MEBS6006 Environmental Services I
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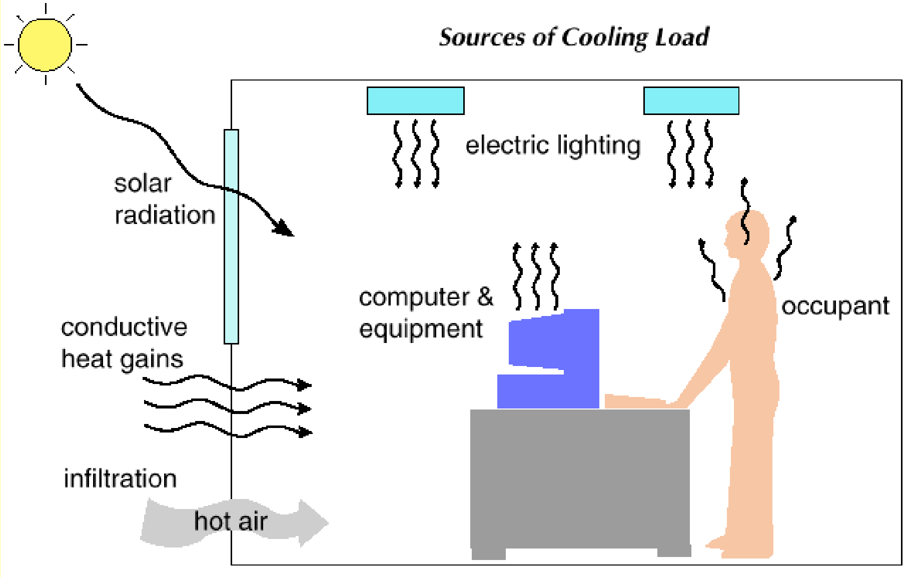

Load Estimation

Dr. Benjamin P.L. Ho
Department of Mechanical Engineering
The University of Hong Kong
E-mail: benjamin.ho@hku.hk

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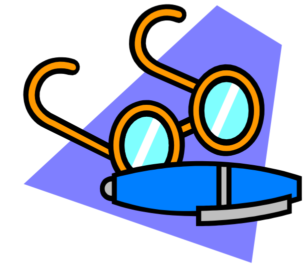
Contents

This lecture is the first of the 2 lectures on loading and energy calculation.

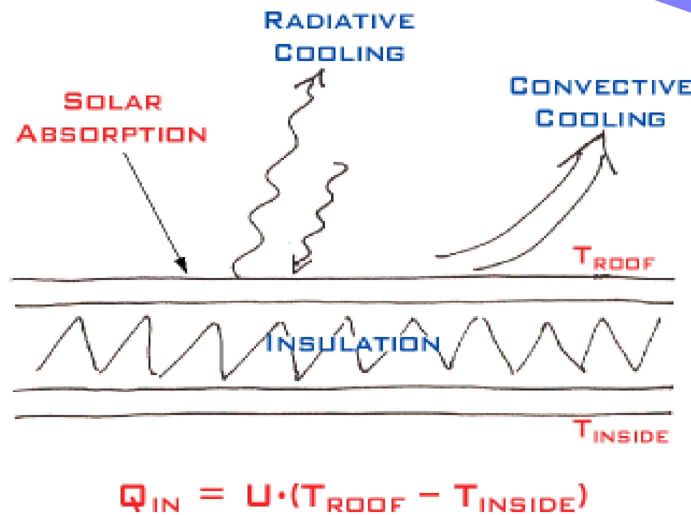
The first lecture will give a brief review of the various components contributing to cooling/heating load of an occupied space.

- Basic Concepts
- Outdoor Design Conditions
- Indoor Design Conditions
- Cooling Load Components
- Cooling Load Principles
- Cooling Coil Load
- Heating Load

Basic Concepts



- Heat transfer mechanism
  - Conduction
  - Convection
  - Radiation



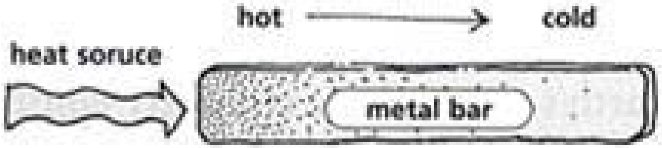
- Thermal properties of building materials
  - Overall thermal transmittance (U-value) (W/m^{2}K)
  - Thermal conductivity k (W/mK)
    - thermal conductance = kA/L (W/K)
    - heat transfer coefficient = k/L, (W/m^{2}K)
  - Thermal capacity (specific heat) (kJ/kgK)

$$Q = U\,A\,(\Delta t)$$

Four forms of heat transfer

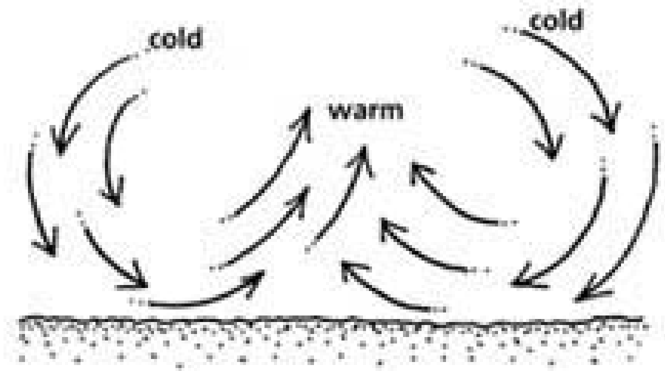
CONDUCTION

From molecule to molecule



SENSIBLE HEAT

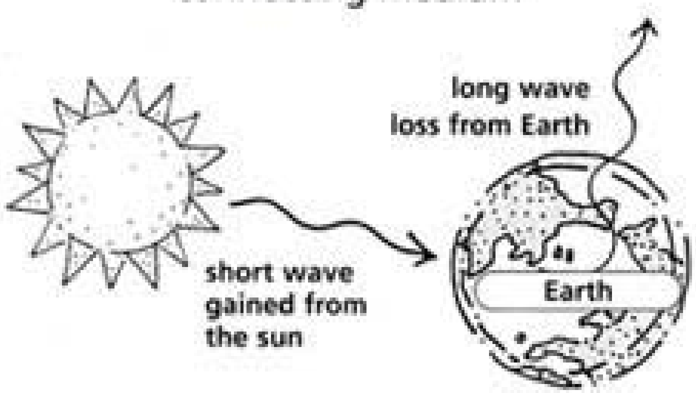
Fluid movement of heated air



CONVECTION

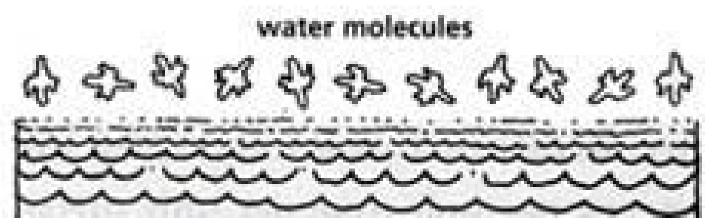
RADIATION

Energy passing from one object to another without a connecting medium



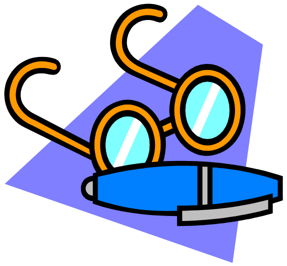
LATENT HEAT

Chemical energy due to water phase changes (evaporation, condensation, etc.) and water vapour transfer



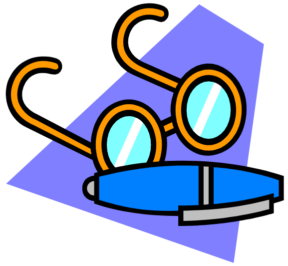
(Source: Food and Agriculture Organization of the United Nations, www.fao.org)

Basic Concepts



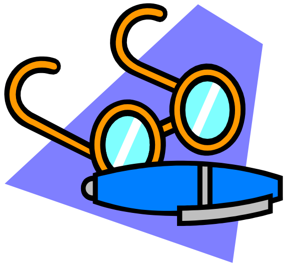
- Heat transfer basic relationships (for air at sea level)
  - Sensible heat transfer rate:
    - $q_{sensible}$ = 1.23 (air flow rate, L/s) (Δt) (why?)
  - Latent heat transfer rate:
    - q_{latent} = 3010 (air flow rate, L/s) (Δw) (why?)
  - Total heat transfer rate:
    - q_{total} = 1.2 (Flow rate, L/s) (Δh) (why?)
  - $q_{total} = q_{sensible} + q_{latent}$

Basic Concepts



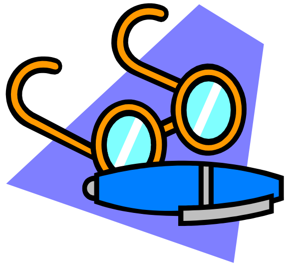
- Thermal load
  - The amount of heat that must be added or removed from the space to maintain the proper temperature in the space
- When thermal loads push conditions outside of the comfort range, HVAC systems are used to bring the thermal conditions back to comfort conditions

Basic Concepts



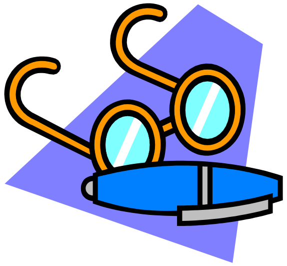
- Purpose of HVAC load estimation
  - Calculate peak design loads (cooling/heating)
  - Estimate likely plant/equipment capacity or size
  - Provide info for HVAC design e.g. load profiles
  - Form the basis for building energy analysis
- Cooling load is our main target
  - Important for warm climates & summer design
  - Affect building performance & its first cost

Basic Concepts

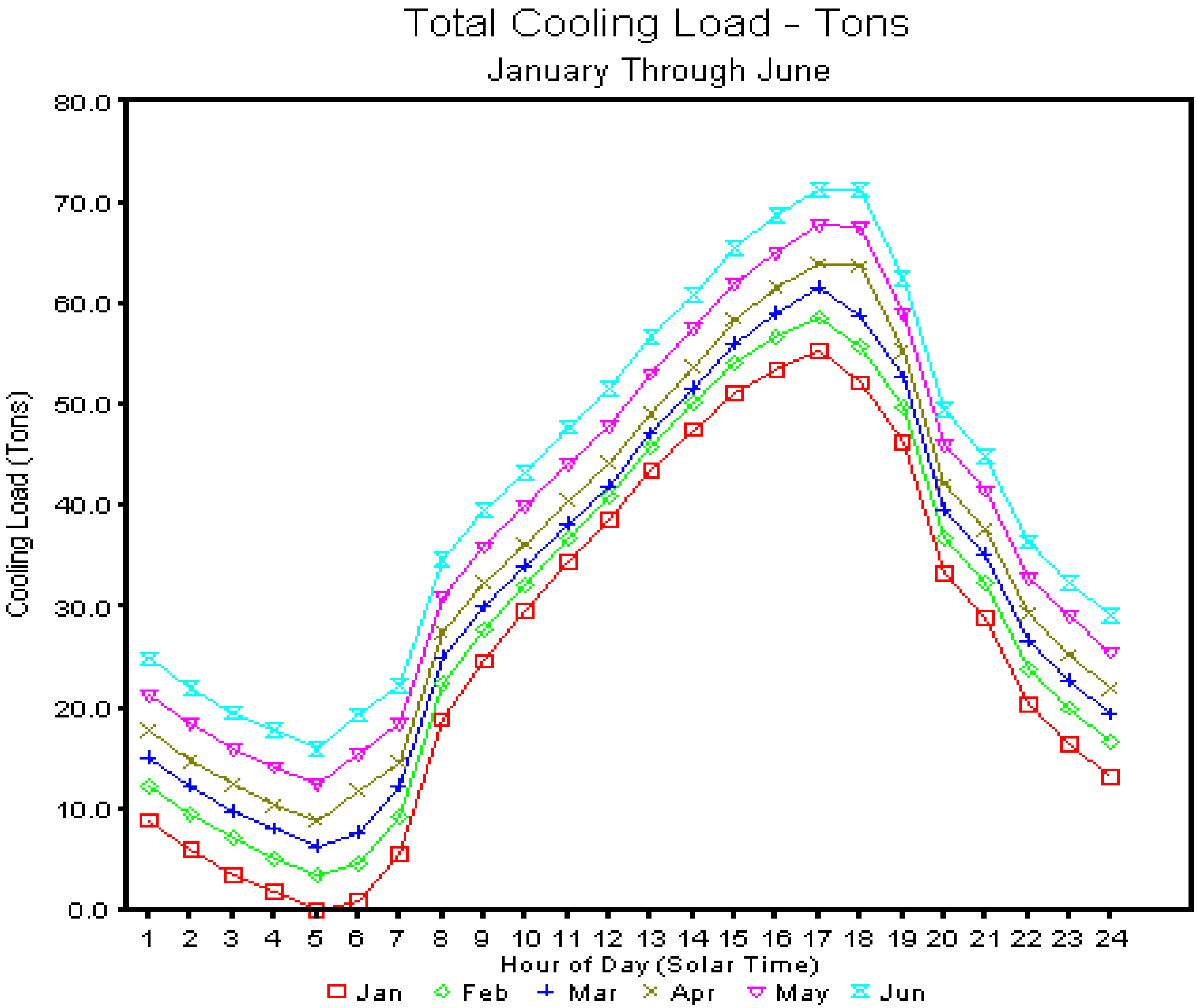


- General procedure for cooling load calculations
  - Obtain the characteristics of the building, building materials, components, etc. from building plans and specifications
  - Determine the building location, orientation, external shading (like adjacent buildings)
  - Obtain appropriate weather data and select outdoor design conditions
  - Select indoor design conditions (include permissible variations and control limits)

Basic Concepts

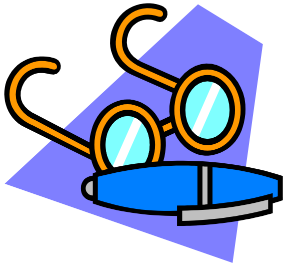


- General procedure for cooling load calculations (cont’d)
  - Obtain a proposed schedule of lighting, occupants, internal equipment appliances and processes that would contribute to internal thermal load
  - Select the time of day and month for the cooling load calculation
  - Calculate the space cooling load at design conditions
  - Assess the cooling loads at several different time or a design day to find out the peak design load

