CAE 464/517 HVAC Systems Design

Spring 2023

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Indoor and outdoor design conditions and heating loads

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ANNOUNCEMENTS

Announcements

- Homework 1 is due tonight
- Homework 2 is posted
- No class on Thursday 01/26 (Video training will be posted)

Announcements

- Start thinking about your group for the project

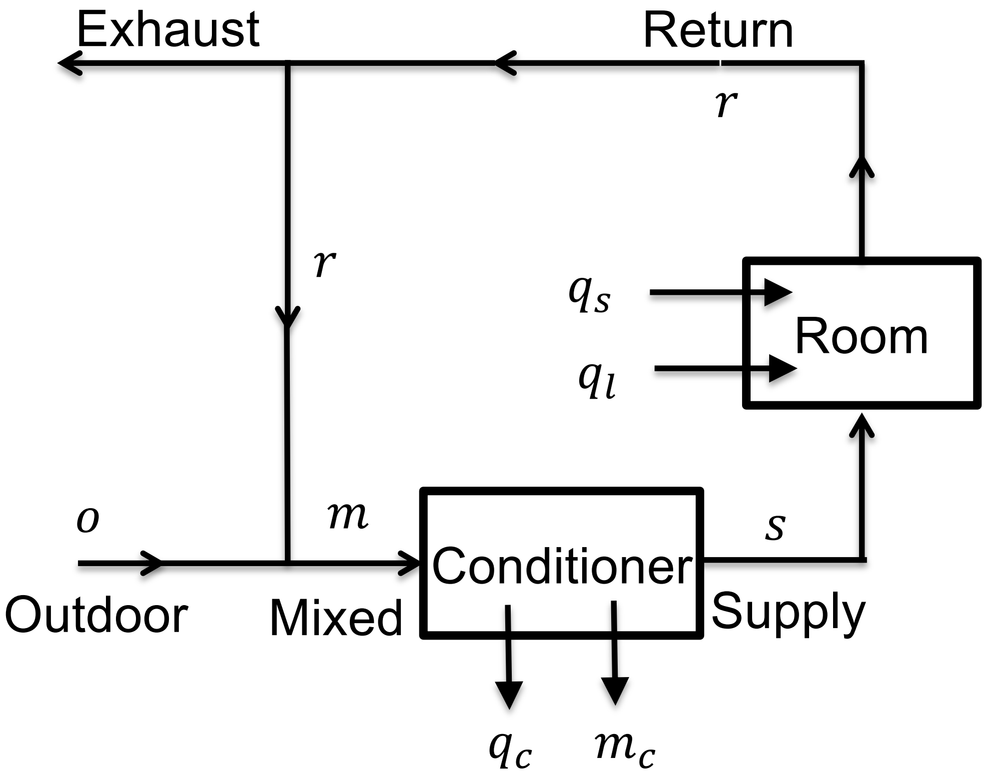
Group #	Team Members
1	
2	
3	
4	
5	
6	
7	

RECAP

Recap

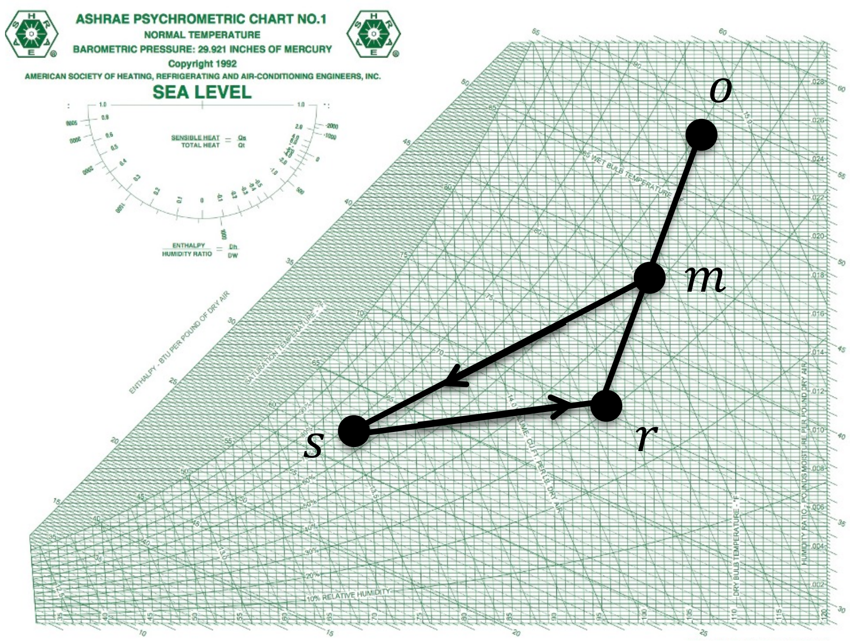
- Step 1: Develop state condition property table

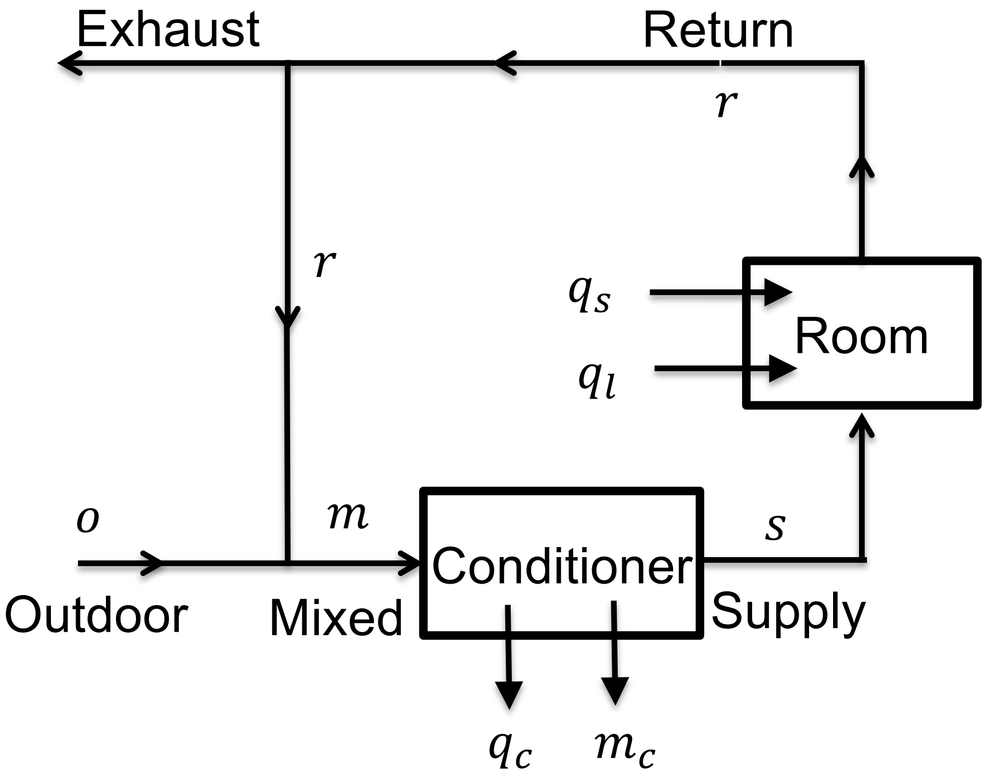
Point	**OA**	**RA**	**MA**	**DA**	**SA**
Dry bulb					
Wet bulb					
RH					
Enthalpy					
W					
V					
m_a					
Airflow					



Recap

- Step 2: Develop Psychrometric chart





DESIGN CONDITIONS

Design Conditions

- Temperature difference is the main driver for the heat transfer (How about moisture?):

$$\Delta T = T_i - T_o$$

- T_i:
  - Varies from space to space (e.g., from an office space to a classroom)
  - Exists reference for various environments
  - Uses rules of thumbs
- T_o:
  - Outdoor design conditions

