
- It is more fundamentally linked than other approaches
 - Makes fewer assumptions than the other methods
 - But is more complex to solve
 - HBM provides the basis for modern energy simulation programs

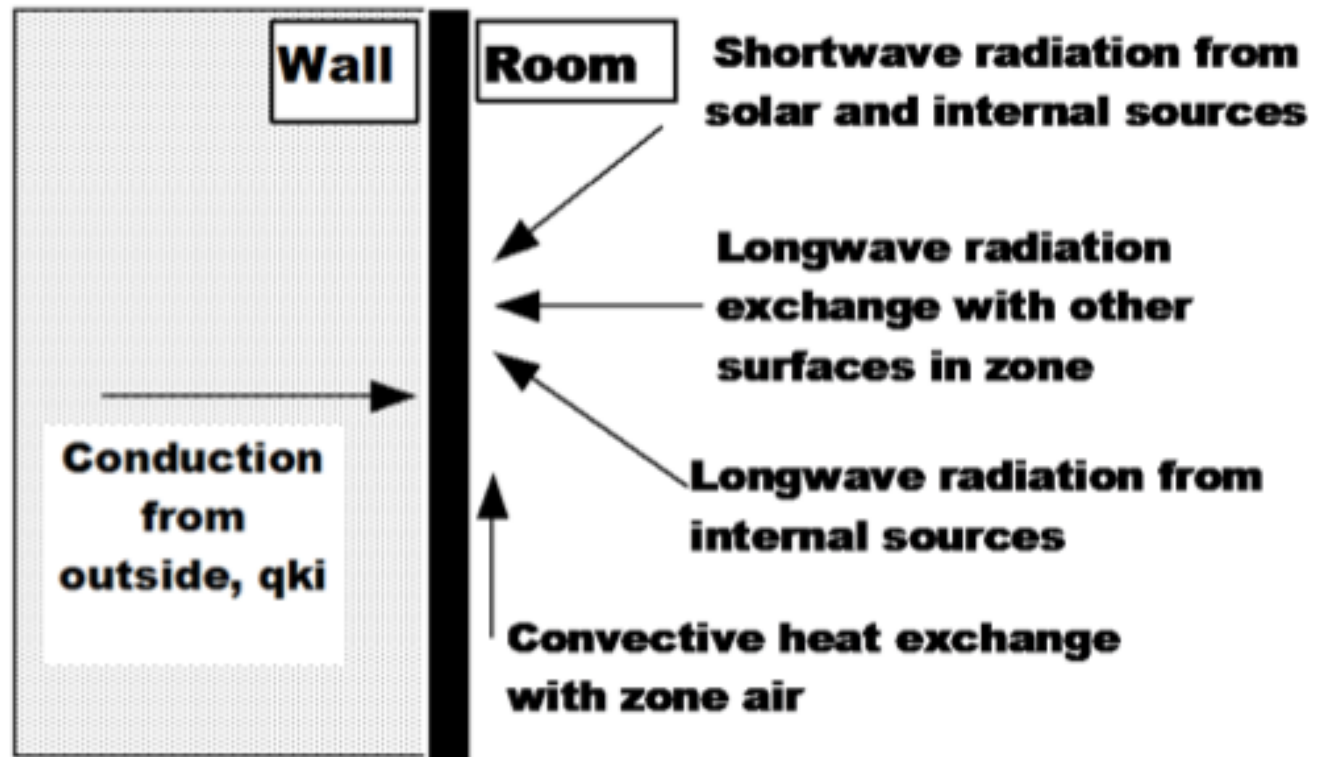
Heat balance method (HBM)



Heat balance method (HBM): **Outside surface** heat balance

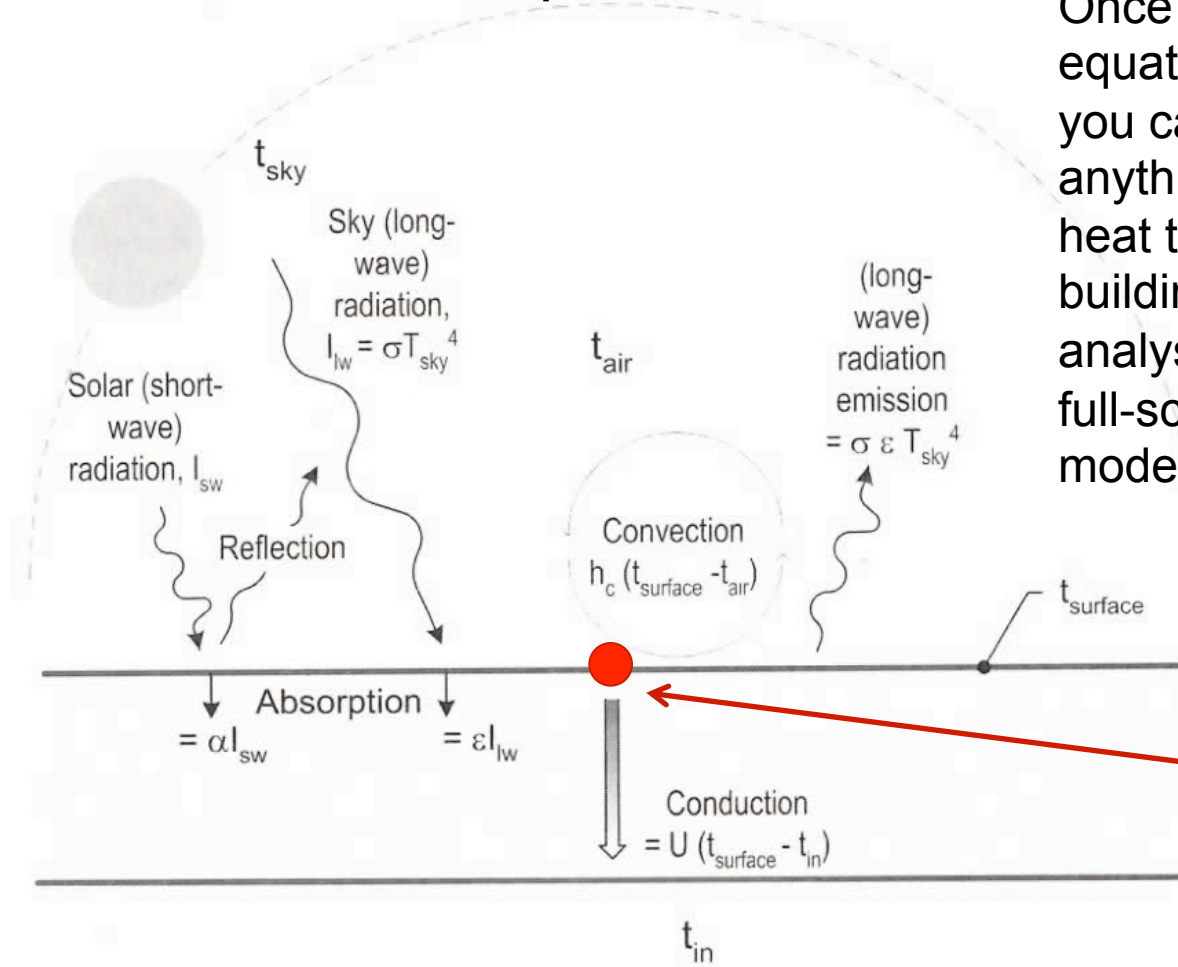


Heat balance method (HBM): **Inside surface** heat balance



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)

