2103-454 Ventilation and Air Conditioning

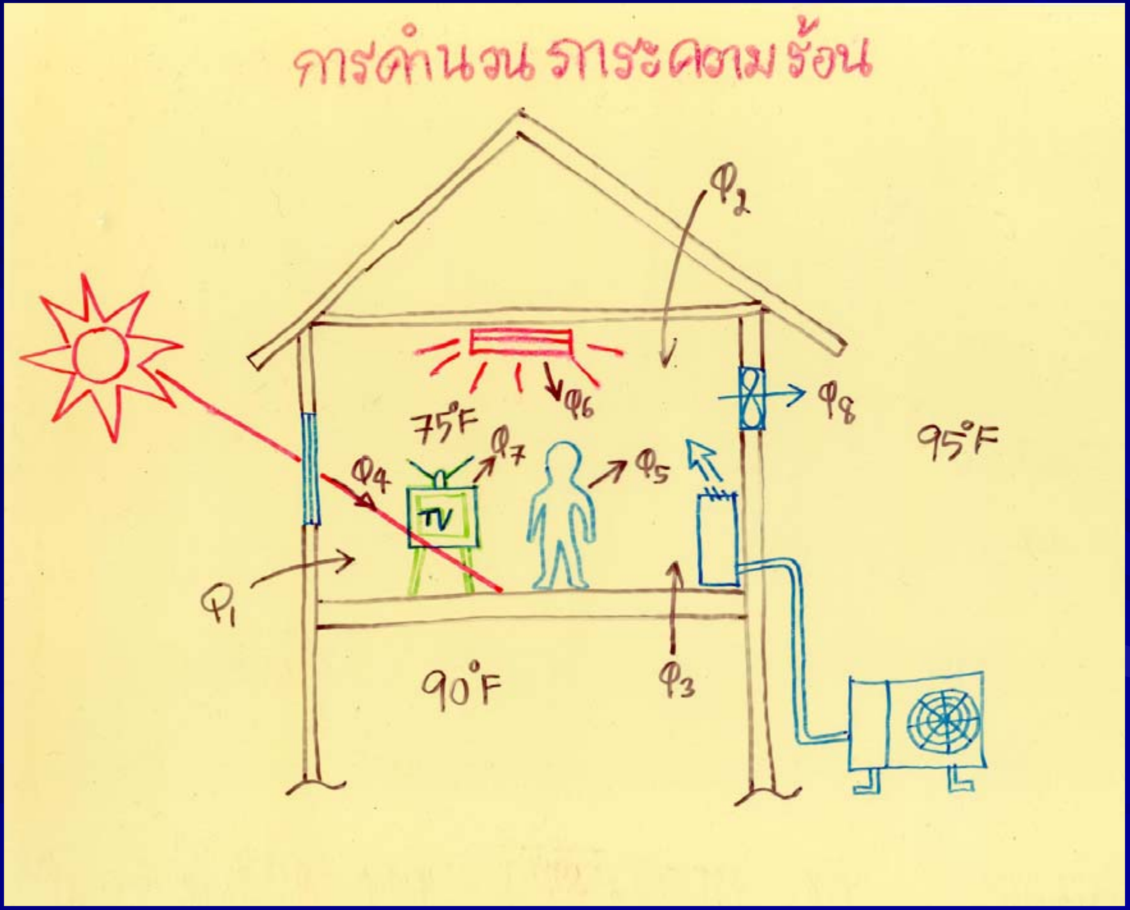
Cooling Load Calculations

by

Assist. Prof. Dr. Tul Manewattana.
Chulalongkorn University
Bangkok, THAILAND

November 2010

Principles of Cooling Load



Principles of Cooling Load

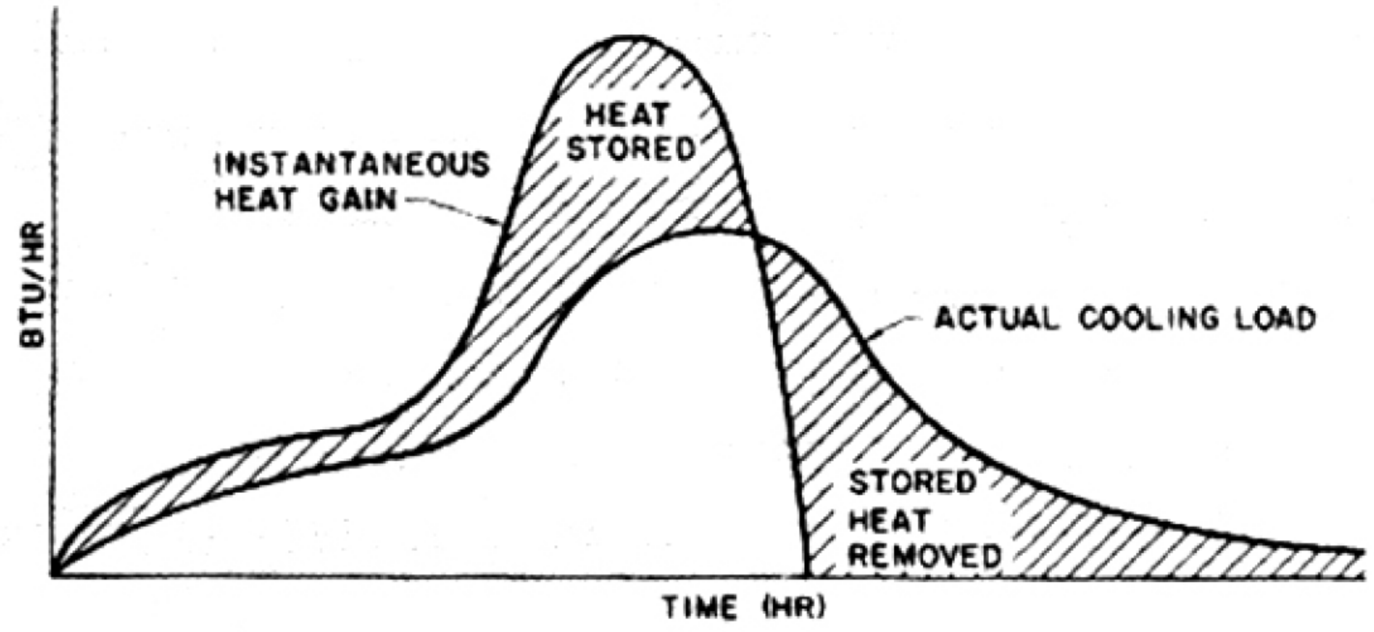


FIG. 3-ACTUAL COOLING LOAD, SOLAR HEAT GAIN, WEST EXPOSURE, AVERAGE CONSTRUCTION

Principles of Cooling Load

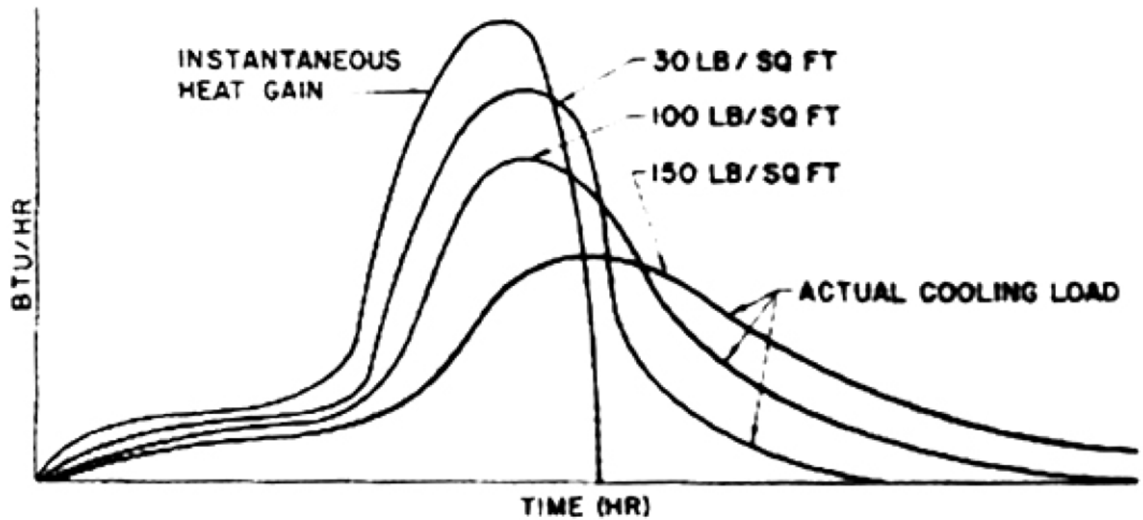


FIG. 5-ACTUAL COOLING LOAD, SOLAR HEAT GAIN, LIGHT, MEDIUM AND HEAVY CONSTRUCTION

Principles of Cooling Load

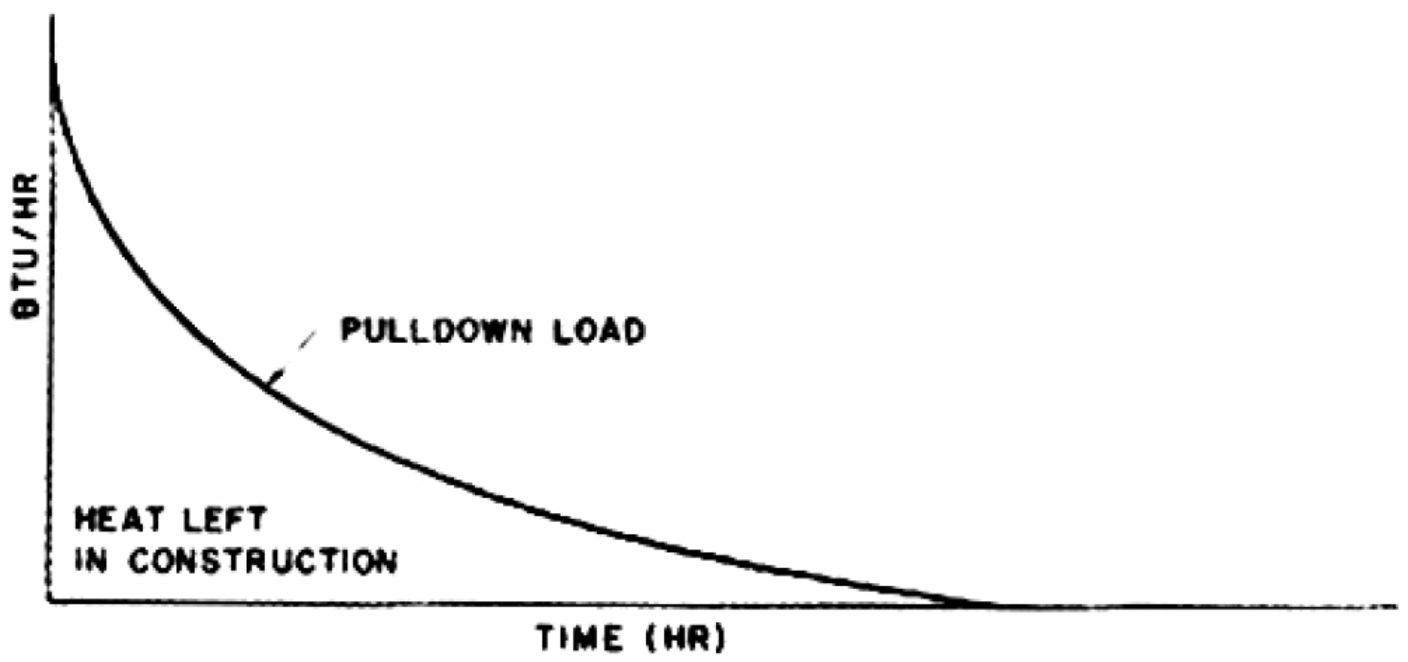


FIG. 6-PULLDOWN LOAD, SOLAR HEAT GAIN, WEST EXPOSURE, 16-HOUR OPERATION

Principles of Cooling Load

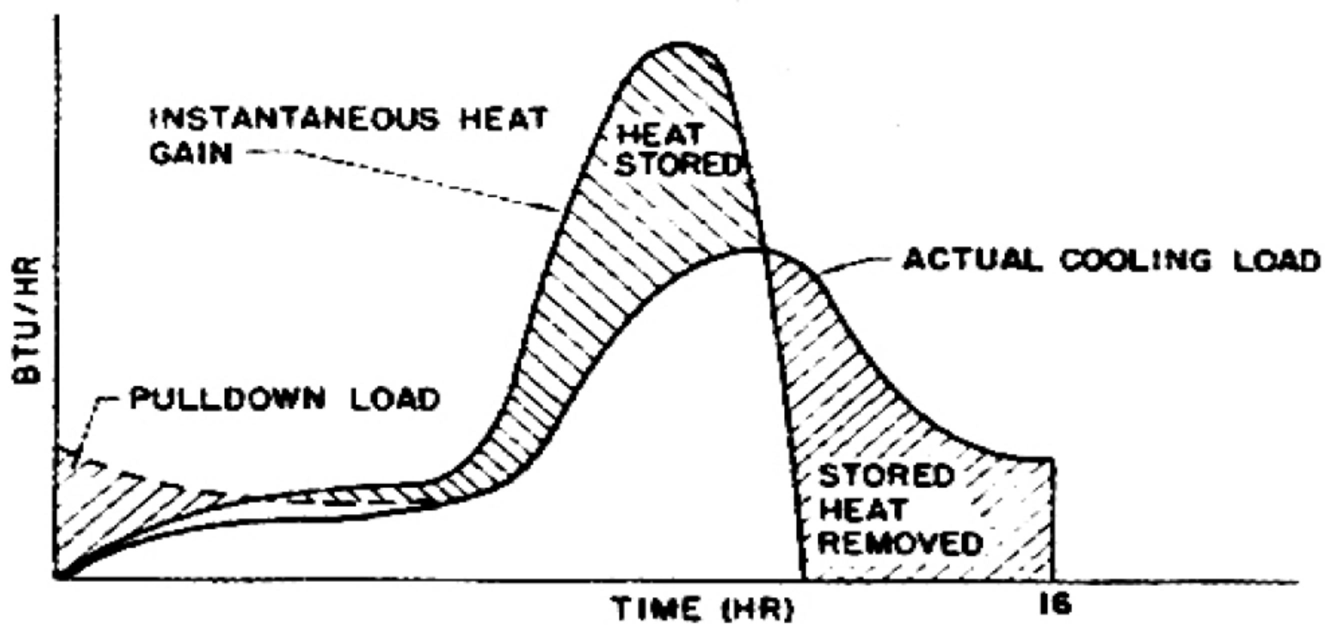


FIG. 7-ACTUAL COOLING LOAD, SOLAR HEAT GAIN, WEST EXPOSURE, 16-HOUR OPERATION

Principles of Cooling Load

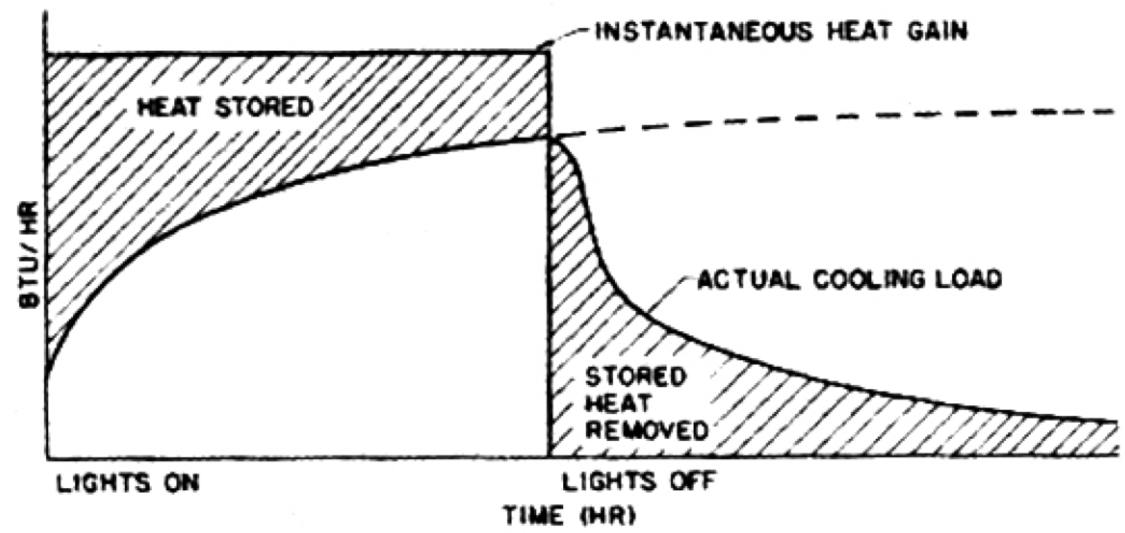


FIG. 4- ACTUAL COOLING LOAD FROM FLUORESCENT LIGHTS, AVERAGE CONSTRUCTION

Outdoor Design Condition

Design conditions for BANGKOK, Thailand

Station Information

Station name	WMO#	Lat	Long	Elev	StdP	Hours +/- UTC	Time zone code	Period
1a	*1b*	*1c*	*1d*	*1e*	*1f*	*1g*	*1h*	*1i*
BANGKOK	**484550**	**13.73N**	**100.57E**	**20**	**101.08**	**7.00**	**SEA**	**8201**

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*
12	**18.7**	**20.3**	**11.7**	**8.6**	**23.0**	**13.3**	**9.5**	**23.7**	**6.8**	**27.4**	**5.6**	**27.8**	**1.0**	**N/A**

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*
4	**7.1**	**35.7**	**26.4**	**35.0**	**26.4**	**34.4**	**26.2**	**28.0**	**33.0**	**27.6**	**32.4**	**27.2**	**31.8**	**2.9**	**N/A**

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*
26.7	**22.4**	**30.2**	**26.4**	**21.9**	**29.9**	**26.1**	**21.6**	**29.7**	**89.5**	**33.0**	**87.9**	**32.8**	**86.4**	**32.1**

Outdoor Design Condition

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*
6.4	**5.7**	**5.1**	**33.2**	**37.4**	**16.3**	**0.8**	**2.4**	**38.0**	**14.6**	**38.4**	**13.2**	**38.9**	**11.8**	**39.5**	**10.1**

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%	**33.9**	**24.3**	**34.6**	**24.4**	**35.8**	**24.7**	**36.7**	**25.9**	**36.7**	**26.7**	**35.2**	**26.5**
1%	**33.5**	**24.3**	**34.0**	**24.8**	**35.2**	**25.1**	**36.2**	**26.3**	**36.2**	**26.9**	**34.8**	**26.4**
2%	**33.0**	**24.3**	**33.5**	**24.9**	**34.7**	**25.4**	**35.8**	**26.5**	**35.7**	**26.9**	**34.2**	**26.4**