Design Conditions

- Indoor design conditions
    - ❑ Temperature
    - ❑ Relative humidity

- Outdoor design conditions
    - ❑ Temperature (e.g., dry bulb, wet bulb, …)
    - ❑ Solar radiation
    - ❑ …

Design Conditions

- Relevant standards to determine the indoor and outdoor conditions are:
  - ❑ ASHRAE Handbook-Fundamentals
  - ❑ ASHRAE 55 Thermal Environmental Conditions for Human Occupancy
  - ❑ ASHRAE 62.1: Ventilation for Acceptable Indoor Air Quality (IAQ) (Commercial)
  - ❑ ASHRAE 62.2: Ventilation for Acceptable Indoor Air Quality (IAQ) (Residential)
  - ❑ ASHRAE 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings

Access to standards: https://www.ashrae.org/technical-resources/standards-and-guidelines

INDOOR DESIGN CONDITIONS

(Please, see Chapter 9 for additional materials)

Indoor Design Conditions

- Indoor heating design condition:
  - ☐ Temperature: 70 °F – 72 °F
  - ☐ RH = 30%

- Indoor cooling design condition:
  - ☐ Temperature: 75°F – 78 °F
  - ☐ RH = 50%

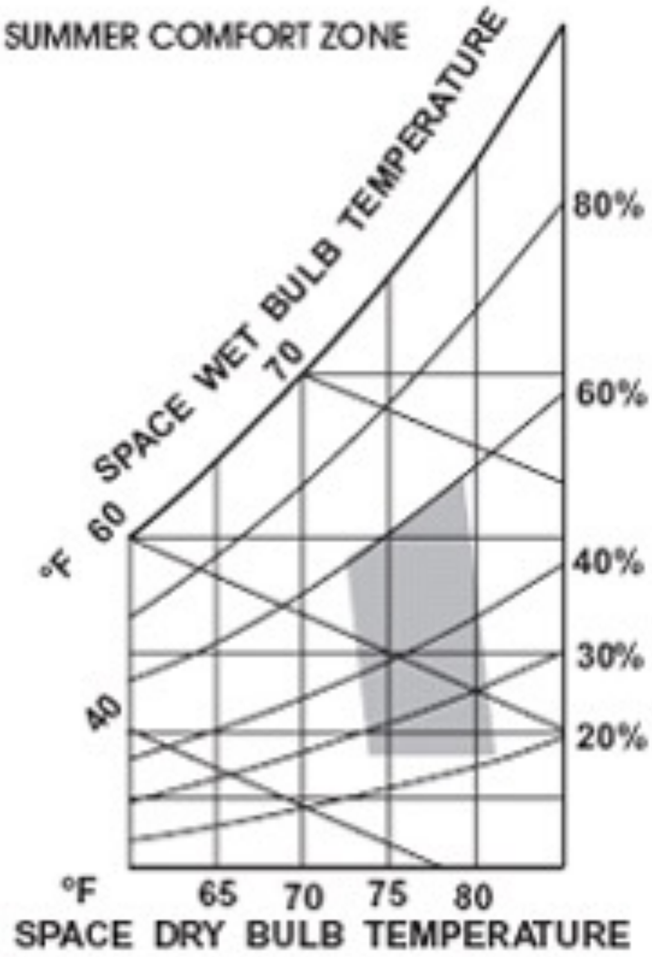
What do these temperatures and relative humidity mean?

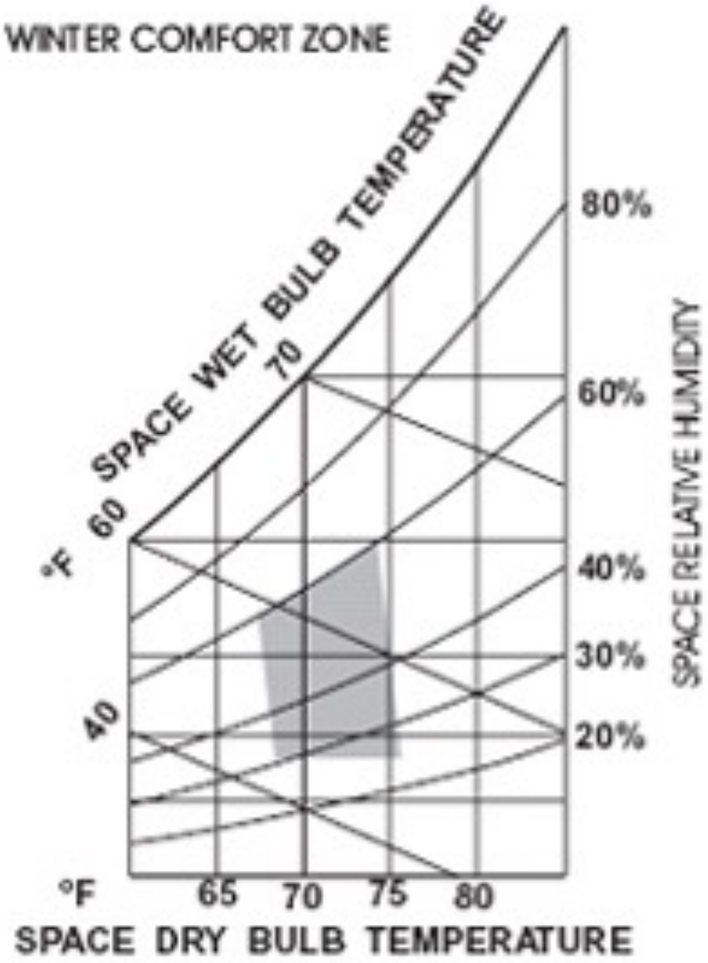
Where do you find more accurate values?

Reference: ASHRAE Load Calculation Applications Manual, 2nd Version

Indoor Design Conditions

- Consider the middle of the ASHRAE comfort zone for the appropriate season





ASHRAE 55, ASHRAE Fundamentals

Indoor Design Conditions

- Other resources to find the setpoints:
  - ❑ ASHRAE 170 for healthcare facilities (e.g., Table 7-1, 2017):