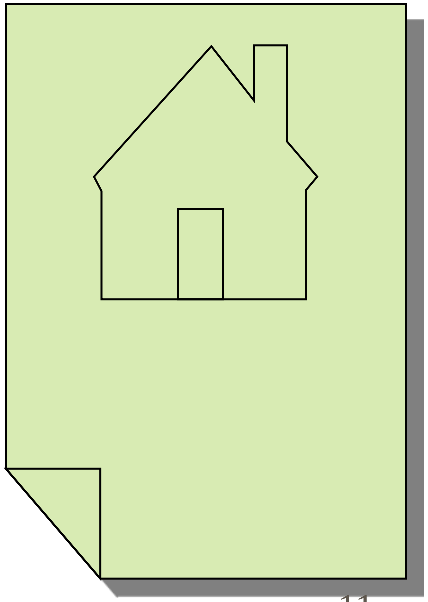


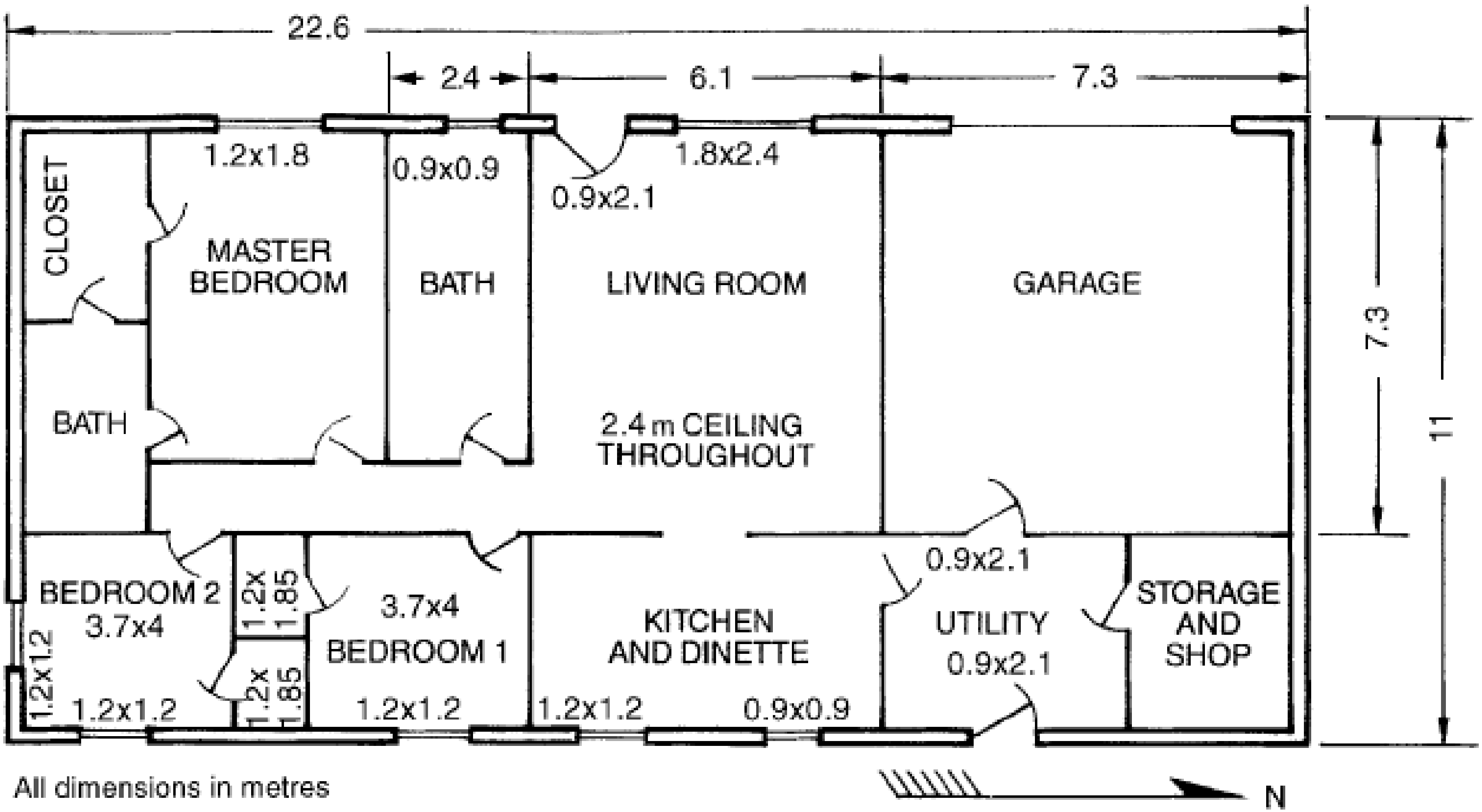
Cooling load profiles

Basic Concepts



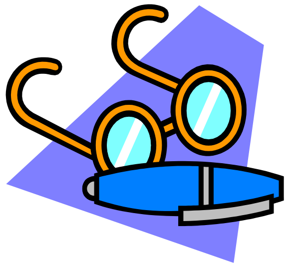
- A building survey will help us achieve a realistic estimate of thermal loads
  - Orientation of the building
  - Use of spaces
  - Physical dimensions of spaces
  - Ceiling height
  - Columns and beams
  - Construction materials
  - Surrounding conditions
  - Windows, doors, stairways





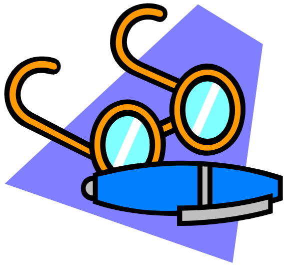
(Source: ASHRAE Handbook Fundamentals 2005)

Basic Concepts



- Key info for load estimation
  - People (number or density, duration of occupancy, nature of activity)
  - Lighting (W/m^2, types of luminaire and lamp)
  - Appliances (wattage, location, usage)
  - Ventilation (criteria, requirements)
  - Thermal storage (if any)
  - Continuous or intermittent operation

Basic Concepts



- Typical HVAC load design process
  - 1. Rough estimates of design loads & energy use
    - Such as by rules of thumb & floor areas
    - See “Cooling Load Check Figures”
    - See references for some examples of databooks
  - 2. Develop & assess more info (design criteria, building info, system info)
    - Building layouts & plans are developed
  - 3. Perform detailed load & energy calculations

Outdoor Design Conditions

- They are used to calculate design space loads
- Climatic design information
  - General info: e.g. latitude, longitude, altitude, atmospheric pressure
  - Outdoor design conditions include
    - Derived from statistical analysis of weather data
    - Typical data can be found in handbooks/databooks, such as ASHRAE Fundamentals Handbook

Outdoor Design Conditions

- Climatic design info from ASHRAE
  - Previous data & method (before 1997)
    - For Summer (Jun to Sep) & Winter (Dec, Jan, Feb)
    - Based on 1%, 2.5% & 5% nos. hours of occurrence
  - New method (ASHRAE Fundamentals 2001+):
    - Based on annual percentiles and cumulative frequency of occurrence, e.g. 0.4%, 1%, 2% (of whole year)
    - More info on coincident conditions
    - Findings obtained from ASHRAE research projects
      - Data can be found on a relevant CD-ROM

Outdoor Design Conditions

- Climatic design conditions (ASHRAE, 2009):
  - Annual heating & humidif. design conditions
    - Coldest month
    - Heating dry-bulb (DB) temp.
    - Humidification dew point (DP)/ mean coincident dry-bulb temp. (MCDB) and humidity ratio (HR)
    - Coldest month wind speed (WS)/mean coincident dry-bulb temp. (MCDB)
    - Mean coincident wind speed (MCWS) & prevailing coincident wind direction (PCWD) to 99.6% DB

(Latest information from ASHRAE Handbook Fundamentals 2009)

Outdoor Design Conditions

- Climatic design conditions (ASHRAE, 2009):
  - Cooling and dehumidification design conditions
    - Hottest month and DB range
    - Cooling DB/MCWB: Dry-bulb temp. (DB) + Mean coincident wet-bulb temp. (MCWB)
    - Evaporation WB/MCDB: Web-bulb temp. (WB) + Mean coincident dry-bulb temp. (MCDB)
    - MCWS/PCWD to 0.4% DB
    - Dehumidification DP/MCDB and HR: Dew-point temp. (DP) + MDB + Humidity ratio (HR)
    - Enthalpy/MCDB

Outdoor Design Conditions

- Climatic design conditions (ASHRAE, 2009):
  - Extreme annual design conditions
  - Monthly climatic design conditions
    - Temperature, degree-days and degree-hours
    - Monthly design DB and mean coincident WB
    - Monthly design WB and mean coincident DB
    - Mean daily temperature range
    - Clear sky solar irradiance

Outdoor Design Conditions

- Other sources of climatic info:
  - Joint frequency tables of psychrometric conditions
    - Annual, monthly and hourly data
  - Degree-days (cooling/heating) & climatic normals
    - To classify climate characteristics
  - Typical year data sets (1 year: 8,760 hours)
    - For energy calculations & analysis

Recommended Outdoor Design Conditions for Hong Kong

Location	Hong Kong (latitude 22° 18′ N, longitude 114° 10′ E, elevation 33 m)			
Weather station	Royal Observatory Hong Kong			
Summer months	June to September (four hottest months), total 2928 hours			
Winter months	December, January & February (three coldest months), total 2160 hours			
Design temperatures:	For comfort HVAC (based on summer 2.5% or annualised 1% and winter 97.5% or annualised 99.3%)		For critical processes (based on summer 1% or annualised 0.4% and winter 99% or annualised 99.6%)	
	Summer	Winter	Summer	Winter
DDB / CWB	32.0 °C / 26.9 °C	9.5 °C / 6.7 °C	32.6 °C / 27.0 °C	8.2 °C / 6.0 °C
CDB / DWB	31.0 °C / 27.5 °C	10.4 °C / 6.2 °C	31.3 °C / 27.8 °C	9.1 °C / 5.0 °C

Note:
1. DDB is the design dry-bulb and CWB is the coincident wet-bulb temperature with it; DWB is the design wet-bulb and CDB is the coincident dry-bulb with it.
2. The design temperatures and daily ranges were determined based on hourly data for the 35-year period from 1960 to 1994; extreme temperatures were determined based on extreme values between 1884-1939 and 1947-1994.

(Source: Research findings from Dr. Sam C M Hui)

Recommended Outdoor Design Conditions for Hong Kong (cont'd)

Extreme temperatures:	Hottest month: July mean DBT = 28.6 °C absolute max. DBT = 36.1 °C mean daily max. DBT = 25.7 °C		Coldest month: January mean DBT = 15.7 °C absolute min. DBT = 0.0 °C mean daily min. DBT = 20.9 °C	
Diurnal range:	Summer	Winter	Whole year	
- Mean DBT	28.2	16.4	22.8	
- Daily range	4.95	5.01	5.0	
Wind data:	Summer	Winter	Whole year	
- Wind direction	090 (East)	070 (N 70° E)	080 (N 80° E)	
- Wind speed	5.7 m/s	6.8 m/s	6.3 m/s	

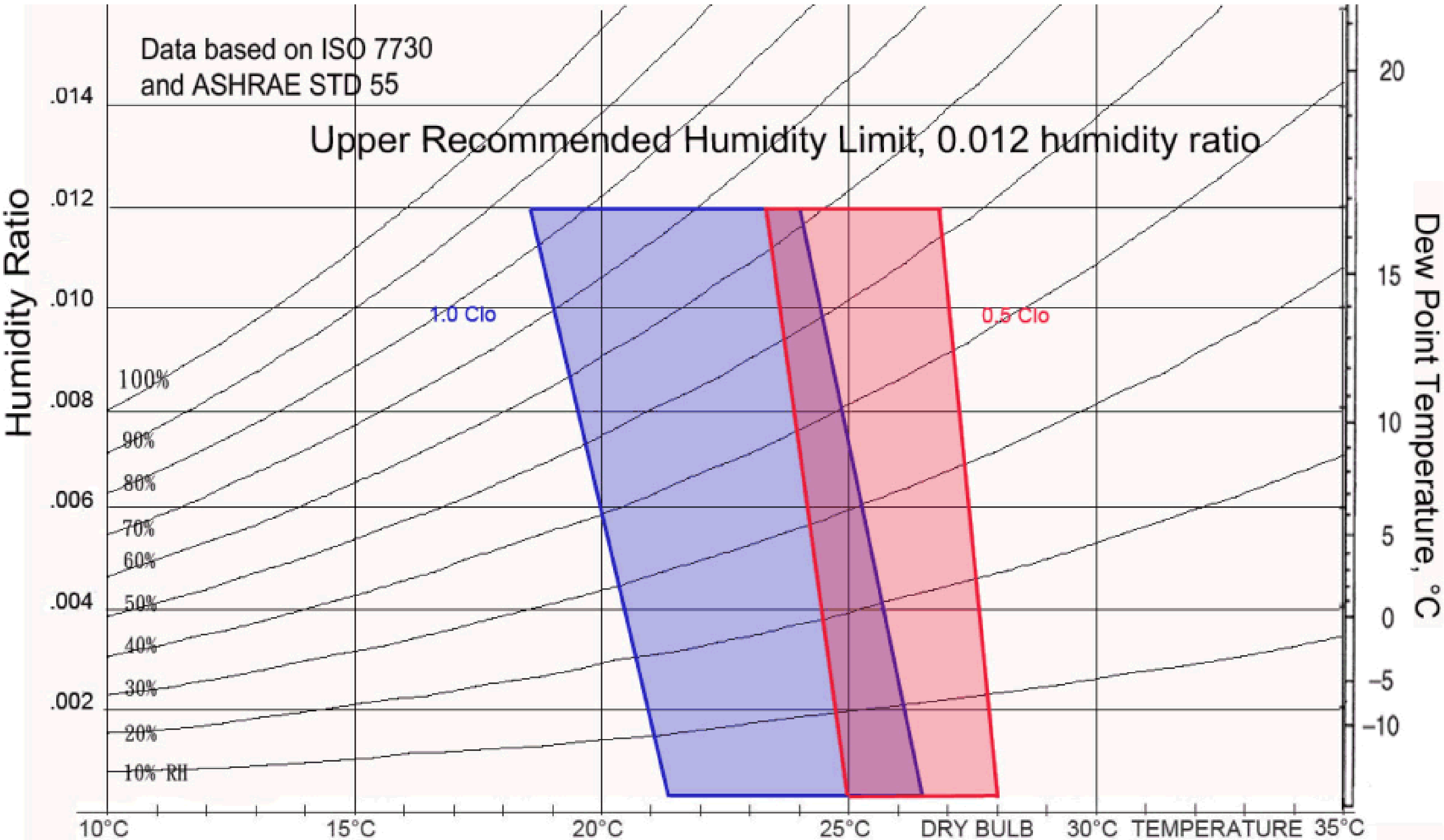
Note: 3. Wind data are the prevailing wind data based on the weather summary for the 30-year period 1960-1990. Wind direction is the prevailing wind direction in degrees clockwise from north and the wind speed is the mean prevailing wind speed.

(Source: Research findings from Dr. Sam C M Hui)

Indoor Design Conditions

- Basic design parameters: (for thermal comfort)
  - Air temp. & air movement
    - Typical: summer 24-26 ^{o}C; winter 21-23 ^{o}C
    - Air velocity: summer < 0.25 m/s; winter < 0.15 m/s
  - Relative humidity
    - Summer: 40-50% (preferred), 30-65 (tolerable)
    - Winter: 25-30% (with humidifier); not specified (w/o humidifier)
  - See also ASHRAE Standard 55-2004
    - ASHRAE comfort zone

ASHRAE Comfort Zones
(based on 2004 version of ASHRAE Standard 55)



Indoor Design Conditions

- Indoor air quality: (for health & well-being)
  - Air contaminants
    - e.g. particulates, VOC, radon, bioeffluents
  - Outdoor ventilation rate provided
    - ASHRAE Standard 62-2007
  - Air cleanliness (e.g. for processing), air movement
- Other design parameters:
  - Sound level (noise criteria)
  - Pressure differential between the space & surroundings (e.g. +ve to prevent infiltration)

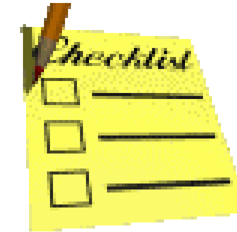
Type of area	Recommended NC or RC range (dB)
Hotel guest rooms	30–35
Office	
Private	30–35
Conference	25–30
Open	30–35
Computer equipment	40–45
Hospital, private	25–30
Churches	25–30
Movie theaters	30–35

(NC = noise critera; RC = room criteria)

* Remark: buildings in HK often have higher NC, say add 5-10 dB (more noisy).