%	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%	**34.8**	**26.3**	**34.3**	**26.3**	**34.0**	**26.2**	**33.8**	**26.2**	**34.0**	**25.3**	**33.9**	**24.5**
1%	**34.3**	**26.2**	**33.8**	**26.1**	**33.6**	**26.1**	**33.3**	**26.1**	**33.5**	**25.2**	**33.3**	**24.3**
2%	**33.9**	**26.1**	**33.3**	**25.9**	**33.1**	**26.1**	**32.9**	**26.1**	**33.1**	**25.1**	**32.9**	**24.1**

Outdoor Design Condition

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%	**26.8**	**30.5**	**27.7**	**32.4**	**27.7**	**32.8**	**28.6**	**34.1**	**28.2**	**33.6**	**27.7**	**32.3**
1%	**26.4**	**30.3**	**27.2**	**31.5**	**27.4**	**32.4**	**28.2**	**33.4**	**28.0**	**33.4**	**27.6**	**32.1**
2%	**26.1**	**30.2**	**26.9**	**31.0**	**27.2**	**32.0**	**28.1**	**33.1**	**27.7**	**32.9**	**27.3**	**31.7**

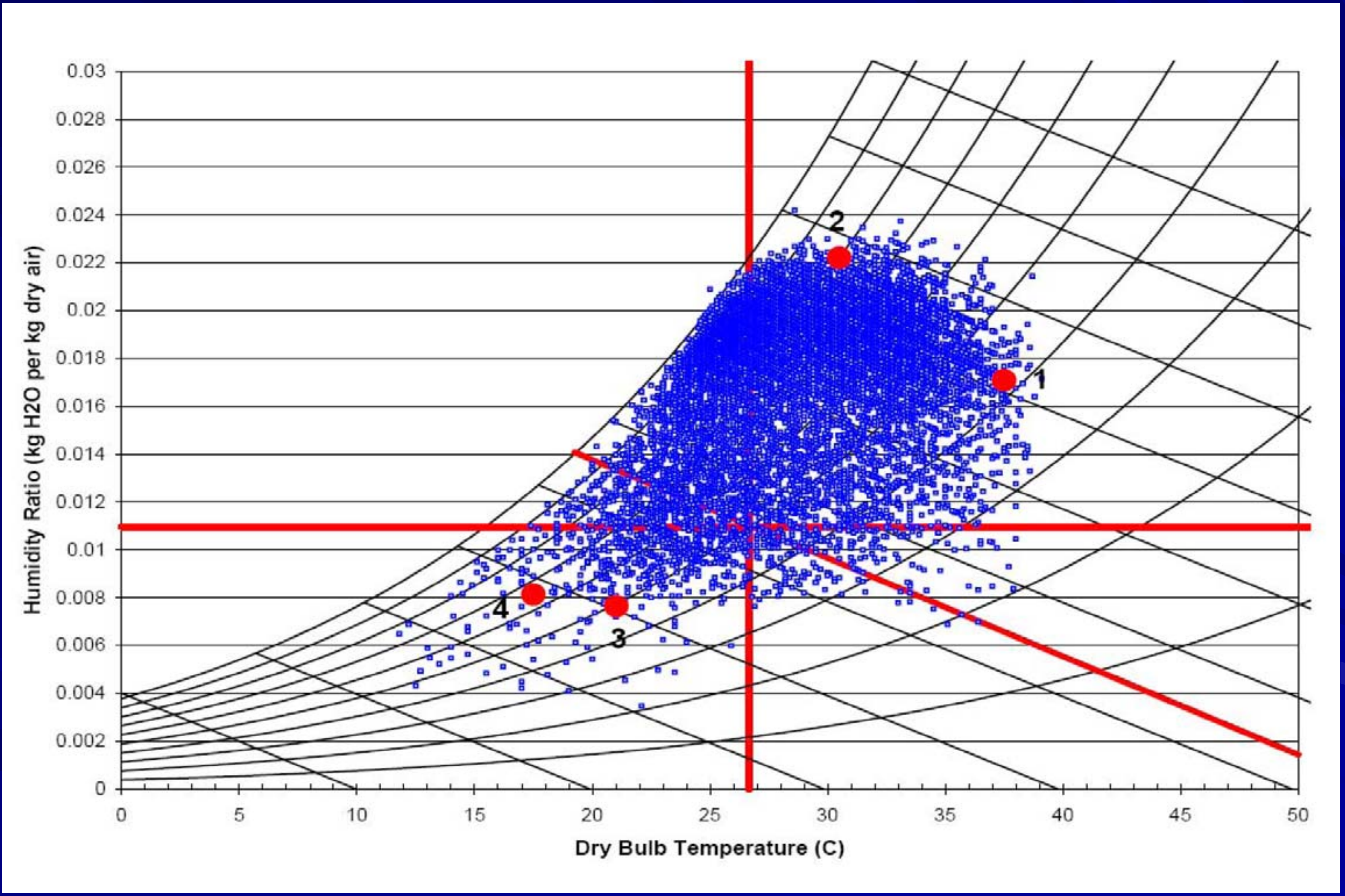
%	Jul		Aug		Sep		Oct		Nov		Dec	
	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB	WB	MCDB
	19m	*19n*	*19o*	*19p*	*19q*	*19r*	*19s*	*19t*	*19u*	*19v*	*19w*	*19x*
0.4%	**27.6**	**32.3**	**27.2**	**31.7**	**27.5**	**31.2**	**27.5**	**31.7**	**26.9**	**31.4**	**26.4**	**30.6**
1%	**27.2**	**31.7**	**27.0**	**31.5**	**27.2**	**31.1**	**27.2**	**31.3**	**26.6**	**31.0**	**25.9**	**30.0**
2%	**27.0**	**31.4**	**26.7**	**31.1**	**26.9**	**30.9**	**26.9**	**30.9**	**26.2**	**30.7**	**25.5**	**30.0**

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*
8.9	**7.8**	**7.3**	**7.1**	**6.8**	**6.1**	**6.1**	**6.0**	**6.4**	**6.4**	**7.3**	**8.8**

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

Outdoor Design Conditions



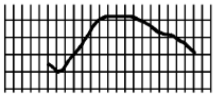
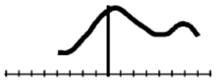
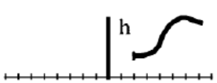
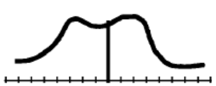
Indoor Design Condition

Table 1 General Design Criteria[a, b]

General Category	Specific Category	Inside Design Conditions: Winter	Inside Design Conditions: Summer	Air Movement	Circulation, air changes per hour
Dining and Entertainment Centers	Cafeterias and Luncheonettes	21 to 23°C 20 to 30% rh	26°C[d] 50% rh	0.25 m/s at 1.8 m above floor	12 to 15
	Restaurants	21 to 23°C 20 to 30% rh	23 to 26°C 55 to 60% rh	0.13 to 0.15 m/s	8 to 12
	Bars	21 to 23°C 20 to 30% rh	23 to 26°C 50 to 60% rh	0.15 m/s at 1.8 m above floor	15 to 20
	Nightclubs and Casinos	21 to 23°C 20 to 30% rh	23 to 26°C 50 to 60% rh	below 0.13 m/s at 1.5 m above floor	20 to 30
	Kitchens	21 to 23°C	29 to 31°C	0.15 to 0.25 m/s	12 to 15[g]
Office Buildings		21 to 23°C 20 to 30% rh	23 to 26°C 50 to 60% rh	0.13 to 0.23 m/s 4 to 10 $L/(s \cdot m^2)$	4 to 10

Indoor Design Condition

Table 1 General Design Criteria[a, b] (*Concluded*)

Noise[c]	Filtering Efficiencies (ASHRAE *Standard* 52.1)	Load Profile	Comments
NC 40 to 50[e]	35% or better	Peak at 1 to 2 PM 	Prevent draft discomfort for patrons waiting in serving lines
NC 35 to 40	35% or better	Peak at 1 to 2 PM 	
NC 35 to 50	Use charcoal for odor control with manual purge control for 100% outside air to exhaust ±35% prefilters	Peak at 5 to 7 PM 	
NC 35 to 45[f]	Use charcoal for odor control with manual purge control for 100% outside air to exhaust ±35% prefilters	Nightclubs peak at 8 PM to 2 AM Casinos peak at 4 PM to 2 AM Equipment, 24 h/day	Provide good air movement but prevent cold draft discomfort for patrons
NC 40 to 50	10 to 15% or better		Negative air pressure required for odor control (also see Chapter 31)
NC 30 to 45	35 to 60% or better	Peak at 4 PM 	

Components of Cooling Load

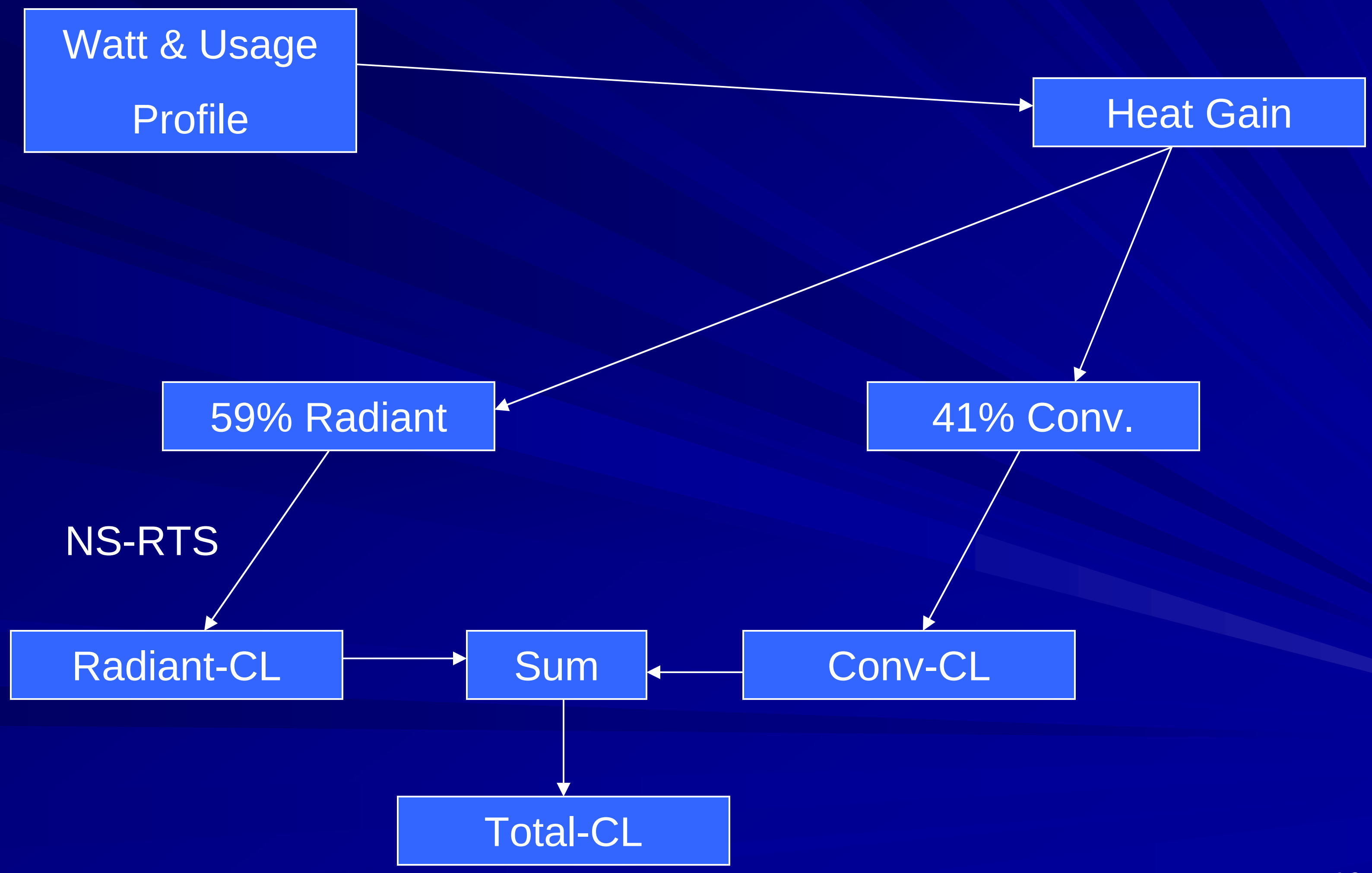
1) External Load
   - 1.1) Roofs
   - 1.2) Wall
   - 1.3) Glass (Windows)
   - 1.4) Ceiling
   - 1.5) Floor
   - 1.6) Partition

2) Internal Load
   - 2.1) People
   - 2.2) Lights
   - 2.3) Power
   - 2.4) Appliances

3) Outdoor Air Load

Lighting Heat Gain

Lighting


Watt & Usage Profile
Heat Gain
59% Radiant
41% Conv.
NS-RTS
Radiant-CL
Sum
Conv-CL
Total-CL

Cooling Load from Lights

ตารางที่ 7: Cooling Load Component of Lighting

Hour	Usage Profile %	Heat Gain, Watt Total 100%	Convective 41%	Radiant 59%	Nonsolar RTS Zone Type 8 %	Radiant Cooling Load Watt	Total Cooling Load Watt
1	0	0	0	0	49	31.2	31.2
2	0	0	0	0	17	31.2	31.2
3	0	0	0	0	9	28.6	28.6
4	0	0	0	0	5	26	26
5	0	0	0	0	3	23.4	23.4
6	0	0	0	0	2	20.8	20.8
7	100	440.7	180.7	260	2	145.6	326.3
8	100	440.7	180.7	260	1	187.2	367.9
9	100	440.7	180.7	260	1	208	388.7
10	100	440.7	180.7	260	1	218.4	399.1
11	100	440.7	180.7	260	1	223.6	404.3
12	100	440.7	180.7	260	1	226.2	406.9
13	100	440.7	180.7	260	1	228.8	409.5
14	100	440.7	180.7	260	1	228.8	409.5
15	100	440.7	180.7	260	1	231.4	412.1
16	100	440.7	180.7	260	1	234	414.7
17	100	440.7	180.7	260	1	236.6	417.3
18	100	440.7	180.7	260	1	239.2	419.9
19	0	0	0	0	1	114.4	114.4
20	0	0	0	0	1	72.8	72.8
21	0	0	0	0	0	52	52
22	0	0	0	0	0	41.6	41.6
23	0	0	0	0	0	36.4	36.4
24	0	0	0	0	0	33.8	33.8
Column Number							
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**

Convective/Radiant Split

ตารางที่ 6: Convective and Radiant Percentages of Total Sensible Heat Gain

Heat Gain Source	Radiant Heat, %	Convective Heat, %
Transmitted solar, no inside shade	100	0
Window solar, with inside shade	63	37
Absorbed (by fenestration) solar	63	37
Fluorescent lights, suspended, unvented	67	33
recessed, vented to return air	59	41
recessed, vented to return air and supply air	19	81
Incandescent lights	80	20
People	See Table 14	
Conduction, exterior walls	63	37
exterior roofs	84	16
Infiltration and ventilation	0	100
Machinery and appliances	20 to 80	80 to 20

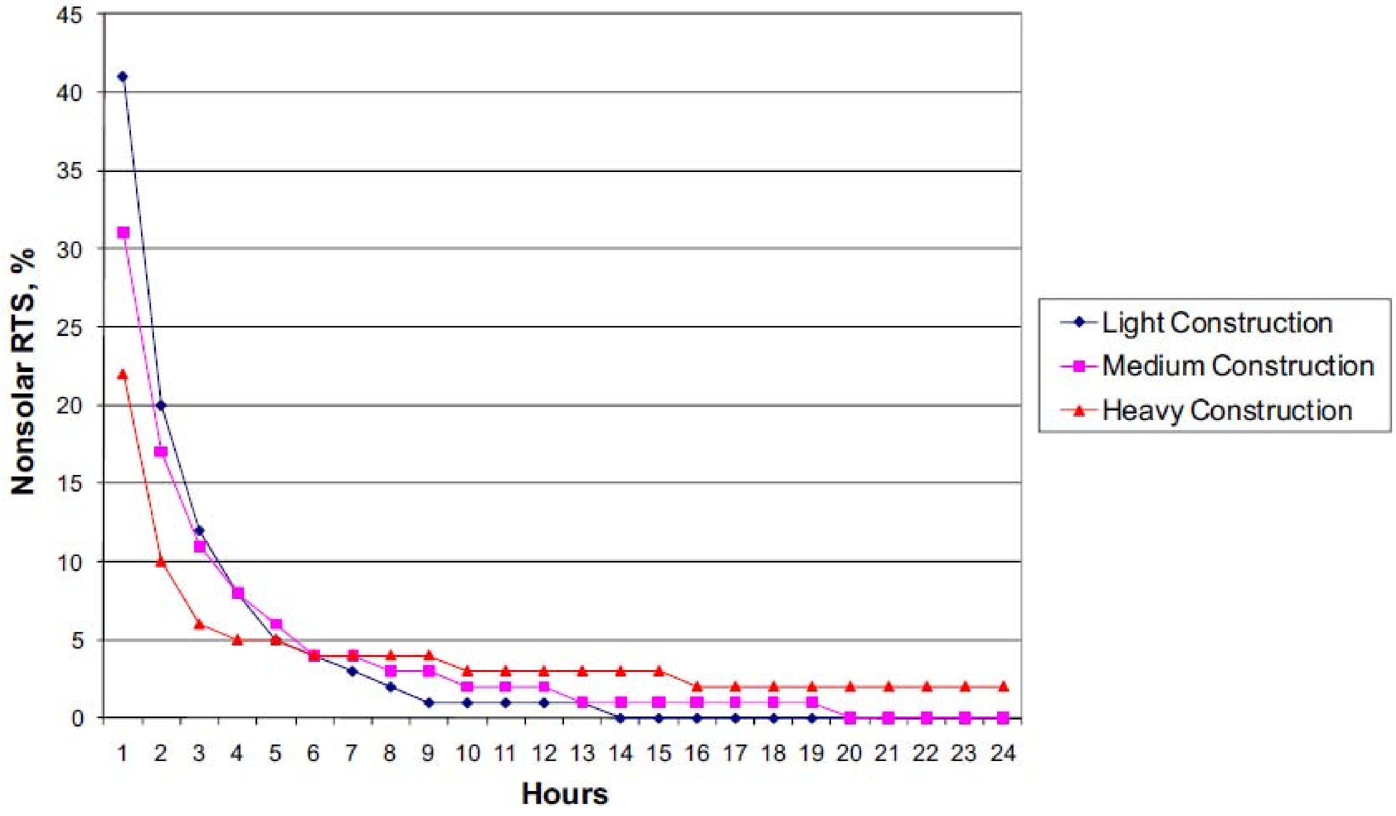
Sources: Pedersen et al. (1998), Hosni et al. (1999).