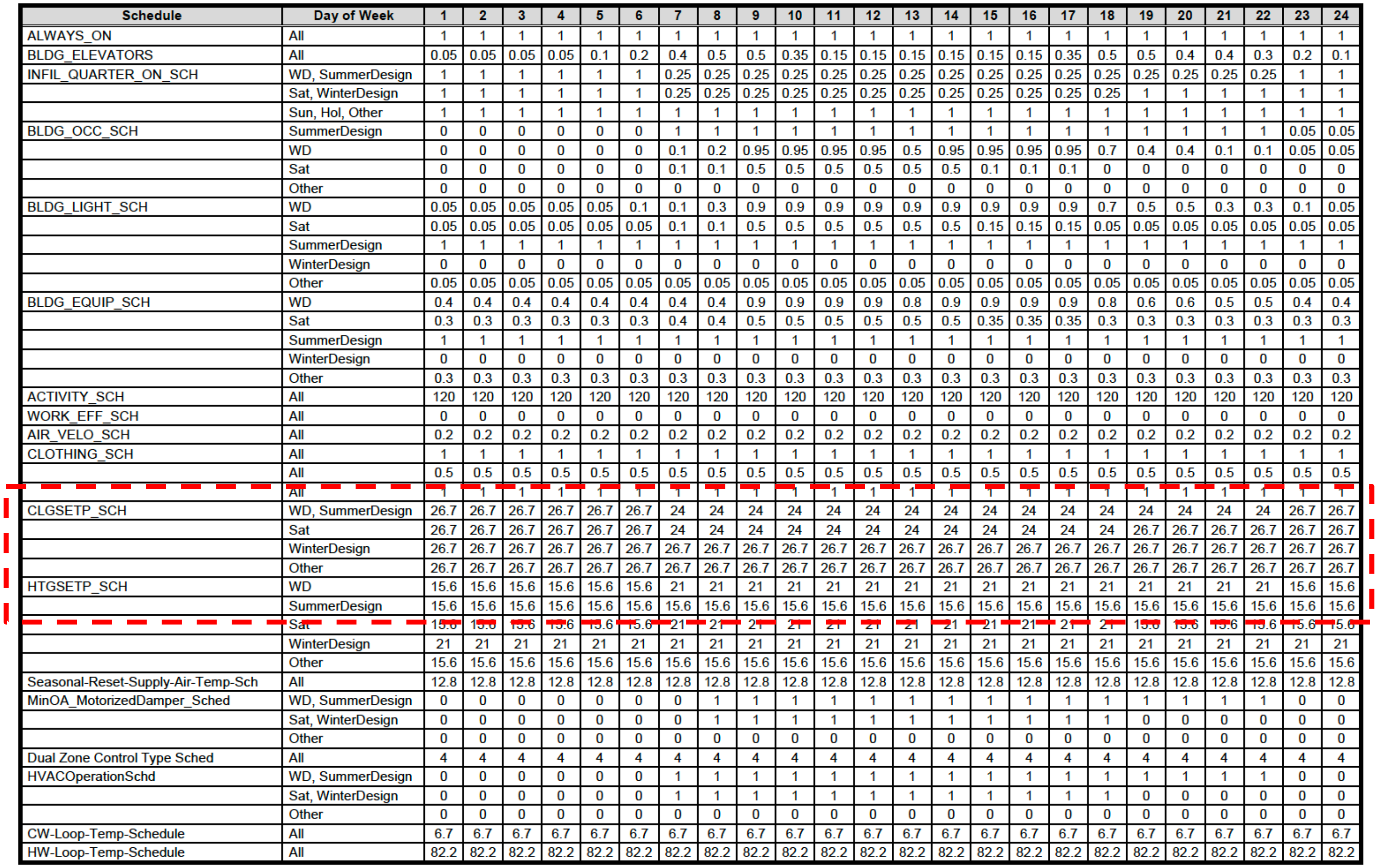
Function of Space	Design Temperature (ºF)
Inpatient nursing – all room	70 - 75
Physical therapy	72 – 80
…	…

Reference: ASHRAE Standard 170

Indoor Design Conditions

- Other resources to find the setpoints:
  - ❑ DOE Reference Buildings:

Table B-4 Large Office Hourly Operation Schedules



Schedule	Day of Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
ALWAYS_ON	All	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
BLDG_ELEVATORS	All	0.05	0.05	0.05	0.05	0.1	0.2	0.4	0.5	0.5	0.35	0.15	0.15	0.15	0.15	0.15	0.15	0.35	0.5	0.5	0.4	0.4	0.3	0.2	0.1
INFIL_QUARTER_ON_SCH	WD, SummerDesign	1	1	1	1	1	1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1	1
	Sat, WinterDesign	1	1	1	1	1	1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1	1	1	1	1	1
	Sun, Hol, Other	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
BLDG_OCC_SCH	SummerDesign	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.05	0.05
	WD	0	0	0	0	0	0	0.1	0.2	0.95	0.95	0.95	0.95	0.5	0.95	0.95	0.95	0.95	0.7	0.4	0.4	0.1	0.1	0.05	0.05
	Sat	0	0	0	0	0	0	0.1	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.1	0.1	0.1	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BLDG_LIGHT_SCH	WD	0.05	0.05	0.05	0.05	0.05	0.1	0.1	0.3	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.5	0.5	0.3	0.3	0.1	0.05
	Sat	0.05	0.05	0.05	0.05	0.05	0.05	0.1	0.1	0.5	0.5	0.5	0.5	0.5	0.5	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	SummerDesign	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	WinterDesign	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
BLDG_EQUIP_SCH	WD	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.9	0.9	0.9	0.9	0.8	0.9	0.9	0.9	0.9	0.8	0.6	0.6	0.5	0.5	0.4	0.4
	Sat	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.35	0.35	0.35	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	SummerDesign	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	WinterDesign	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
ACTIVITY_SCH	All	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
WORK_EFF_SCH	All	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AIR_VELO_SCH	All	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
CLOTHING_SCH	All	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	All	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	All	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CLGSETP_SCH	WD, SummerDesign	26.7	26.7	26.7	26.7	26.7	26.7	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	26.7	26.7
	Sat	26.7	26.7	26.7	26.7	26.7	26.7	24	24	24	24	24	24	24	24	24	24	24	24	26.7	26.7	26.7	26.7	26.7	26.7
	WinterDesign	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7
	Other	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7	26.7
HTGSETP_SCH	WD	15.6	15.6	15.6	15.6	15.6	15.6	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	15.6	15.6
	SummerDesign	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6
	Sat	15.6	15.6	15.6	15.6	15.6	15.6	21	21	21	21	21	21	21	21	21	21	21	21	15.6	15.6	15.6	15.6	15.6	15.6
	WinterDesign	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
	Other	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6	15.6
Seasonal-Reset-Supply-Air-Temp-Sch	All	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
MinOA_MotorizedDamper_Sched	WD, SummerDesign	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
	Sat, WinterDesign	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dual Zone Control Type Sched	All	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
HVACOperationSchd	WD, SummerDesign	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
	Sat, WinterDesign	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
	Other	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CW-Loop-Temp-Schedule	All	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
HW-Loop-Temp-Schedule	All	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2	82.2

Reference: DOE Reference Buildings: https://www.nrel.gov/docs/fy11osti/46861.pdf

Outdoor Design Conditions

- Design HVAC system capacity based on the peak loads which is a combination of:
  - ☐ Internal loads
  - ☐ External loads

What does this mean for heating and cooling loads?

OUTDOOR DESIGN CONDITIONS

(Please, see Chapter 14)