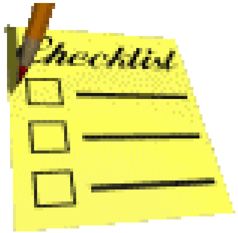
(Source: ASHRAE Handbook Fundamentals 2005)

Cooling Load Components

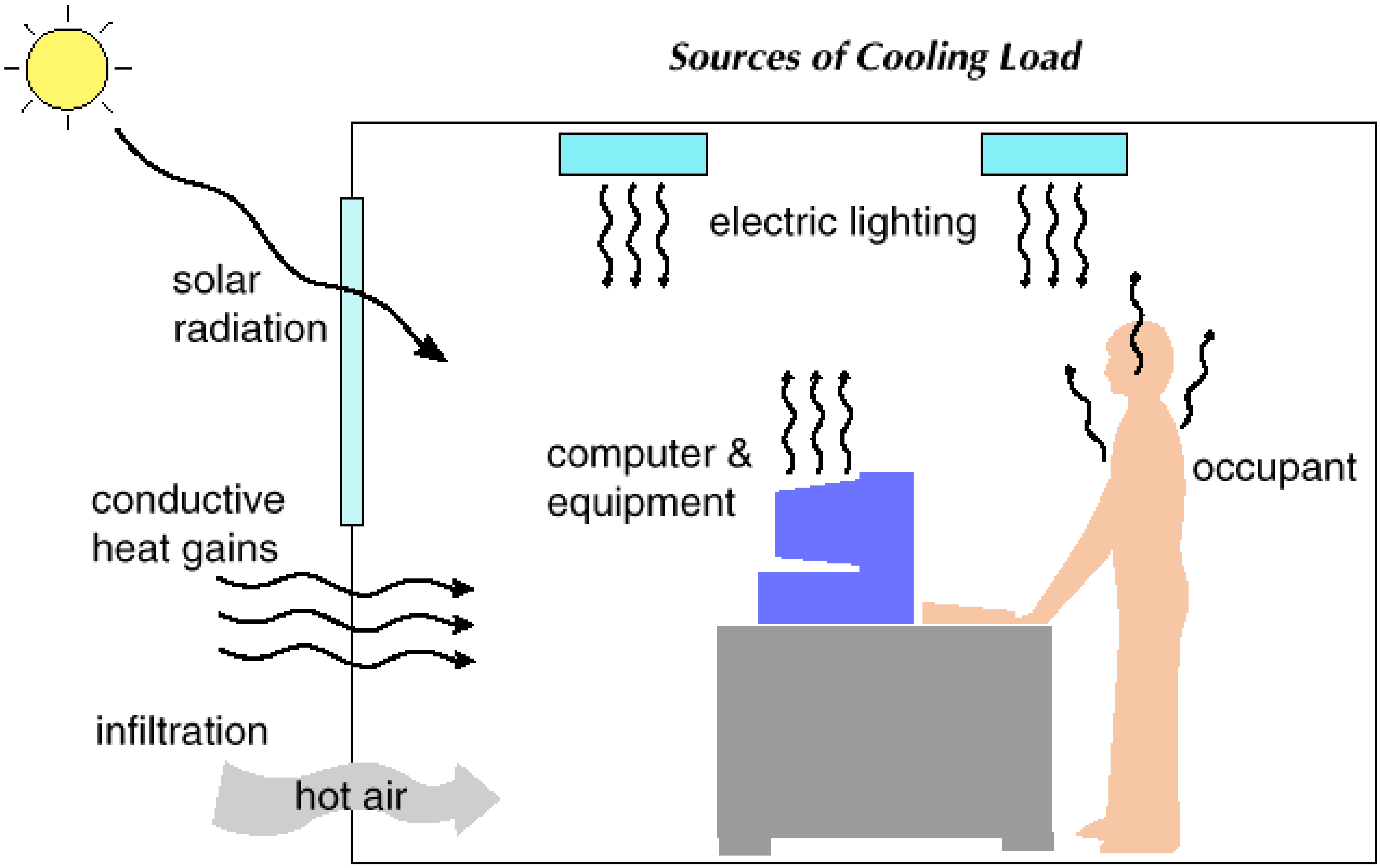


- <u>External</u>
  - 1. Heat gain through exterior walls and roofs
  - 2. Solar heat gain through fenestrations (windows)
  - 3. Conductive heat gain through fenestrations
  - 4. Heat gain through partitions & interior doors
- <u>Internal</u>
  - 1. People
  - 2. Electric lights
  - 3. Equipment and appliances

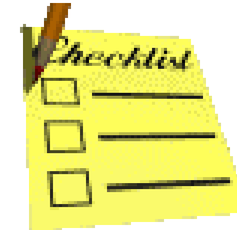
Cooling Load Components



- Infiltration
  - Air leakage and moisture migration, e.g. flow of outdoor air into a building through cracks, unintentional openings, normal use of exterior doors for entrance
- System (HVAC)
  - Outdoor ventilation air
  - System heat gain: duct leakage & heat gain, reheat, fan & pump energy, energy recovery


Sources of Cooling Load
electric lighting
solar
radiation
computer &
equipment
occupant
conductive
heat gains
infiltration
hot air

Cooling Load Components



- Total cooling load
  - Sensible cooling load + Latent cooling load
  - = Σ(sensible items) + Σ(latent items)
- Which components have latent loads? Which only have sensible load? Why?
- Three major parts for load calculation
  - External cooling load
  - Internal cooling load
  - Ventilation and infiltration air

Table 1 Representative Rates at Which Heat and Moisture Are Given Off by Human Beings in Different States of Activity

Degree of Activity		Total Heat, W: Adult Male	Total Heat, W: Adjusted, M/F[a]	Sensible Heat, W	Latent Heat, W	% Sensible Heat that is Radiant[b]: Low V	% Sensible Heat that is Radiant[b]: High V
Seated at theater	Theater, matinee	115	95	65	30		
Seated at theater, night	Theater, night	115	105	70	35	60	27
Seated, very light work	Offices, hotels, apartments	130	115	70	45		
Moderately active office work	Offices, hotels, apartments	140	130	75	55		
Standing, light work; walking	Department store; retail store	160	130	75	55	58	38
Walking, standing	Drug store, bank	160	145	75	70		
Sedentary work	Restaurant[c]	145	160	80	80		
Light bench work	Factory	235	220	80	140		
Moderate dancing	Dance hall	265	250	90	160	49	35
Walking 4.8 km/h; light machine work	Factory	295	295	110	185		
Bowling[d]	Bowling alley	440	425	170	255		
Heavy work	Factory	440	425	170	255	54	19
Heavy machine work; lifting	Factory	470	470	185	285		
Athletics	Gymnasium	585	525	210	315		

Notes:

1. Tabulated values are based on 24°C room dry-bulb temperature. For 27°C room dry bulb, the total heat remains the same, but the sensible heat values should be decreased by approximately 20%, and the latent heat values increased accordingly.
2. Also refer to Table 4, Chapter 8, for additional rates of metabolic heat generation.
3. All values are rounded to nearest 5 W.

[a] Adjusted heat gain is based on normal percentage of men, women, and children for the application listed, with the postulate that the gain from an adult female is 85% of that for an adult male, and that the gain from a child is 75% of that for an adult male.

[b] Values approximated from data in Table 6, Chapter 8, where is air velocity with limits shown in that table.

[c] Adjusted heat gain includes 18 W for food per individual (9 W sensible and 9 W latent).

[d] Figure one person per alley actually bowling, and all others as sitting (117 W) or standing or walking slowly (231 W).

(Source: ASHRAE Handbook Fundamentals 2005)

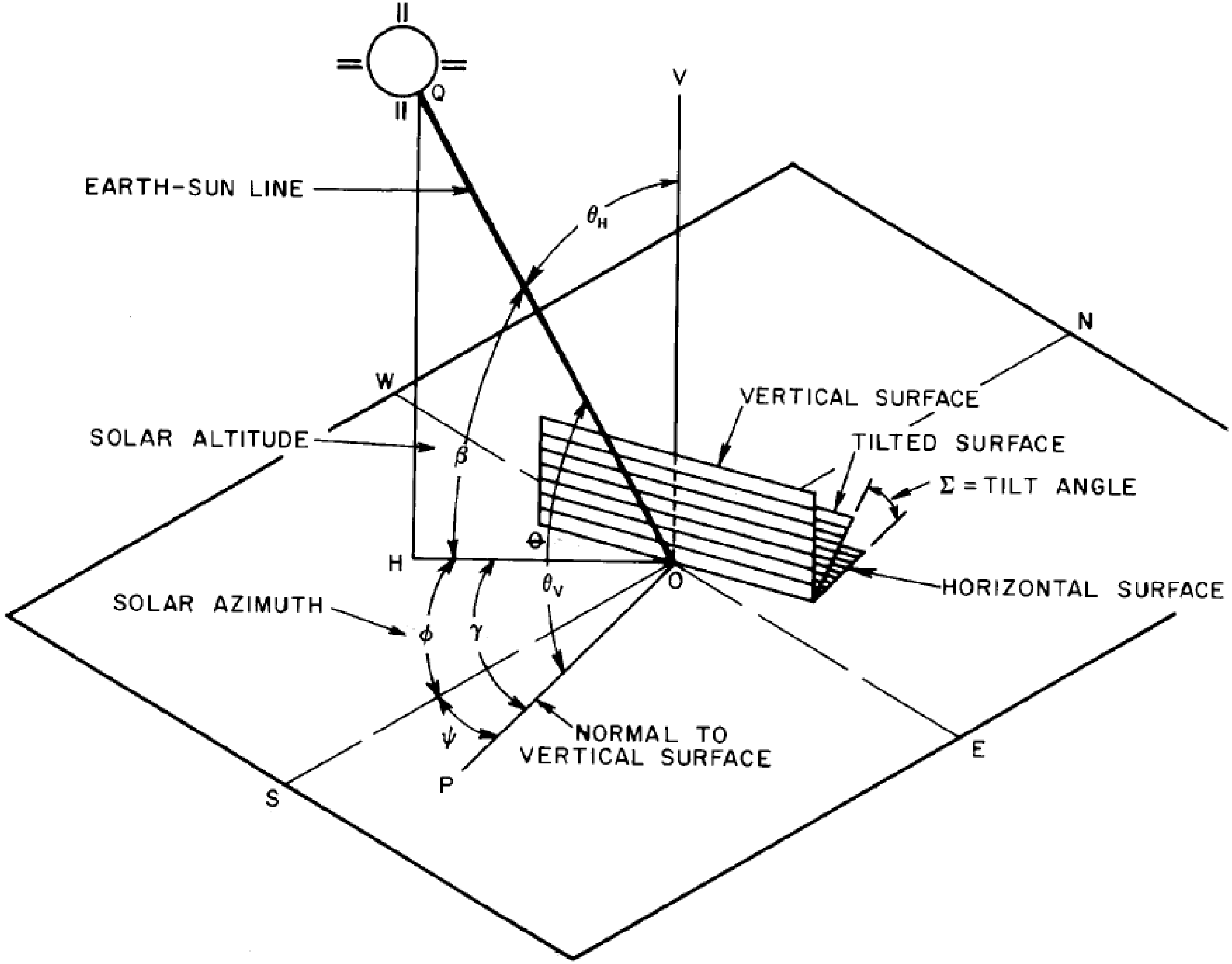


Fig. 10 Solar Angles for Vertical and Horizontal Surfaces

(Source: ASHRAE Handbook Fundamentals 2005)

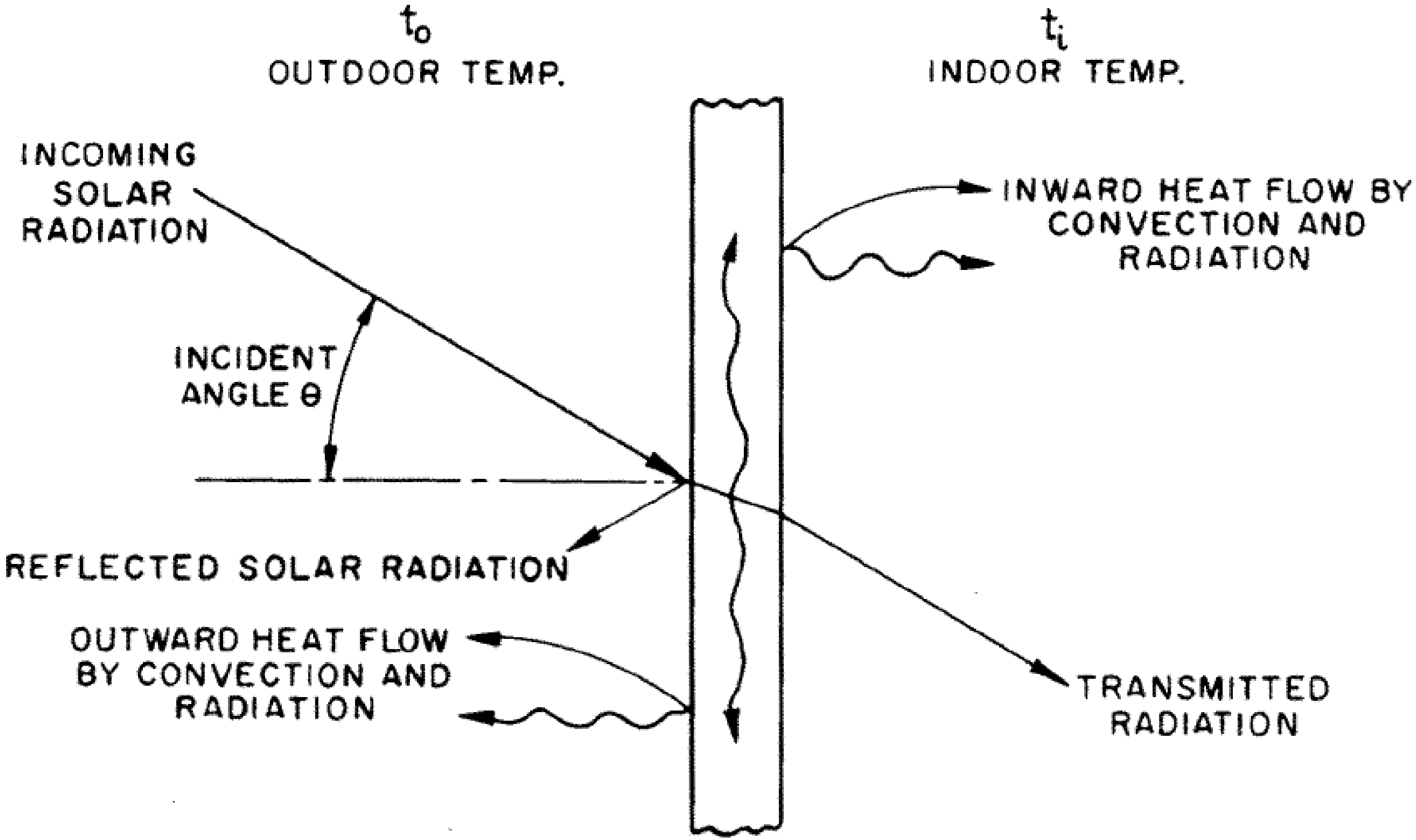
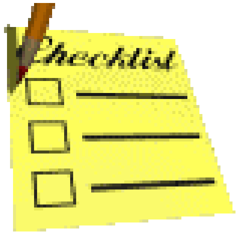


Fig. 26 Instantaneous Heat Balance for Sunlit Glazing Material

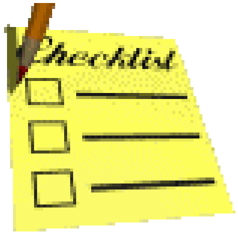
(Source: ASHRAE Handbook Fundamentals 2005)