Nonsolar RTS Values

ตารางที่ 4: Nonsolar RTS Values

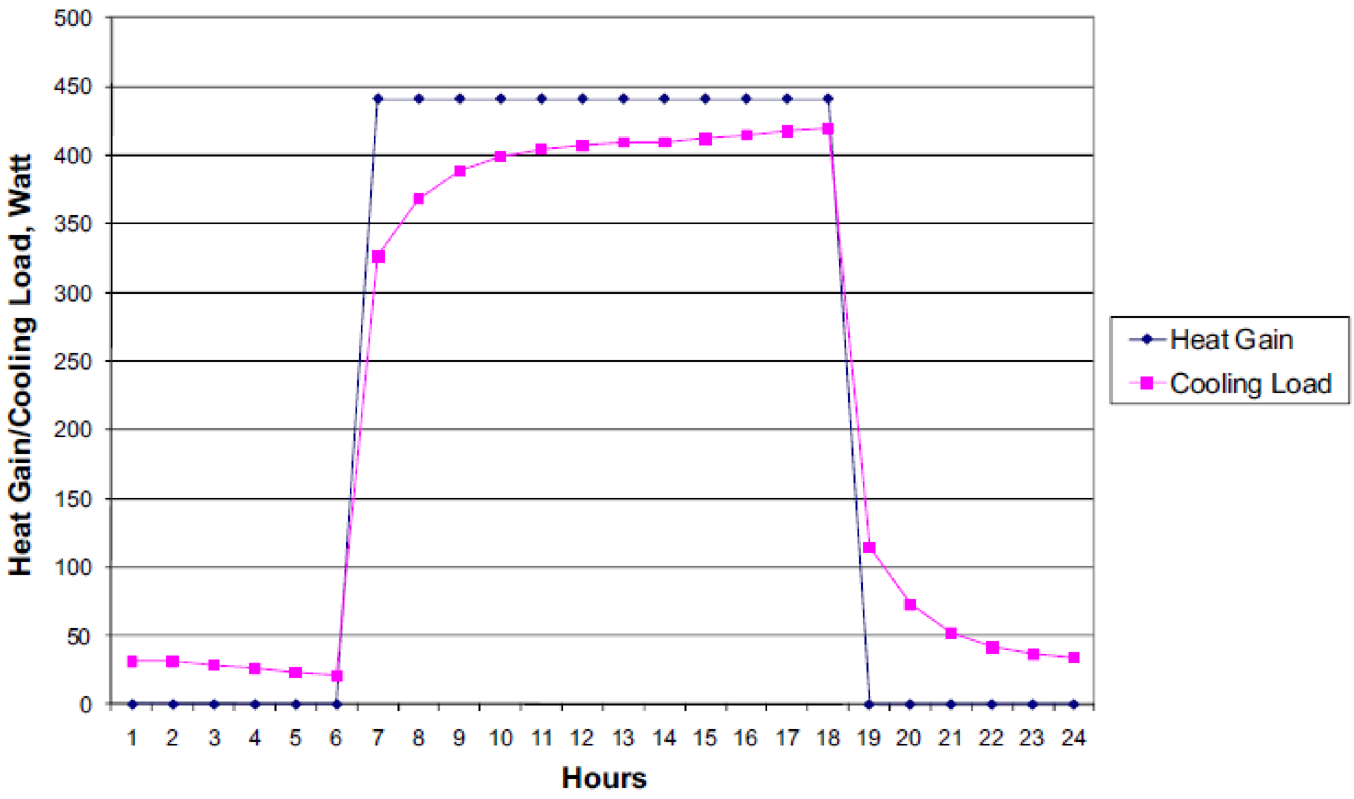
	Light						Medium						Heavy						Interior Zones					
																			Light		Medium		Heavy	
	With Carpet			No Carpet			With Carpet			No Carpet			With Carpet			No Carpet			With Carpet	No Carpet	With Carpet	No Carpet	With Carpet	No Carpet
% Glass	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%						
Zone Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Hour	Radiant Time Factor,%																							
0	47	50	53	41	43	46	46	49	52	31	33	35	34	38	42	22	25	28	46	40	46	31	33	21
1	19	18	17	20	19	19	18	17	16	17	16	15	9	9	9	10	9	9	19	20	18	17	9	9
2	11	10	9	12	11	11	10	9	8	11	10	10	6	6	5	6	6	6	11	12	10	11	6	6
3	6	6	5	8	7	7	6	5	5	8	7	7	4	4	4	5	5	5	6	8	6	8	5	5
4	4	4	3	5	5	5	4	3	3	6	5	5	4	4	4	5	5	4	4	5	3	6	4	5
5	3	3	2	4	3	3	2	2	2	4	4	4	4	3	3	4	4	4	3	4	2	4	4	4
6	2	2	2	3	3	2	2	2	2	4	3	3	3	3	3	4	4	4	2	3	2	4	3	4
7	2	1	1	2	2	2	1	1	1	3	3	3	3	3	3	4	4	4	2	2	1	3	3	4
8	1	1	1	1	1	1	1	1	1	3	2	2	3	3	3	4	3	3	1	1	1	3	3	4
9	1	1	1	1	1	1	1	1	1	2	2	2	3	3	2	3	3	3	1	1	1	2	3	3
10	1	1	1	1	1	1	1	1	1	2	2	2	3	2	2	3	3	3	1	1	1	2	3	3
11	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3	1	1	1	2	2	3
12	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	3	3	3	1	1	1	1	2	3
13	1	1	1	0	1	0	1	1	1	1	1	1	2	2	2	3	3	2	1	1	1	1	2	3
14	0	0	1	0	1	0	1	1	1	1	1	1	2	2	2	3	2	2	1	0	1	1	2	3
15	0	0	1	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	0	0	1	1	2	3
16	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	0	0	1	1	2	3
17	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	0	0	1	1	2	2
18	0	0	0	0	0	0	1	1	1	1	1	1	2	2	1	2	2	2	0	0	1	1	2	2
19	0	0	0	0	0	0	0	1	0	0	1	1	2	2	1	2	2	2	0	0	1	0	2	2
20	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	2	2	2	0	0	0	0	2	2
21	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	2	2	2	0	0	0	0	2	2
22	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	2	2	2	0	0	0	0	1	2
23	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	1	0	0	0	0	1	2
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Nonsolar RTS



รูปที่ 2: Nonsolar RTS ของ Room Construction แบบต่าง ๆ

Cooling Load from Lights



รูปที่ 4: Time-delay Effect ของ Cooling Load จากไฟฟ้าแสงสว่าง

Calculation Example

ตารางที่ 8: รายละเอียดวิธีการคำนวณ Radiant Cooling Load

Column Number															
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Day	Hour	Radiant Heat Gain 59% (Watt)	Effect from HR = 7 (Watt)	Effect from HR = 8 (Watt)	Effect from HR = 9 (Watt)	Effect from HR = 10 (Watt)	Effect from HR = 11 (Watt)	Effect from HR = 12 (Watt)	Effect from HR = 13 (Watt)	Effect from HR = 14 (Watt)	Effect from HR = 15 (Watt)	Effect from HR = 16 (Watt)	Effect from HR = 17 (Watt)	Effect from HR = 18 (Watt)	Radiant Cooling Load (Watt)
1	1	0													
1	2	0													
1	3	0													
1	4	0													
1	5	0													
1	6	0													
1	7	260	127.4												
1	8	260	44.2	127.4											
1	9	260	23.4	44.2	127.4										
1	10	260	13.0	23.4	44.2	127.4									
1	11	260	7.8	13.0	23.4	44.2	127.4								
1	12	260	5.2	7.8	13.0	23.4	44.2	127.4							
1	13	260	5.2	5.2	7.8	13.0	23.4	44.2	127.4						
1	14	260	2.6	5.2	5.2	7.8	13.0	23.4	44.2	127.4					
1	15	260	2.6	2.6	5.2	5.2	7.8	13.0	23.4	44.2	127.4				
1	16	260	2.6	2.6	2.6	5.2	5.2	7.8	13.0	23.4	44.2	127.4			
1	17	260	2.6	2.6	2.6	2.6	5.2	5.2	7.8	13.0	23.4	44.2	127.4		
1	18	260	2.6	2.6	2.6	2.6	2.6	5.2	5.2	7.8	13.0	23.4	44.2	127.4	**239.2**
1	19	0	2.6	2.6	2.6	2.6	2.6	2.6	5.2	5.2	7.8	13.0	23.4	44.2	**114.4**
1	20	0	2.6	2.6	2.6	2.6	2.6	2.6	2.6	5.2	5.2	7.8	13.0	23.4	**72.8**
1	21	0	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	5.2	5.2	7.8	13.0	**52.0**
1	22	0	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	5.2	5.2	7.8	**41.6**
1	23	0	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	5.2	5.2	**36.4**
1	24	0	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	5.2	**33.8**

Example of Calculations

จำนวนชั่วโมงหลังจากชั่วโมงที่ 7 ของวันที่ 1	Cooling Load ของ Heat Gain 260 Watt ที่เกิดขึ้นในแต่ละชั่วโมงหลังจากชั่วโมงที่ 7 ของวันที่ 1
0	260 x 0.49 = 127.4 Watt
1	260 x 0.17 = 44.2 Watt
2	260 x 0.09 = 23.4 Watt
3	260 x 0.05 = 13.0 Watt
4	260 x 0.03 = 7.8 Watt
5	260 x 0.02 = 5.2 Watt
6	260 x 0.02 = 5.2 Watt
7	260 x 0.01 = 2.6 Watt

Plenum Heat Balance

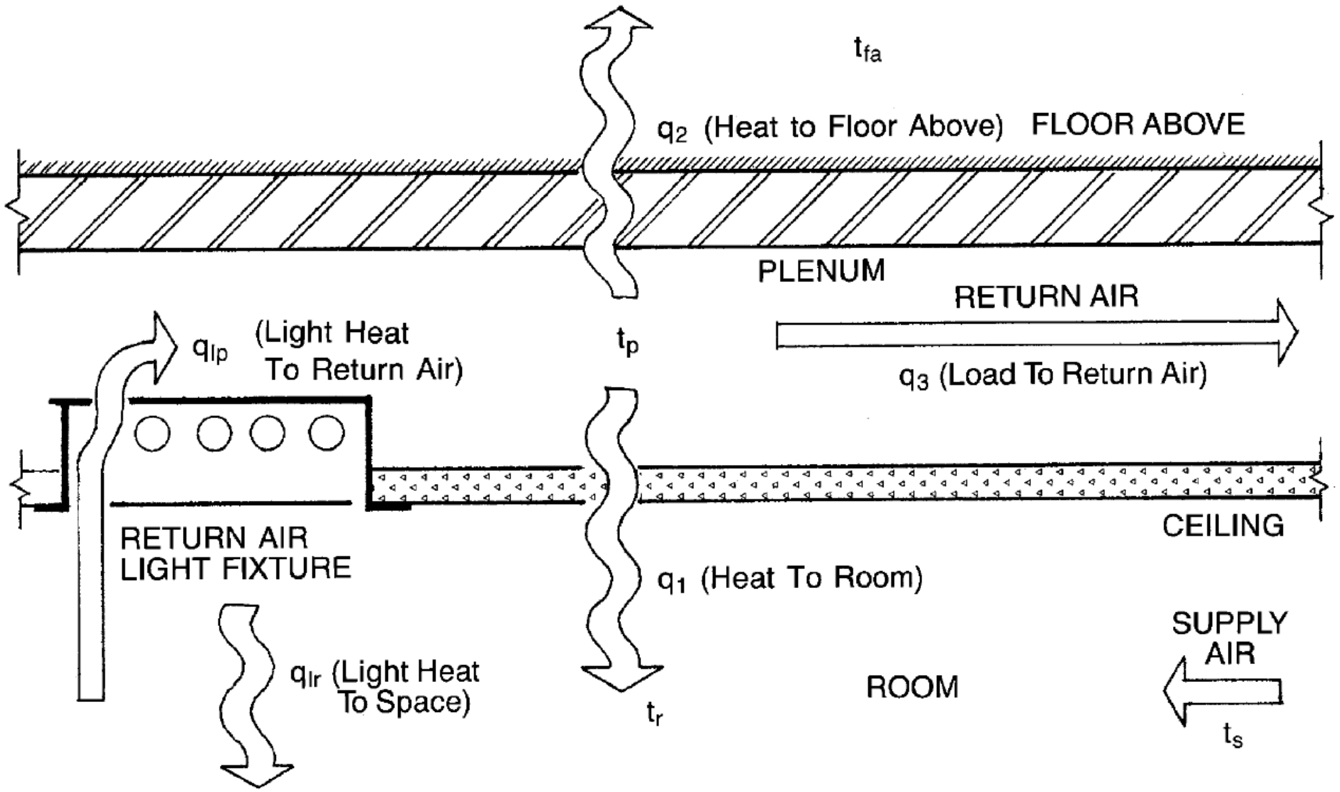
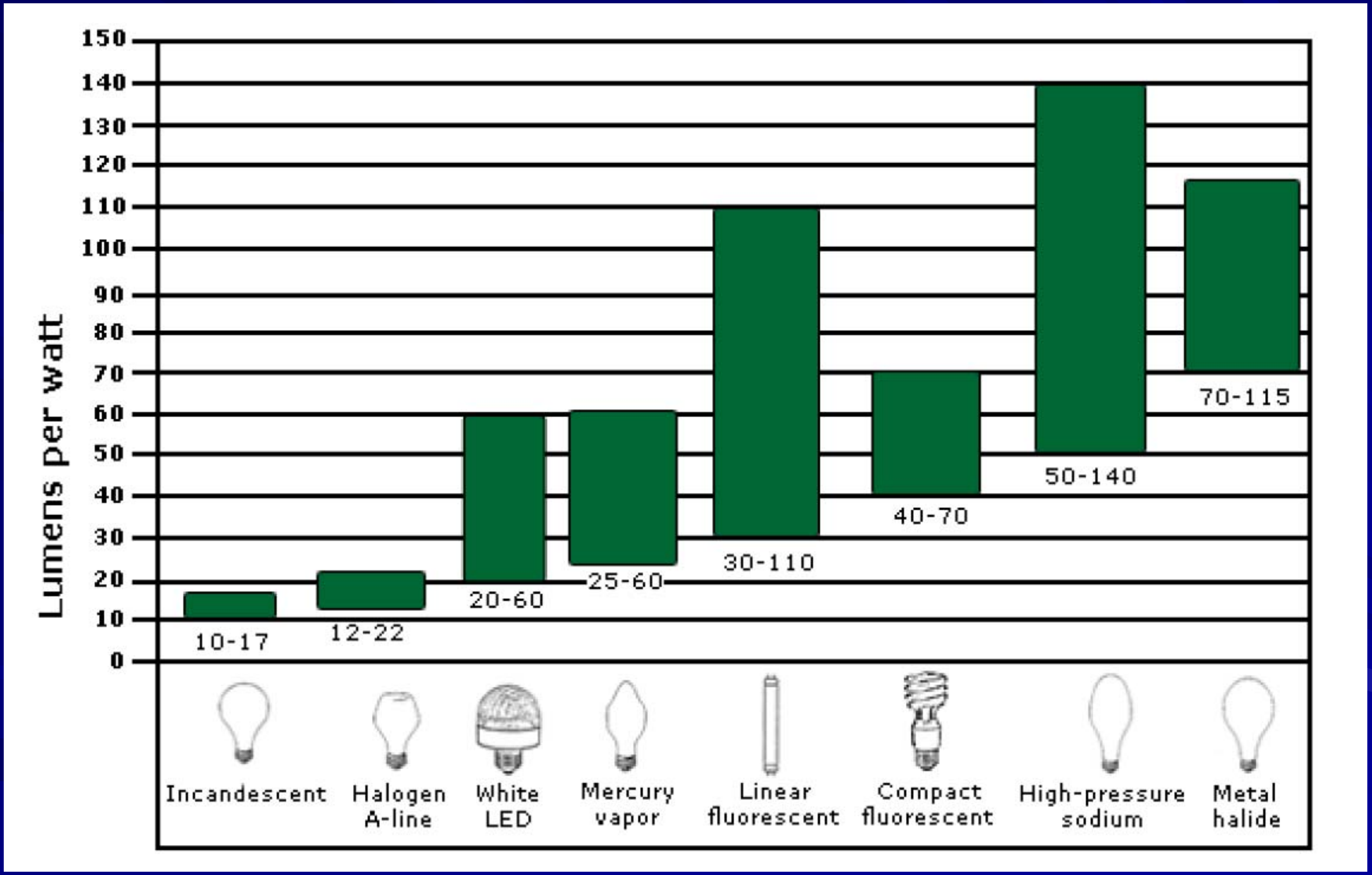


Fig. 3 Schematic Diagram of Typical Return Air Plenum

Approximate Watt/Sq.m

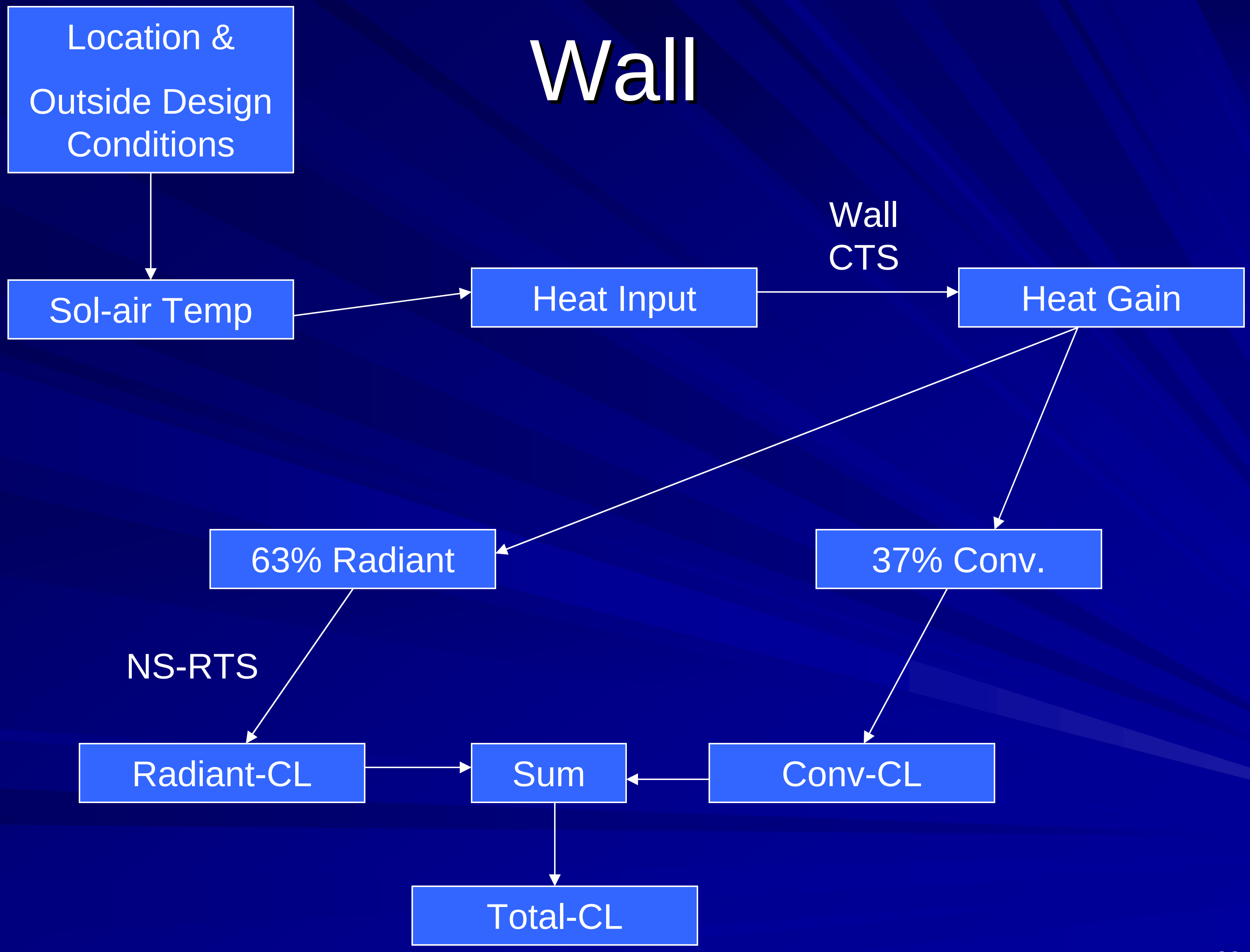
Activity	Illumination (lux, lumen/m^2)	Watt/Sq.m (Assume Eff. = 40 lu/Watt)
Warehouses, Homes, Theaters, Archives	150	3.75
Easy Office Work, Classes	250	6.25
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	500	12.5
Supermarkets, Mechanical Workshops, Office Landscapes	750	18.75
Normal Drawing Work, Detailed Mechanical Workshops, Operation Theatres	1,000	25
Detailed Drawing Work, Very Detailed Mechanical Works	1,500 - 2,000	37.5 - 50