Outdoor Design Conditions

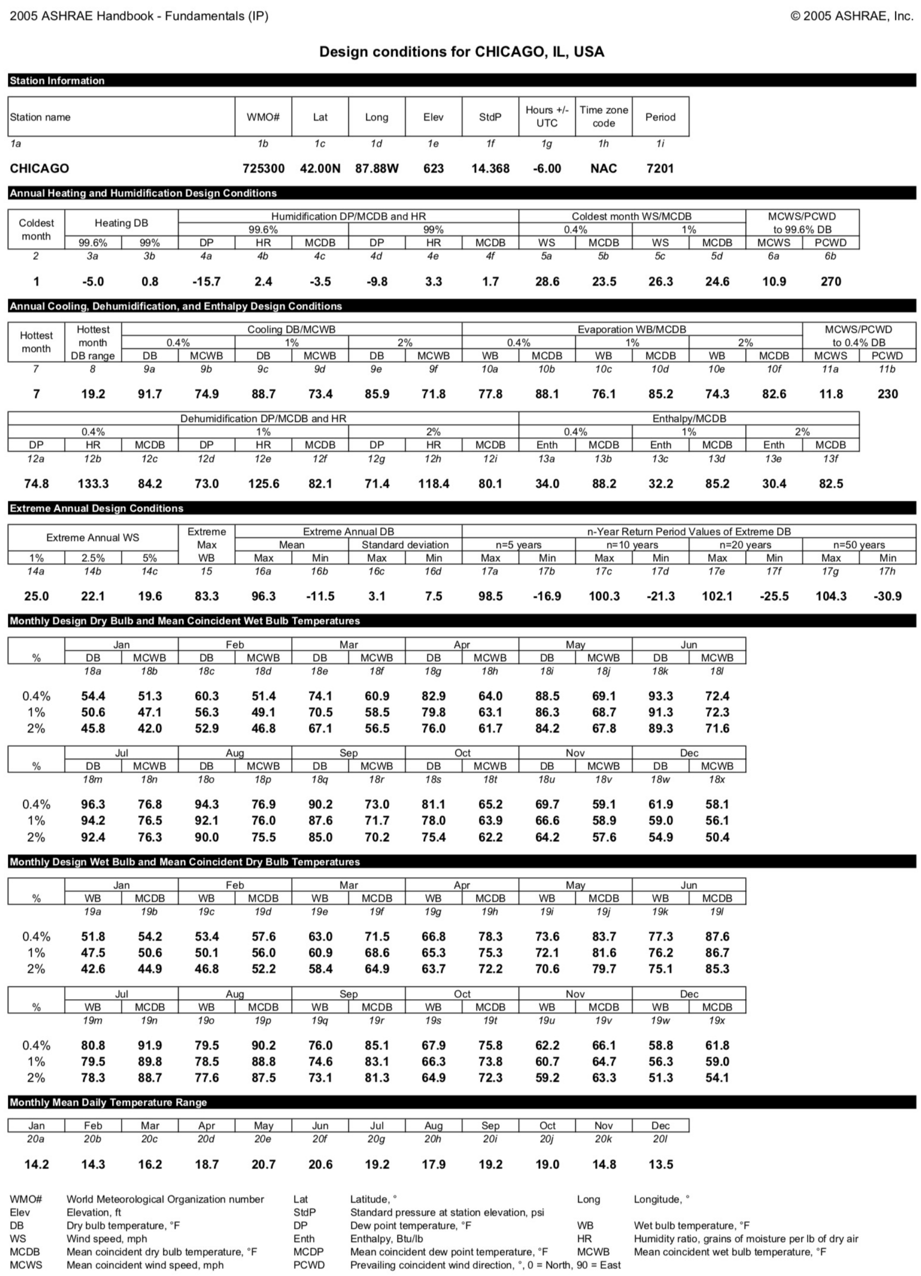
- Winter design conditions:
  - ❑ Use ASHRAE Design Data from the Fundamentals Handbook
  - ❑ The 99.6% and 99% indicate the risk level desired
  - ❑ When 99% is selected, it means the outdoor temperatures have been equaled or exceeded by 99% of the total number of hours in a year (8760 hours):
    - 99.6% (0.4%) ~ 35 hours
    - 99.0% (1.0%) ~ 88 hours
    - 98.0 (2.0%) ~ 175 hours
    - 95.0 (5.0%) ~ 438 hours

Outdoor Design Conditions

- Summer design conditions
  - ❑ DB is dry-bulb temperature
  - ❑ MWB is the mean-coincident-wet-bulb temperature
  - ❑ The 0.4%, 1% and 2% mean the percentile of the total hours may not meet indoor design conditions

Outdoor Design Conditions

- Basic Information
- Annual Heating
- Annual Cooling
- Extreme Annual
- Monthly Design



2005 ASHRAE Handbook - Fundamentals (IP)

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Design conditions for CHICAGO, IL, USA

Station Information

Station name	WMO#	Lat	Long	Elev	StdP	Hours +/- UTC	Time zone code	Period
1a	*1b*	*1c*	*1d*	*1e*	*1f*	*1g*	*1h*	*1i*
CHICAGO	**725300**	**42.00N**	**87.88W**	**623**	**14.368**	**-6.00**	**NAC**	**7201**

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	*3a*	*3b*	*4a*	*4b*	*4c*	*4d*	*4e*	*4f*	*5a*	*5b*	*5c*	*5d*	*6a*	*6b*
1	**-5.0**	**0.8**	**-15.7**	**2.4**	**-3.5**	**-9.8**	**3.3**	**1.7**	**28.6**	**23.5**	**26.3**	**24.6**	**10.9**	**270**

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	*8*	*9a*	*9b*	*9c*	*9d*	*9e*	*9f*	*10a*	*10b*	*10c*	*10d*	*10e*	*10f*	*11a*	*11b*
7	**19.2**	**91.7**	**74.9**	**88.7**	**73.4**	**85.9**	**71.8**	**77.8**	**88.1**	**76.1**	**85.2**	**74.3**	**82.6**	**11.8**	**230**

Dehumidification DP/MCDB and HR									Enthalpy/MCDB					
0.4%			1%			2%			0.4%		1%		2%	
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB
12a	*12b*	*12c*	*12d*	*12e*	*12f*	*12g*	*12h*	*12i*	*13a*	*13b*	*13c*	*13d*	*13e*	*13f*
74.8	**133.3**	**84.2**	**73.0**	**125.6**	**82.1**	**71.4**	**118.4**	**80.1**	**34.0**	**88.2**	**32.2**	**85.2**	**30.4**	**82.5**

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%		Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
14a	*14b*	*14c*	*15*	*16a*	*16b*	*16c*	*16d*	*17a*	*17b*	*17c*	*17d*	*17e*	*17f*	*17g*	*17h*
25.0	**22.1**	**19.6**	**83.3**	**96.3**	**-11.5**	**3.1**	**7.5**	**98.5**	**-16.9**	**100.3**	**-21.3**	**102.1**	**-25.5**	**104.3**	**-30.9**

Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures

%	Jan		Feb		Mar		Apr		May		Jun	
	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB
	18a	*18b*	*18c*	*18d*	*18e*	*18f*	*18g*	*18h*	*18i*	*18j*	*18k*	*18l*
0.4%	**54.4**	**51.3**	**60.3**	**51.4**	**74.1**	**60.9**	**82.9**	**64.0**	**88.5**	**69.1**	**93.3**	**72.4**
1%	**50.6**	**47.1**	**56.3**	**49.1**	**70.5**	**58.5**	**79.8**	**63.1**	**86.3**	**68.7**	**91.3**	**72.3**
2%	**45.8**	**42.0**	**52.9**	**46.8**	**67.1**	**56.5**	**76.0**	**61.7**	**84.2**	**67.8**	**89.3**	**71.6**

%	Jul		Aug		Sep		Oct		Nov		Dec	
	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB	DB	MCWB
	18m	*18n*	*18o*	*18p*	*18q*	*18r*	*18s*	*18t*	*18u*	*18v*	*18w*	*18x*
0.4%	**96.3**	**76.8**	**94.3**	**76.9**	**90.2**	**73.0**	**81.1**	**65.2**	**69.7**	**59.1**	**61.9**	**58.1**
1%	**94.2**	**76.5**	**92.1**	**76.0**	**87.6**	**71.7**	**78.0**	**63.9**	**66.6**	**58.9**	**59.0**	**56.1**
2%	**92.4**	**76.3**	**90.0**	**75.5**	**85.0**	**70.2**	**75.4**	**62.2**	**64.2**	**57.6**	**54.9**	**50.4**

Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures

%	Jan		Feb		Mar		Apr		May		Jun	
	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB
	19a	*19b*	*19c*	*19d*	*19e*	*19f*	*19g*	*19h*	*19i*	*19j*	*19k*	*19l*
0.4%	**51.8**	**54.2**	**53.4**	**57.6**	**63.0**	**71.5**	**66.8**	**78.3**	**73.6**	**83.7**	**77.3**	**87.6**
1%	**47.5**	**50.6**	**50.1**	**56.0**	**60.9**	**68.6**	**65.3**	**75.3**	**72.1**	**81.6**	**76.2**	**86.7**
2%	**42.6**	**44.9**	**46.8**	**52.2**	**58.4**	**64.9**	**63.7**	**72.2**	**70.6**	**79.7**	**75.1**	**85.3**

%	Jul		Aug		Sep		Oct		Nov		Dec	
	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB
	19m	*19n*	*19o*	*19p*	*19q*	*19r*	*19s*	*19t*	*19u*	*19v*	*19w*	*19x*
0.4%	**80.8**	**91.9**	**79.5**	**90.2**	**76.0**	**85.1**	**67.9**	**75.8**	**62.2**	**66.1**	**58.8**	**61.8**
1%	**79.5**	**89.8**	**78.5**	**88.8**	**74.6**	**83.1**	**66.3**	**73.8**	**60.7**	**64.7**	**56.3**	**59.0**
2%	**78.3**	**88.7**	**77.6**	**87.5**	**73.1**	**81.3**	**64.9**	**72.3**	**59.2**	**63.3**	**51.3**	**54.1**