Cooling Load Components



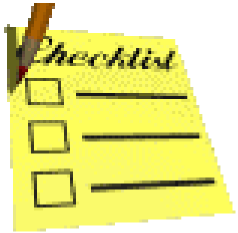
- Cooling load calculation method
  - HB / RTS method (ASHRAE Fundamentals 2009)
  - TFM method / TETD/TA method
  - CLTD/SCL/CLF method (older versions of Fundamentals)
    - It is a one-step, simple calculation procedure developed by ASHRAE
    - CLTD = cooling load temperature difference
    - SCL = solar cooling load
    - CLF = cooling load factor
  - See ASHRAE Handbook Fundamentals for details
    - Tables for CLTD, SCL and CLF

Cooling Load Components



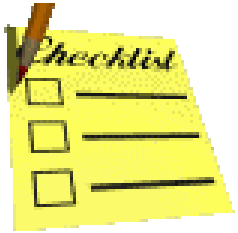
- External
  - Roofs, walls, and glass conduction
    - $q = U\,A\,(\mathrm{CLTD})$ U = U-value; A = area
  - Solar load through glass
    - $q = A\,(\mathrm{SC})\,(\mathrm{SCL})$ SC = shading coefficient
      - For unshaded area and shaded area
  - Partitions, ceilings, floors
    - $q = U\,A\,(t_{\mathrm{adjacent}} - t_{\mathrm{inside}})$

Cooling Load Components

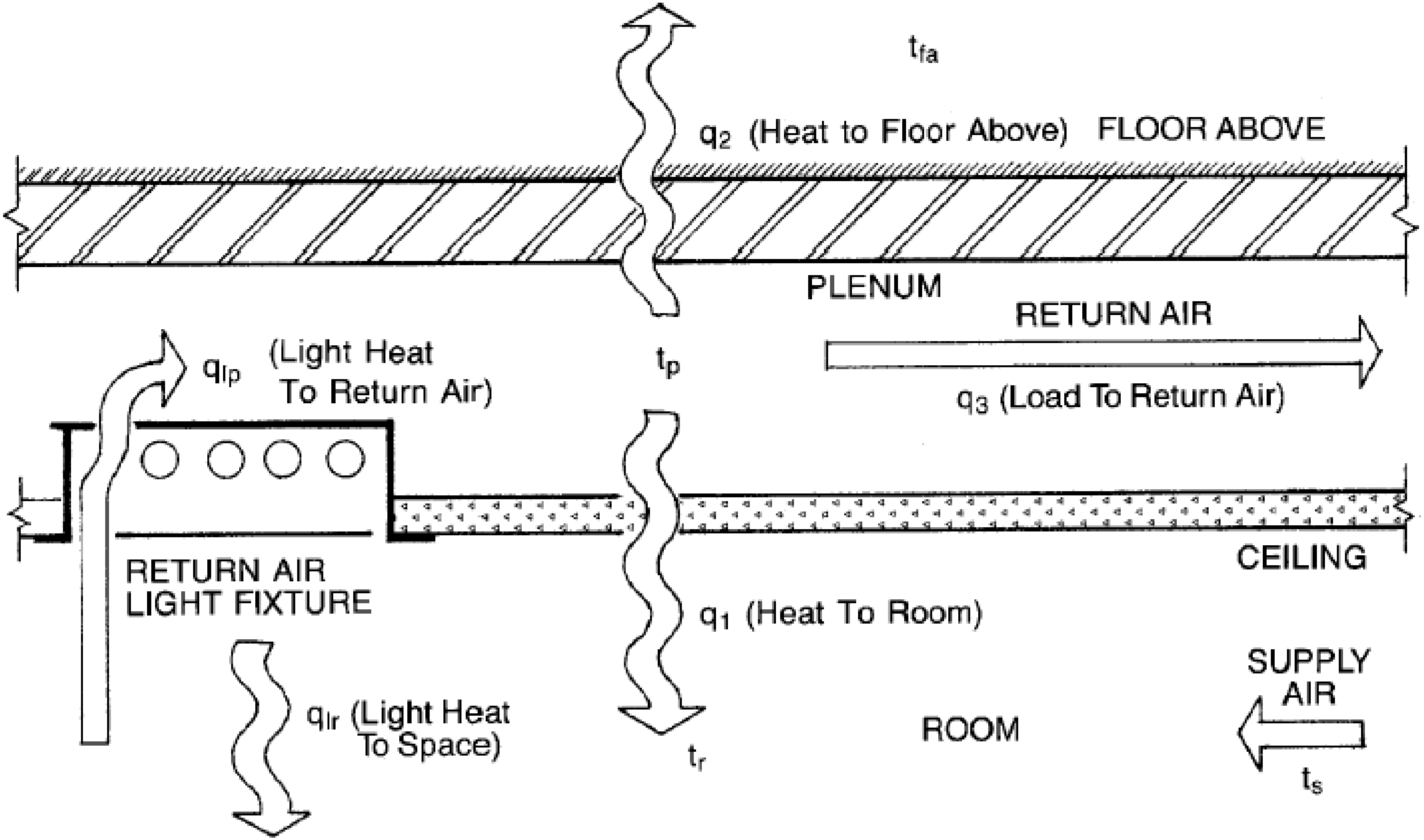


- Internal
  - People
    - $q_{sensible} = N$ (Sensible heat gain) (CLF)
    - $q_{latent} = N$ (Latent heat gain)
  - Lights
    - q = Watt x F_{ul} x F_{sa} (CLF)
      - F_{ul} = lighting use factor; F_{sa} = special allowance factor
  - Appliances
    - $q_{sensible} = q_{input}$ x usage factors (CLF)
    - $q_{latent} = q_{input}$ x load factor (CLF)

Cooling Load Components



- Ventilation and infiltration air
  - $q_{sensible} = 1.23\ Q\ (t_{outside} - t_{inside})$
  - $q_{latent} = 3010\ Q\ (w_{outside} - w_{inside})$
  - $q_{total} = 1.2\ Q\ (h_{outside} - h_{inside})$
- System heat gain
  - Fan heat gain
  - Duct heat gain and leakage
  - Ceiling return air plenum



Schematic diagram of typical return air plenum

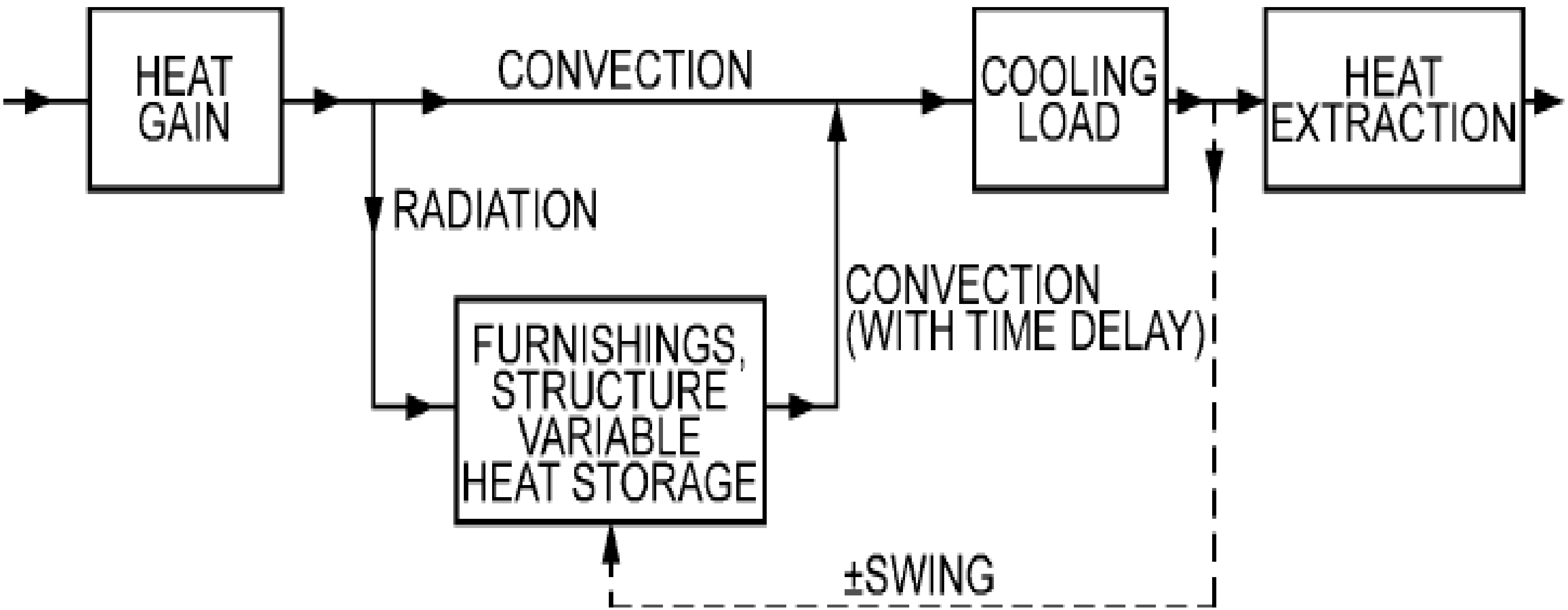
(Source: ASHRAE Handbook Fundamentals 2005)

Cooling Load Principles

- Terminology:
  - Space – a volume w/o a partition, or a partitioned room, or group of rooms
  - Room – an enclosed space (a single load)
  - Zone – a space, or several rooms, or units of space having some sort of coincident loads or similar operating characteristics
    - Thermal zoning

Cooling Load Principles

- Definitions
  - Space heat gain: instantaneous rate of heat gain that enters into or is generated within a space
  - Space cooling load: the rate at which heat must be removed from the space to maintain a constant space air temperature
  - Space heat extraction rate: the actual rate of heat removal when the space air temp. may swing
  - Cooling coil load: the rate at which energy is removed at a cooling coil serving the space

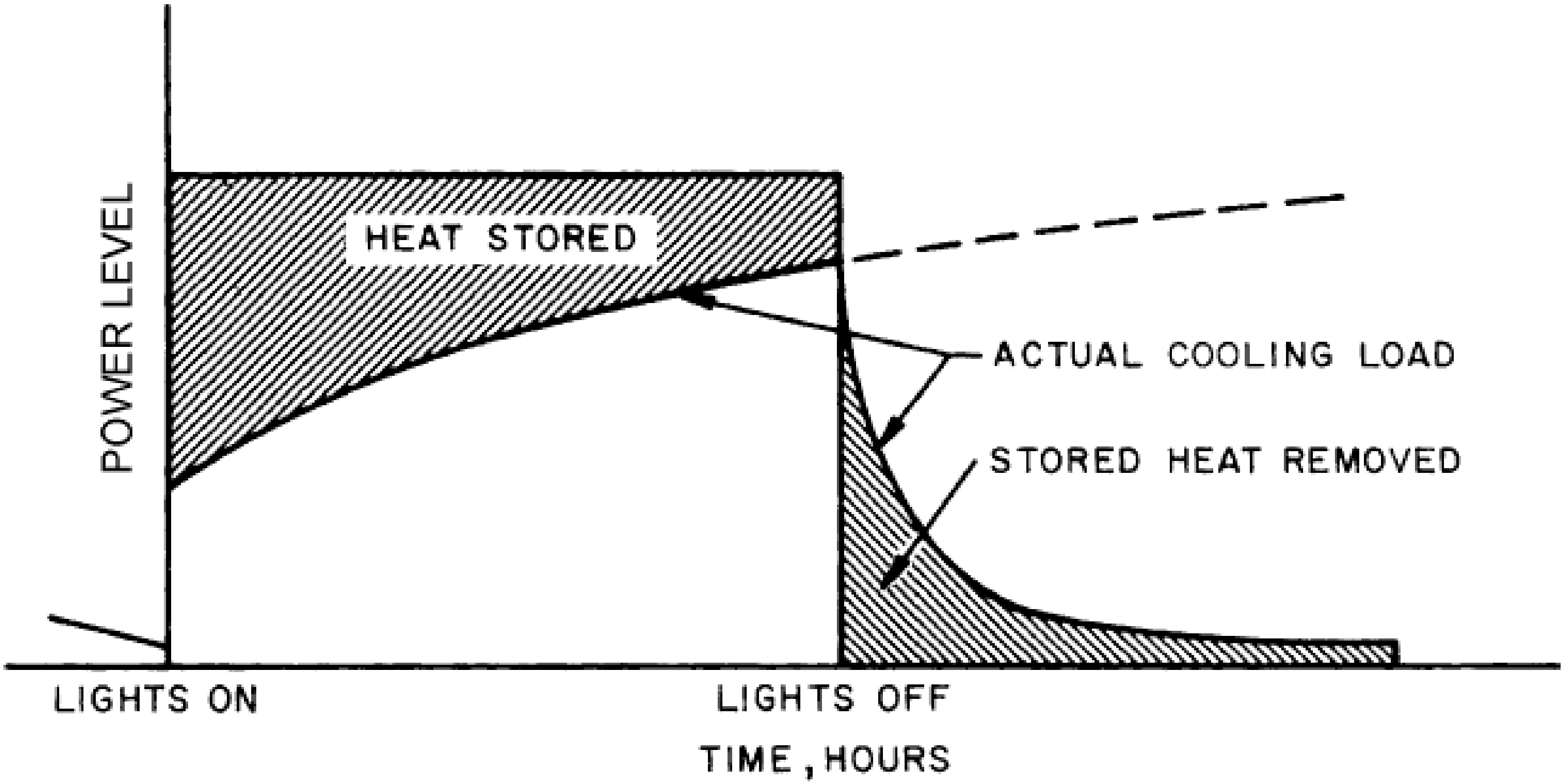


Conversion of heat gain into cooling load

(Source: ASHRAE Handbook Fundamentals 2005)

Cooling Load Principles

- Instantaneous heat gain vs space cooling loads
  - They are NOT the same
- Effect of heat storage
  - Night shutdown period
    - HVAC is switched off. What happens to the space?
  - Cool-down or warm-up period
    - When HVAC system begins to operate
    - Need to cool or warm the building fabric
  - Conditioning period
    - Space air temperature within the limits