Lighting Efficiency Compare



Wall Heat Gain

Wall


Location &
Outside Design Conditions
Sol-air Temp
Heat Input
Wall CTS
Heat Gain
63% Radiant
37% Conv.
NS-RTS
Radiant-CL
Sum
Conv-CL
Total-CL

Solar Irradiance on W-Wall

ตารางที่ 10: Wall Component of Solar Irradiance

	Solar Angles				Direct Solar			Diffuse Solar				
Local Standard Time *LST* Hour	Apparent Solar Time *AST* Hour	Hour Angle *H* Degree	Solar Altitude β Degree	Solar Azimuth ϕ Degree	Direct Normal E_{DN} W/m^2	Surface Incident Angle θ Degree	Surface Direct E_D W/m^2	Ground Reflected E_r W/m^2	Ratio *Y*	Sky Diffuse E_d W/m^2	Surface Diffuse E_d+E_r W/m^2	Total Surface Irradiance E_t W/m^2
1	0.72	-169.2	-62.5	-156.5	0	100.6	0	0	0.48	0	0	0
2	1.72	-154.2	-54	-133.5	0	115.3	0	0	0.45	0	0	0
3	2.72	-139.2	-42.2	-120.1	0	129.8	0	0	0.45	0	0	0
4	3.72	-124.2	-29.1	-111.9	0	144.2	0	0	0.45	0	0	0
5	4.72	-109.2	-15.3	-106.4	0	157.7	0	0	0.45	0	0	0
6	5.72	-94.2	-1.2	-102.3	0	167.7	0	0	0.45	0	0	0
7	6.72	-79.2	13.1	-99.0	548.3	164.2	0	19.0	0.45	29.6	48.6	48.6
8	7.72	-64.2	27.6	-96.1	792.7	151.8	0	46.2	0.45	42.8	89	89.0
9	8.72	-49.2	42.1	-93.3	884.7	137.8	0	69.9	0.45	47.8	117.7	117.7
10	9.72	-34.2	56.6	-90.3	928.5	123.4	0	88.7	0.45	50.1	138.8	138.8
11	10.72	-19.2	71.2	-85.7	950.3	108.7	0	101.4	0.45	51.3	152.7	152.7
12	11.72	-4.2	85.4	-62.7	958.6	94.1	0	107.1	0.52	59.9	166.9	166.9
13	12.72	10.8	79.2	79.8	956.3	79.4	176.2	105.4	0.64	73.6	179.0	355.2
14	13.72	25.8	64.7	88.1	942.5	64.7	402.5	96.5	0.79	89.8	186.3	588.8
15	14.72	40.8	50.1	91.7	912.6	50.2	584.7	81	0.96	105	186	770.6
16	15.72	55.8	35.6	94.6	852.5	35.8	691.1	59.8	1.11	113.5	173.4	864.4
17	16.72	70.8	21.1	97.3	716.5	22.3	663	34.4	1.22	105.1	139.5	802.5
18	17.72	85.8	6.7	100.4	277.1	12.3	270.7	6.6	1.28	42.4	49	319.7
19	18.72	100.8	-7.5	104.0	0	15.8	0	0	1.26	0	0	0
20	19.72	115.8	-21.5	108.6	0	28.2	0	0	1.18	0	0	0
21	20.72	130.8	-35.1	115.1	0	42.2	0	0	1.05	0	0	0
22	21.72	145.8	-47.7	125.2	0	56.6	0	0	0.89	0	0	0
23	22.72	160.8	-58.3	142.2	0	71.3	0	0	0.72	0	0	0
24	23.72	175.8	-64.3	170.6	0	85.9	0	0	0.58	0	0	0
Column Number												
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**

Solar Angle

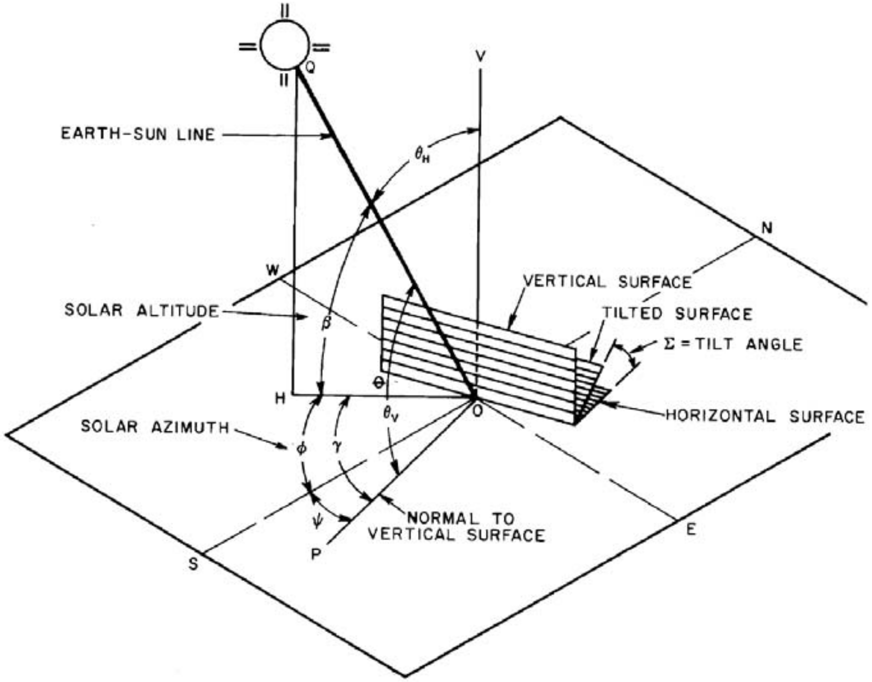


Fig. 10 Solar Angles for Vertical and Horizontal Surfaces

Table 9 Surface Orientations and Azimuths, Measured from South

Orientation	N	NE	E	SE	S	SW	W	NW
Surface azimuth ψ	180°	–135°	–90°	–45°	0	45°	90°	135°

Solar Equations

Solar Angles

All angles are in degrees. The solar azimuth ϕ and the surface azimuth ψ are measured in degrees from south; angles to the east of south are negative, and angles to the west of south are positive. Calculate solar altitude, azimuth, and surface incident angles as follows:

Apparent solar time AST, in decimal hours:

$$AST = LST + ET/60 + (LSM - LON)/15$$

Hour angle H, degrees:

$$H = 15(\text{hours of time from local solar noon}) = 15(AST - 12)$$

Solar altitude β:

$$\sin\beta = \cos L \ \cos\delta \cos H + \sin L \ \sin\delta$$

Solar azimuth ϕ:

$$\cos\phi = (\sin\beta \sin L - \sin\delta)/(\cos\beta \cos L)$$

Surface-solar azimuth γ :

$$\gamma = \phi - \psi$$

Incident angle θ:

$$\cos\theta = \cos\beta \cos\gamma \sin\Sigma + \sin\beta \cos\Sigma$$

where

- ET = equation of time, decimal minutes
- L = latitude
- LON = local longitude, decimal degrees of arc
- LSM = local standard time meridian, decimal degrees of arc
  - = 60° for Atlantic Standard Time
  - = 75° for Eastern Standard Time
  - = 90° for Central Standard Time
  - = 105° for Mountain Standard Time
  - = 120° for Pacific Standard Time
  - = 135° for Alaska Standard Time
  - = 150° for Hawaii-Aleutian Standard Time
- LST = local standard time, decimal hours
- δ = solar declination, °
- ψ = surface azimuth, °
- Σ = surface tilt from horizontal, horizontal = 0°

Values of ET and δ are given in Table 7 of Chapter 31 for the 21st day of each month.

Direct, Diffuse, and Total Solar Irradiance

Direct normal irradiance E_{DN}

If $\beta > 0$ $\quad E_{DN} = \left[\frac{A}{\exp(B/\sin\beta)}\right]CN$

Otherwise, $\quad E_{DN} = 0$

Surface direct irradiance E_D

If $\cos\theta > 0$ $\quad E_D = E_{DN}\cos\theta$

Otherwise, $\quad E_D = 0$

Ratio Y of sky diffuse on vertical surface to sky diffuse on horizontal surface

If $\cos\theta > -0.2$ $\quad Y = 0.55 + 0.437\cos\theta + 0.313\cos^2\theta$

Otherwise, $\quad Y = 0.45$

Diffuse irradiance E_d

Vertical surfaces	$E_d = CYE_{DN}$
Surfaces other than vertical	$E_d = CE_{DN}(1 + \cos\Sigma)/2$
Ground-reflected irradiance	$E_r = E_{DN}(C + \sin\beta)\rho_g(1 - \cos\Sigma)/2$
Total surface irradiance	$E_t = E_D + E_d + E_r$

where

- A = apparent solar constant
- B = atmospheric extinction coefficient
- C = sky diffuse factor
- CN = clearness number multiplier for clear/dry or hazy/humid locations. See Figure 5 in Chapter 33 of the 2003 *ASHRAE Handbook—HVAC Applications* for CN values.
- E_d = diffuse sky irradiance
- E_r = diffuse ground-reflected irradiance
- ρ_g = ground reflectivity

Values of A, B, and C are given in Table 7 of Chapter 31 for the 21st day of each month. Values of ground reflectivity ρ_g are given in Table 10 of Chapter 31.

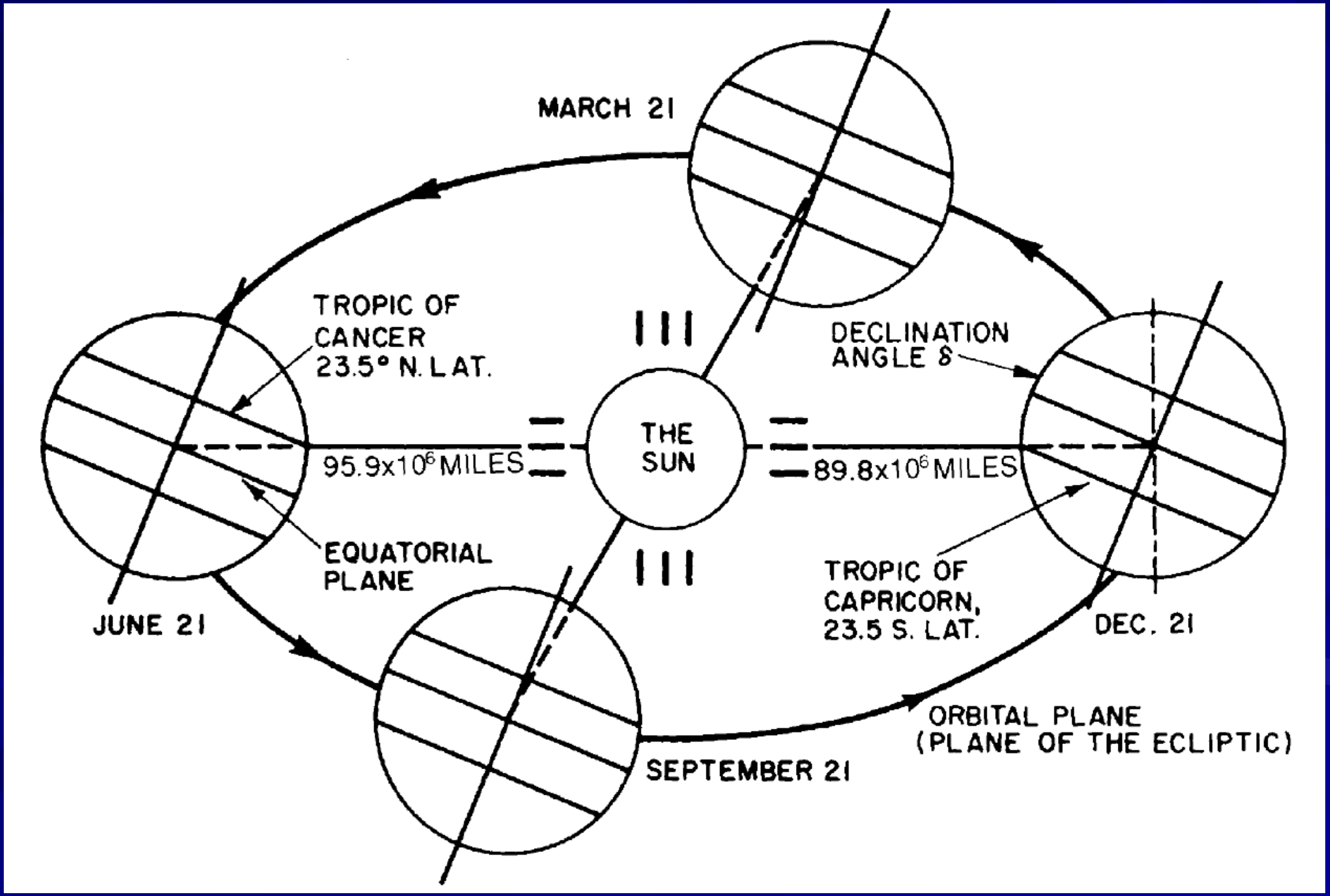
Solar Irradiance Data

Table 7 Extraterrestrial Solar Irradiance and Related Data

	I_o, W/m²	Equation of Time, min.	Declination, degrees	*A* W/m²	*B* (Dimensionless Ratios)	*C*
Jan	1416	–11.2	–20.0	1202	0.141	0.103
Feb	1401	–13.9	–10.8	1187	0.142	0.104
Mar	1381	–7.5	0.0	1164	0.149	0.109
Apr	1356	1.1	11.6	1130	0.164	0.120
May	1336	3.3	20.0	1106	0.177	0.130
June	1336	–1.4	23.45	1092	0.185	0.137
July	1336	–6.2	20.6	1093	0.186	0.138
Aug	1338	–2.4	12.3	1107	0.182	0.134
Sep	1359	7.5	0.0	1136	0.165	0.121
Oct	1380	15.4	–10.5	1166	0.152	0.111
Nov	1405	13.8	–19.8	1190	0.144	0.106
Dec	1417	1.6	–23.45	1204	0.141	0.103

Note: Data are for 21st day of each month during the base year of 1964.

Earth Orbit


MARCH 21
TROPIC OF
CANCER
23.5° N. LAT.
THE
SUN
95.9x10⁶ MILES
89.8x10⁶ MILES
DECLINATION
ANGLE δ
EQUATORIAL
PLANE
TROPIC OF
CAPRICORN,
23.5 S. LAT.
JUNE 21
DEC. 21
SEPTEMBER 21
ORBITAL PLANE
(PLANE OF THE ECLIPTIC)