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

HBM: Surface energy balance

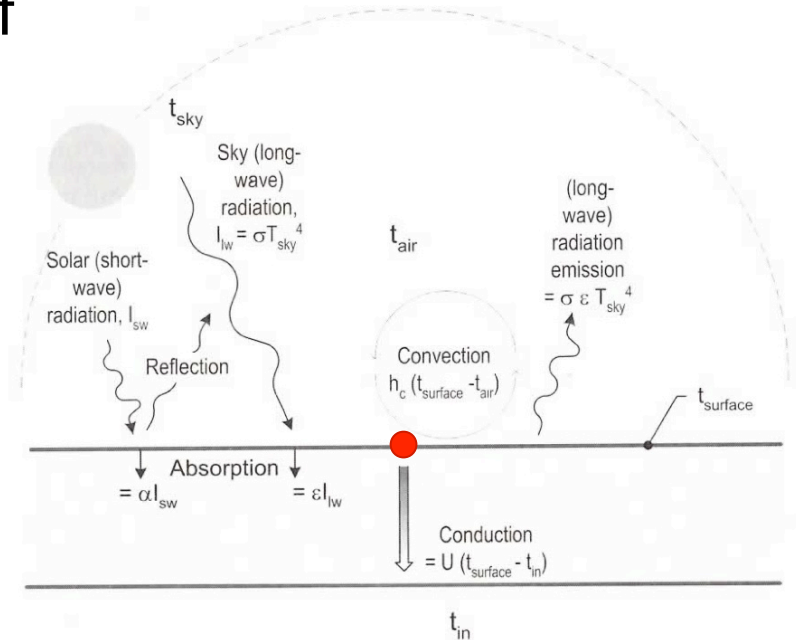
- Exterior surface example: roof

$$\sum q = 0$$

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

$$\alpha I_{solar}$$

$$q_{sw,solar}$$

Surface-sky radiation

$$+\epsilon_{surface} \sigma F_{sky} (T_{sky}^4 - T_{surf}^4)$$

$$+q_{lw,surface-sky}$$

Convection on external wall

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

$$+q_{convection}$$

Conduction through wall

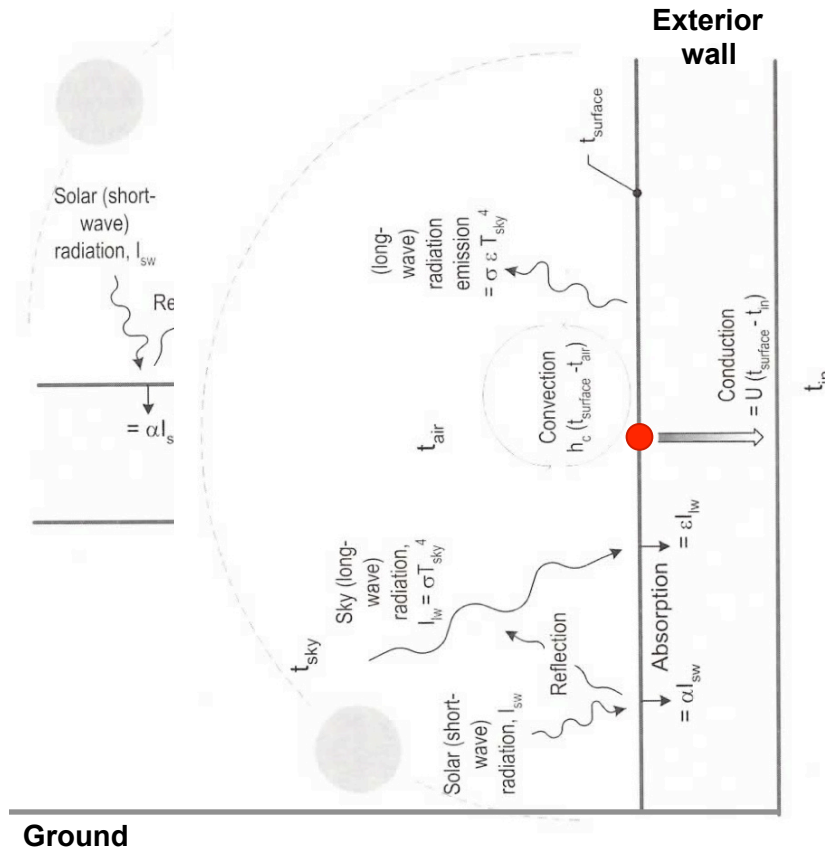
$$-U(T_{surface} - T_{surface,interior}) = 0$$

$$-q_{conduction} = 0$$

HBM: Surface energy balance

- Similarly, for a vertical surface:

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



$$\begin{aligned} & \alpha I_{solar} \\ & + \epsilon_{surface} \sigma F_{sky} (T_{sky}^4 - T_{surface,ext}^4) \\ & + \epsilon_{surface} \sigma F_{ground} (T_{ground}^4 - T_{surface,ext}^4) \\ & + h_{conv} (T_{air} - T_{surface,ext}) \\ & - U (T_{surface,ext} - T_{surface,int}) = 0 \end{aligned}$$

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

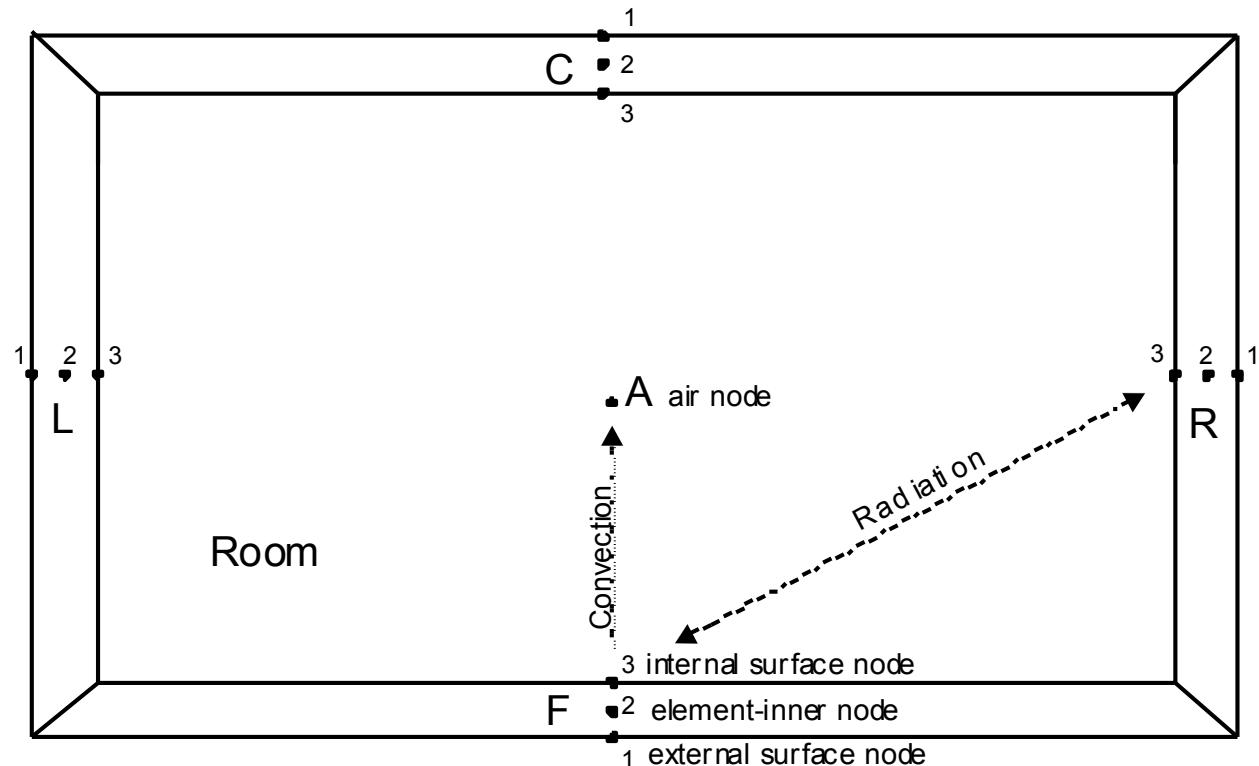
At surface nodes:

$$\sum q = 0$$

At nodes inside materials:

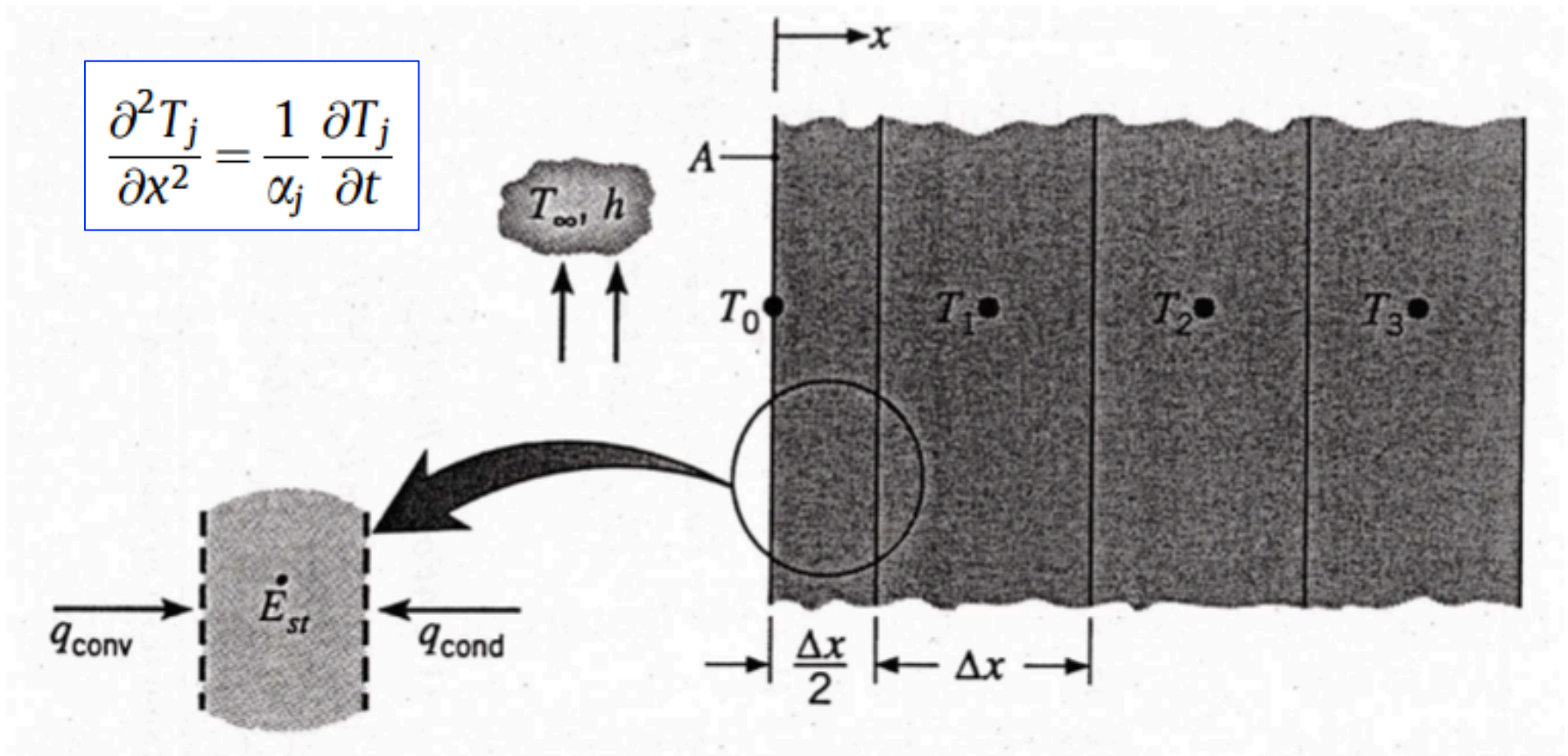
$$mc_p \frac{dT}{dt} = \sum q_{at\ boundaries}$$

Based on density and heat capacity of material...