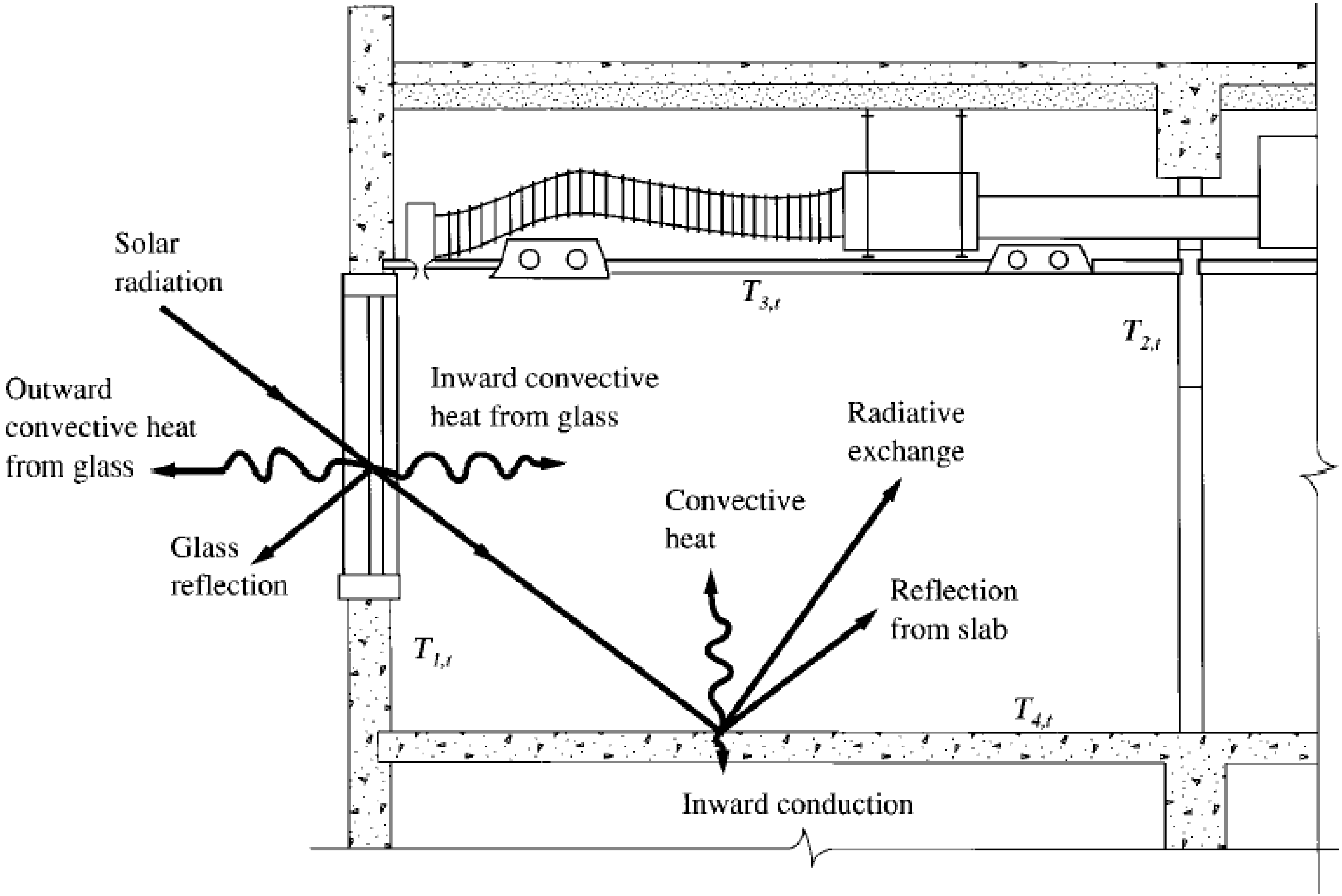


Thermal Storage Effect in Cooling Load from Lights

(Source: ASHRAE Handbook Fundamentals 2005)

Cooling Load Principles

- Space load and equipment load
  - Space heat gain (sensible, latent, total)
  - Space cooling / heating load [*at building*]
  - Space heat extraction rate
  - Cooling / heating coil load [*at air-side system*]
  - Refrigeration load [*at the chiller plant*]
- Instantaneous heat gain
  - Convective heat
  - Radiative heat (heat absorption)

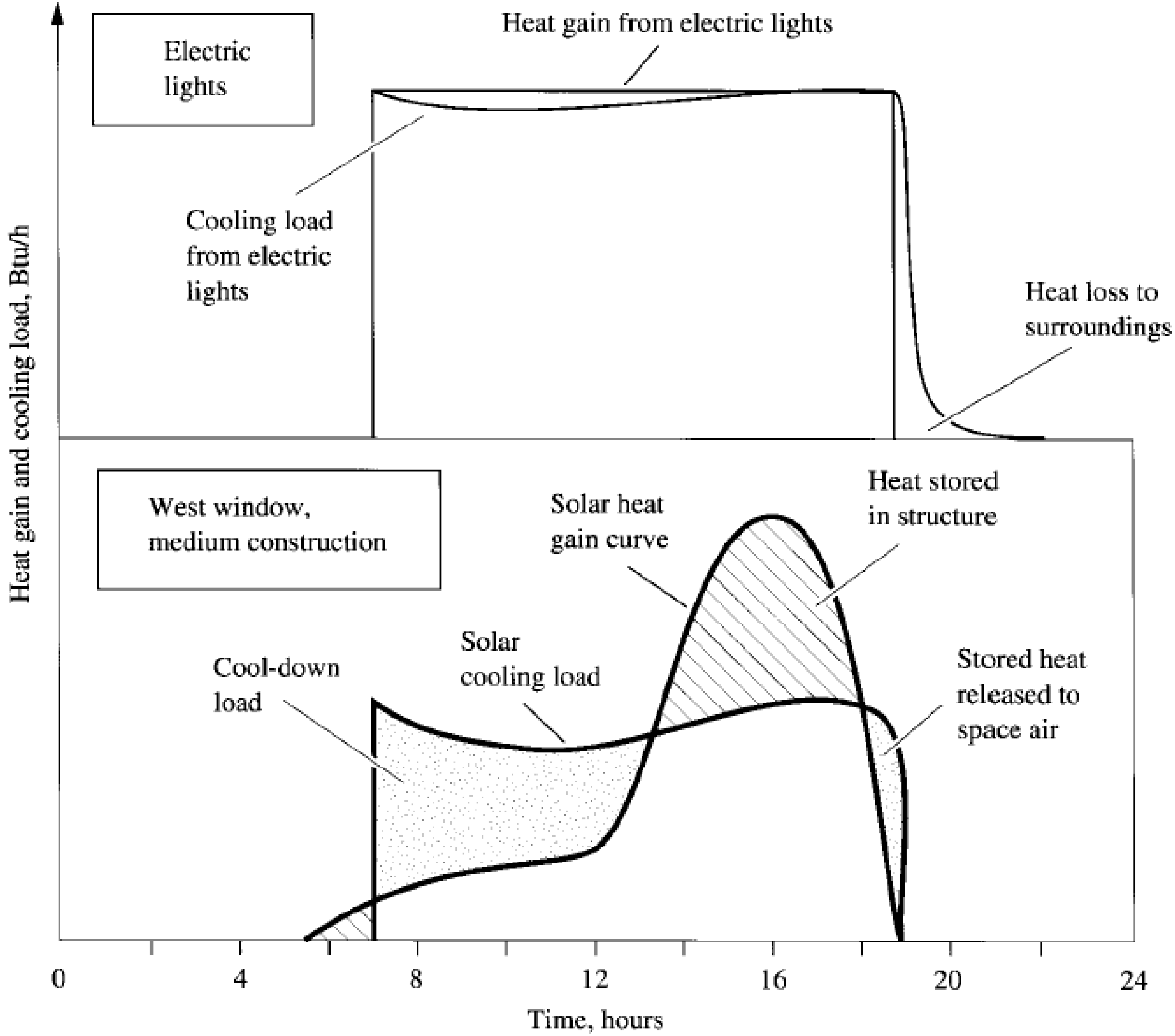


Convective and radiative heat in a conditioned space

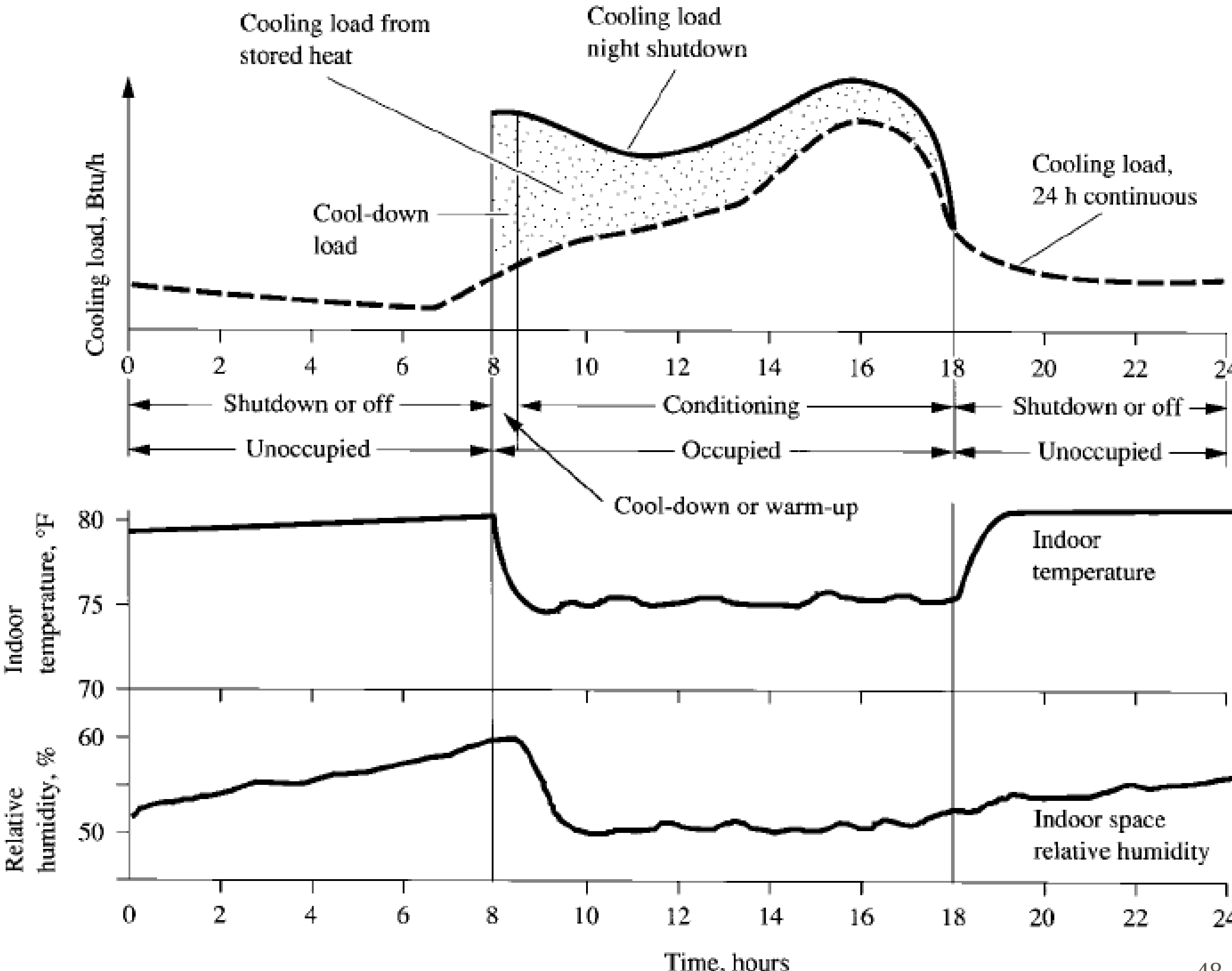
(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.)

Sensible heat gains	Convective (%)	Radiative (%)
Solar radiation with internal shading	42	58
Fluorescent lights	50	50
Occupants	67	33
External wall, inner surface	40	60

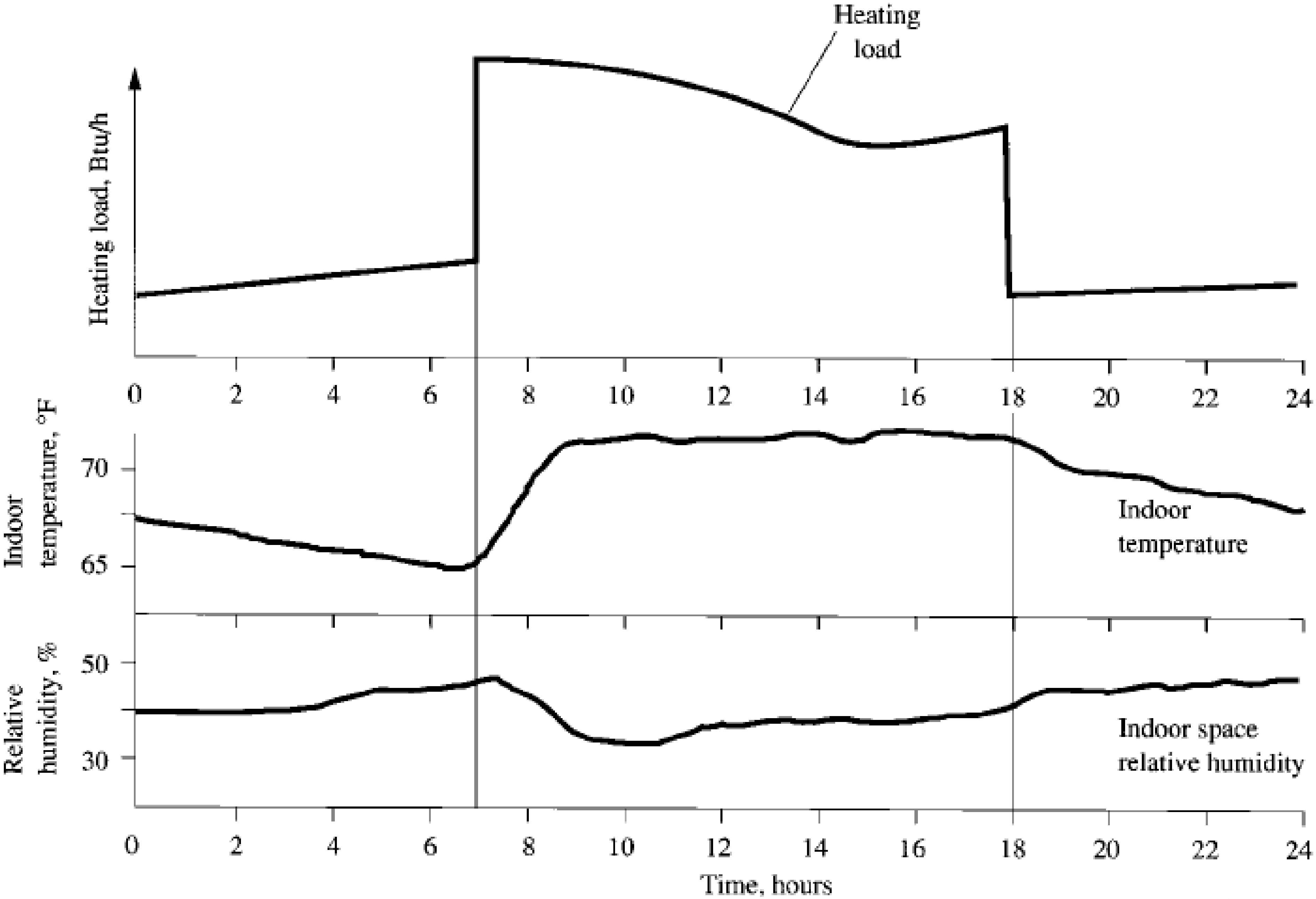
(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.)



(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.)



(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.)