Declination

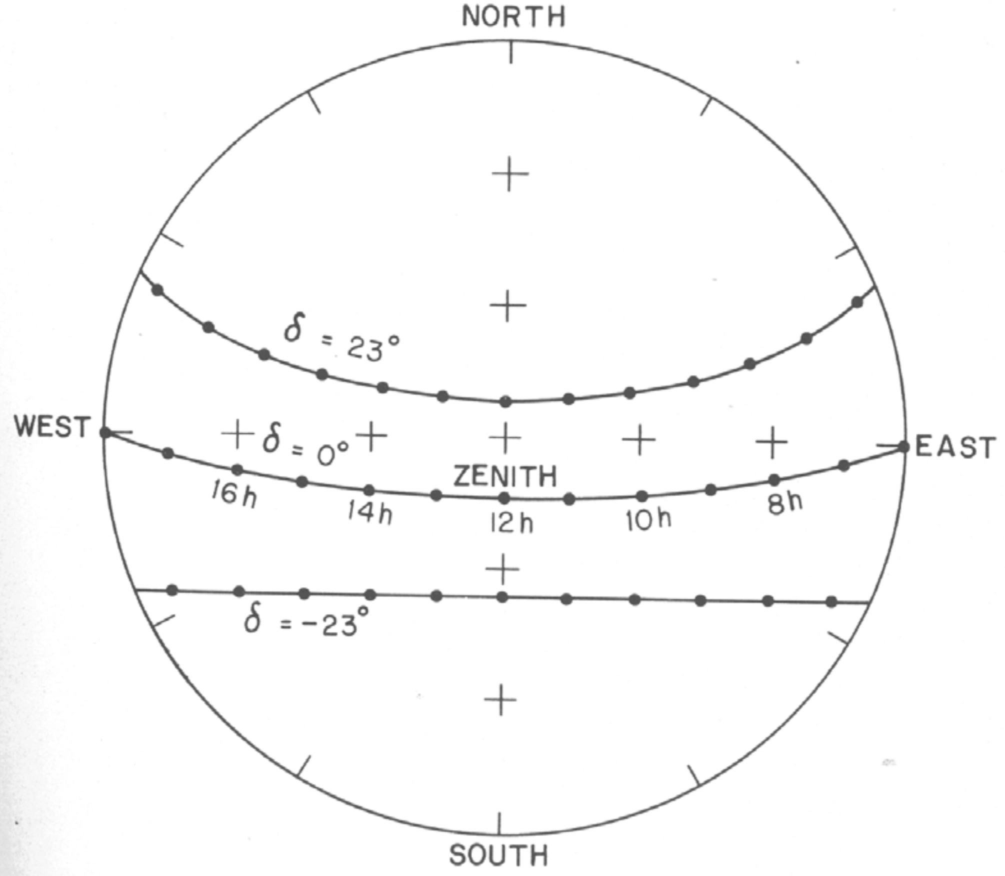


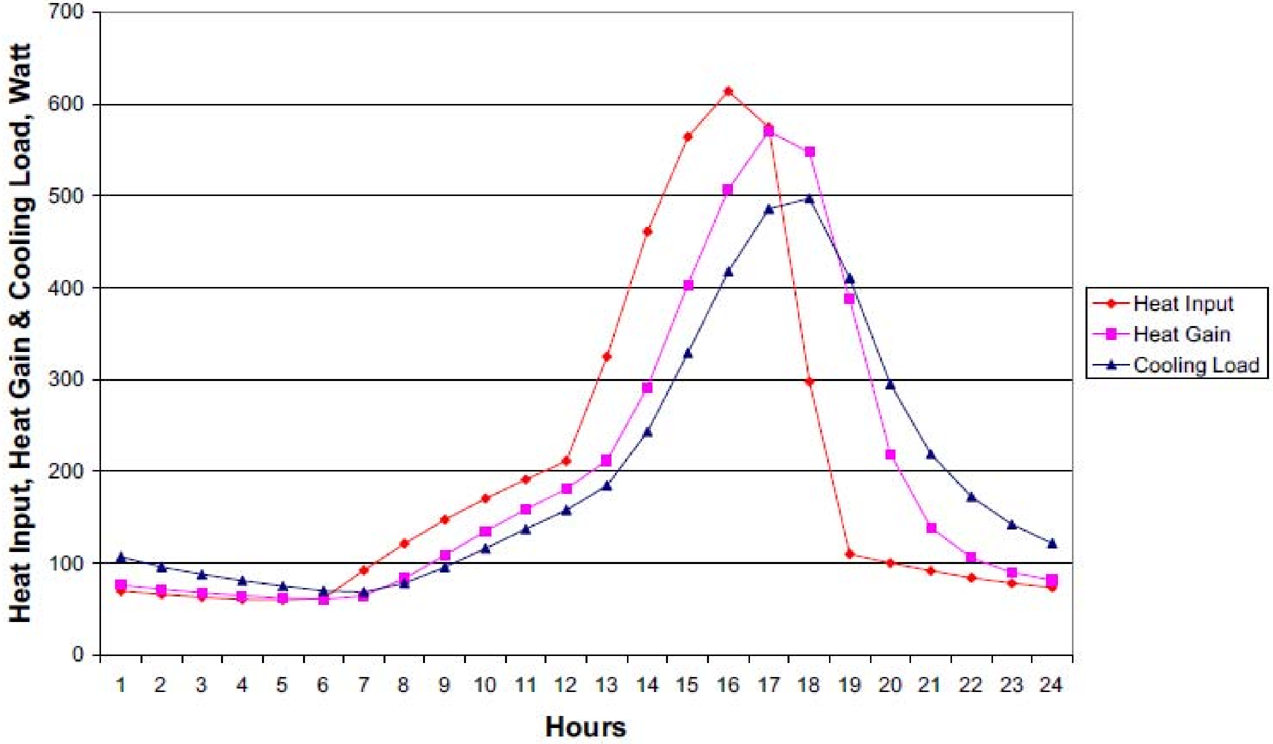
Fig. 2 Apparent motion of the sun in latitude 14° N for three values of the solar declination.

W-Wall Cooling Load

ตารางที่ 11: Wall Component of Cooling Load

Local Standard Time *LST* Hour	Total Surface Irradiance E_t W/m^2	Outside Temp. t_o °C	Sol-air Temp. t_e °C	Inside Temp. t_{rc} °C	Heat Input q_i Watt	Wall CTS Wall No.8 %	Heat Gain			Nonsolar RTS Zone Type 4 %	Radiant Cooling Load Watt	Total Cooling Load Watt
							Total 100% Watt	Convective 37% Watt	Radiant 63% Watt			
1	0	30.5	30.5	24	69.7	11	76	28.1	47.9	41	78.6	106.7
2	0	30.2	30.2	24	65.9	50	71.7	26.5	45.2	20	69.2	95.8
3	0	29.9	29.9	24	62.9	26	67.8	25.1	42.7	12	62.5	87.6
4	0	29.7	29.7	24	60.6	9	64.5	23.9	40.6	8	57.1	81
5	0	29.6	29.6	24	59.9	3	62	22.9	39.1	5	52.1	75
6	0	29.7	29.7	24	61.4	1	60.8	22.5	38.3	4	47.5	69.9
7	48.6	30.1	32.6	24	92.2	0	64.4	23.8	40.6	3	44.6	68.4
8	89	30.7	35.4	24	121.4	0	83.2	30.8	52.4	2	47.4	78.2
9	117.7	31.7	37.8	24	147.3	0	108.8	40.3	68.6	1	55.4	95.6
10	138.8	32.7	39.9	24	170.4	0	134.7	49.8	84.9	1	66.3	116.1
11	152.7	33.9	41.9	24	191	0	158.8	58.8	100	1	78.4	137.2
12	166.9	35.1	43.7	24	211.1	0	180.8	66.9	113.9	1	90.8	157.7
13	355.2	35.9	54.4	24	324.8	0	211.9	78.4	133.5	1	106	184.4
14	588.8	36.5	67.1	24	460.7	0	291.7	107.9	183.8	0	135.2	243.1
15	770.6	36.7	76.8	24	564	0	403.3	149.2	254.1	0	179.6	328.8
16	864.4	36.5	81.4	24	613.9	0	506.8	187.5	319.3	0	230.2	417.7
17	802.5	36	77.7	24	574.2	0	570.1	210.9	359.1	0	274.6	485.5
18	319.7	35.2	51.8	24	297.5	0	547.2	202.5	344.8	0	294.6	497.1
19	0	34.3	34.3	24	109.9	0	386.9	143.1	243.7	0	267.3	410.5
20	0	33.4	33.4	24	100.1	0	219.1	81	138	0	213.9	295
21	0	32.6	32.6	24	91.7	0	138.8	51.4	87.5	0	167.3	218.7
22	0	31.9	31.9	24	84.1	0	105.7	39.1	66.6	0	133.3	172.4
23	0	31.3	31.3	24	78.1	0	89.8	33.2	56.6	0	109	142.3
24	0	30.9	30.9	24	73.5	0	81.4	30.1	51.3	0	91.5	121.6
Column Number												
1	2	3	4	5	6	7	8	9	10	11	12	13

W-Wall Time-delay Effect



รูปที่ 7: Time-delay Effect จาก Wall CTS และ Nonsolar RTS Values ที่มีต่อ Heat Input ของผนังด้านตะวันตก

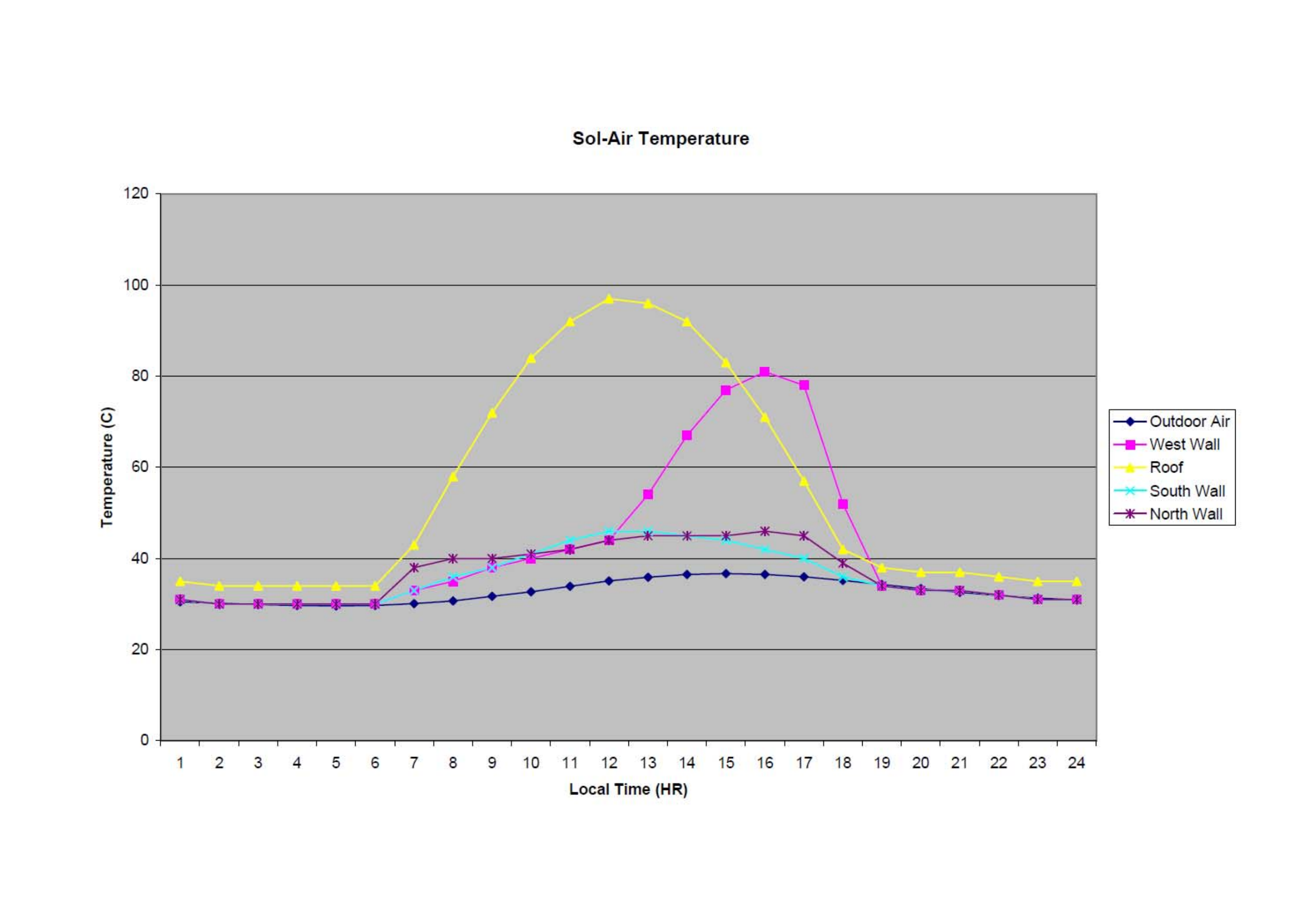
Sol-Air Temperature

$$t_e = t_o + \frac{\alpha E_t}{h_o} - \frac{\varepsilon \Delta R}{h_o}$$

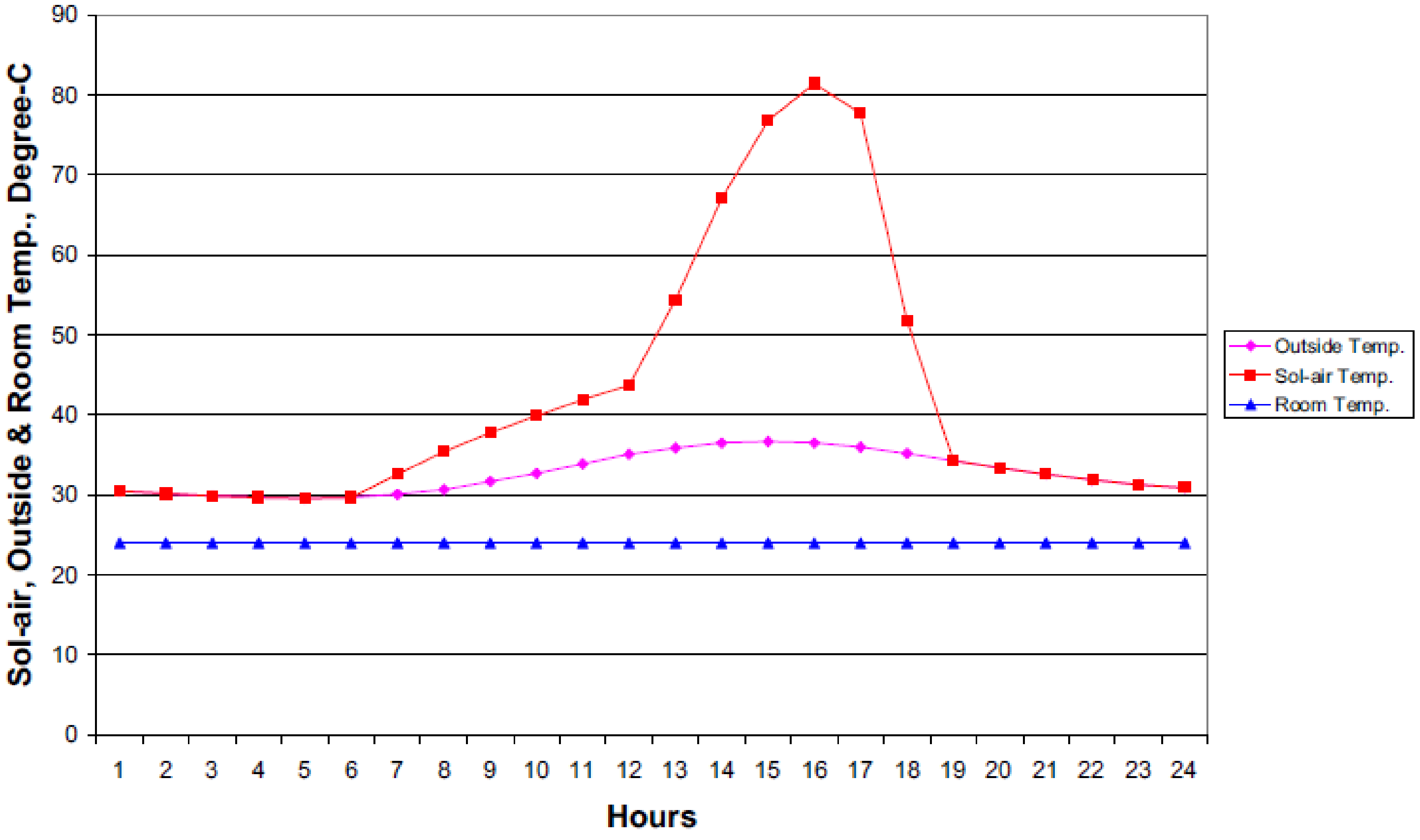
where

α = absorptance of surface for solar radiation
E_t = total solar radiation incident on surface, $W/(m^2 \cdot K)$
h_o = coefficient of heat transfer by long-wave radiation and convection at outer surface, $W/(m^2 \cdot K)$
t_o = outdoor air temperature, °C
t_s = surface temperature, °C
ε = hemispherical emittance of surface
ΔR = difference between long-wave radiation incident on surface from sky and surroundings and radiation emitted by blackbody at outdoor air temperature, W/m^2

Sol-Air Temperature



Sol-air Temperature



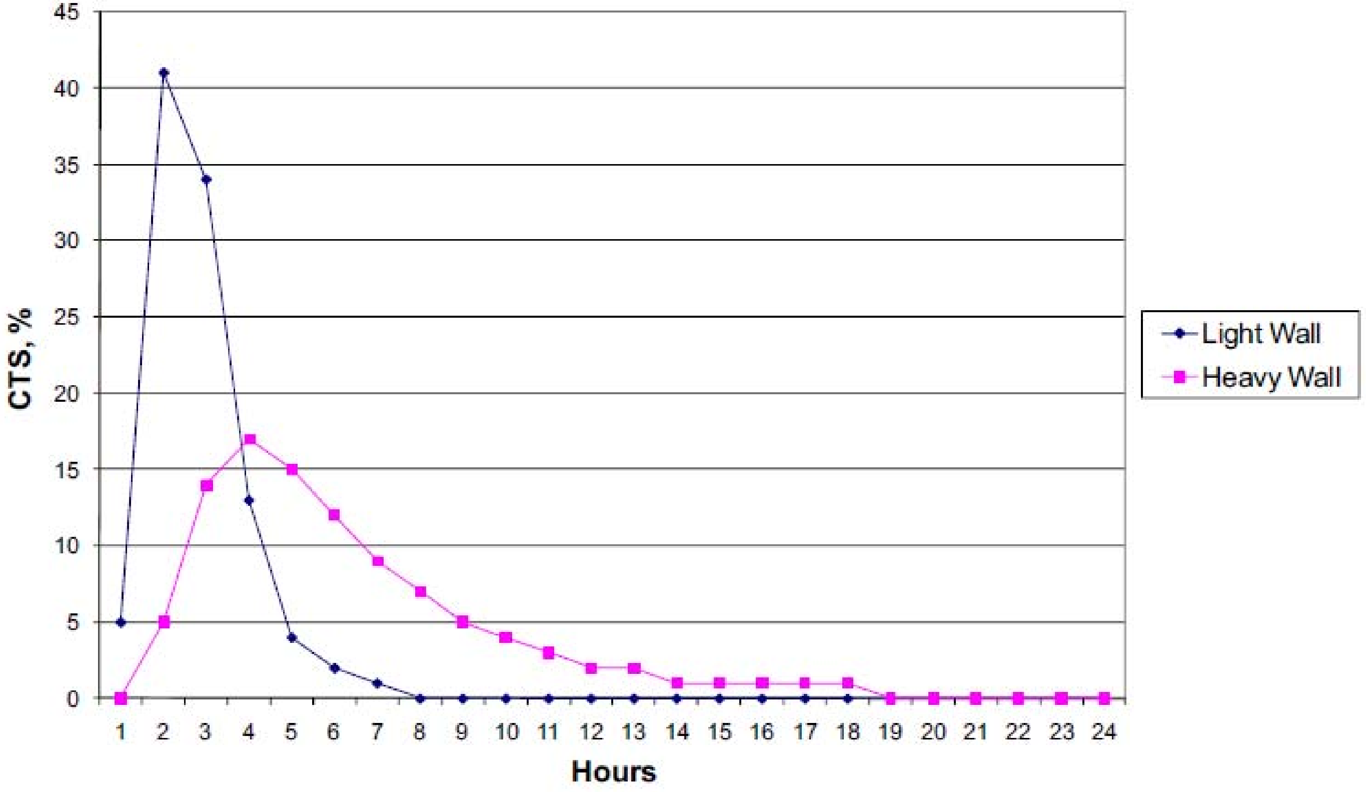
รูปที่ 6: Sol-air temperature ของผนังด้านตะวันตก

Wall CTS

ตารางที่ 1: Wall Conduction Time Series (CTS)