Modeling thermal mass: Transient (unsteady) conduction

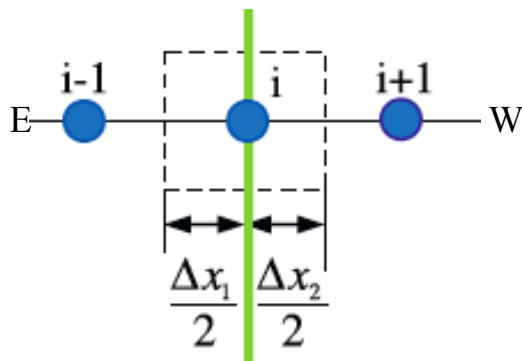
- Divide material assembly into multiple nodes



Transient conduction: Example numerical approach

- Conduction finite difference solution (**implicit**)

$$C_p \rho \Delta x \frac{T_i^{j+1} - T_i^j}{\Delta t} = \frac{1}{2} \left[\left(k_w \frac{(T_{i+1}^{j+1} - T_i^{j+1})}{\Delta x} + k_E \frac{(T_{i-1}^{j+1} - T_i^{j+1})}{\Delta x} \right) + \left(k_w \frac{(T_{i+1}^j - T_i^j)}{\Delta x} + k_E \frac{(T_{i-1}^j - T_i^j)}{\Delta x} \right) \right] \quad (36)$$



Where:

T = node temperature

Subscripts:

i = node being modeled

$i+1$ = adjacent node to interior of construction

$i-1$ = adjacent node to exterior of construction

$j+1$ = new time step

j = previous time step

Δt = calculation time step

Δx = finite difference layer thickness (always less than construction layer thickness)

C_p = specific heat of material

k_w = thermal conductivity for interface between i node and $i+1$ node

k_E = thermal conductivity for interface between i node and $i-1$ node

ρ = density of material

Selecting grid size:

$$\left(Fo = \alpha \Delta t / \Delta x^2 \right) < 0.5$$

Implicit = temperatures are evaluated at time $j+1$ as a function of temperatures at time j

Modeling thermal mass: Transient (unsteady) conduction

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

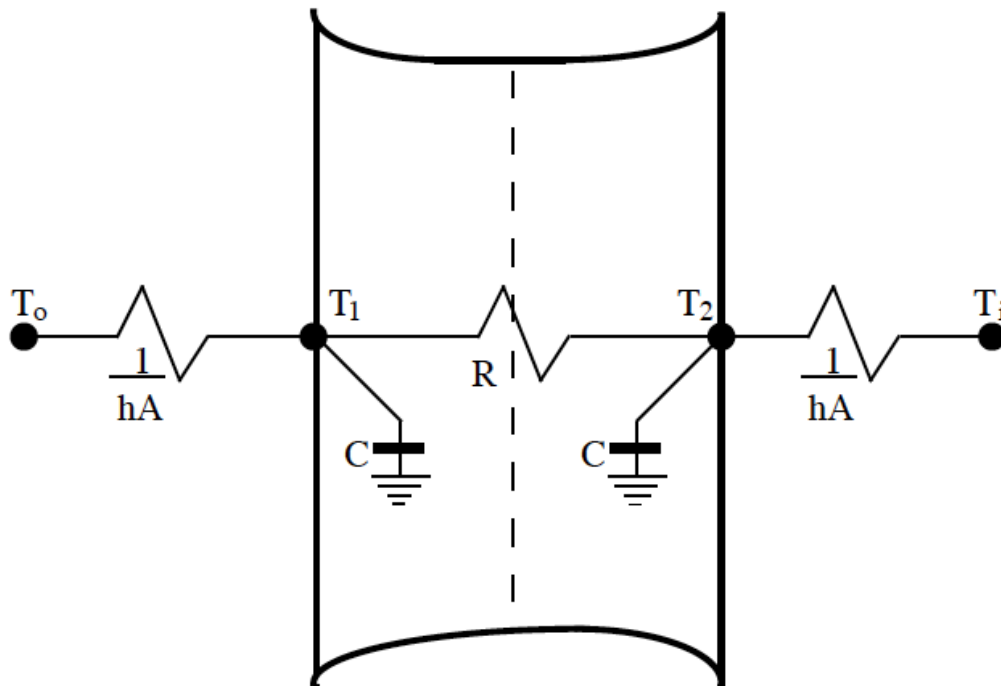


Figure 9. Two Node State Space Example.

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

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

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

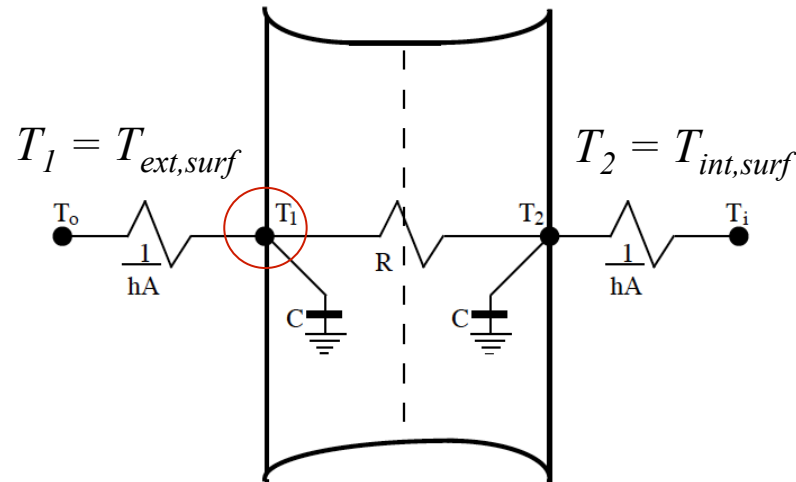


Figure 9. Two Node State Space Example.

$$q_{sw,solar}$$

$$+q_{lw,surface-sky}$$

From:

$$+q_{lw,surface-ground}$$

$$+q_{convection}$$

$$-q_{conduction} = 0$$

$$q_{sw,solar}$$

$$+q_{lw,surface-sky}$$

To:

$$+q_{lw,surface-ground}$$

$$+q_{convection}$$

$$-q_{conduction} = \rho C_p \frac{L}{2} \frac{dT}{dt}$$

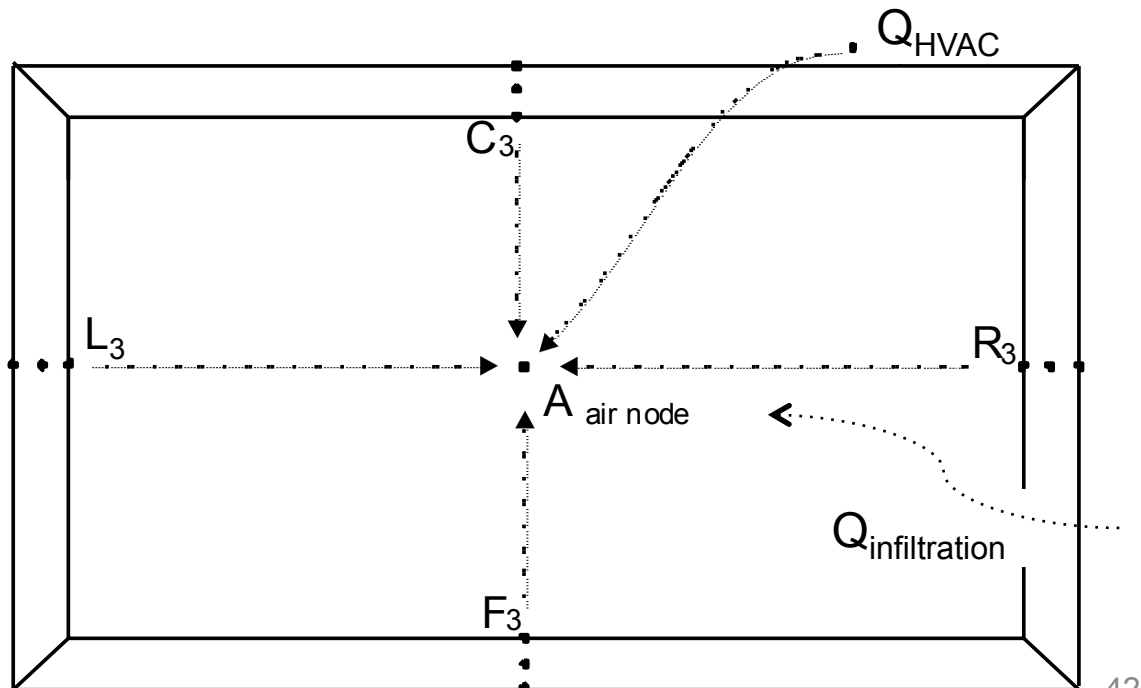
HBM: Indoor air energy balance

- 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)