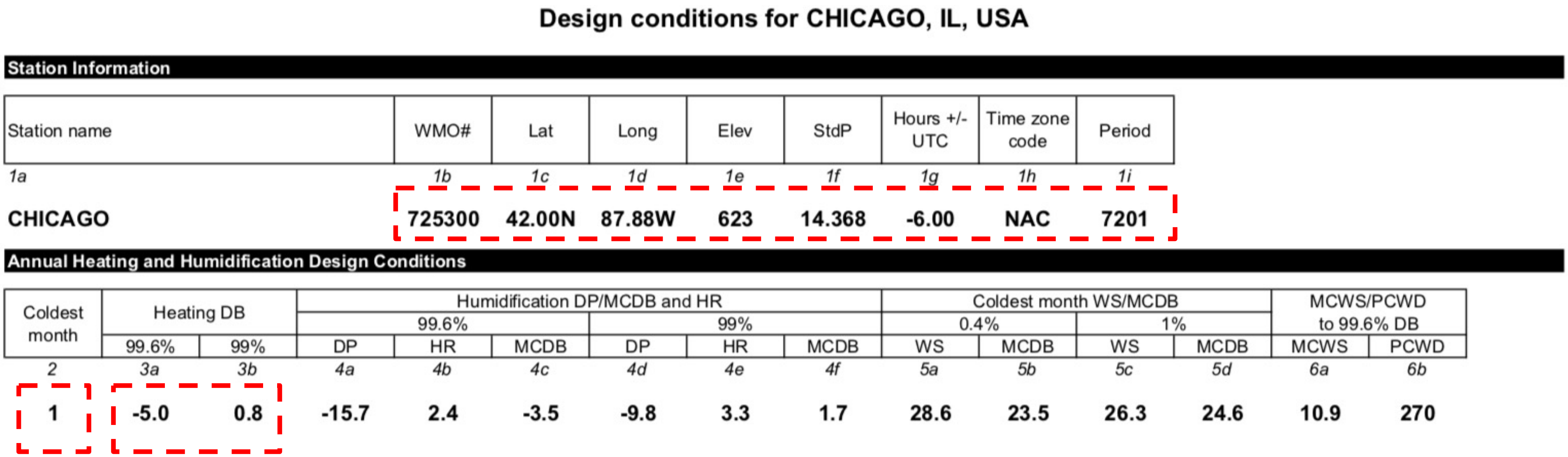
Monthly Mean Daily Temperature Range

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
20a	*20b*	*20c*	*20d*	*20e*	*20f*	*20g*	*20h*	*20i*	*20j*	*20k*	*20l*
14.2	**14.3**	**16.2**	**18.7**	**20.7**	**20.6**	**19.2**	**17.9**	**19.2**	**19.0**	**14.8**	**13.5**

WMO#	World Meteorological Organization number	Lat	Latitude, °	Long	Longitude, °
Elev	Elevation, ft	StdP	Standard pressure at station elevation, psi		
DB	Dry bulb temperature, °F	DP	Dew point temperature, °F	WB	Wet bulb temperature, °F
WS	Wind speed, mph	Enth	Enthalpy, Btu/lb	HR	Humidity ratio, grains of moisture per lb of dry air
MCDB	Mean coincident dry bulb temperature, °F	MCDP	Mean coincident dew point temperature, °F	MCWB	Mean coincident wet bulb temperature, °F
MCWS	Mean coincident wind speed, mph	PCWD	Prevailing coincident wind direction, °, 0 = North, 90 = East		

Outdoor Design Conditions

- Heating Load Design



Design conditions for CHICAGO, IL, USA

Station Information

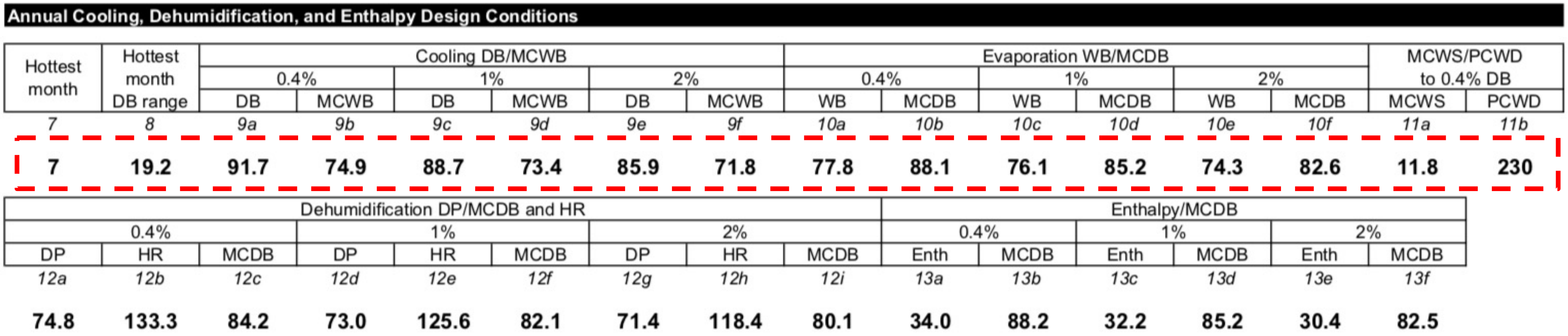
Station name	WMO#	Lat	Long	Elev	StdP	Hours +/- UTC	Time zone code	Period
1a	*1b*	*1c*	*1d*	*1e*	*1f*	*1g*	*1h*	*1i*
CHICAGO	**725300**	**42.00N**	**87.88W**	**623**	**14.368**	**-6.00**	**NAC**	**7201**

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	*3a*	*3b*	*4a*	*4b*	*4c*	*4d*	*4e*	*4f*	*5a*	*5b*	*5c*	*5d*	*6a*	*6b*
1	**-5.0**	**0.8**	**-15.7**	**2.4**	**-3.5**	**-9.8**	**3.3**	**1.7**	**28.6**	**23.5**	**26.3**	**24.6**	**10.9**	**270**

Outdoor Design Conditions

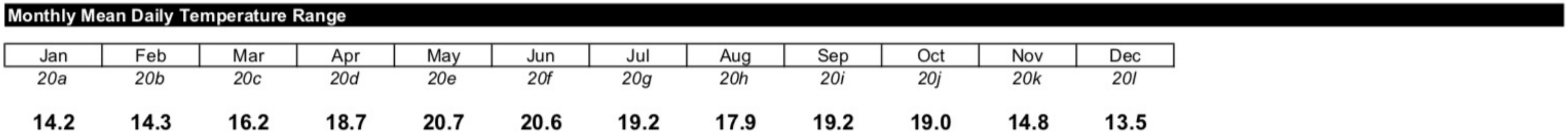
- Cooling Load Design



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	*8*	*9a*	*9b*	*9c*	*9d*	*9e*	*9f*	*10a*	*10b*	*10c*	*10d*	*10e*	*10f*	*11a*	*11b*
7	**19.2**	**91.7**	**74.9**	**88.7**	**73.4**	**85.9**	**71.8**	**77.8**	**88.1**	**76.1**	**85.2**	**74.3**	**82.6**	**11.8**	**230**

Dehumidification DP/MCDB and HR									Enthalpy/MCDB					
0.4%			1%			2%			0.4%		1%		2%	
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB
12a	*12b*	*12c*	*12d*	*12e*	*12f*	*12g*	*12h*	*12i*	*13a*	*13b*	*13c*	*13d*	*13e*	*13f*
74.8	**133.3**	**84.2**	**73.0**	**125.6**	**82.1**	**71.4**	**118.4**	**80.1**	**34.0**	**88.2**	**32.2**	**85.2**	**30.4**	**82.5**



Monthly Mean Daily Temperature Range

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
20a	*20b*	*20c*	*20d*	*20e*	*20f*	*20g*	*20h*	*20i*	*20j*	*20k*	*20l*
14.2	**14.3**	**16.2**	**18.7**	**20.7**	**20.6**	**19.2**	**17.9**	**19.2**	**19.0**	**14.8**	**13.5**

Outdoor Design Conditions

- How does the daily hourly design temperature profile look like?