	CURTAIN WALLS			STUD WALLS				EIFS			BRICK WALLS									
Wall Number =	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
U-Factor, W/(m^2.K)	0.428	0.429	0.428	0.419	0.417	0.406	0.413	0.668	0.305	0.524	0.571	0.377	0.283	0.581	0.348	0.628	0.702	0.514	0.581	0.389
Total R	2.3	2.3	2.3	2.4	2.4	2.5	2.4	1.5	3.3	1.9	1.7	2.7	3.5	1.7	2.9	1.6	1.4	1.9	1.7	2.6
Mass, kg/m^2	31.0	20.9	80.0	25.5	84.6	25.6	66.7	36.6	38.3	130.9	214.1	214.7	215.8	290.6	304.0	371.7	391.5	469.3	892.2	665.1
Thermal Capacity, kJ/(m^2.K)	30.7	20.4	67.5	24.5	73.6	32.7	61.3	36.7	38.8	120.6	177.8	177.8	177.8	239.1	253.5	320.9	312.7	388.4	784.9	580.5
Hour	**Wall Conduction Time Series (CTS)**																			
0	18	25	8	19	6	7	5	11	2	1	0	0	0	1	2	2	1	3	4	3
1	58	57	45	59	42	42	41	50	25	2	5	4	1	1	2	2	1	3	4	3
2	20	15	32	18	33	33	34	26	31	6	14	13	7	2	2	2	3	3	4	3
3	4	3	11	3	13	13	13	9	20	9	17	17	12	5	3	4	6	3	4	4
4	0	0	3	1	4	4	4	3	11	9	15	15	13	8	5	5	7	3	4	4
5	0	0	1	0	1	1	2	1	5	9	12	12	13	9	6	6	8	4	4	4
6	0	0	0	0	1	0	1	0	3	8	9	9	11	9	7	6	8	4	4	5
7	0	0	0	0	0	0	0	0	2	7	7	7	9	9	7	7	8	5	4	5
8	0	0	0	0	0	0	0	0	1	6	5	5	7	8	7	7	8	5	4	5
9	0	0	0	0	0	0	0	0	0	6	4	4	6	7	7	6	7	5	4	5
10	0	0	0	0	0	0	0	0	0	5	3	3	5	7	6	6	6	5	4	5
11	0	0	0	0	0	0	0	0	0	5	2	2	4	6	6	6	6	5	5	5
12	0	0	0	0	0	0	0	0	0	4	2	2	3	5	5	5	5	5	5	5
13	0	0	0	0	0	0	0	0	0	4	1	2	2	4	5	5	4	5	5	5
14	0	0	0	0	0	0	0	0	0	3	1	2	2	4	5	5	4	5	5	5
15	0	0	0	0	0	0	0	0	0	3	1	1	1	3	4	4	3	5	4	4
16	0	0	0	0	0	0	0	0	0	3	1	1	1	3	4	4	3	5	4	4
17	0	0	0	0	0	0	0	0	0	2	1	1	1	2	3	4	3	4	4	4
18	0	0	0	0	0	0	0	0	0	2	0	0	1	2	3	3	2	4	4	4
19	0	0	0	0	0	0	0	0	0	2	0	0	1	2	3	3	2	4	4	4
20	0	0	0	0	0	0	0	0	0	2	0	0	0	1	3	3	2	4	4	4
21	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	2	1	4	4	4
22	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	2	1	4	4	3
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	4	3
Total Percentage	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Wall CTS



รูปที่ 1: CTS ของผนังบางกับผนังหนา

U-Value

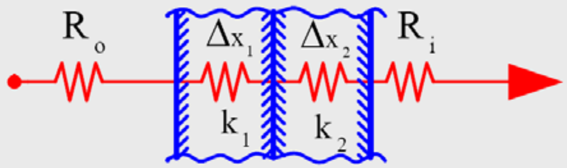
ค่า U

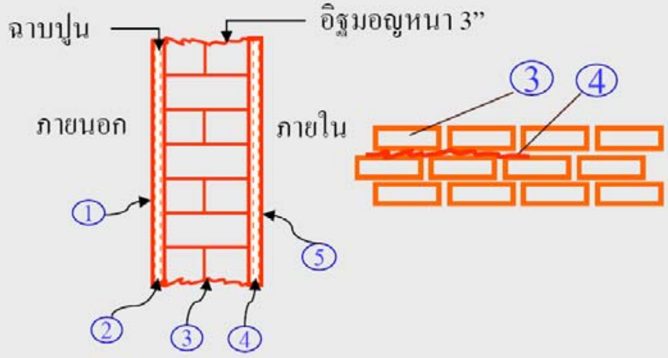
$$U = \frac{1}{R_T} = \frac{1}{\text{ความต้านทานความร้อนรวม}}$$

$$R_T = R_o + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \ldots + R_i$$

Δx = ความหนาของวัสดุ

k_1 = สัมประสิทธิ์การนำความร้อนของวัสดุ





1) OUTSIDE AIR FILM R_1 $= 0.17$

2) ฉาบปูน 0.5" $R_2 = 0.5/5$ $= 0.1$

3) อิฐมอญ 3" $R_3 = 3/5$ $= 0.6$

4) ฉาบปูน 0.5" $R_4 = 0.5/5$ $= 0.1$

5) INSIDE AIR FILM R_5 $= 0.68$

R_T $= 1.65$

$$U = \frac{1}{R_T} = \frac{1}{1.65} = 0.61$$

Film Coefficient of Air

Table 5-12 Surface Conductances and Resistances

(Table 1, Chapter 24, 1997 *ASHRAE Handbook—Fundamentals*)

Position of Surface	Direction of Heat Flow	Surface Emittance, ε: Non-reflective ε = 0.90 h_i	R	Reflective ε = 0.20 h_i	R	Reflective ε = 0.05 h_i	R
STILL AIR							
Horizontal	Upward	1.63	0.61	0.91	1.10	0.76	1.32
Sloping—45°	Upward	1.60	0.62	0.88	1.14	0.73	1.37
Vertical	Horizontal	1.46	0.68	0.74	1.35	0.59	1.70
Sloping—45°	Downward	1.32	0.76	0.60	1.67	0.45	2.22
Horizontal	Downward	1.08	0.92	0.37	2.70	0.22	4.55
MOVING AIR (Any position)		h_o	R				
15-mph Wind (for winter)	Any	6.00	0.17	—	—	—	—
7.5-mph Wind (for summer)	Any	4.00	0.25	—	—	—	—

Air Gap

Table 5-14 Thermal Resistances of Plane Airspaces
(Table 3, Chapter 24, 1997 *ASHRAE Handbook—Fundamentals*)

Position of Air Space	Direction of Heat Flow	Air Space: Mean Temp.[d], °F	Air Space: Temp. Diff.[d], °F	0.5-in. Air Space[c]: Effective Emittance ε_{eff}[d,e] 0.03	0.05	0.2	0.5	0.82	0.75-in. Air Space[c]: Effective Emittance ε_{eff}[d,e] 0.03	0.05	0.2	0.5	0.82
Horiz.	Up ↑	90	10	2.13	2.03	1.51	0.99	0.73	2.34	2.22	1.61	1.04	0.75
		50	30	1.62	1.57	1.29	0.96	0.75	1.71	1.66	1.35	0.99	0.77
		50	10	2.13	2.05	1.60	1.11	0.84	2.30	2.21	1.70	1.16	0.87
		0	20	1.73	1.70	1.45	1.12	0.91	1.83	1.79	1.52	1.16	0.93
		0	10	2.10	2.04	1.70	1.27	1.00	2.23	2.16	1.78	1.31	1.02
		−50	20	1.69	1.66	1.49	1.23	1.04	1.77	1.74	1.55	1.27	1.07
		−50	10	2.04	2.00	1.75	1.40	1.16	2.16	2.11	1.84	1.46	1.20
45° Slope	Up ↗	90	10	2.44	2.31	1.65	1.06	0.76	2.96	2.78	1.88	1.15	0.81
		50	30	2.06	1.98	1.56	1.10	0.83	1.99	1.92	1.52	1.08	0.82
		50	10	2.55	2.44	1.83	1.22	0.90	2.90	2.75	2.00	1.29	0.94
		0	20	2.20	2.14	1.76	1.30	1.02	2.13	2.07	1.72	1.28	1.00
		0	10	2.63	2.54	2.03	1.44	1.10	2.72	2.62	2.08	1.47	1.12
		−50	20	2.08	2.04	1.78	1.42	1.17	2.05	2.01	1.76	1.41	1.16
		−50	10	2.62	2.56	2.17	1.66	1.33	2.53	2.47	2.10	1.62	1.30
Vertical	Horiz. →	90	10	2.47	2.34	1.67	1.06	0.77	3.50	3.24	2.08	1.22	0.84
		50	30	2.57	2.46	1.84	1.23	0.90	2.91	2.77	2.01	1.30	0.94
		50	10	2.66	2.54	1.88	1.24	0.91	3.70	3.46	2.35	1.43	1.01
		0	20	2.82	2.72	2.14	1.50	1.13	3.14	3.02	2.32	1.58	1.18
		0	10	2.93	2.82	2.20	1.53	1.15	3.77	3.59	2.64	1.73	1.26
		−50	20	2.90	2.82	2.35	1.76	1.39	2.90	2.83	2.36	1.77	1.39
		−50	10	3.20	3.10	2.54	1.87	1.46	3.72	3.60	2.87	2.04	1.56
45° Slope	Down ↘	90	10	2.48	2.34	1.67	1.06	0.77	3.53	3.27	2.10	1.22	0.84
		50	30	2.64	2.52	1.87	1.24	0.91	3.43	3.23	2.24	1.39	0.99
		50	10	2.67	2.55	1.89	1.25	0.92	3.81	3.57	2.40	1.45	1.02
		0	20	2.91	2.80	2.19	1.52	1.15	3.75	3.57	2.63	1.72	1.26
		0	10	2.94	2.83	2.21	1.53	1.15	4.12	3.91	2.81	1.80	1.30
		−50	20	3.16	3.07	2.52	1.86	1.45	3.78	3.65	2.90	2.05	1.57
		−50	10	3.26	3.16	2.58	1.89	1.47	4.35	4.18	3.22	2.21	1.66
Horiz.	Down ↓	90	10	2.48	2.34	1.67	1.06	0.77	3.55	3.29	2.10	1.22	0.85
		50	30	2.66	2.54	1.88	1.24	0.91	3.77	3.52	2.38	1.44	1.02
		50	10	2.67	2.55	1.89	1.25	0.92	3.84	3.59	2.41	1.45	1.02
		0	20	2.94	2.83	2.20	1.53	1.15	4.18	3.96	2.83	1.81	1.30
		0	10	2.96	2.85	2.22	1.53	1.16	4.25	4.02	2.87	1.82	1.31
		−50	20	3.25	3.15	2.58	1.89	1.47	4.60	4.41	3.36	2.28	1.69
		−50	10	3.28	3.18	2.60	1.90	1.47	4.71	4.51	3.42	2.30	1.71
		Air Space		1.5-in. Air Space[c]					3.5-in. Air Space[c]				
Horiz.	Up ↑	90	10	2.55	2.41	1.71	1.08	0.77	2.84	2.66	1.83	1.13	0.80
		50	30	1.87	1.81	1.45	1.04	0.80	2.09	2.01	1.58	1.10	0.84
		50	10	2.50	2.40	1.81	1.21	0.89	2.80	2.66	1.95	1.28	0.93
		0	20	2.01	1.95	1.63	1.23	0.97	2.25	2.18	1.79	1.32	1.03
		0	10	2.43	2.35	1.90	1.38	1.06	2.71	2.62	2.07	1.47	1.12
		−50	20	1.94	1.91	1.68	1.36	1.13	2.19	2.14	1.86	1.47	1.20
		−50	10	2.37	2.31	1.99	1.55	1.26	2.65	2.58	2.18	1.67	1.33

K-Value

Table 5-15 Typical Thermal Properties of Common Building and Insulating Materials[a] (*Continued*)
(Table 4, Chapter 24, 1997 *ASHRAE Handbook—Fundamentals*)

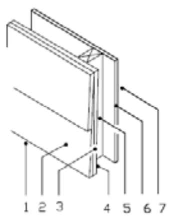
Description	Density, lb/ft³	Conductivity[b] (*k*), Btu·in / h·ft²·°F	Conductance (*C*), Btu / h·ft²·°F	Resistance[c] (*R*): Per Inch Thickness (1/*k*), °F·ft²·h / Btu·in	Resistance[c] (*R*): For Thickness Listed (1/*C*), °F·ft²·h / Btu	Specific Heat, Btu / lb·°F
Expanded polystyrene, extruded (smooth skin surface) (CFC-12 exp.)	1.8-3.5	0.20	—	5.00	—	0.29
Expanded polystyrene, extruded (smooth skin surface) (HCFC-142b exp.)[h]	1.8-3.5	0.20	—	5.00	—	0.29
Expanded polystyrene, molded beads	1.0	0.26	—	3.85	—	—
	1.25	0.25	—	4.00	—	—
	1.5	0.24	—	4.17	—	—
	1.75	0.24	—	4.17	—	—
	2.0	0.23	—	4.35	—	—
Cellular polyurethane/polyisocyanurate[il] (CFC-11 exp.) (unfaced)	1.5	0.16-0.18	—	6.25-5.56	—	0.38
Cellular polyisocyanurate[i] (CFC-11 exp.) (gas-permeable facers)	1.5-2.5	0.16-0.18	—	6.25-5.56	—	0.22
Cellular polyisocyanurate[j] (CFC-11 exp.) (gas-impermeable facers)	2.0	0.14	—	7.04	—	0.22
Cellular phenolic (closed cell) (CFC-11, CFC-113 exp.)[k]	3.0	0.12	—	8.20	—	—
Cellular phenolic (open cell)	1.8-2.2	0.23	—	4.40	—	—
Mineral fiber with resin binder	15.0	0.29	—	3.45	—	0.17
Mineral fiberboard, wet felted						
Core or roof insulation	16-17	0.34	—	2.94	—	—
Acoustical tile	18.0	0.35	—	2.86	—	0.19
Acoustical tile	21.0	0.37	—	2.70	—	—
Mineral fiberboard, wet molded						
Acoustical tile[l]	23.0	0.42	—	2.38	—	0.14
Wood or cane fiberboard						
Acoustical tile[l] 0.5 in.	—	—	0.80	—	1.25	0.31
Acoustical tile[l] 0.75 in.	—	—	0.53	—	1.89	—

U-Value

Table 3.2A Coefficients of Transmission (U) and Heat Capacities of Frame Walls

There U-coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph. The Heat Capacity Units are Btu/ft^2.F.

Replace Air Space with 3.5-in. R-11 Blanket Insulation (New Item 4)



Construction	1 Resistance (R) Between Framing	1 Resistance (R) At Framing	2 Resistance (R) Between Framing	2 Resistance (R) At Framing	1 Heat Capacity Between Framing	2 Heat Capacity Between Framing
1. Outside surface (15mph wind)	0.17	0.17	0.17	0.17	-	-
2. Siding, wood, 0.5 in. x 8 in. lapped (average)	0.81	0.81	0.81	0.81	0.47	0.47
3. Sheathing, 0.5-in. asphalt impregnated	1.32	1.32	1.32	1.32	0.23	0.23
4. Nonreflective air space, 3.5 in. (50 F mean; 10 deg F temperature difference)	1.01	-	11.00	-	-	.08
5. Nominal 2-in. x 4-in. wood stud	-	4.38	-	4.38	-	-
6. Gypsum wallboard, 0.5 in.	0.45	0.45	0.45	0.45	0.54	0.54
7. Inside surface (still air)	0.68	0.68	0.68	0.68		
Total Thermal Resistance (R) ………………………	R_i =4.44	R_s =7.81	R_i =14.43	R_s =7.81	1.24	1.32

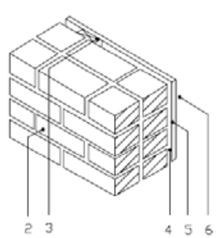
Construction No.1: U_i = 1/4.44 = 0.225; U_s = 1/ 7.81 = 0.128.With 20% framing (typical of 2-in. x 4-in. studs @ 16-in. o.c.), U_{av} = 0.8 (0.225)+ 0.2 (0.128) = 0.206 (See Eq 9)

Construction No.2: U_i = 1/ 14.43 = 0.069; U_s = 0.128. With framing unchanged, U_{av} = 0.8 (0.069) + 0.2 (0.128) = 0.081

Table 3.2B Coefficients of Transmission (U) and Heat Capacities of Solid Masonry Walls

Coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph. The Heat Capacity Units are Btu/ft^2.F.

Replace Furring Strips and Air Space with 1-in. Extruded Polystyrene (New Item 4)



Construction	1 Resistance (R) Between Furring	1 Resistance (R) At Furring	2 Resistance (R)	1 Heat Capacity Between Furring	2 Heat Capacity Between Furring
1. Outside surface (15mph wind)	0.17	0.17	0.17	-	-
2. Common brick, 8 in.	1.60	1.60	1.60	15.2	15.2
3. Nominal 1-in. x 3-in. vertical furring	-	0.94	-	-	-
4. Nonreflective air space, 0.75 in. (50 F mean; 10 deg F temperature difference)	1.01	-	5.00	-	0.05
5. Gypsum wallboard, 0.5 in.	0.45	0.45	0.45	0.54	0.54
6. Inside surface (still air)	0.68	0.68	0.68	-	-
Total Thermal Resistance (R) ………………………..	R_i =3.91	R_s =3.84	R_i =7.90	R_S =15.74	15.79

Construction No.1: U_i = 1/3.91 = 0.256; U_s = 1/ 3.84 = 0.260.With 20% framing (typical of 1-in. x 3-in. vertical furring on masonry @ 16-in. o.c.) U_{av} = 0.8 (0.256)+ 0.2 (0.260) = 0.257

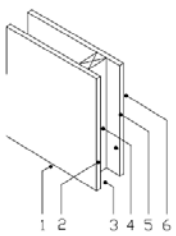
Construction No.2: U_i = U_s = U_{av} = 1/7.90 = 0.127

U-Value

Table 3.2C Coefficients of Transmission (U) and Heat Capacities of Frame Partitions or Interior Walls

Coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based on still air (no wind) condition on both sides. The Heat Capacity Units are Btu/ft^2.F.