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

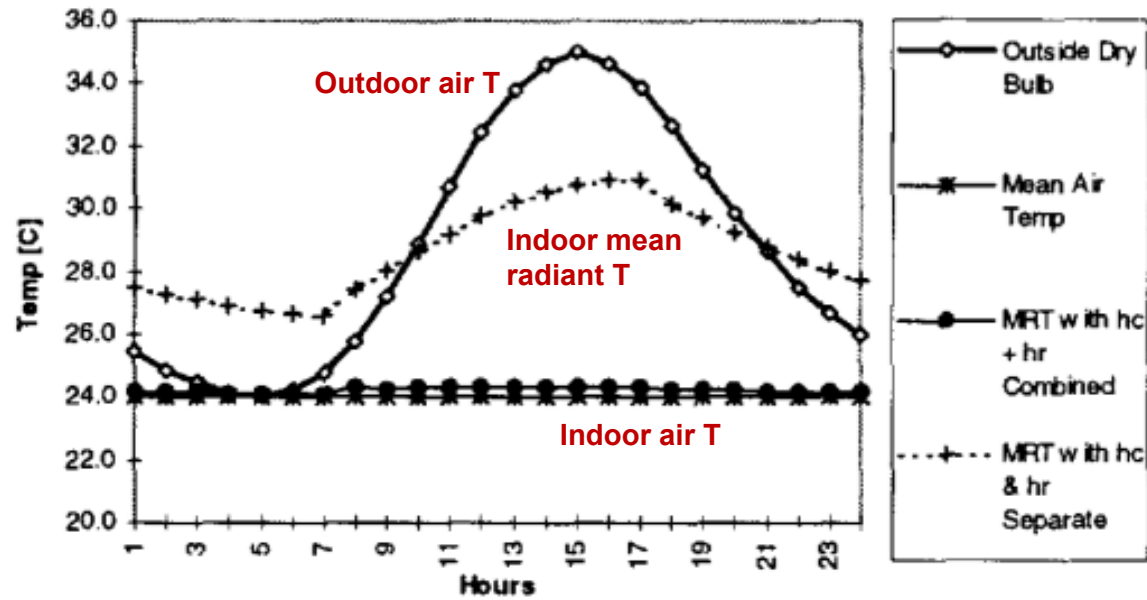
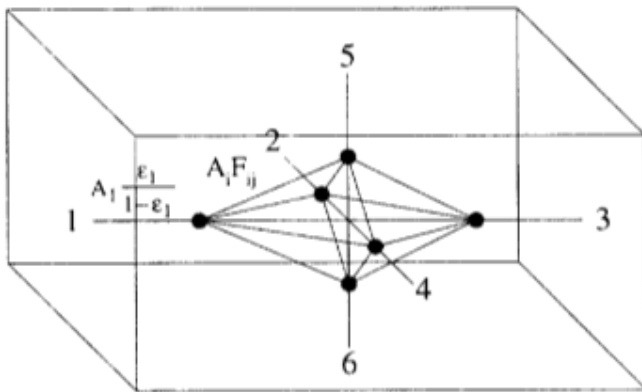
In plain English:

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



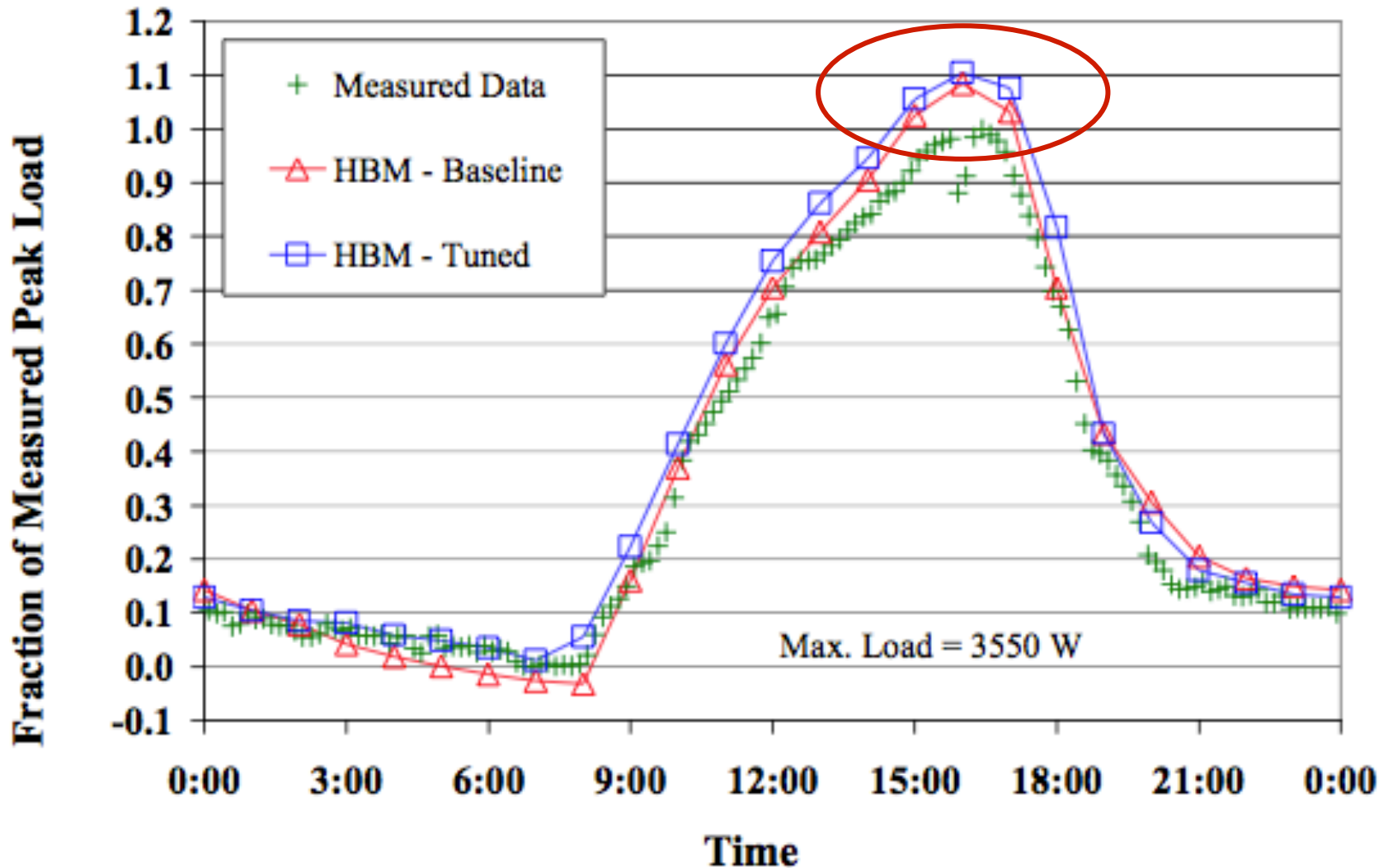
Using HBM to calculate peak loads

- Tracking indoor and outdoor temperatures for a simple space:



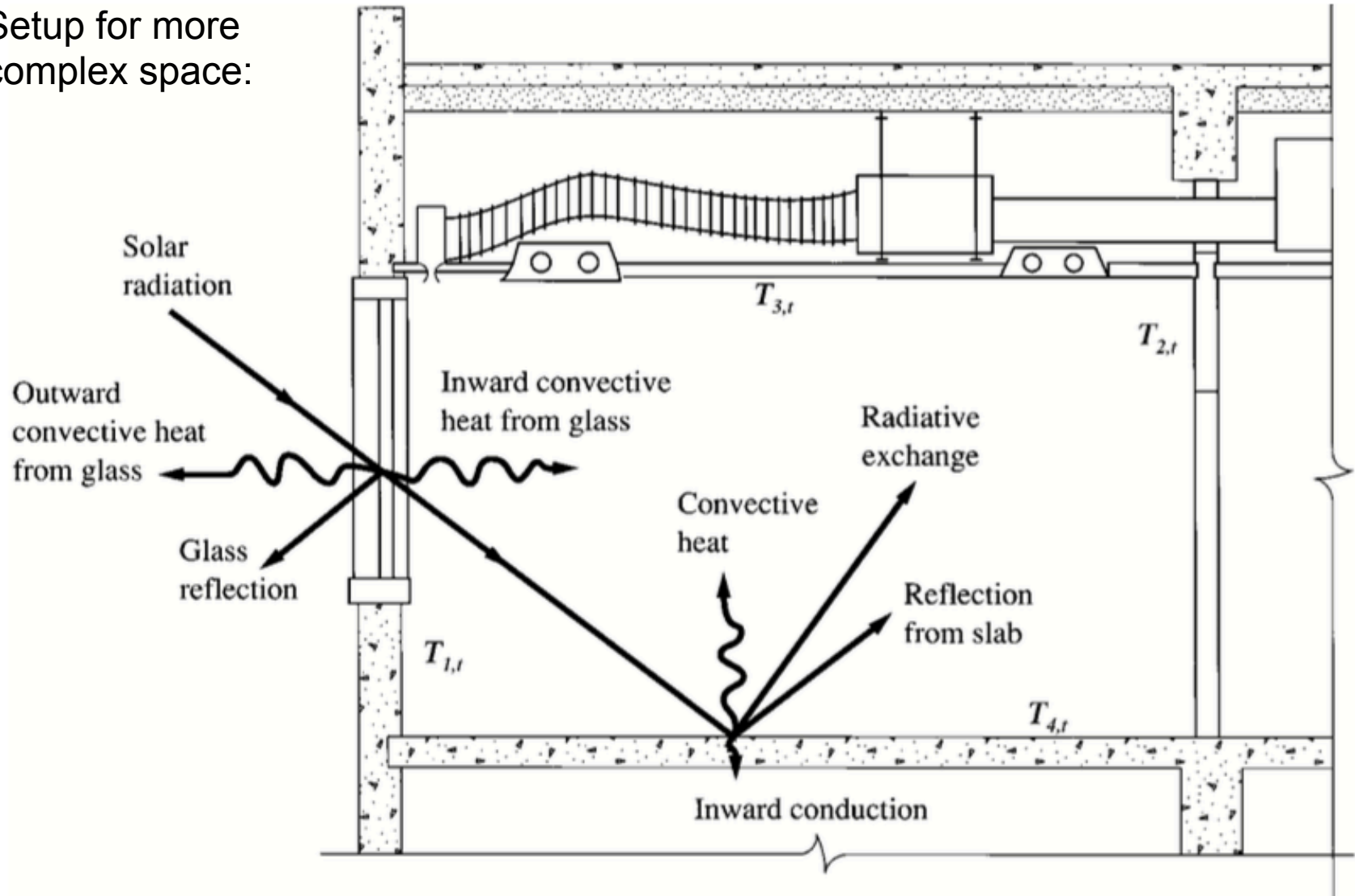
Using HBM to calculate peak loads

- Tracking the cooling load for a simple space:

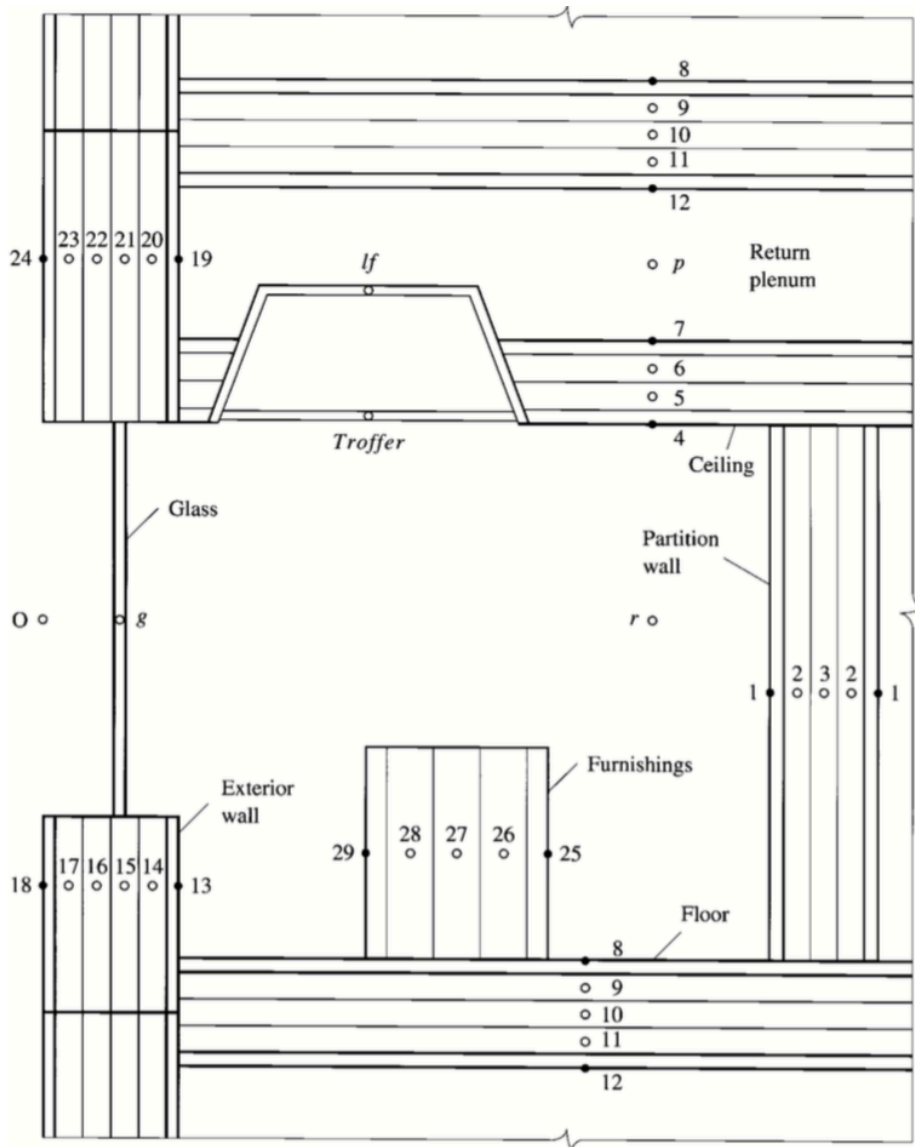


Using HBM to calculate peak loads

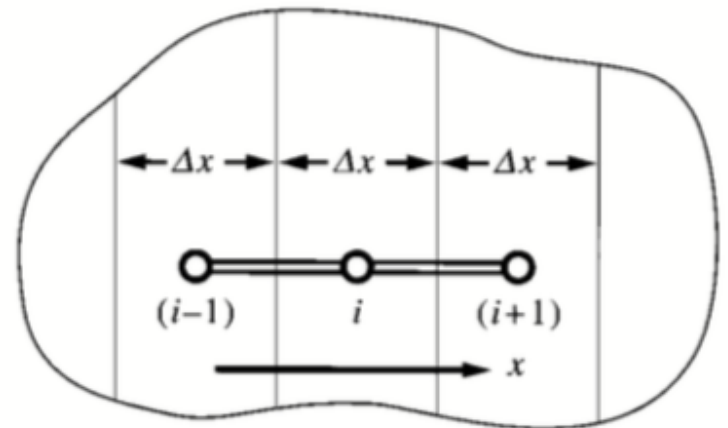
Setup for more complex space:



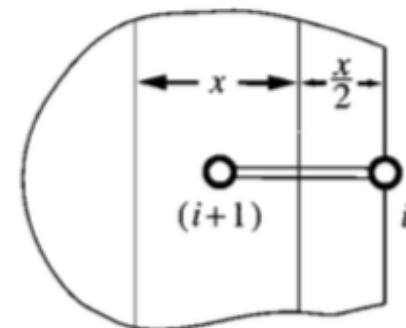
Using HBM to calculate peak loads: Complex



Setup for more complex space:



Interior node



Surface node

Notes on estimating cooling loads

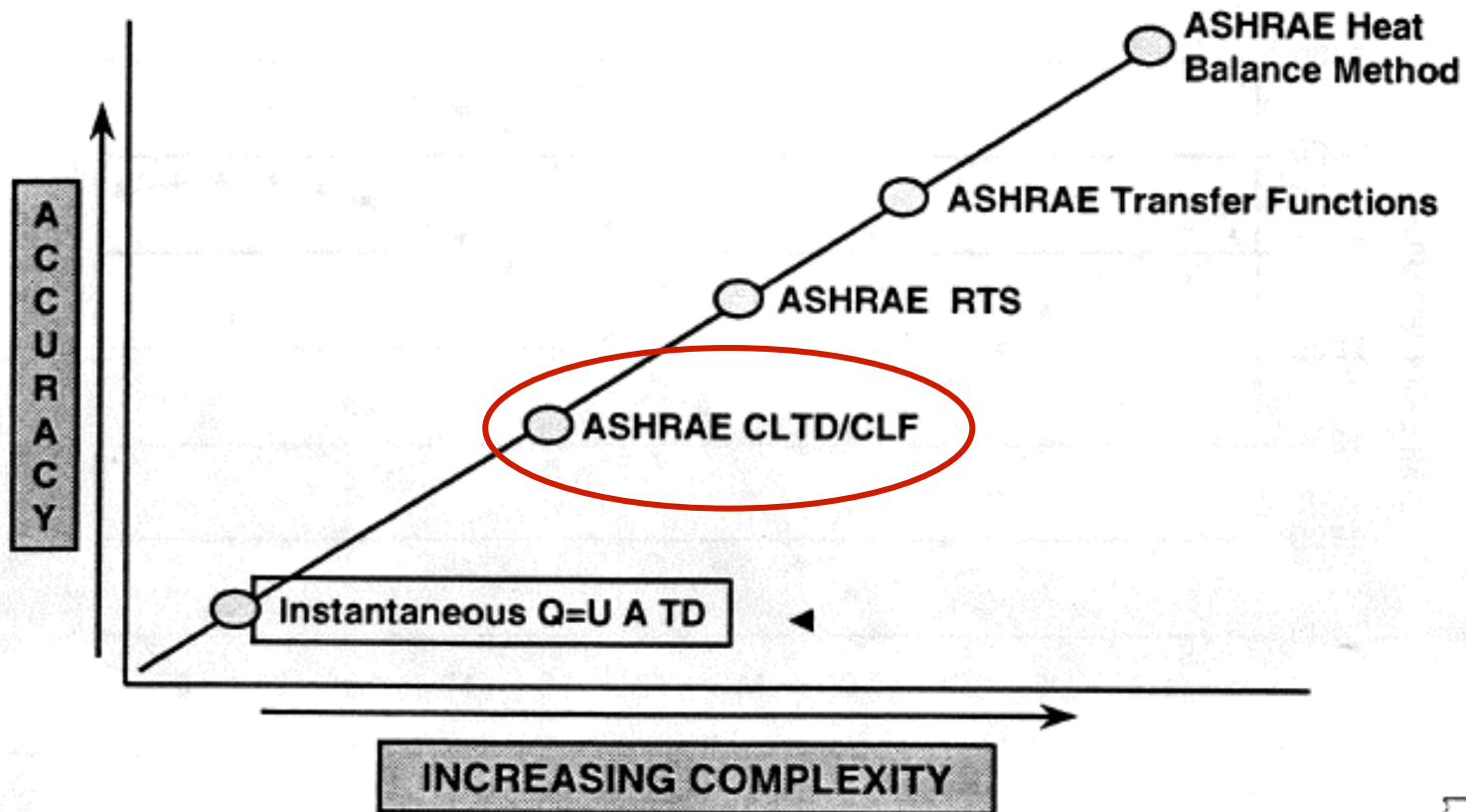
- Frequently, a cooling load must be calculated before every parameter in the conditioned space can be properly or completely defined
 - An example is a cooling load estimate for a new building with many floors of un-leased spaces where detailed partition requirements, furnishings, lighting selection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