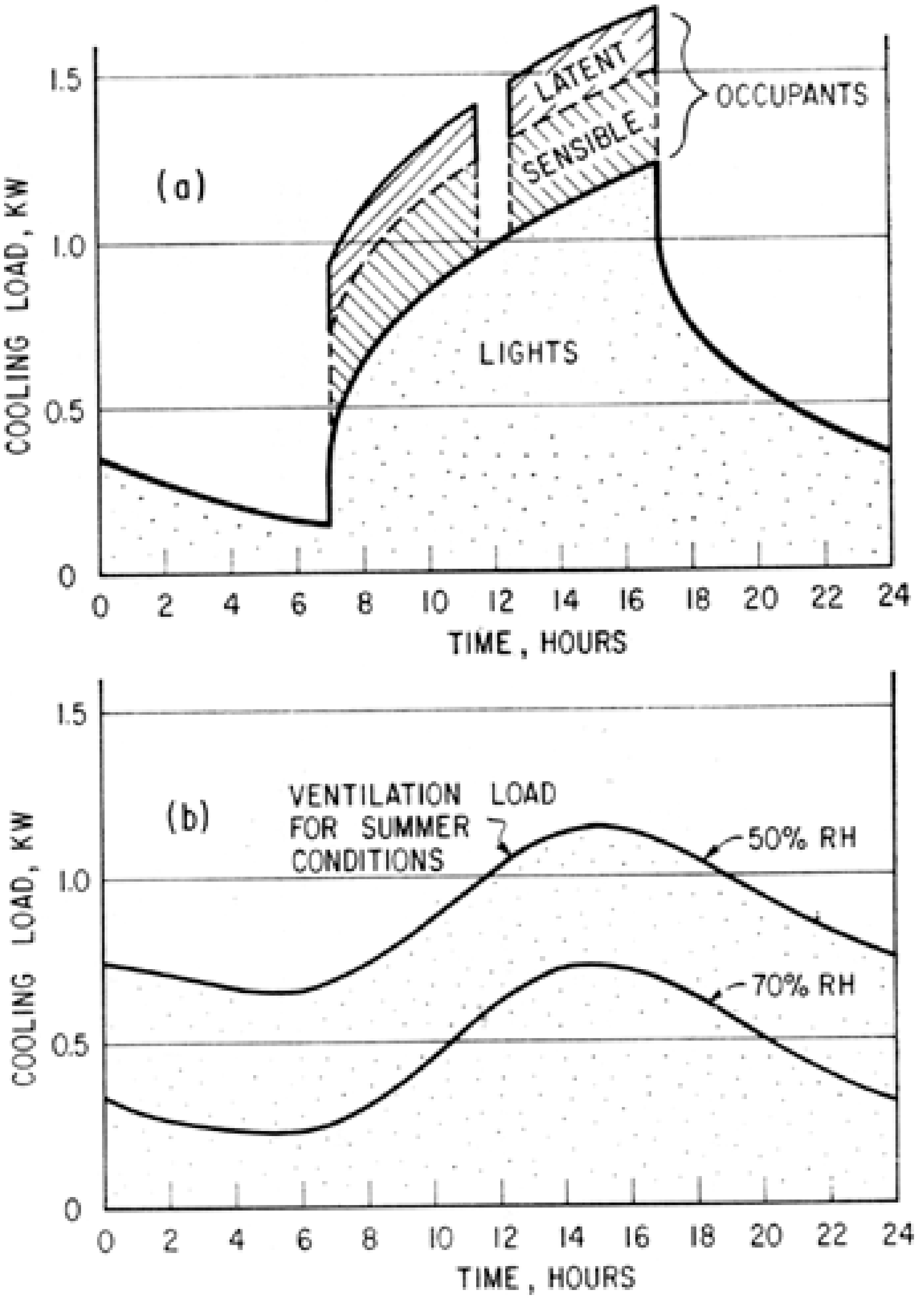


(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.)

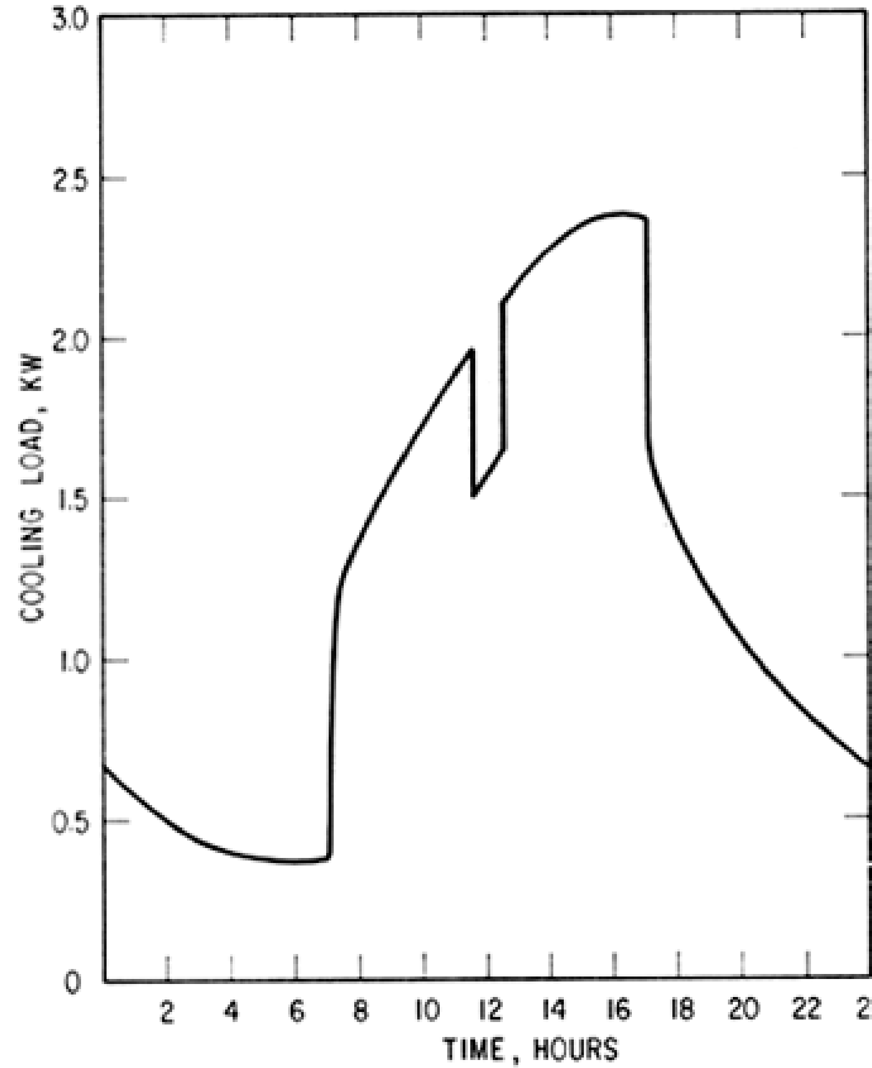
Cooling Load Principles

- Cooling load profiles
  - Shows the variation of space cooling load
  - Such as 24-hr cycle
  - Useful for building operation & energy analysis
  - What factors will affect load profiles?
- Peak load and block load
  - Peak load = max. cooling load
  - Block load = sum of zone loads at a specific time

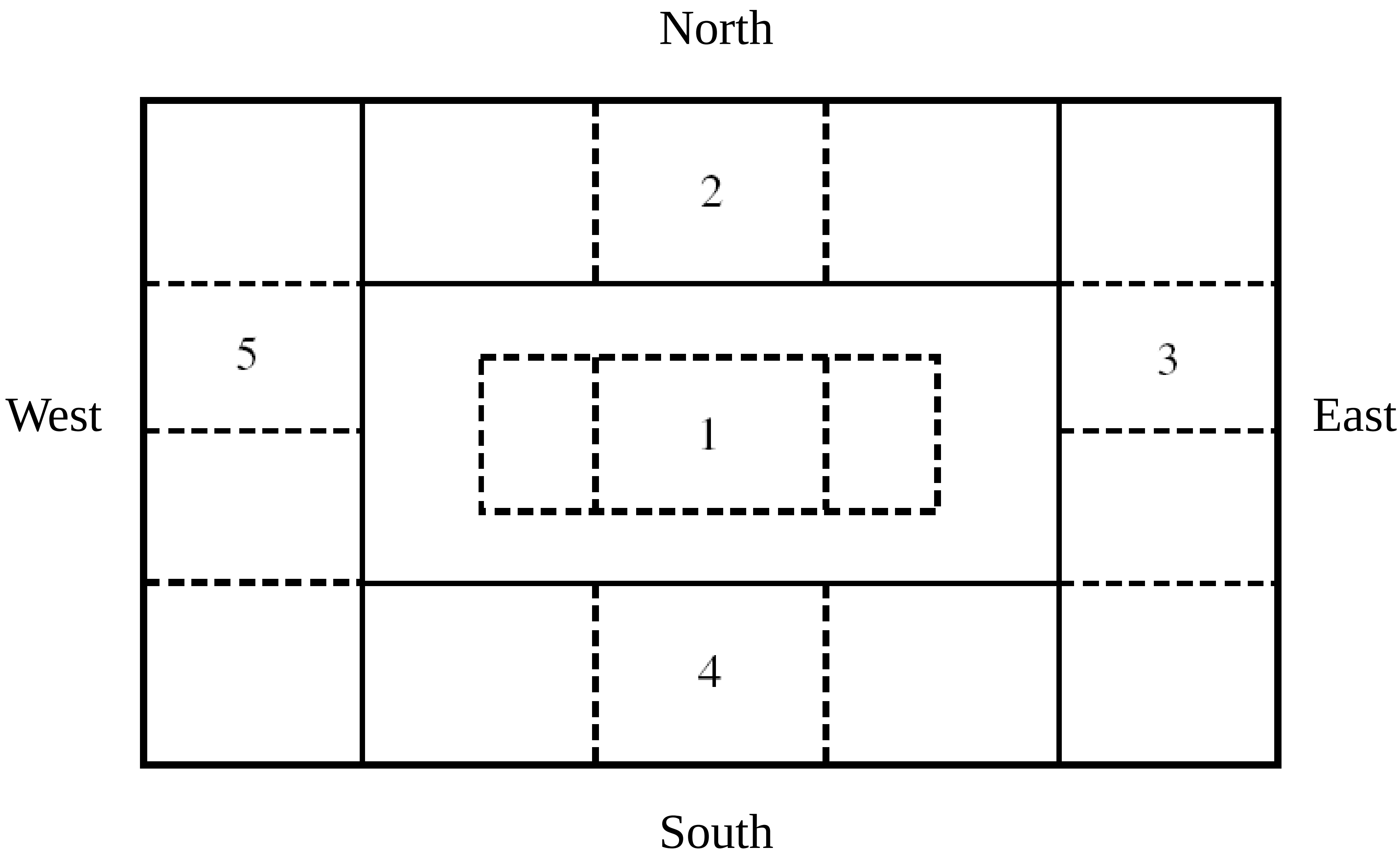
Cooling load profiles



Total cooling load

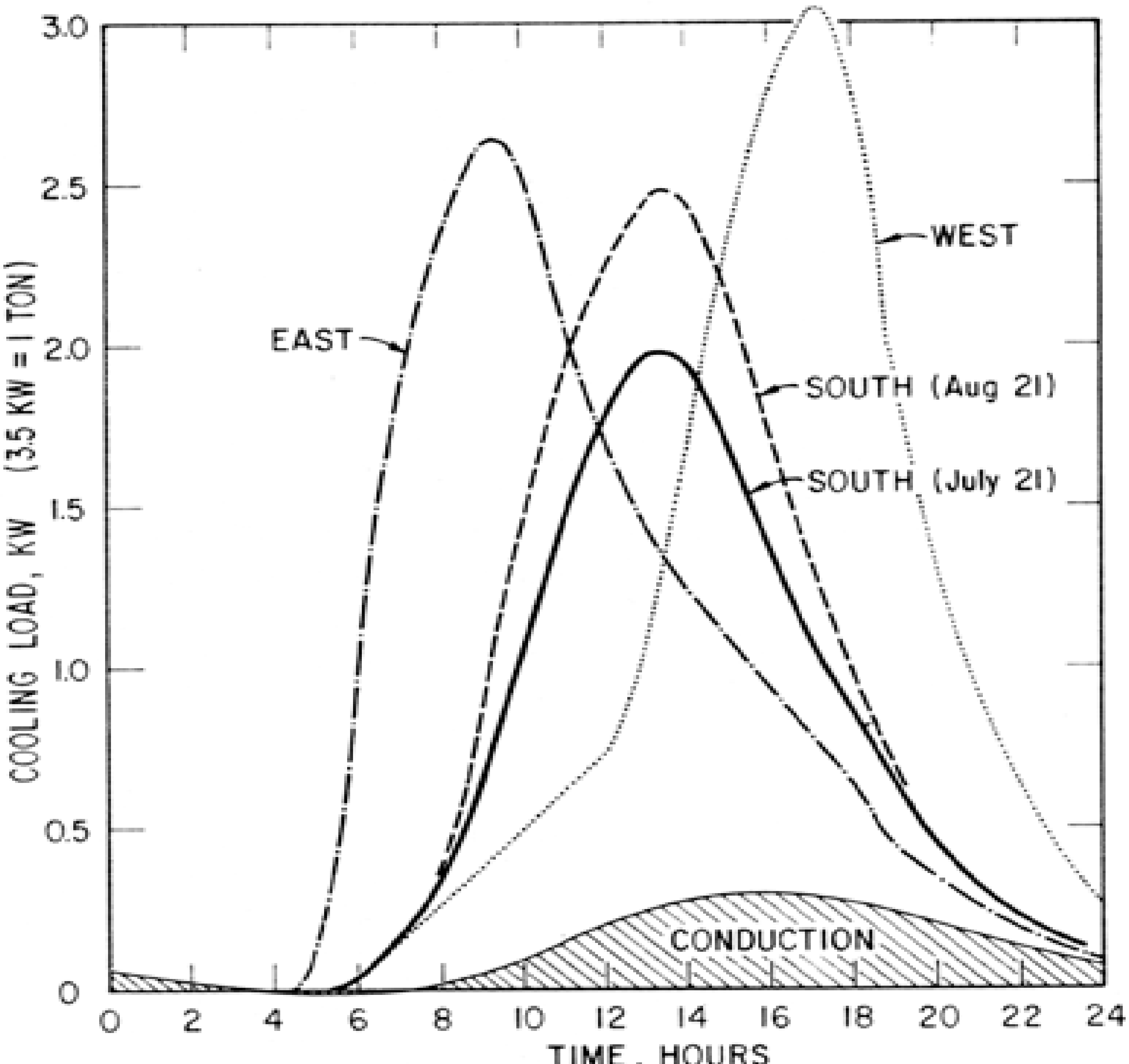


(Source: D.G. Stephenson, 1968)