Replace Air Space with 3.5-in.R-11 Blanket Insulation (New Item 3)



Construction	Resistance (R) 1		Resistance (R) 2		Heat Capacity 1	Heat Capacity 2
	Between Framing	At Framing	Between Framing	At Framing	Between Framing	
1. Inside surface (still air)	0.68	0.68	0.68	0.68	-	-
2. Gypsum wallboard, 0.5 in.	0.45	0.45	0.45	0.45	0.54	0.54
3. Nonreflective air space, 3.5 in. (50 F mean; 10 deg F temperature difference)	1.01	-	11.00	-	-	0.08
4. Nominal 2-in. x 4-in. wood stud	-	4.38	-	4.38		
5. Gypsum wallboard 0.5 in.	0.45	0.45	0.45	0.45	0.54	0.54
6. Inside surface (still air)	0.68	0.68	0.68	0.68		
Total Thermal Resistance (R)……………………….	R_i =3.27	R_s =6.64	R_i =13.26	R_s =6.64	1.08	1.16

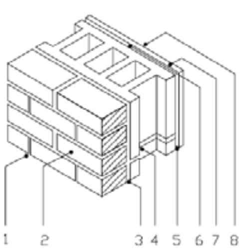
Construction No.1: U_i = 1/3.27 = 0.306; U_s = 1/ 6.64 = 0.151.With 10% framing (typical of 2-in. x 4-in. studs @ 24-in. o.c), U_{av}= 0.9 (0.306) + 0.1 (0.151) = 0.290

Construction No.2: U_i = 1/13.26 = 0.075_4 U_s = 1/ 6.64 = 0.151. With framing unchanged, U_{av} = 0.9 (0.075) + 0.1 (0.151) = 0.083

Table 3.2 D Coefficients of Transmission (U) and Heat Capacities of Masonry Walls

Coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph. The Heat Capacity Units are Btu/ft^2.F.

Replace Cinder Aggregate Block with 6-in. Light-weight Aggregate Block with Cores Filled (New Item 4)



Construction	Resistance (R) 1		Resistance (R) 2		Heat Capacity 1	Heat Capacity 2
	Between Furring	At Furring	Between Furring	At Furring	Between Furring	
1. Outside surface (15mph wind)	0.17	0.17	0.17	0.17	-	-
2. Face brick, 4 in.	0.44	0.44	0.44	0.44	8.23	8.23
3. Cement mortar, 0.5 in	0.10	0.10	0.10	0.10	0.97	0.97
4. Concrete block, cinder aggregate, 8 in.	1.72	1.72	2.99	2.99	7.90	7.90
5. Reflective air space, 0.75 in. (50 F mean; 30 deg F temperature difference)	2.77	-	2.77	-		
6. Nominal 1-in. x 3-in. vertical furring	-	0.94	-	0.94		
7. Gypsum wallboard, 0.5 in., foil backed	0.45	0.45	0.45	0.45	0.54	0.54
8. Inside surface (still air)	0.68	0.68	0.68	0.68		
Total Thermal Resistance (R)……………………….	R_i =6.33	R_s =4.50	R_i =7.60	R_s =5.77	17.64	17.64

Construction No.1: U_i = 1/6.33 = 0.158; U_s = 1/ 4.50 = 0.222.With 20% framing (typical of 1-in. x 3-in. vertical furring on masonry @ 16-in.o.c), U_{av} = 0.8 (0.158)+ 0.2 (0.222) = 0.171

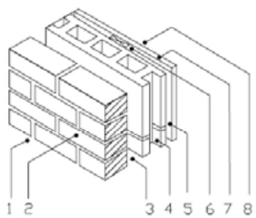
Construction No.2: U_i = 1/7.60 = 0.132_4 U_s = 1/ 5.77 = 0.173. With 20% framing unchanged, U_{av} = 0.8 (0.132) + 0.2 (0.173) = 1.40

U-Value

Table 3.2E Coefficients of Transmission (U) and Heat Capacities of Masonry Cavity Walls

Coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based on an outside wind velocity of 15 mph. The Heat Capacity Units are Btu/ft^2.F.

Replace Furring Strips and Gypsum Wallboard with 0.625-in. Plaster (Sand Aggregate) Applied Directly to Concrete Block-Fill 2.5-in. Air Space with Vermiculite Insulation (New Items 3 and 7.)



Construction	Resistance (R) 1 Between Furring	Resistance (R) 1 At Furring	Resistance (R) 2	Heat Capacity 1 Between Furring	Heat Capacity 2 Between Furring
1. Outside surface (15 mph wind)	0.17	0.17	0.17	-	-
2. Common brick, 8 in.	0.80	0.80	0.80	15.2	15.2
3. Nonreflective air space, 2.5 in. (30 F mean; 10 deg F temperature difference)	1.10*	1.10*	5.32*	-	0.32
4. Concrete block, stone aggregate, 4 in.	0.71	0.71	0.71	5.1	5.1
5. Nonreflective air space, 0.75 in. (50 F mean; 10 deg F temperature difference)	1.01	-	-		
6. Nominal 1-in. x 3-in. vertical furring	-	0.94	-		
7. Gypsum wallboard, 0.5 in.	0.45	0.45	0.11	0.54	1.09
8. Inside surface (still air)	0.68	0.68	0.68	-	-
Total Thermal Resistance (R)	R_i =4.92	R_s =4.85	$R_i = R_S$ =7.79	20.8	21.7

Construction No.1: $U_i = 1/4.92 = 0.203$; $U_s = 1/4.85 = 0.206$. With 20% framing (typical of 1-in. x 3-in. vertical furring on masonry @ 16-in. o.c.) $U_{av} = 0.8\,(0.203) + 0.2\,(0.206) = 0.204$

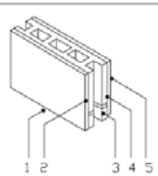
Construction No.2: $U_i = U_s = U_{av} = 1/7.9 = 0.128$

* Interpolated value from Table 3.4

** Calculated value from Table 3.1.

Table 3.2F Coefficients of Transmission (U) and Heat Capacities of Masonry Partitions

Coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based on still air (no wind) condition on both sides. The Heat Capacity Units are Btu/ft^2.F.

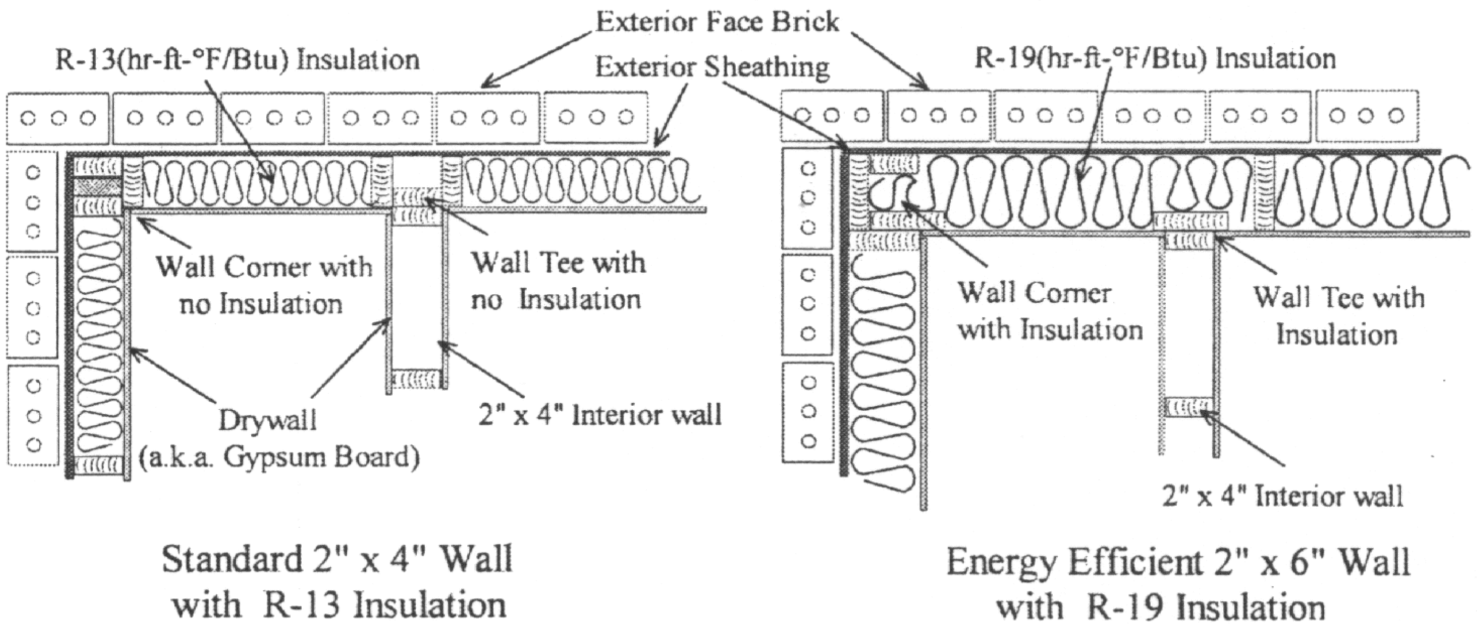


Replace Concrete Block with 4-in. Gypsum Tile (New Item 3) Construction	Resistance (R) 1	Resistance (R) 2	Heat Capacity 1	Heat Capacity 2
1. Inside surface (still air)	0.68	0.68	-	-
2. Plaster, lightweight aggregate, 0.625 in.	0.39	0.39	0.47	0.47
3. Concrete block, cinder aggregate, 4 in.	1.11	1.67	4.20	2.47
4. Plaster, lightweight aggregate, 0.625 in.	0.39	0.39	0.47	0.47
5. Inside surface (still air)	0.68	0.68	-	-
Total Thermal Resistance (R).................................	3.25	3.81	5.14	3.41

Construction No.1: $U_i = 1/3.25 = 0.308$

Construction No.2: $U_i = 1/3.81 = 0.262$

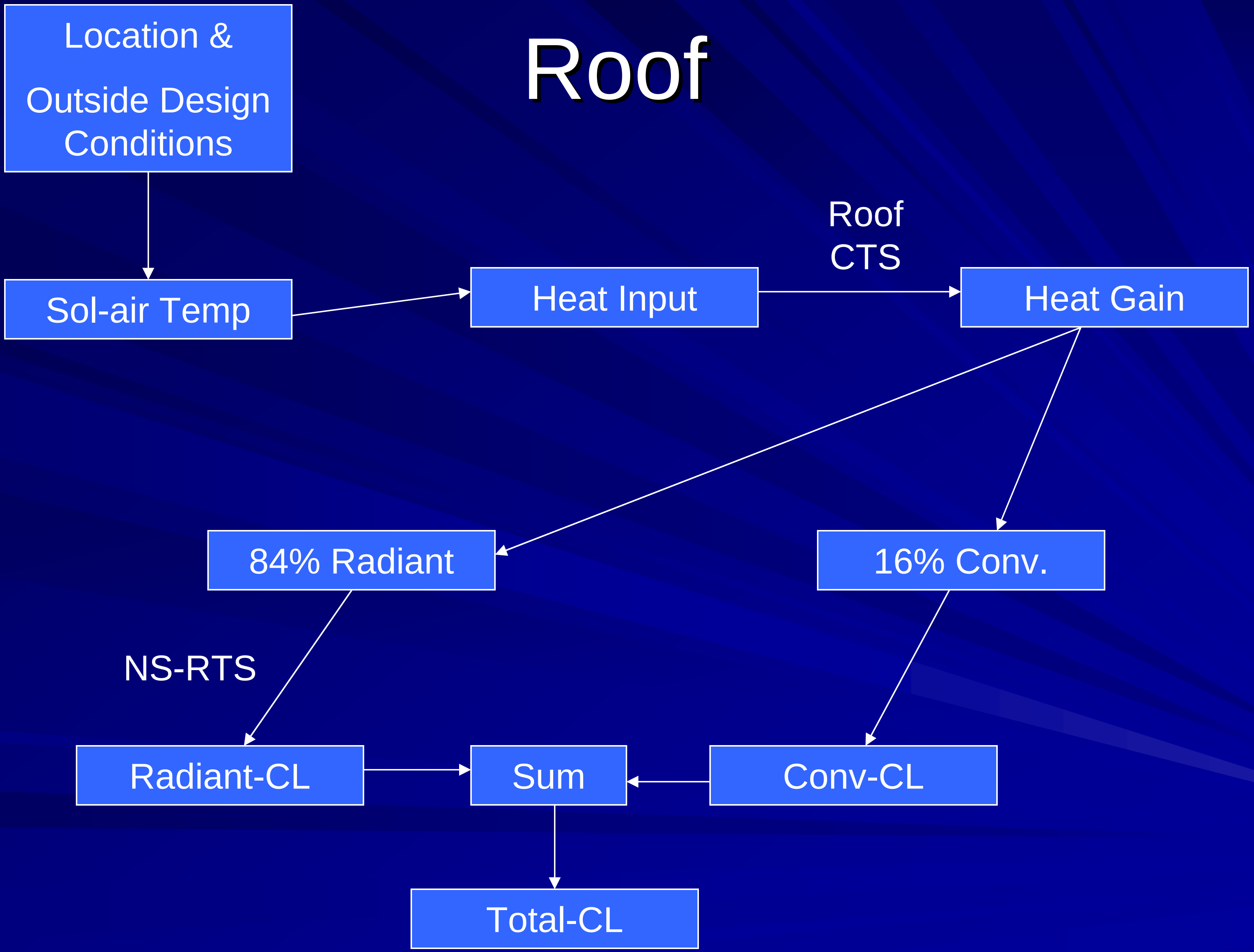
Energy Efficient Wall



Plan view of standard and energy-efficient wood-frame wall construction.

Roof Heat Gain

Roof



Location &
Outside Design Conditions
Sol-air Temp
Heat Input
Roof CTS
Heat Gain
84% Radiant
16% Conv.
NS-RTS
Radiant-CL
Sum
Conv-CL
Total-CL

Roof CTS

ตารางที่ 3: Roof Conduction Time Series (CTS)

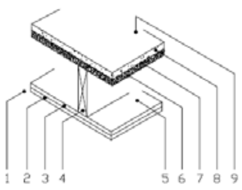
	SLOPED FRAME ROOFS						WOOD DECK		METAL DECK ROOFS					CONCRETE ROOFS					
Roof Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
U-Factor, W/(m^2.K)	0.249	0.227	0.255	0.235	0.239	0.231	0.393	0.329	0.452	0.370	0.323	0.206	0.297	0.304	0.296	0.288	0.315	0.313	0.239
Total R	4.0	4.4	3.9	4.2	4.2	4.3	2.5	3.0	2.2	2.7	3.1	4.9	3.4	3.3	3.4	3.5	3.2	3.2	4.2
Mass, kg/m^2	26.7	21.0	14.0	34.7	55.5	34.9	48.9	55.9	23.9	30.9	25.0	27.2	57.6	149.2	214.3	279.3	360.7	474.5	362.3
Thermal Capacity, kJ/(m^2.K)	26.6	16.4	12.3	47.0	73.5	47.0	75.6	79.7	28.6	32.7	28.6	32.7	57.2	134.9	190.1	245.2	333.2	437.4	331.1
Hour	**Roof Conduction Time Series(CTS)**																		
0	6	10	27	1	1	1	0	1	18	4	8	1	0	1	2	2	2	3	1
1	45	57	62	17	17	12	7	3	61	41	53	23	10	2	2	2	2	3	2
2	33	27	10	31	34	25	18	8	18	35	30	38	22	8	3	3	5	3	6
3	11	5	1	24	25	22	18	10	3	14	7	22	20	11	6	4	6	5	8
4	3	1	0	14	13	15	15	10	0	4	2	10	14	11	7	5	7	6	8
5	1	0	0	7	6	10	11	9	0	1	0	4	10	10	8	6	7	6	8
6	1	0		4	3	6	8	8	0	1	0	2	7	9	8	6	6	6	7
7	0	0	0	2	1	4	6	7	0	0	0	0	5	7	7	6	6	6	7
8	0	0	0	0	0	2	5	6	0	0	0	0	4	6	7	6	6	6	6
9	0	0	0	0	0	1	3	5	0	0	0	0	3	5	6	6	5	5	5
10	0	0	0	0	0	1	3	5	0	0	0	0	2	5	5	6	5	5	5
11	0	0	0	0	0	1	2	4	0	0	0	0	1	4	5	5	5	5	5
12	0	0	0	0	0	0	1	4	0	0	0	0	1	3	5	5	4	5	4
13	0	0	0	0	0	0	1	3	0	0	0	0	1	3	4	5	4	4	4
14	0	0	0	0	0	0	1	3	0	0	0	0	0	3	4	4	4	4	3
15	0	0	0	0	0	0	1	3	0	0	0	0	0	2	3	4	4	4	3
16	0	0	0	0	0	0	0	2	0	0	0	0	0	2	3	4	3	4	3
17	0	0	0	0	0	0	0	2	0	0	0	0	0	2	3	4	3	4	3
18	0	0	0	0	0	0	0	2	0	0	0	0	0	1	3	3	3	3	2
19	0	0	0	0	0	0	0	2	0	0	0	0	0	1	2	3	3	3	2
20	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2	3	3	3	2
21	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2	3	3	3	2
22	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2	3	2	2	2
23	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2	2
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

U-Value

Table 3.2I Coefficients of Transmission (U) and Heat Capacities of Wood Construction Flat Roofs and Ceilings (Winter Conditions, Upward Flow)

Coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based upon outside wind velocity of 15 mph. The Heat Capacity Units are Btu/ft^2.F.

Replace Roof Deck Insulation and 7.25-in. Air Space with 6-in. R-19 Blanket Insulation and 1.25-in. Air Space (New Items 5 and 7)



Construction (Heat Flow up)	1 Resistance (R) Between Joists	1 Resistance (R) At Joists	2 Resistance (R) Between Joists	2 Resistance (R) At Joists	1 Heat Capacity Between Joists	2 Heat Capacity Between Joists
1. Inside surface (Still Air)	0.61	0.61	0.61	0.61	-	-
2. Acoustical tile, fiberboard, glued, 0.5 in.	1.25	1.25	1.25	1.25	0.31	0.31
3. Gypsum wallboard, 0.5 in	0.45	0.45	0.45	0.45	0.54	0.54
4. Nominal 2-in. x 8-in. ceiling joists	-	9.06	-	9.06	-	-
5. Non reflective air space, 7.25 in. (50 F mean;10deg F temperature difference)	0.93*	-	1.05**	-	-	0.14
6. Plywood deck, 0.625 in.	0.78	0.78	0.78	0.78	0.51	0.51
7. Rigid roof deck insulation, C= 0.72, (R = 1/C)	1.39	1.39	19.00	-	-	NA
8. Built-up roof	0.33	0.33	0.33	0.33	0.77	0.77
9. Outside surface (15 mph wind)	0.17	0.17	0.17	0.17	-	-
Total Thermal Resistance (R)…………	R_i =5.91	R_s =14.04	R_i =23.64	R_s =12.65	2.13	2.27+

Construction No.1: $U_i = 1/5.91 = 0.169$; $U_s = 1/ 14.04 = 0.071$.With 10% framing (typical of 2-in. joists @ 16-in.o.c.), $U_{av} = 0.9 (0.169) + 0.1 (0.071) = 0.159$

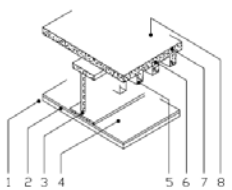
Construction No.2: $U_i = 1/ 23.64 = 0.042$; $U_s =1/12.65 = 0.079$ With framing unchanged, $U_{av} = 0.9 (0.042) + 0.1 (0.079) = 0.046$

* Use largest air space (3.5 in.) value shown in Table 3.4

Table 3.2J Coefficients of Transmission (U) and Heat Capacities of Metal Construction Flat Roofs and Ceilings (Winter Conditions, Upward Flow)

Coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based on upon an outside wind velocity of 15 mph. The Heat Capacity Units are Btu/ft^2.F.