Cooling load calculation methods

Load Estimating Methods



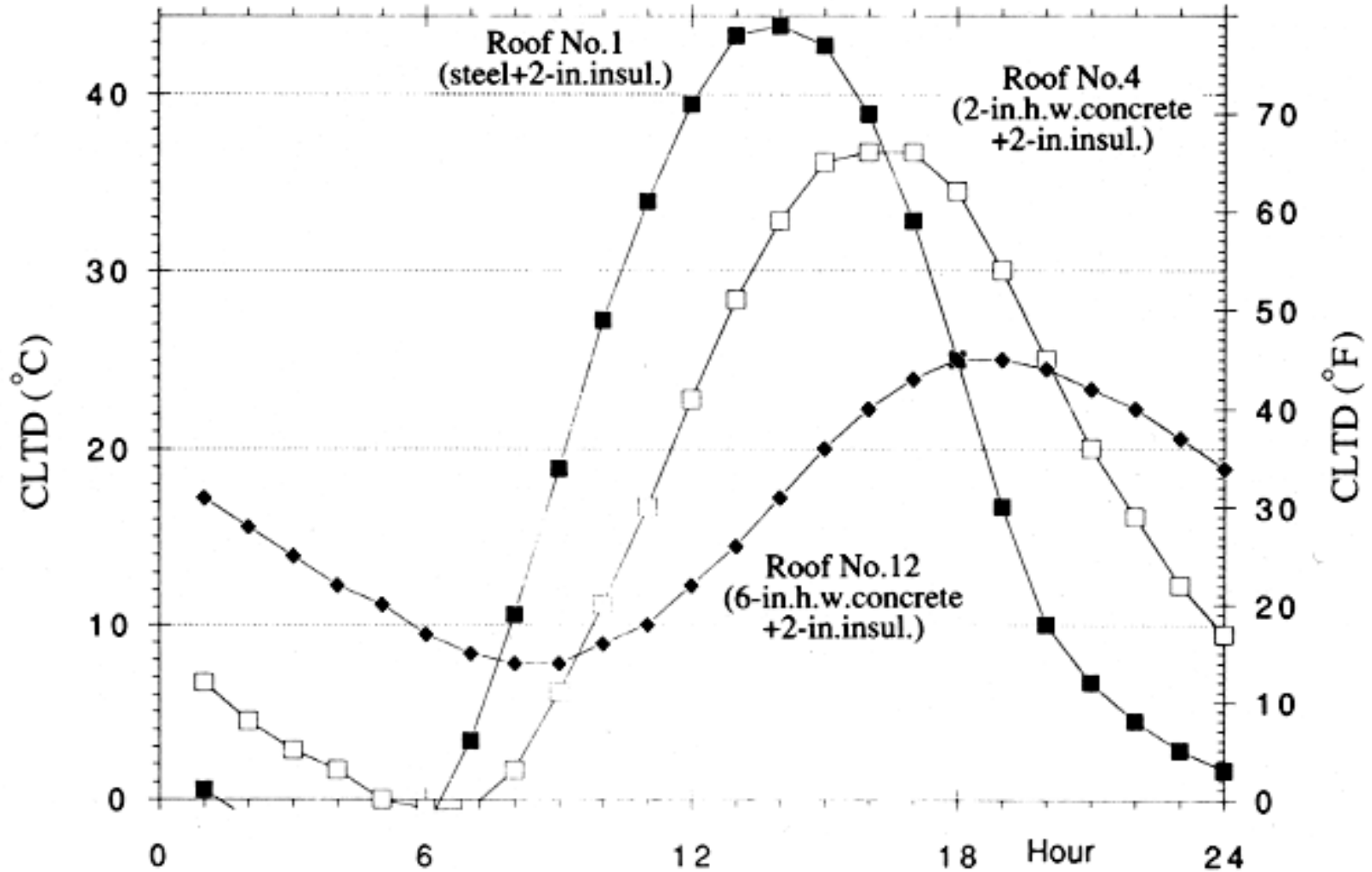
Simpler method: The ASHRAE CLTD/CLF method

- One method of accounting for periodic responses for conduction and radiation (simpler than others) is the CLTD/CLF method (it's a mouthful)
- 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