Outdoor Design Conditions

$$t = t_{peak} - DR\boxed{\sum_{i=0}^{11}[a_i\cos\left(\frac{2\times\pi\times\theta}{24}\right) + b_i\sin\left(\frac{2\times\pi\times\theta}{24}\right)]}$$

- t = air temperature $°F$
- t_{peak} = peak design temperature $°F$
- DR = daily range $°F$
- a_i, b_i = coefficients from the ASHRAE Load Calculation Table
- θ = The apparent solar time in decimal form, dimensionless

i	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
a_i	0.5363	0.3482	-0.0732	0.002	0.0104	-0.0041	0.0025	-0.0004	-0.0038	-0.0003	0.0032	-0.0005
b_i	0	0.3426	-0.0491	-0.0194	0.0123	0.0049	-0.0017	-0.0027	0.0036	0.0006	0	0.0002

Outdoor Design Conditions

- Use proxy for the series part of calculation:

$$t = t_{peak} - DR \times f$$

Time (Hr)	f	Time (Hr)	f	Time (Hr)	f
1	0.88	9	0.55	17	0.14
2	0.92	10	0.38	18	0.24
3	0.95	11	0.23	19	0.39
4	0.98	12	0.13	20	0.5
5	1	13	0.05	21	0.59
6	0.98	14	0	22	0.68
7	0.91	15	0	23	0.75
8	0.74	16	0.06	24	0.82

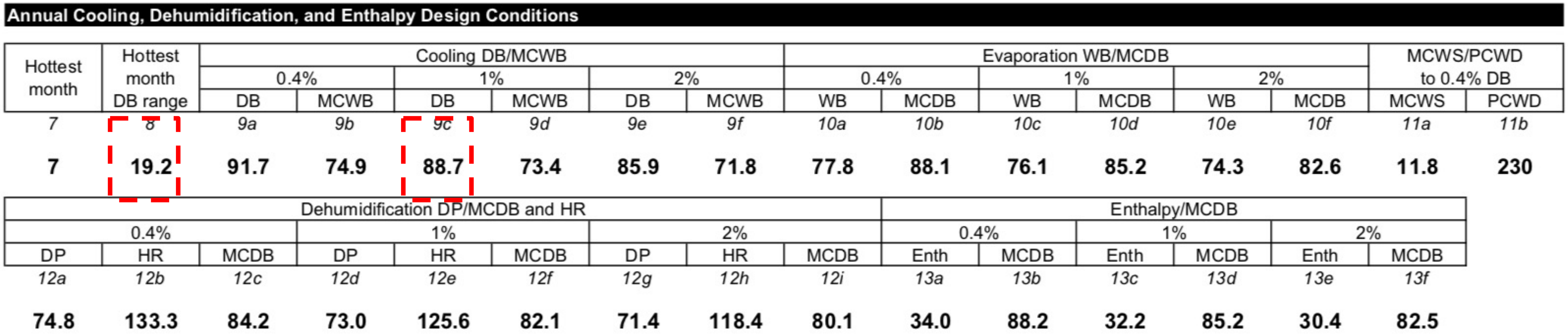
DR: Daily range $°F$

CLASS ACTIVITY

Class Activity

- Question: From the tables, calculate the following variables (Use both the uploaded page and your handbook):
  - ☐ 1% condition in Chicago for the hottest month
  - ☐ Daily range
  - ☐ Temperature at 5 PM

Class Activity



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	*8*	*9a*	*9b*	*9c*	*9d*	*9e*	*9f*	*10a*	*10b*	*10c*	*10d*	*10e*	*10f*	*11a*	*11b*
7	**19.2**	**91.7**	**74.9**	**88.7**	**73.4**	**85.9**	**71.8**	**77.8**	**88.1**	**76.1**	**85.2**	**74.3**	**82.6**	**11.8**	**230**

Dehumidification DP/MCDB and HR									Enthalpy/MCDB					
0.4%			1%			2%			0.4%		1%		2%	
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB
12a	*12b*	*12c*	*12d*	*12e*	*12f*	*12g*	*12h*	*12i*	*13a*	*13b*	*13c*	*13d*	*13e*	*13f*
74.8	**133.3**	**84.2**	**73.0**	**125.6**	**82.1**	**71.4**	**118.4**	**80.1**	**34.0**	**88.2**	**32.2**	**85.2**	**30.4**	**82.5**

Time (Hr)	f	Time (Hr)	f	Time (Hr)	f
1	0.88	9	0.55	17	0.14
2	0.92	10	0.38	18	0.24
3	0.95	11	0.23	19	0.39
4	0.98	12	0.13	20	0.5
5	1	13	0.05	21	0.59
6	0.98	14	0	22	0.68
7	0.91	15	0	23	0.75
8	0.74	16	0.06	24	0.82

$$t = 88.7\ °F\ - 0.14 \times 19.2\ °F = 86.01\ °F$$

INTRO TO BUILDING LOAD CALCULATIONS

(Please, see Chapters 17 and 18 for additional information)

Intro to Building Load Calculation

- Sizing HVAC systems is among one of important reasons for heating and cooling load calculations:
  - ❑ Size for the worst peak load condition (When that would be in summer and winter?)
  - ❑ Avoid running the system part-load (What does it mean?)
  - ❑ Consider realistic sizing factors (What’s the current practice?)

Intro to Building Load Calculation

- There is a different process to identify the worst peak load conditions for heating and cooling loads

- For the cooling load, we need to make a distinction between:
  - ☐ Radiative and convective parts
  - ☐ Time delay (building thermal mass)

Intro to Building Load Calculation

- **Heating Loads:**
  - ☐ Simple
  - ☐ Steady-state
  - ☐ Solar radiation is ignored
  - ☐ No effect of thermal mass or heat gain

- **Cooling Loads:**
  - ☐ Complex (require separating the convective and radiative from the loads)
  - ☐ Time-dependent (usually 24 hours)
  - ☐ Solar radiation is considered
  - ☐ Effects of internal heat gains and thermal mass are important

Intro to Building Load Calculation

- Five main heat and mass processes are important for the heating and cooling load calculations:

  1. **Transmission** (e.g., walls, floor, roof, windows)
  2. **Solar Heat Gain** (e.g., walls, windows)
  3. **Infiltration** (e.g., through window frame, door openings)
  4. **Internal heat gain** (e.g., lights, people, equipment)
  5. **Ventilation** (e.g., mechanical systems)

BUILDING LOAD CALCULATIONS (CHAPTER 17 AND 18)

Building Load Calculations

- Step 1: Identify building materials, characteristics, spaces, zones, …. (from architectural and mechanical drawings)

Why?

- Step 2: Understand the location of the building, orientation of the space, adjacent spaces and surfaces

Why?