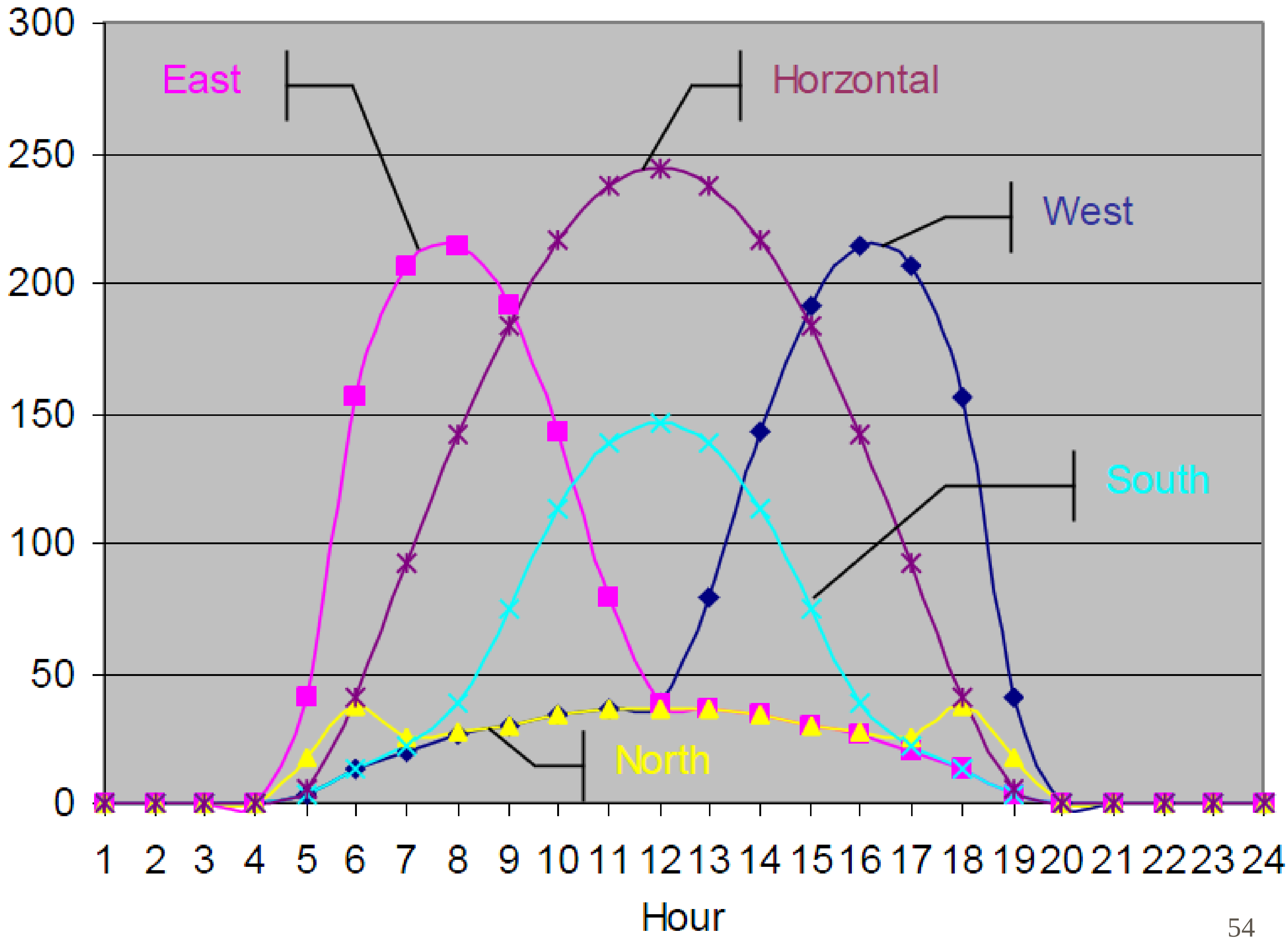
Block load and thermal zoning

Cooling loads due to windows at different orientations



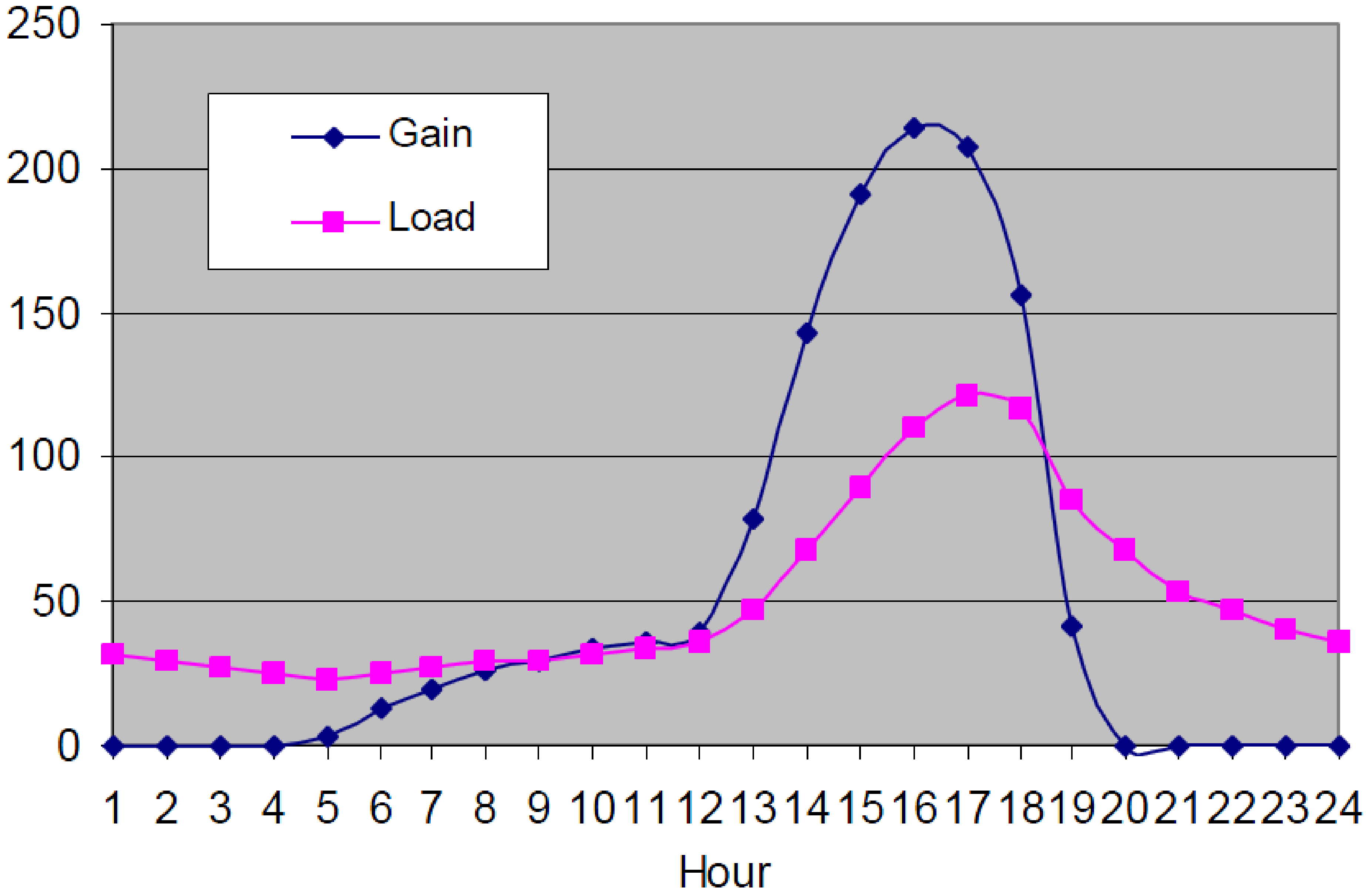
(Source: D.G. Stephenson, 1968)

Profiles of solar heat gain (July) (for latitude 48 deg N)



(Source: Keith E. Elder)

Solar cooling load vs. heat gain (July, west) (latitude 48 deg N)



(Source: Keith E. Elder)

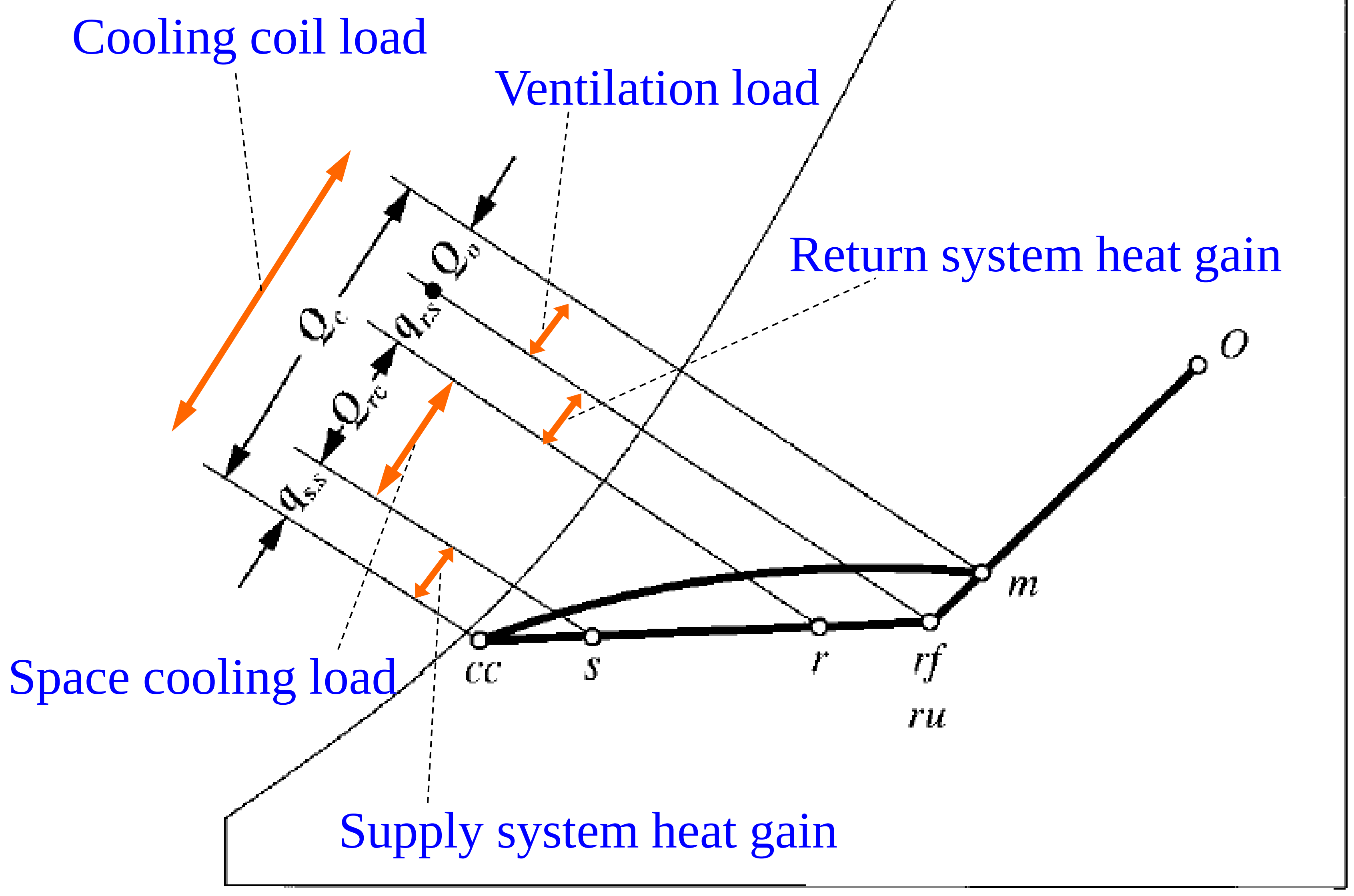
Cooling Load Principles

- Moisture transfer
  - Two paths:
    - Moisture migrates in building envelope
    - Air leakage (infiltration or exfiltration)
  - If slight RH variation is acceptable, then storage effect of moisture can be ignored
    - Latent heat gain = latent cooling load (instantaneously)
- What happens if both temp. & RH need to be controlled?

Cooling Coil Load

- Cooling coil load consists of:
  - Space cooling load (sensible & latent)
  - Supply system heat gain (fan + air duct)
  - Return system heat gain (plenum + fan + air duct)
  - Load due to outdoor ventilation rates (or ventilation load)
- Do you know how to construct a summer air conditioning cycle on a psychrometric chart?
  - See also notes in Psychrometrics

Typical summer air conditioning cycle



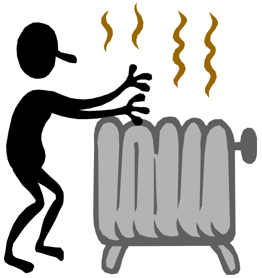
(Source: Wang, S. K., 2001. *Handbook of Air Conditioning and Refrigeration*, 2nd ed.)

Cooling Coil Load

$$\text{Supply airflow (L/s)} = \frac{\text{Sensible load (kW)}}{1.2 \times \Delta t}$$

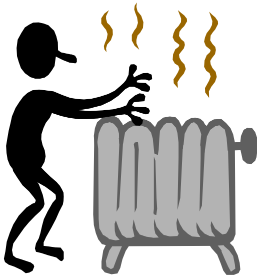
- <u>Space cooling load</u>
  - To determine supply air flow rate & size of air system, ducts, terminals, diffusers
  - It is a component of cooling coil load
  - Infiltration heat gain is an instant. cooling load
- <u>Cooling coil load</u>
  - To determine the size of cooling coil & refrigeration system
  - Remember, ventilation load is a coil load

Heating Load



- Design heating load
  - Max. heat energy required to maintain winter indoor design temp.
    - Usually occurs before sunrise on the coldest days
    - Include transmission losses & infiltration/ventilation
  - Assumptions:
    - All heating losses are instantaneous heating loads
    - Credit for solar & internal heat gains is not included
    - Latent heat often not considered (unless w/ humidifier)
    - Thermal storage effect of building structure is ignored

Heating Load



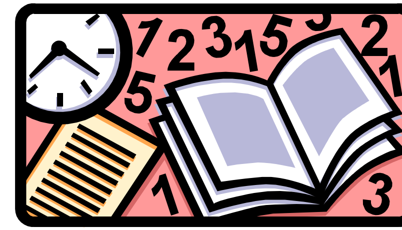
- A simplified approach to evaluate worst-case conditions based on
  - Design interior and exterior conditions
  - Including infiltration and/or ventilation
  - No solar effect (at night or on cloudy winter days)
  - Before the presence of people, light, and appliances has an offsetting effect
- Also, a warm-up/safety allowance of 20-25% is fairly common

Table 12 Summary of Loads, Equations, and References for Calculating Design Heating Loads

Heating Load	Equation	Reference, Table, Description
Roofs, ceilings, walls, glass	$q = U\,A\,\Delta t$	U: Chapter 24, Tables 1, 2, and 4 Δt: Temperature difference between inside and outside design dry bulbs, Chapter 26. For temperatures in unheated spaces, see Equation (2); for attic temperatures, see Equation (3). A: Area calculated from plans
Walls below grade	$q = U\,A\,\Delta t$	U: See Table 14. Δt: Use Figure 6 to assist in determining Δt.
Floors		
Above grade	$q = U\,A\,\Delta t$	Δt: For crawl space temperatures, see Equation (4).
On grade	$q = F_2\,P\,\Delta t$	F_2: See Table 16. Δt: See Equation (6). P: Perimeter of slab
Below grade	$q = U\,A\,\Delta t$	Δt: Use Figure 6 to assist in determining Δt. U: See Table 15.
Infiltration and ventilation air		
Sensible	$q_s = 0.018\,Q\,\Delta t$	Q: Volume of outdoor air entering building. See Chapter 25 for estimating methods for infiltration.
Latent	$q_l = 80.7\,Q\,\Delta W$	ΔW: Humidity ratio difference, if humidification is to be added

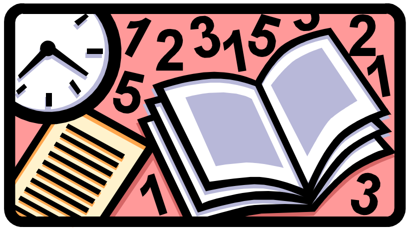
(Source: ASHRAE Handbook Fundamentals 2005)

References



- Air Conditioning and Refrigeration Engineering (Wang and Norton, 2000)
  - Chapter 6 – Load Calculations
- ASHRAE Handbook Fundamentals (2009 edition)
  - Chapter 14 – Climatic Design Information
  - Chapter 15 – Fenestration
  - Chapter 17 – Residential Cooling and Heating Load Calculations
  - Chapter 18 – Nonresidential Cooling and Heating Load Calculations

References



- Remarks:
  - "Load & Energy Calculations" in *ASHRAE Handbook Fundamentals*
  - The following previous cooling load calculations are described in earlier editions of the ASHRAE Handbook (1997 and 2001 versions)
    - CLTD/SCL/CLF method
    - TETD/TA method
    - TFM method