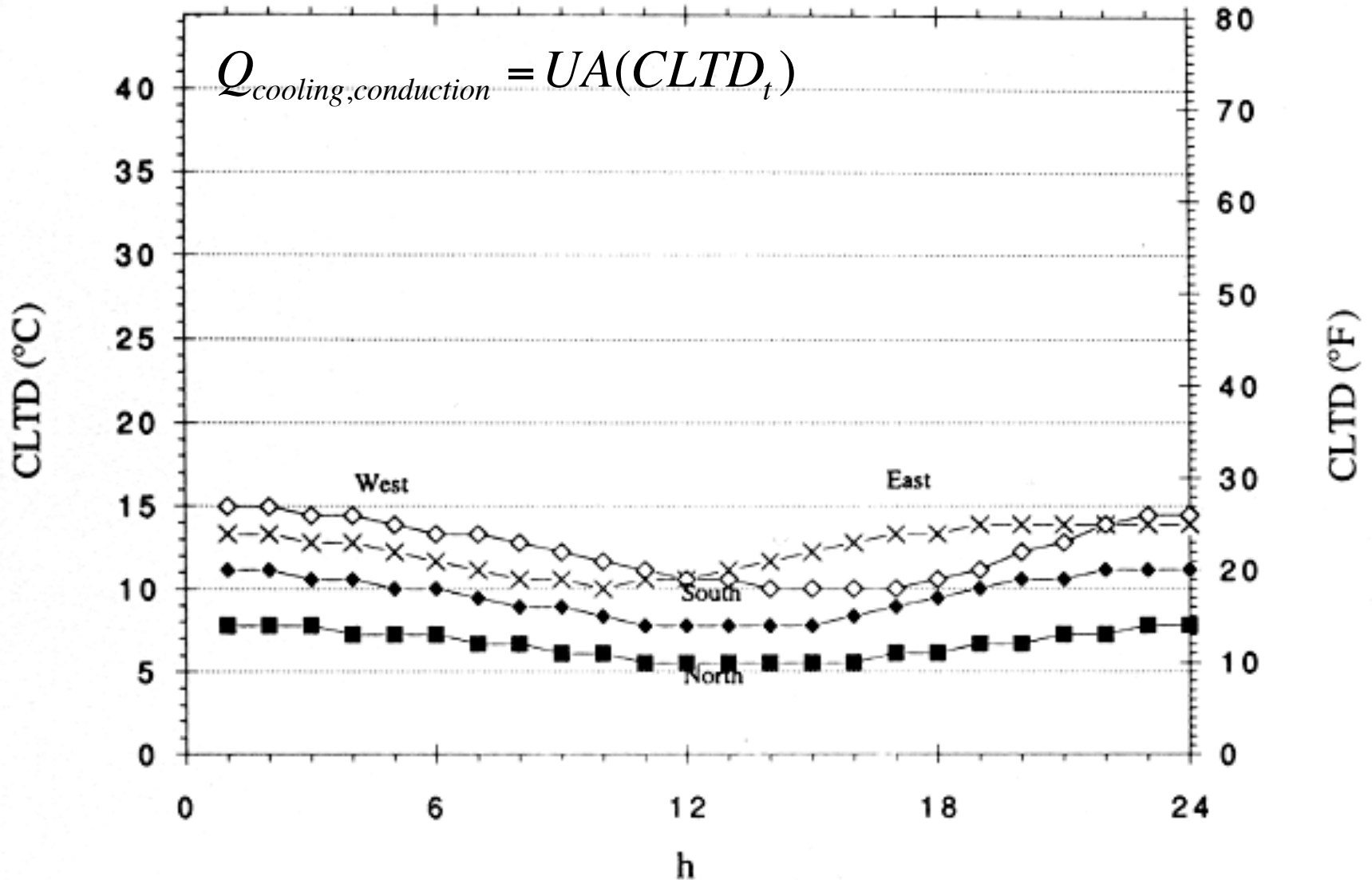
CLTD for typical roof materials



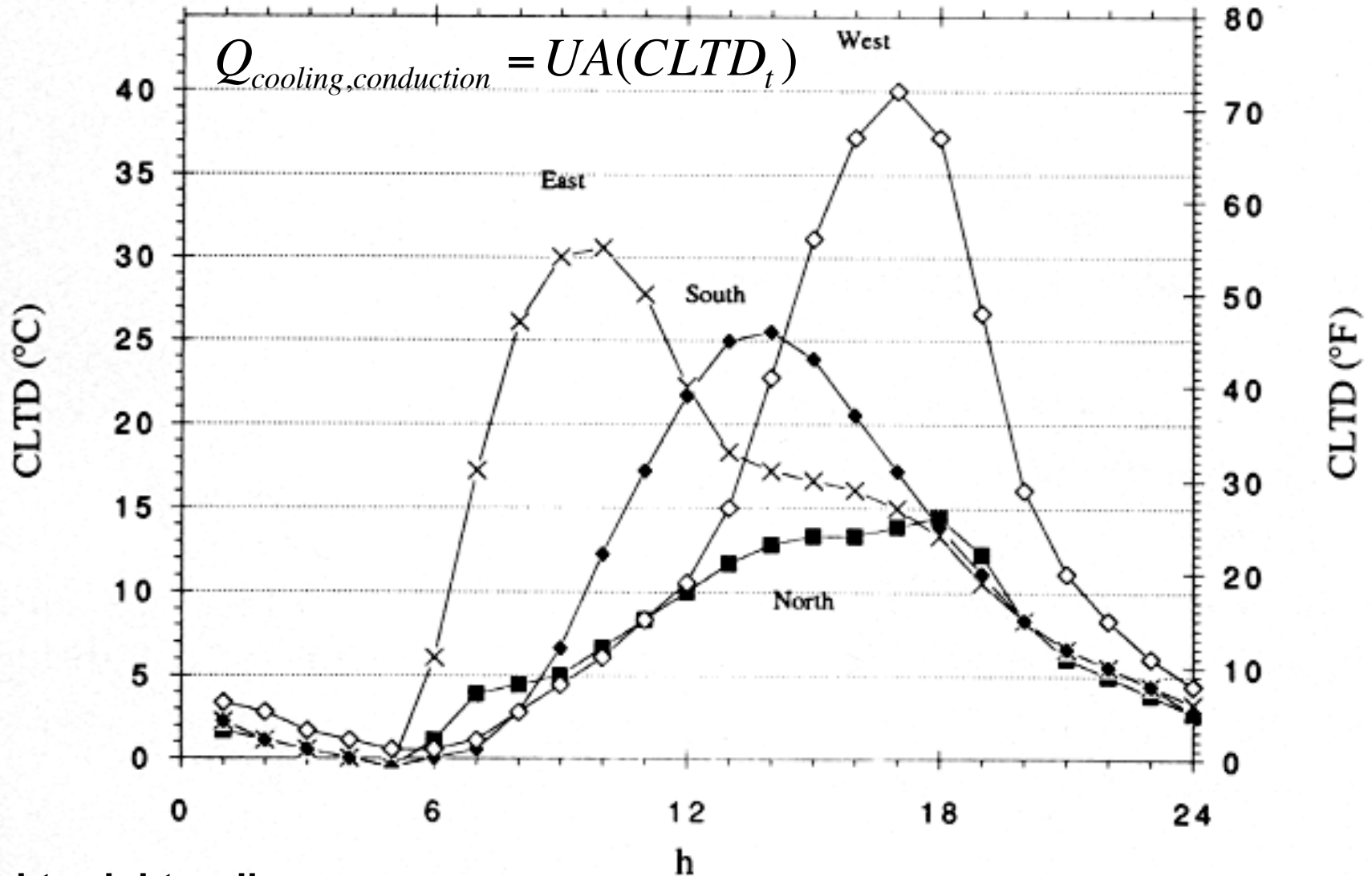
$$Q_{cooling,conduction} = UA(CLTD_t)$$

h

CLTD for typical “heavy” or “massive” walls

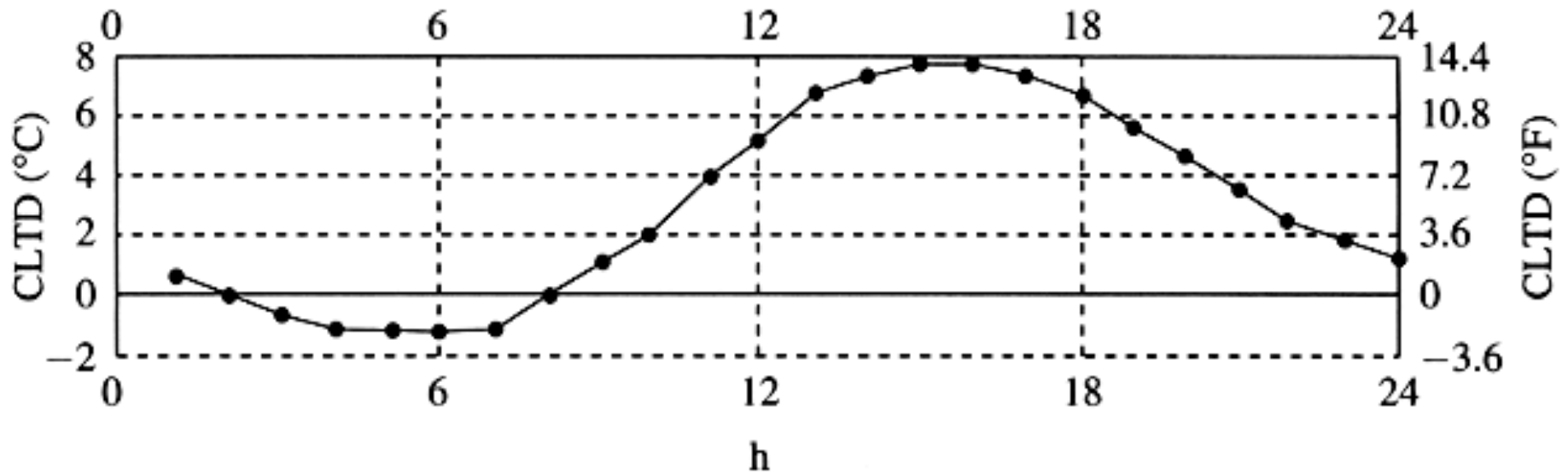


CLTD for typical “lightweight” walls



Lightweight walls

CLTD for typical glazing



$$Q_{cooling,conduction} = UA(CLTD_t)$$

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

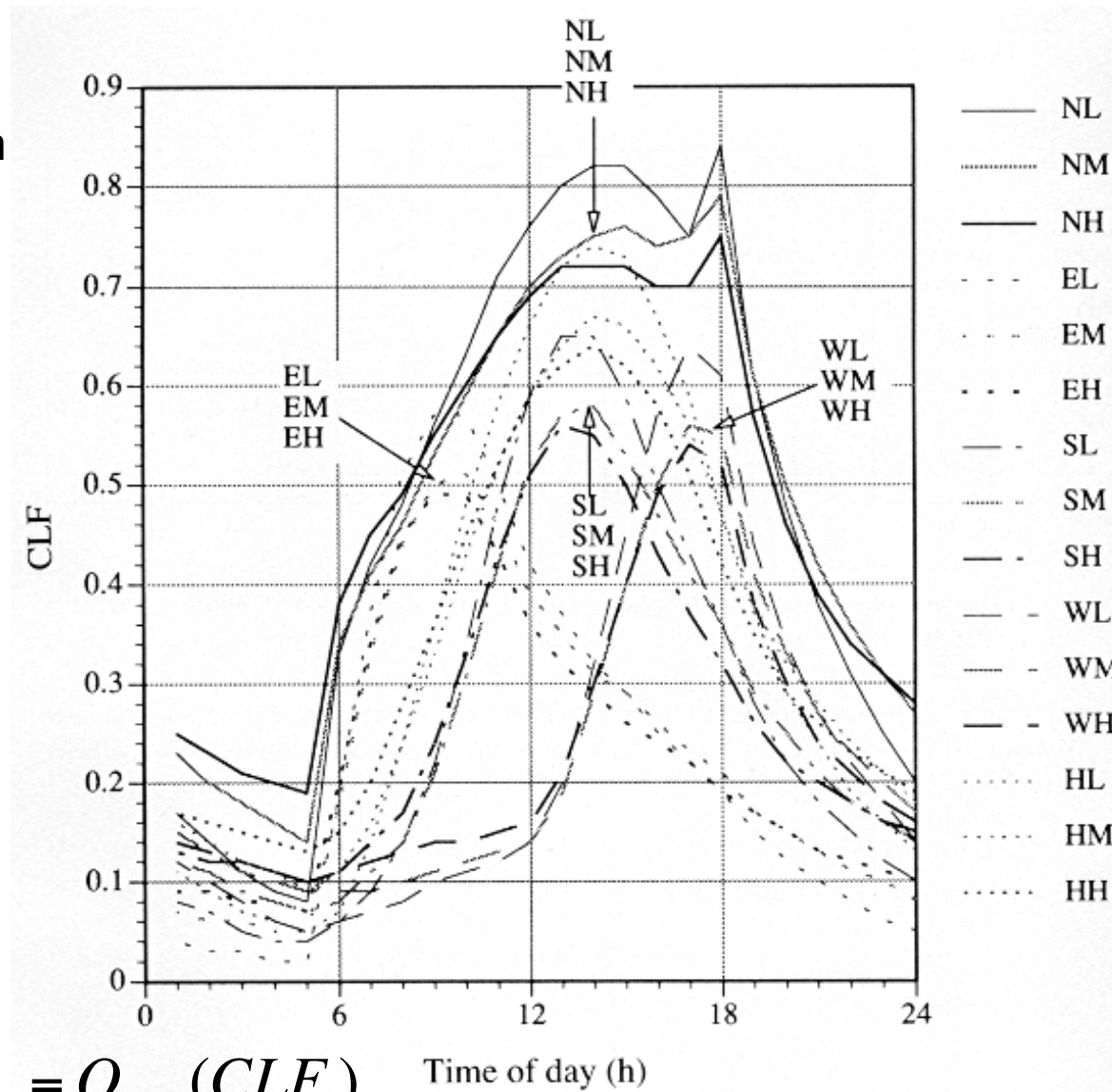
Instead of: $Q_{solar} = \alpha I_{solar} A$