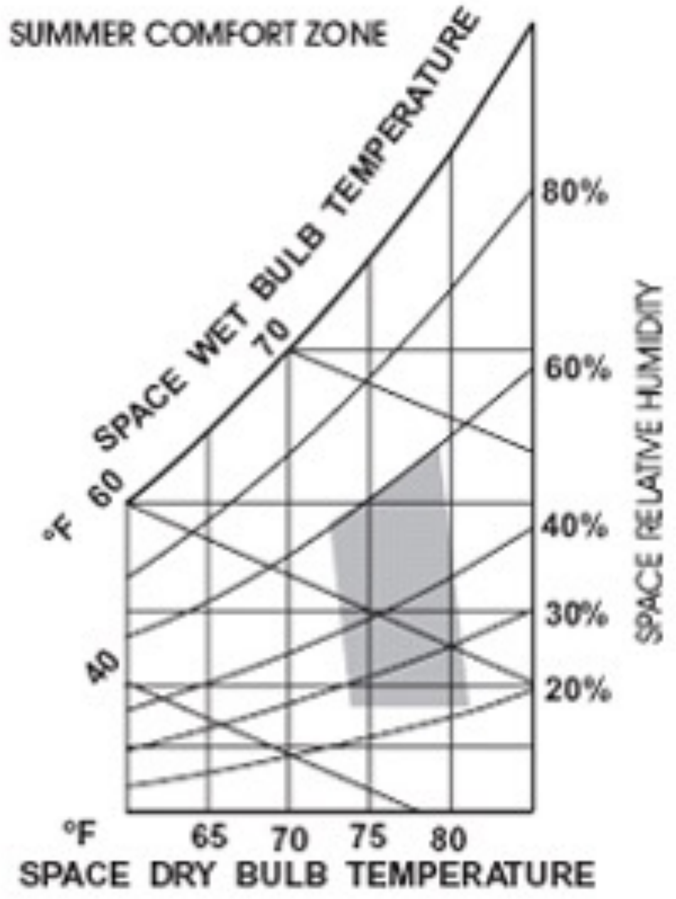
Building Load Calculations

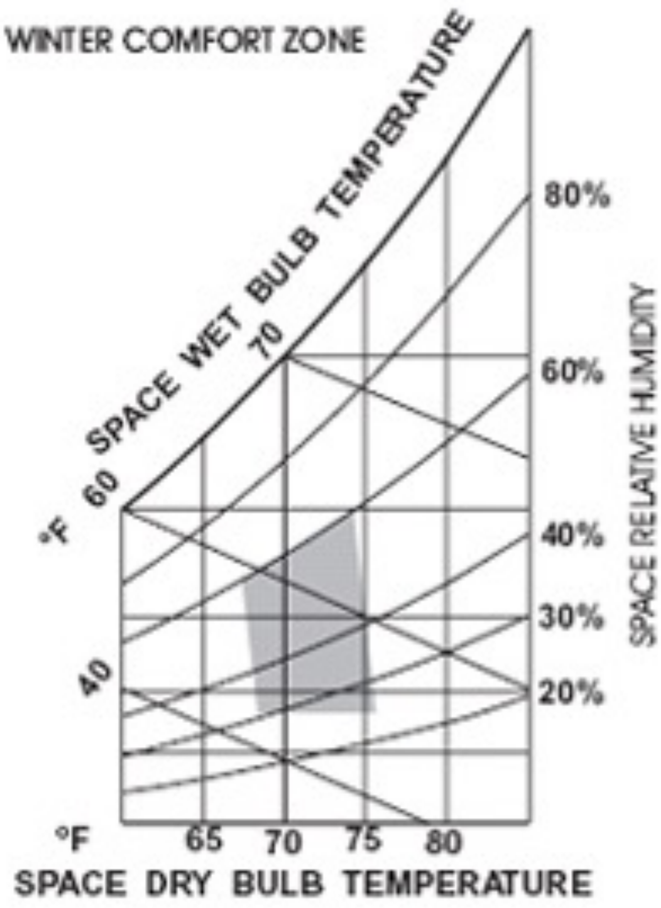
- Step 3: Select outdoor design conditions
  - ❑ Consider the risk factor for the design conditions
  - ❑ $\Delta T = (Outdoor\ temperature\ - Indoor\ temperature)$

Why?

Building Load Calculations

- Step 4: Select indoor design conditions





Building Load Calculations

- Step 5: Identify loads
  - ☐ Purpose of this lecture for heating and the next lecture for cooling
  - ☐ Requires careful consideration of all contributions

Building Load Calculations

- Building loads impact:
  - ☐ Sizes of HVAC systems and components
  - ☐ First, maintenance, and operational costs
  - ☐ Thermal comfort
  - ☐ Energy use of the building
  - ☐ Indoor air quality

Building Load Calculations

- Building loads are important to size the HVAC systems and components:
  - ❑ The peak conditions (worst condition)
  - ❑ Avoid running the system part load
  - ❑ Realistic safety factors (what is the common practice?)
  - ❑ Consider distinction between perimeter zones and internal zones

Building Load Calculations

- What are the main differences between residential and commercial load calculations?
  - ☐ Smaller internal gains
  - ☐ Different principal building activities (space types)
  - ☐ Fewer zones (commercial building sum of all zones)
  - ☐ Grater distribution losses
  - ☐ Partial loads

HEATING LOAD CALCULATIONS

(Please, see Chapters 17 and 18 for additional information)

Heating Load Calculations

- For the heating load calculations:
  - ☐ Assume outdoor temperature is lower than the conditioned space temperature
  - ☐ Do not consider any credits for the impacts of solar, internal heat gains, or building thermal mass
  - ☐ Thermal bridging has impact on the heating loads than the cooling loads

Heating Load Calculations

- Imagine a commercial retail store at night nighttime:
  - ☐ Temperature setbacks are in place
  - ☐ Lights and internal gains are off
  - ☐ Heat flux is only due to conduction and infiltration

How is this different than the day time?

Is it better to consider the day-time or night-time for the load calculation?

Heating Load Calculation

- Consider the following heat loads:
    - Transmission
    - Infiltration
    - Ventilation

Why one these three?

Heating Load Calculation

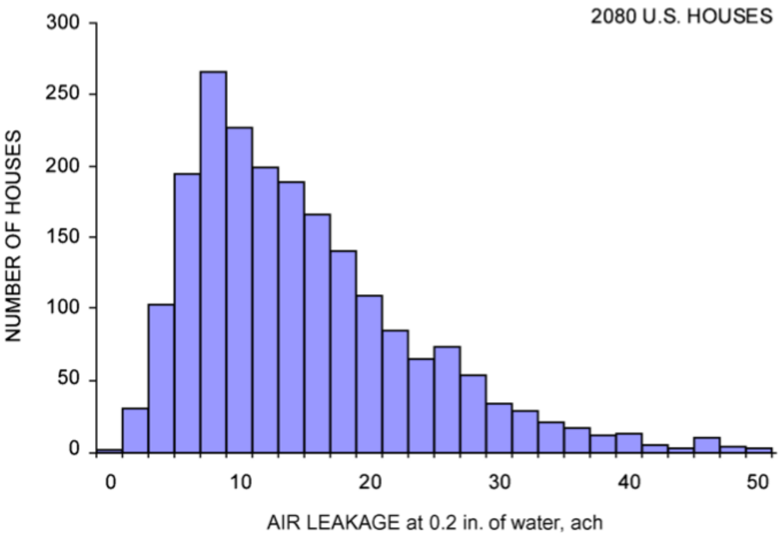
- Consider the following heat loads:
  - Transmission

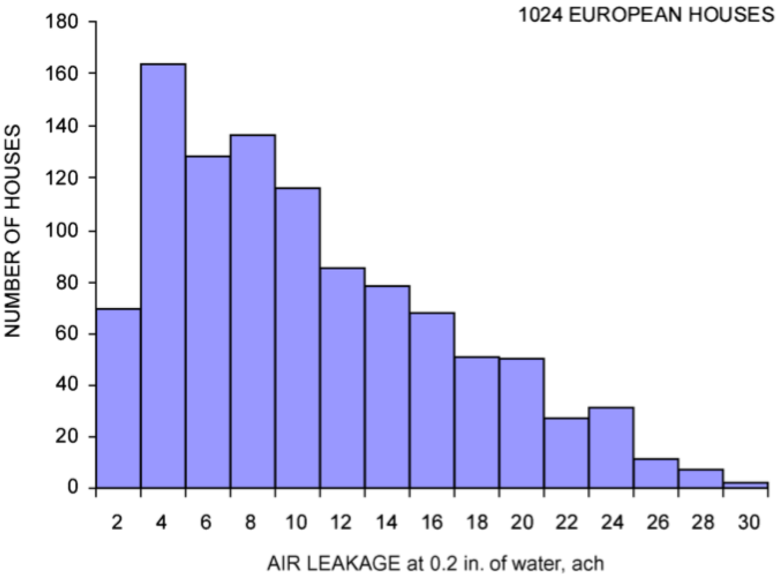
$$R_{tot} = \frac{1}{UA}$$

$$q_x = UA\Delta T_{overall}$$

Heating Load Calculation

- Consider the following heat loads:
  - ❑ Infiltration
    - ▪ An unintentional air through building envelops
    - ▪ There are databases of values for the infiltration values