HONG KONG OBSERVATO, China

WMO#: **450050**

Lat: **22.30N** Long: **114.17E** Elev: **62** StdP: **100.58** Time Zone: **8.00 (CHN)** Period: **82-92** WBAN: **99999**

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
2	**9.6**	**10.9**	**-1.1**	**3.5**	**13.0**	**1.8**	**4.3**	**14.0**	**9.2**	**15.9**	**8.4**	**15.8**	**2.2**	**10**

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
7	**3.5**	**32.2**	**26.5**	**31.7**	**26.4**	**31.2**	**26.3**	**27.4**	**30.5**	**27.1**	**30.1**	**26.9**	**29.9**	**3.4**	**270**

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours 8 to 4 & 12.8/20.6
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
26.6	**22.3**	**29.3**	**26.2**	**21.8**	**29.1**	**26.1**	**21.6**	**29.0**	**87.5**	**30.6**	**86.4**	**30.3**	**85.3**	**30.1**	**970**

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
8.6	**7.4**	**6.5**	**28.4**	**7.6**	**33.5**	**1.7**	**0.3**	**6.3**	**33.7**	**5.3**	**33.9**	**4.4**	**34.1**	**3.1**	**34.4**

Monthly Climatic Design Conditions

			Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours	Tavg		**23.1**	**16.2**	**16.1**	**18.5**	**21.9**	**25.8**	**27.9**	**29.0**	**28.8**	**27.8**	**25.5**	**21.7**	**17.6**
	Sd			**2.37**	**2.57**	**3.33**	**2.70**	**2.01**	**1.70**	**1.29**	**1.27**	**1.50**	**1.85**	**2.49**	**2.85**
	HDD10.0		**2**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**
	HDD18.3		**237**	**72**	**71**	**39**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**46**
	CDD10.0		**4782**	**192**	**171**	**264**	**357**	**489**	**538**	**588**	**581**	**534**	**481**	**350**	**236**
	CDD18.3		**1976**	**6**	**8**	**46**	**111**	**231**	**288**	**330**	**323**	**284**	**223**	**104**	**23**
	CDH23.3		**18618**	**0**	**1**	**79**	**436**	**1826**	**3226**	**4110**	**3924**	**3126**	**1657**	**228**	**5**
	CDH26.7		**5853**	**0**	**0**	**0**	**31**	**366**	**1081**	**1696**	**1521**	**957**	**200**	**3**	**0**
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		**22.1**	**23.1**	**26.0**	**28.6**	**31.2**	**32.2**	**33.0**	**32.9**	**32.5**	**30.6**	**26.9**	**24.0**
		MCWB		**18.5**	**19.8**	**22.7**	**24.3**	**26.2**	**26.5**	**26.8**	**26.6**	**25.6**	**25.2**	**21.9**	**19.3**
	2%	DB		**20.9**	**21.9**	**25.1**	**27.6**	**30.2**	**31.5**	**32.2**	**32.1**	**31.5**	**29.3**	**26.0**	**22.6**
		MCWB		**17.5**	**19.3**	**22.6**	**24.2**	**26.0**	**26.6**	**26.7**	**26.6**	**25.8**	**24.6**	**21.7**	**18.1**
	5%	DB		**20.0**	**20.7**	**24.3**	**26.7**	**29.4**	**30.9**	**31.6**	**31.5**	**30.8**	**28.5**	**25.2**	**21.7**
		MCWB		**16.9**	**18.4**	**22.2**	**23.8**	**25.7**	**26.5**	**26.6**	**26.5**	**25.7**	**24.2**	**21.4**	**17.6**
	10%	DB		**19.1**	**19.6**	**23.3**	**26.0**	**28.6**	**30.3**	**31.1**	**31.0**	**30.1**	**27.7**	**24.7**	**21.0**
		MCWB		**16.2**	**17.4**	**21.4**	**23.6**	**25.4**	**26.4**	**26.4**	**26.4**	**25.5**	**23.8**	**21.1**	**17.2**
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		**19.5**	**21.1**	**23.6**	**25.3**	**26.9**	**27.7**	**27.7**	**27.7**	**27.3**	**26.2**	**23.9**	**20.1**
		MCDB		**21.0**	**22.4**	**25.2**	**27.1**	**29.8**	**30.6**	**30.9**	**31.1**	**30.3**	**28.9**	**25.6**	**22.6**
	2%	WB		**18.5**	**19.9**	**23.1**	**24.6**	**26.5**	**27.2**	**27.3**	**27.2**	**26.9**	**25.6**	**23.0**	**19.4**
		MCDB		**20.2**	**21.5**	**24.7**	**26.6**	**29.3**	**30.0**	**30.4**	**30.3**	**29.6**	**28.1**	**25.0**	**21.8**
	5%	WB		**17.6**	**18.9**	**22.5**	**24.2**	**26.1**	**27.0**	**27.1**	**27.0**	**26.6**	**25.1**	**22.4**	**18.6**
		MCDB		**19.4**	**20.5**	**24.1**	**26.3**	**28.8**	**29.8**	**30.3**	**30.0**	**29.3**	**27.6**	**24.6**	**21.0**
	10%	WB		**16.8**	**18.0**	**21.5**	**23.8**	**25.7**	**26.7**	**26.9**	**26.7**	**26.2**	**24.6**	**21.8**	**17.8**
		MCDB		**18.7**	**19.2**	**23.1**	**25.9**	**28.2**	**29.4**	**30.0**	**29.6**	**29.0**	**27.2**	**24.2**	**20.4**
Mean Daily Temperature Range		MDBR		**3.5**	**3.1**	**3.4**	**3.3**	**3.3**	**3.0**	**3.5**	**3.5**	**3.4**	**3.2**	**3.5**	**3.8**
	5% DB	MCDBR		**4.1**	**4.6**	**4.3**	**4.2**	**4.0**	**3.6**	**4.1**	**4.3**	**4.2**	**3.7**	**3.6**	**4.1**
		MCWBR		**2.7**	**3.1**	**2.6**	**2.2**	**1.7**	**1.3**	**1.3**	**1.6**	**1.8**	**1.9**	**2.2**	**2.4**
	5% WB	MCDBR		**3.5**	**4.2**	**4.0**	**4.0**	**3.6**	**3.3**	**3.6**	**3.9**	**3.7**	**3.2**	**3.1**	**3.6**
		MCWBR		**2.7**	**3.2**	**3.0**	**2.4**	**1.9**	**1.4**	**1.5**	**1.6**	**1.6**	**1.5**	**2.2**	**2.6**
Clear Sky Solar Irradiance	taub			**0.631**	**0.658**	**0.766**	**0.775**	**0.701**	**0.659**	**0.617**	**0.682**	**0.741**	**0.725**	**0.621**	**0.604**
	taud			**1.519**	**1.499**	**1.395**	**1.410**	**1.530**	**1.612**	**1.693**	**1.568**	**1.467**	**1.469**	**1.591**	**1.581**
	Ebn,noon			**636**	**656**	**611**	**617**	**662**	**685**	**714**	**670**	**619**	**599**	**641**	**638**
	Edh,noon			**256**	**279**	**324**	**327**	**289**	**264**	**244**	**276**	**297**	**281**	**236**	**233**

CDD*n* Cooling degree-days base n°C, °C-day
CDH*n* Cooling degree-hours base n°C, °C-hour
DB Dry bulb temperature, °C
DP Dew point temperature, °C
Ebn,noon } Clear sky beam normal and diffuse hori-
Edh,noon } zontal irradiances at solar noon, W/m2
Elev Elevation, m
Enth Enthalpy, kJ/kg
HDD*n* Heating degree-days base n°C, °C-day
Hours 8/4 & 12.8/20.6 Number of hours between 8 a.m. and 4 p.m with DB between 12.8 and 20.6 °C
HR Humidity ratio, g of moisture per kg of dry air

Lat Latitude, °
Long Longitude, °
MCDB Mean coincident dry bulb temperature, °C
MCDBR Mean coincident dry bulb temp. range, °C
MCDP Mean coincident dew point temperature, °C
MCWB Mean coincident wet bulb temperature, °C
MCWBR Mean coincident wet bulb temp. range, °C
MCWS Mean coincident wind speed, m/s
MDBR Mean dry bulb temp. range, °C
PCWD Prevailing coincident wind direction, °, 0 = North, 90 = East

Period Years used to calculate the design conditions
Sd Standard deviation of daily average temperature, °C
StdP Standard pressure at station elevation, kPa
taub Clear sky optical depth for beam irradiance
taud Clear sky optical depth for diffuse irradiance
Tavg Average temperature, °C
Time Zone Hours ahead or behind UTC, and time zone code
WB Wet bulb temperature, °C
WBAN Weather Bureau Army Navy number
WMO# World Meteorological Organization number
WS Wind speed, m/s

HONG KONG INTERNATI, China

WMO#: **450070**

Lat: **22.32N** Long: **113.92E** Elev: **8** StdP: **101.23** Time Zone: **8.00 (CHN)** Period: **82-06** WBAN: **99999**

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
1	**9.0**	**10.8**	**-3.2**	**2.9**	**13.7**	**-0.1**	**3.8**	**14.9**	**10.5**	**18.1**	**9.5**	**17.6**	**4.2**	**30**

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
7	**4.7**	**33.8**	**26.5**	**33.0**	**26.3**	**32.2**	**26.1**	**27.7**	**30.8**	**27.3**	**30.5**	**27.0**	**30.3**	**5.0**	**240**

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours 8 to 4 & 12.8/20.6
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
26.9	**22.6**	**30.0**	**26.2**	**21.7**	**29.5**	**26.1**	**21.5**	**29.5**	**88.3**	**31.3**	**86.7**	**31.0**	**85.4**	**30.7**	**730**

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
10.2	**8.9**	**8.0**	**29.6**	**7.2**	**35.7**	**1.5**	**1.1**	**6.1**	**36.4**	**5.3**	**37.1**	**4.5**	**37.7**	**3.4**	**38.5**

Monthly Climatic Design Conditions

			Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours	Tavg		24.0	16.9	17.2	19.6	23.4	26.7	28.7	29.5	29.4	28.6	26.4	22.7	18.5
	Sd			3.05	3.12	3.29	2.96	2.08	1.66	1.40	1.45	1.60	1.85	2.63	3.09
	HDD10.0		2	1	1	0	0	0	0	0	0	0	0	0	1
	HDD18.3		182	62	53	26	2	0	0	0	0	0	0	3	36
	CDD10.0		5114	216	202	298	403	518	562	605	600	557	509	382	263
	CDD18.3		2253	19	22	65	155	260	312	347	342	307	251	134	40
	CDH23.3		22772	14	26	178	928	2464	3762	4495	4373	3648	2244	579	59
	CDH26.7		8410	0	0	8	173	704	1516	2066	1953	1407	522	59	2
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		25.0	25.4	27.8	31.0	32.2	33.9	34.9	34.9	34.2	32.0	29.8	26.3
		MCWB		19.4	20.6	23.0	24.5	25.6	26.7	26.9	26.5	26.0	24.1	22.6	20.7
	2%	DB		23.1	24.1	26.2	29.2	31.5	32.8	33.2	33.6	33.0	30.9	28.1	25.0
		MCWB		18.1	19.4	22.3	24.3	25.7	26.4	26.6	26.5	25.5	24.1	21.7	19.8
	5%	DB		22.0	22.9	25.1	28.8	30.8	32.0	32.8	32.9	32.1	30.0	27.1	23.8
		MCWB		17.6	18.8	21.9	24.1	25.6	26.3	26.6	26.4	25.4	23.7	21.2	18.9
	10%	DB		21.0	21.2	24.1	27.8	29.9	31.1	32.0	32.0	31.1	29.1	26.1	22.8
		MCWB		17.0	17.8	21.2	23.7	25.3	26.5	26.5	26.3	25.4	23.1	20.8	17.8
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		20.5	22.0	24.1	25.9	27.1	28.0	28.2	28.1	27.7	26.3	24.2	22.9
		MCDB		23.0	23.9	26.1	28.7	30.0	30.7	31.8	31.2	30.9	29.6	27.2	25.0
	2%	WB		19.5	20.6	23.5	25.2	26.6	27.5	27.6	27.6	27.0	25.6	23.5	20.9
		MCDB		22.0	22.9	25.5	28.1	29.6	30.3	31.0	30.8	30.3	28.8	26.6	23.7
	5%	WB		18.5	19.5	22.6	24.7	26.3	27.1	27.2	27.2	26.6	25.1	22.8	19.6
		MCDB		21.1	21.9	24.7	27.6	29.2	30.1	30.6	30.5	29.9	28.5	26.0	22.7
	10%	WB		17.6	18.6	21.6	24.2	25.9	26.7	26.9	26.8	26.3	24.6	22.0	18.6
		MCDB		20.3	20.9	23.7	26.9	28.8	29.8	30.4	30.2	29.6	28.1	25.3	21.8
Mean Daily Temperature Range		MDBR		5.2	4.6	4.7	4.6	4.5	4.2	4.7	4.7	4.7	4.8	5.3	5.5
	5% DB	MCDBR		6.3	6.5	5.9	5.7	5.2	4.9	5.4	5.7	5.6	5.4	5.8	6.3
		MCWBR		3.4	3.5	3.1	2.4	2.1	2.0	2.1	2.4	2.5	2.6	3.0	3.1
	5% WB	MCDBR		5.8	5.8	5.4	5.1	4.6	4.3	4.7	4.9	4.9	4.6	4.8	5.2
		MCWBR		3.7	3.8	3.5	2.7	2.3	2.0	2.1	2.3	2.3	2.3	2.9	3.3
Clear Sky Solar Irradiance	taub			0.690	0.710	0.813	0.846	0.804	0.751	0.694	0.768	0.832	0.815	0.696	0.684
	taud			1.432	1.424	1.342	1.332	1.390	1.462	1.547	1.437	1.357	1.362	1.473	1.455
	Ebn,noon			590	618	581	574	597	624	662	614	561	540	581	573
	Edh,noon			276	299	341	353	332	307	282	314	331	310	262	260

CDD*n* Cooling degree-days base n°C, °C-day
CDH*n* Cooling degree-hours base n°C, °C-hour
DB Dry bulb temperature, °C
DP Dew point temperature, °C
Ebn,noon } Clear sky beam normal and diffuse hori-
Edh,noon } zontal irradiances at solar noon, W/m2
Elev Elevation, m
Enth Enthalpy, kJ/kg
HDD*n* Heating degree-days base n°C, °C-day
Hours 8/4 & 12.8/20.6 Number of hours between 8 a.m. and 4 p.m with DB between 12.8 and 20.6 °C
HR Humidity ratio, g of moisture per kg of dry air
Lat Latitude, °
Long Longitude, °
MCDB Mean coincident dry bulb temperature, °C
MCDBR Mean coincident dry bulb temp. range, °C
MCDP Mean coincident dew point temperature, °C
MCWB Mean coincident wet bulb temperature, °C
MCWBR Mean coincident wet bulb temp. range, °C
MCWS Mean coincident wind speed, m/s
MDBR Mean dry bulb temp. range, °C
PCWD Prevailing coincident wind direction, °, 0 = North, 90 = East
Period Years used to calculate the design conditions
Sd Standard deviation of daily average temperature, °C
StdP Standard pressure at station elevation, kPa
taub Clear sky optical depth for beam irradiance
taud Clear sky optical depth for diffuse irradiance
Tavg Average temperature, °C
Time Zone Hours ahead or behind UTC, and time zone code
WB Wet bulb temperature, °C
WBAN Weather Bureau Army Navy number
WMO# World Meteorological Organization number
WS Wind speed, m/s