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

CLF for typical glazing

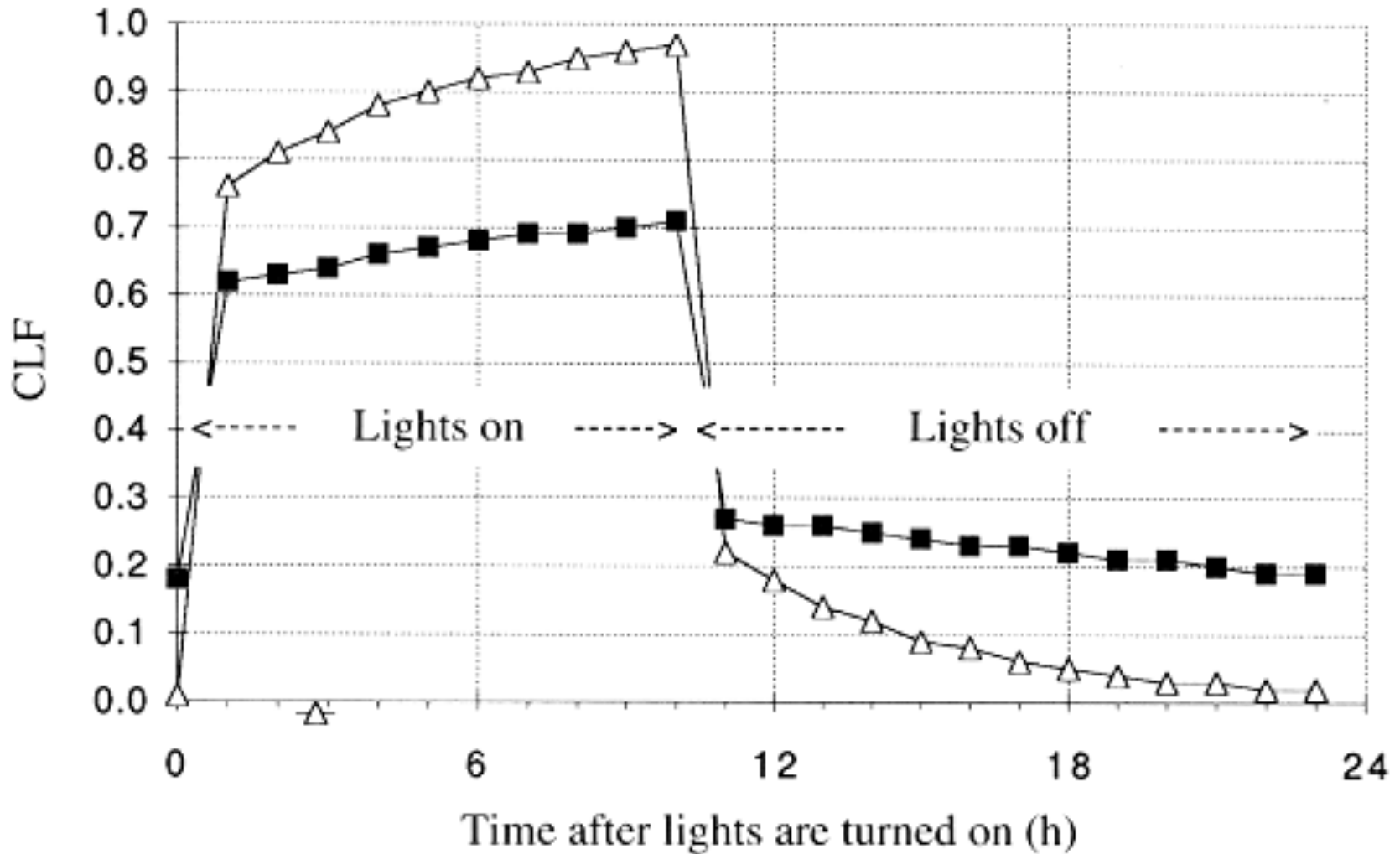
L = light
M = medium
H = heavy

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



$$Q_{cooling, radiation, t} = Q_{max} (CLF_t) \quad \text{Time of day (h)}$$

CLF for typical internal gains



■ "Heavy"; △ "Light"

$$Q_{cooling,radiation,t} = Q_{max} (CLF_t)$$

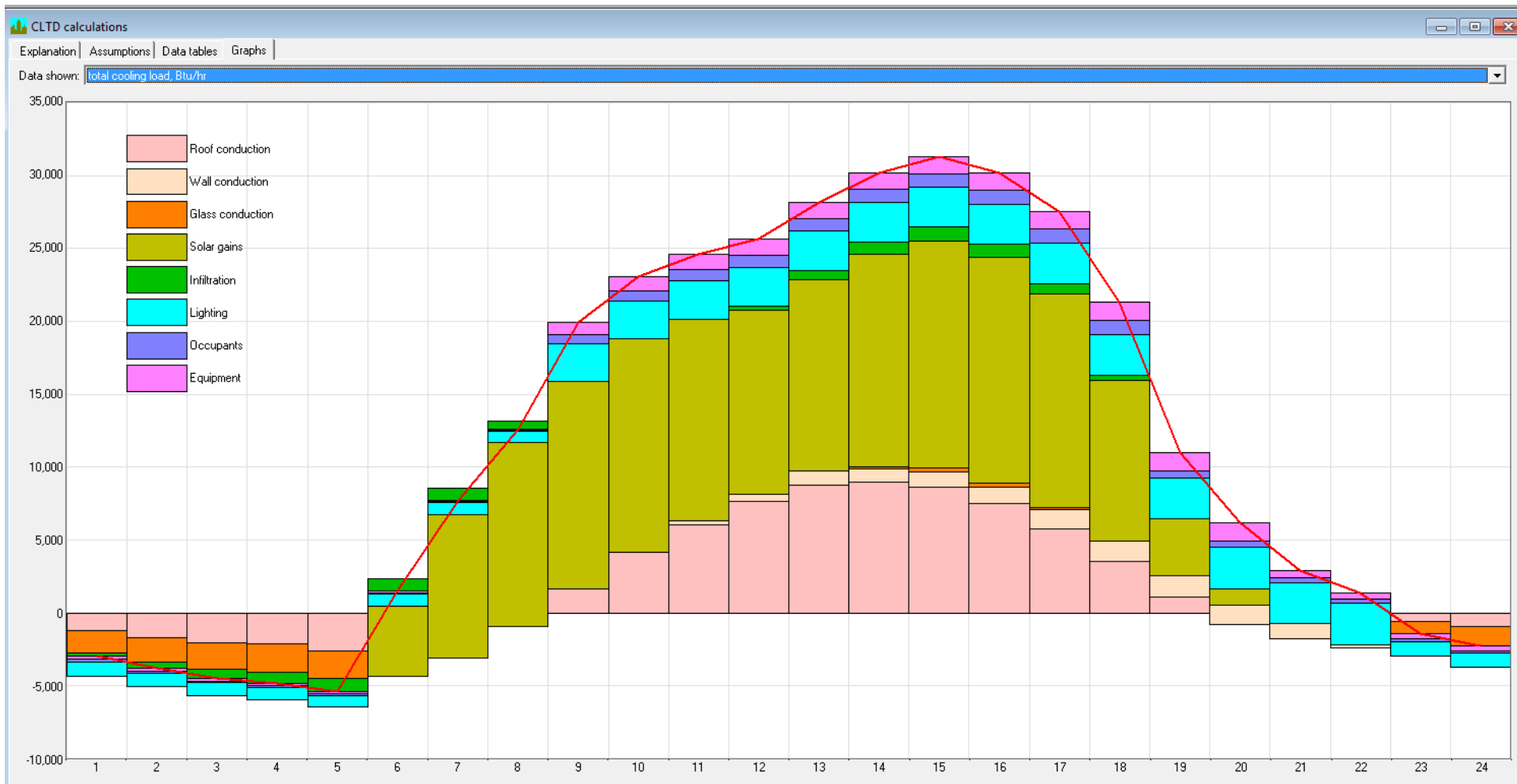
Finding peak cooling load with CLTD/CLF method

- 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 within about 3 hours)
- Typically late afternoon or early evening
- Use a spreadsheet tool

ASHRAE CLTD/CLF method

Sensible loads					3p	hour t 4p	5p	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									

CLTD/CLF method applied: HCB tool



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

Cooling load calculation methods

Load Estimating Methods