(See Figure 10 – Chapter 16)

Heating Load Calculations

- The recommended steps are:
  - ☐ Select outdoor design condition criteria and numbers
  - ☐ Select indoor conditioned space temperature
  - ☐ Estimate temperature in any adjacent unheated spaces
  - ☐ Identify transmission coefficients and compute conduction heat losses to exterior
  - ☐ Consider infiltration load

Heating Load Calculations

- Consider the following heat loads for exterior surfaces above grade:

$$R_{tot} = \frac{1}{UA}$$

$$Q = UA\Delta t = A \times HF$$

HF is the heating load factor in Btu/h-ft^2

Heating Load Calculations

- How do you account for A, $\Delta T_{overall}$ and U?
  - ☐ Exterior surface above grade
  - ☐ Below grade surface
  - ☐ At grade surface
  - ☐ Surface adjacent to unconditioned spaces

- Define heating load factor:

$$HF = U\Delta T_{overall}$$

Heating Load Calculations

- The recommended steps are:
  - ☐ Select outdoor design condition criteria and numbers
  - ☐ Select indoor conditioned space temperature
  - ☐ Estimate temperature in any adjacent unheated spaces
  - ☐ Identify transmission coefficients and compute conduction heat losses to exterior
  - ☐ Calculate infiltration and other outdoor air
  - ☐ Sum the losses

Heating Load Calculations

- See Section 9 of Chapter 18 for the three examples:
  - ☐ Single room example
  - ☐ Single room example peak heating load
  - ☐ Whole building example

RSTM (RADIANT TIME SERIES METHOD)

RSTM

- Radiant Time Series Method (RTSM) is a simplified method for the calculation of cooling loads with these assumptions:
  - ☐ *Calculation Period:* Consider only a single day (ignore the stored energy)
  - ☐ *Exterior Surface Heat Balance:* Assume the sol-air temperature to account for solar irradiance and convection
  - ☐ *Interior Surface Heat Balance and Room Temperature:* Consider the delay radiative fractions

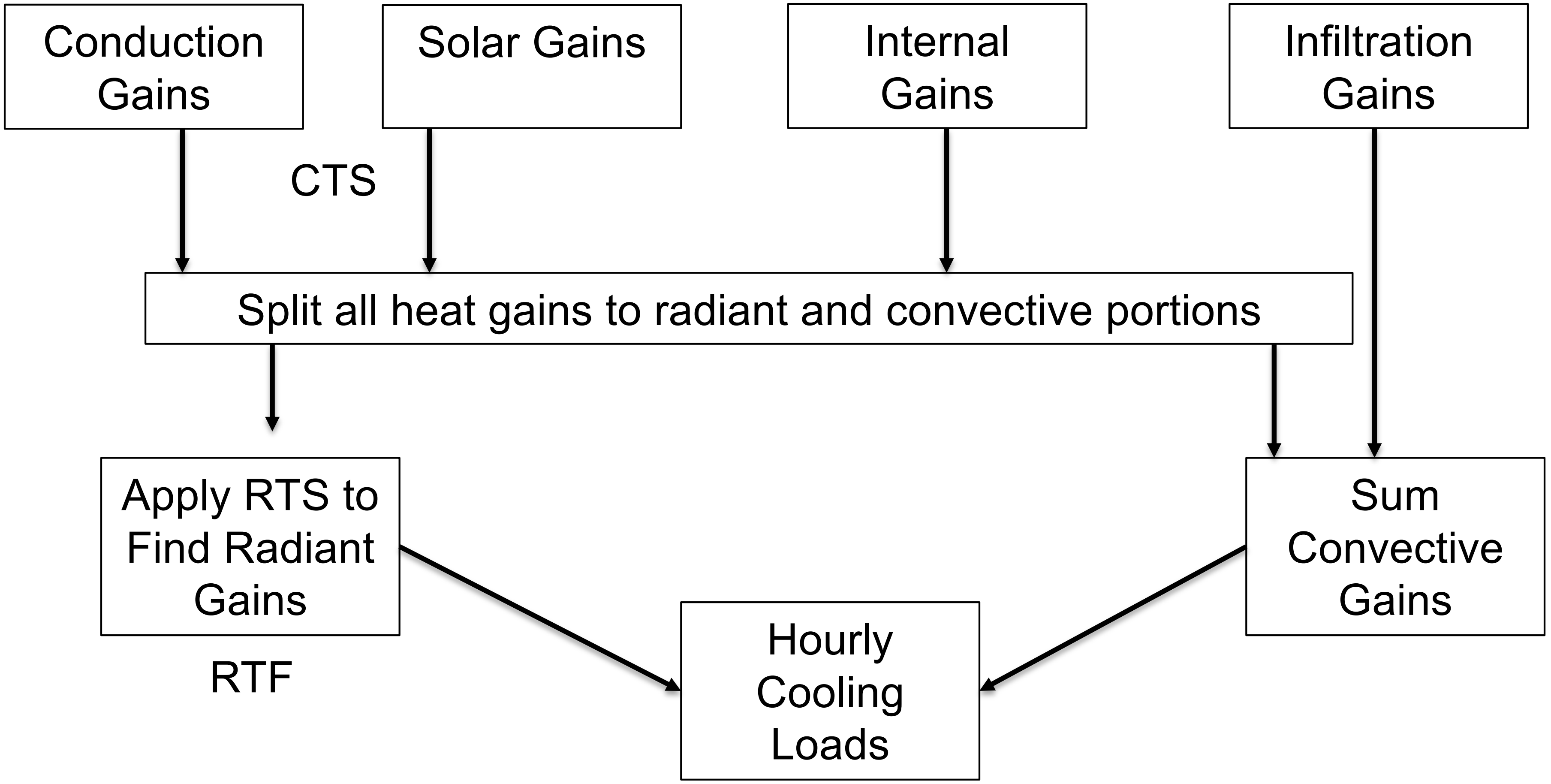
RSTM

- Separate sensible and latent components of the loads for cooling load calculations:
  - ❑ Sensible heat is directly added to the conditioned space(s) by conduction or radiation
  - ❑ Latent heat gain occurs when moisture is added
  - ❑ Designs may be influenced by sensible/latent loads or both
  - ❑ In a space with sensible-load-driven, the cooling supply air has surplus capacity to dehumidify
  - ❑ In a space with latent-load-driven, calculating the supply airflow using sensible load does not meet the dehumidification needed (needs subcooling, reheat, or other means)

COOLING LOAD CALCULATIONS

Cooling Load Calculation

- Radiant Transfer Series Method (RTSM)


Conduction Gains

Solar Gains

Internal Gains

Infiltration Gains

CTS

Split all heat gains to radiant and convective portions

Apply RTS to Find Radiant Gains

RTF

Sum Convective Gains

Hourly Cooling Loads

CTS = Conduction Transfer Series

RTF = Radiant Transfer Function

Cooling Load Calculation

- Space heat gain is the instantaneous rate of heat transfer in the space

- Main components to consider are:
  1. **Internal** (e.g., Interior lights, appliance and equipment)
  2. **External** (e.g., walls, roof)
  3. **Infiltration**
  4. **Systems** (e.g., ventilation, fan heat)