Replace Rigid Roof Dick Insulation (C = 0.24) and Sand Aggregate Plaster with Rigid Roof Deck In Sulation, C = 0.36 and Lightweight Aggregate Plaster (New Item 2 and 6)



Construction (Heat Flow Up)	1 Resistance (R)	2 Resistance (R)	1 Heat Capacity	2 Heat Capacity
1. Inside surface (still air)	0.61	0.61	-	-
2. Metal lath and lightweight aggregate plaster, 0.75 in.	0.13	0.47	1.31	0.56
3. Structural beam	0.00*	0.00*	-	-
4. Nonreflective air space (50 F mean; 10 deg F temperature difference)	0.93**	0.93**	-	-
5. Metal deck	0.00*	0.00*	0.24	0.24
6. Rigid roof deck insulation, C = 0.24 (R=1/C)	4.17	2.78	NA	NA
7. Built-up roofing, 0.375 in.	0.33	0.33	0.77	0.77
8. Outside surface (15 mph wind)	0.17	0.17	-	-
Total Thermal Resistance (R) …………………………	6.34	5.29	2.32	1.57

Construction No.1: $U_i = 1/6.34 = 0.158$

Construction No.2: $U_i = 1/5.29 = 0.189$

* If structural beams and metal deck are to be considered, the technique shown in Example A3.1 may be used to estimate total R. Full scale testing of a suitable portion of the construction is, however, preferable.

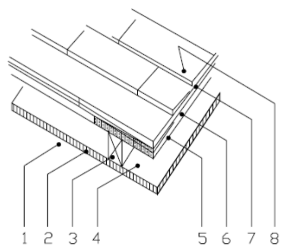
** Use largest air space (3.5 in.) value shown in Table 3.4.

U-Value

Table 3.2K Coefficients of Transmission (U) and Heat Capacities of Pitched Roofs [a]

Coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based on outside wind velocity of 15 mph for heat flow upward and 7.5 mph for heat flow downward. The Heat Capacity Units are Btu/ft^2.F.

Find U_{av} for same Construction 2 with Heat Flow Down (Summer Conditions)



Construction 1 (Heat Flow up) (Reflective Air Space)	Resistance (R) 1 Between Rafters	Resistance (R) 1 At Rafters	Resistance (R) 2 Between Rafters	Resistance (R) 2 At Rafters	Heat Capacity 1 Between Rafters	Heat Capacity 2 Between Rafters
1. Inside surface (Still Air)	0.62	0.62	0.76	0.76	-	-
2. Gypsum wallboard, 0.5 in, foil backed	0.45	0.45	0.45	0.45	0.54	0.54
3. Nominal 2-in. x 4-in. ceiling rafter	-	4.38	-	4.38	-	-
4. 45 deg slope reflective air space, 3.5 in. (50 F mean, 30 deg F temperature difference)	2.17	-	4.33	-	-	-
5. Plywood sheathing, 0.625 in.	0.78	0.78	0.78	0.78	0.51	0.51
6. Felt building membrane	0.06	0.06	0.06	0.06	Neg	Neg
7. Asphalt shingle roofing	0.44	0.44	0.44	0.44	0.33	0.33
8. Outside surface (15 mph wind)	0.17	0.17	0.25**	0.25**	-	-
Total Thermal Resistance (R)………………………..	R_i =4.69	R_s =6.90	R_i =7.07	R_s =7.12	1.38	1.38

Construction No.1: U_i = 1/4.69 = 0.213; U_s = 1/ 6.90 = 0145.With 10% framing (typical of 2-in. joists @ 16-in.o.c.), U_{av} = 0.9 (0.213) + 0.1 (0.145) = 0.206

Construction No.2: U_i = 1/ 7.07 = 0.141; U_s =1/7.12 = 0.140 With framing unchanged, U_{av} = 0.9 (0.141) + 0.1 (0.140) = 0.141

Find U_{av} for same Construction 2 with Heat Flow Down (Summer Conditions)

Construction 2 (Heat Flow up) (Non-Reflective Air Space)	Resistance (R) 3 Between Rafters	Resistance (R) 3 At Rafters	Resistance (R) 4 Between Rafters	Resistance (R) 4 At Rafters	Heat Capacity 3 Between Rafters	Heat Capacity 4 Between Rafters
1. Inside surface (Still Air)	0.62	0.62	0.76	0.76	-	-
2. Gypsum wallboard, 0.5 in, foil backed	0.45	0.45	0.45	0.45	0.54	0.54
3. Nominal 2-in. x 4-in. ceiling rafter	-	4.38	-	4.38	-	-
4. 45 deg slope reflective air space, 3.5 in. (50 F mean, 30 deg F temperature difference)	0.96	-	0.90*	-	-	-
5. Plywood sheathing, 0.625 in.	0.78	0.78	0.78	0.78	0.51	0.51
6. Felt building membrane	0.06	0.06	0.06	0.06	Neg	Neg
7. Asphalt shingle roofing	0.44	0.44	0.44	0.44	0.33	0.33
8. Outside surface (15 mph wind)	0.17	0.17	0.25**	0.25**	-	-
Total Thermal Resistance (R)………………………	R_i =3.48	R_s =6.90	R_i =3.64	R_s =7.12	1.38	1.38

Construction No.1: U_i = 1/3.48 = 0.287; U_s = 1/ 6.90 = 0.145.With 10% framing (typical of 2-in. joists @ 16-in.o.c.), U_{av} = 0.9 (0.287) + 0.1 (0.145) = 0.273

Construction No.2: U_i = 1/3.64 = 0.275; U_s =1/7.12 = 0.140 With framing unchanged, U_{av} = 0.9 (0.275) + 0.1 (0.140) = 0.262

Pitch of roof-45 deg.

*Air space value at 90 F mean, 10 deg F temperature difference.

** 7.5 – mph wind.

R-Value of Attics

Table 5 Effective Thermal Resistance of Ventilated Attics[a] (Summer Condition)

Ventilation Air Temperature, °F	Sol-Air[f] Temperature, °F	No Ventilation[b]		Natural Ventilation		Power Ventilation[c]					
		Ventilation Rate, cfm/ft²									
		0		0.1[d]		0.5		1.0		1.5	
		Ceiling Resistance R^e, ft²·°F·h/Btu									
		10	20	10	20	10	20	10	20	10	20
NONREFLECTIVE SURFACES											
80	120	1.9	1.9	2.8	3.4	6.3	9.3	9.6	16	11	20
	140	1.9	1.9	2.8	3.5	6.5	10	9.8	17	12	21
	160	1.9	1.9	2.8	3.6	6.7	11	10	18	13	22
90	120	1.9	1.9	2.5	2.8	4.6	6.7	6.1	10	6.9	13
	140	1.9	1.9	2.6	3.1	5.2	7.9	7.6	12	8.6	15
	160	1.9	1.9	2.7	3.4	5.8	9.0	8.5	14	10	17
100	120	1.9	1.9	2.2	2.3	3.3	4.4	4.0	6.0	4.1	6.9
	140	1.9	1.9	2.4	2.7	4.2	6.1	5.8	8.7	6.5	10
	160	1.9	1.9	2.6	3.2	5.0	7.6	7.2	11	8.3	13
REFLECTIVE SURFACES[g]											
80	120	6.5	6.5	8.1	8.8	13	17	17	25	19	30
	140	6.5	6.5	8.2	9.0	14	18	18	26	20	31
	160	6.5	6.5	8.3	9.2	15	18	19	27	21	32
90	120	6.5	6.5	7.5	8.0	10	13	12	17	13	19
	140	6.5	6.5	7.7	8.3	12	15	14	20	16	22
	160	6.5	6.5	7.9	8.6	13	16	16	22	18	25
100	120	6.5	6.5	7.0	7.4	8.0	10	8.5	12	8.8	12
	140	6.5	6.5	7.3	7.8	10	12	11	15	12	16
	160	6.5	6.5	7.6	8.2	11	14	13	18	15	20

[a]Although the term effective resistance is commonly used when there is attic ventilation, this table includes values for situations with no ventilation. The effective resistance of the attic added to the resistance ($1/U$) of the ceiling yields the effective resistance of this combination based on sol-air (see Chapter 29) and room temperatures. These values apply to wood frame construction with a roof deck and roofing that has a conductance of 1.0 Btu/h·ft²·°F.

[b]This condition cannot be achieved in the field unless extreme measures are taken to tightly seal the attic.

[c]Based on air discharging outward from attic.

[d]When attic ventilation meets the requirements stated in Chapter 26, 0.1 cfm/ft² is assumed as the natural summer ventilation rate.

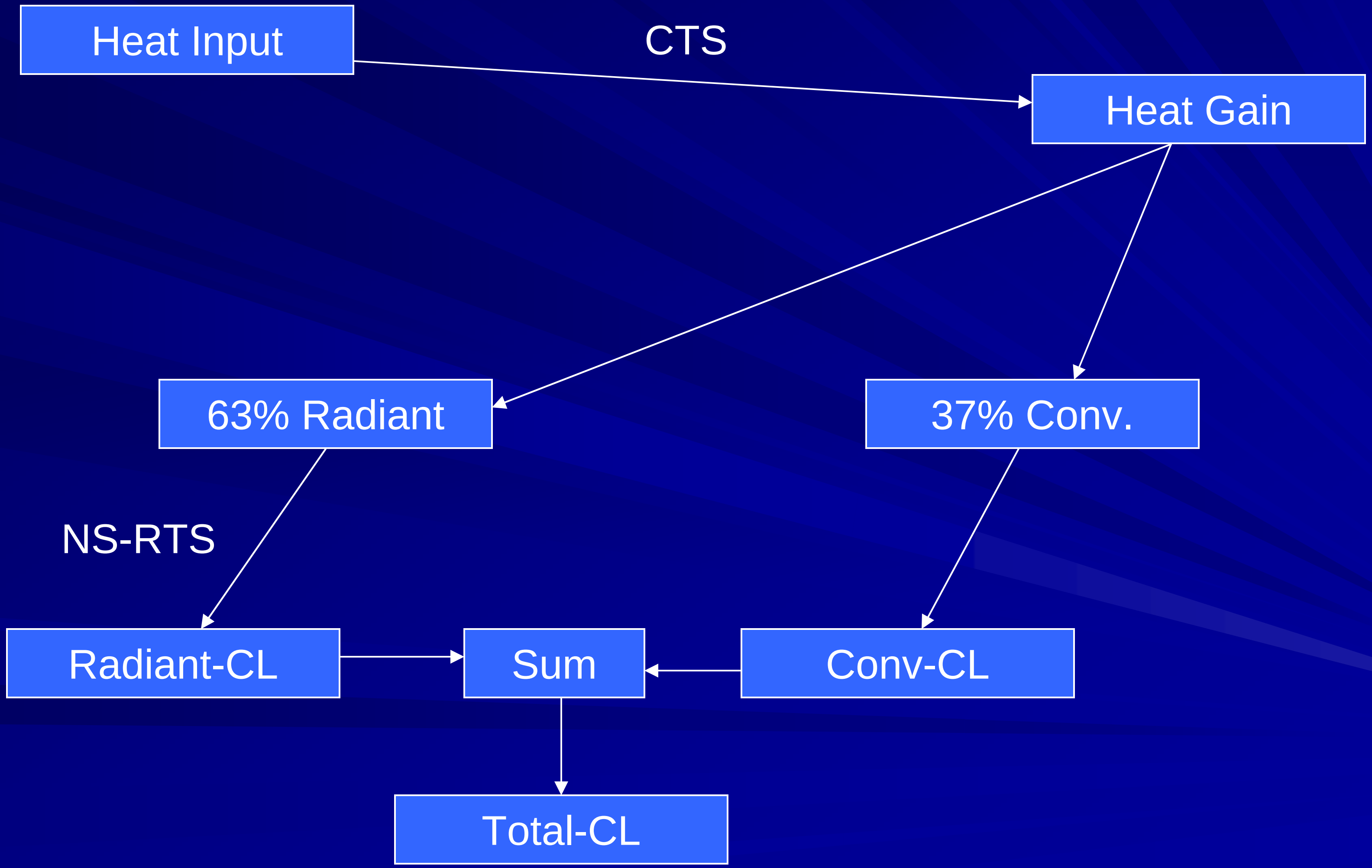
[e]When determining ceiling resistance, do not add the effect of a reflective surface facing the attic, as it is accounted for in the Reflective Surfaces part of the table.

[f]Roof surface temperature rather than sol-air temperature (see Chapter 29) can be used if 0.25 is subtracted from the attic resistance shown.

[g]Surfaces with effective emittance $\varepsilon_{eff} = 0.05$ between ceiling joists facing attic space.

Partition/Floor/Ceiling Heat Gain

Ceiling/Floor/Partition



Partition/Ceiling/Floor

Cooling load from partitions, ceilings, floors

$$q = UA(t_o - t_{rc})$$

U = design heat transfer coefficient for partition, ceiling, or floor, from Chapter 5

A = area of partition, ceiling, or floor, calculated from building plans

t_b = temperature in adjacent space

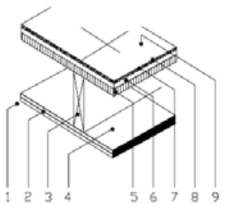
t_{rc} = inside design temperature (constant) in conditioned space

U-Value

Table 3.2G Coefficients of Transmission (U) and Heat Capacities of Frame Construction Ceilings and Floors

Coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based on still air (no wind) on both sides The Heat Capacity Units are Btu/ft^2.F.

Assume Unheated Attic Space above Heated Room with Heat Flow Up-Remove Tile, Felt, Plywoood, Sub-floor and Air Space Replace with T-19 Blanket Insulation (New Item 4)



Heated Room Below	1		2		1	2
Unheated Space	Resistance (R)				Heat Capacity	
Construction (Heat Flow up)	Between Floor Joists	At Floor Joists	Between Floor Joists	At Floor Joists	Between Floor Joists	
1. Botton surface (Still Air)	0.61	0.61	0.61	0.61	-	-
2. Metal lath and ligh weight aggregate, plaster, 0.75 in.	0.47	0.47	0.47	0.47	0.57	0.57
3. Nominal 2-in. x 8-in. floor joists	-	9.06	-	9.06	-	-
4. Nonreflective air space, 7.25 in.	0.93*	-	19.00	-	-	0.14
5. Wood Subfloor, 0.75 in.	0.94	0.94	-	-	0.60	-
6. Plywood, 0.625 in.	0.78	0.78	-	-	0.51	-
7. Felt building membrane	0.06	0.06	-	-	-	-
8. Resilient tile	0.05	0.05	-	-	0.34	-
9. Top surface (still air)	0.61	0.61	0.61	0.61	-	-
Total Thermal Resistance (R)…………	R_i =4.45	R_s =12.58	R_i =20.69	R_s =10.75	20.02	0.71

Construction No.1: U_i = 1/4.45 = 0.225; U_s = 1/ 12.58 = 0.079.With 10% framing (typical of 2-in. joists @ 16-in.o.c.), U_{av} = 0.9 (0.225)+ 0.1 (0.079) = 0.210

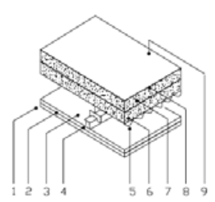
Construction No.2: U_i = 1/ 20.69 = 0.048; U_s =1/10.75 = 0.093 With framing unchanged, U_{av} = 0.9 (0.048) + 0.1 (0.093) = 0.053

* Use largest air space (3.5 in.) value shown in Table 3.4

Table 3.2H Coefficients of Transmission (U) and Heat Capacities of Flat Masonry Roofs with Built-up Roofing, with and without Suspended Ceilings (Winter Conditions, Upward Flow)

Coefficients are expressed in Btu per (hour) (square foot) (degree Fahrenheit difference in temperature between the air on the two sides), and are based upon an outside wind velocity of 15 mph. The Heat Capacity Units are Btu/ft^2.F.

Add Rigid Roof Deck Insulation, C = 0.24 (R=1/C) (New Item 7)



Construction (Heat Flow Up)	1	2	1	2
	Resistance (R)		Heat Capacity	
1. Inside surface (still air)	0.61	0.61	-	-
2. Metal lath and lightweight aggregate plaster, 0.75 in.	0.47	0.47	-	-
3. Non reflective air space, greater than 3.5 in. (50 F mean; 10 deg F temperature difference)	0.93*	0.93*	0.57	0.57
4. Metal ceiling suspension system with metal hanger rods	0**	0**	-	-
5. Corrugated metal deck	0	0	0.24	0.24
6. Concrete slab, lightweight aggregate, 2 in.	2.22	2.22	1.00	1.00
7. Rigid roof deck insulation (none)	-	4.17	-	NA
8. Built-up roofing, 0.375 in.	0.33	0.33	0.77	0.77
9. Outside surface (15 mph wind)	0.17	0.17	-	-
Total Thermal Resistance (R) ……………………………..	4.73	8.90	2.58	2.58+

Construction No.1: U_i = 1/4.73 = 0.211

Construction No.2: U_i = 1/8.90 = 0.112

* Use largest air space (3.5 in.) value shown in Table 3.4

** Area of hanger rods is negligible in relation to ceiling area.

Temperature for Adjacent Uncond-Room

$$t_u = [\, t_i(A_1U_1 + A_2U_2 + \ldots + \text{etc.}) + t_o(KV_o + A_aU_a + A_bU_b + \ldots + \text{etc.})] \div ([\,(A_1U_1 + A_2U_2 + \ldots + \text{etc.})) + (KV_o + A_aU_a + A_bU_b + \ldots + \text{etc.})] \quad (4\text{-}6)$$

where

t_u = temperature in unheated space, °F (°C)

t_i = indoor design temperature of heated room, °F (°C)

t_o = outdoor design temperature, °F (°C)

A_1, A_2, etc. = areas of surface of unheated space adjacent to heated space, ft^2 (m^2)

A_a, A_b, etc. = areas of surface of unheated space exposed to outdoors, ft^2 (m^2)

U_1, U_2, etc. = heat transfer coefficients of surfaces of A_1, A_2, etc., Btu/h· ft^2·°F (W/(m^2· °C))

U_a, U_b, etc = heat transfer coefficients of surfaces of A_a, A_b, etc. Btu/h· ft^2· °F (W/(m^2· °C))

V_o = rate of introduction of outside air into the unheated space by infiltration and/or ventilation, cfm (L/s)

K = 1.10 (1200)

Temperature for Adjacent Uncond-Room

Reasonable accuracy for ordinary unconditioned spaces may be attained if the following approximations for adjacent rooms are used:

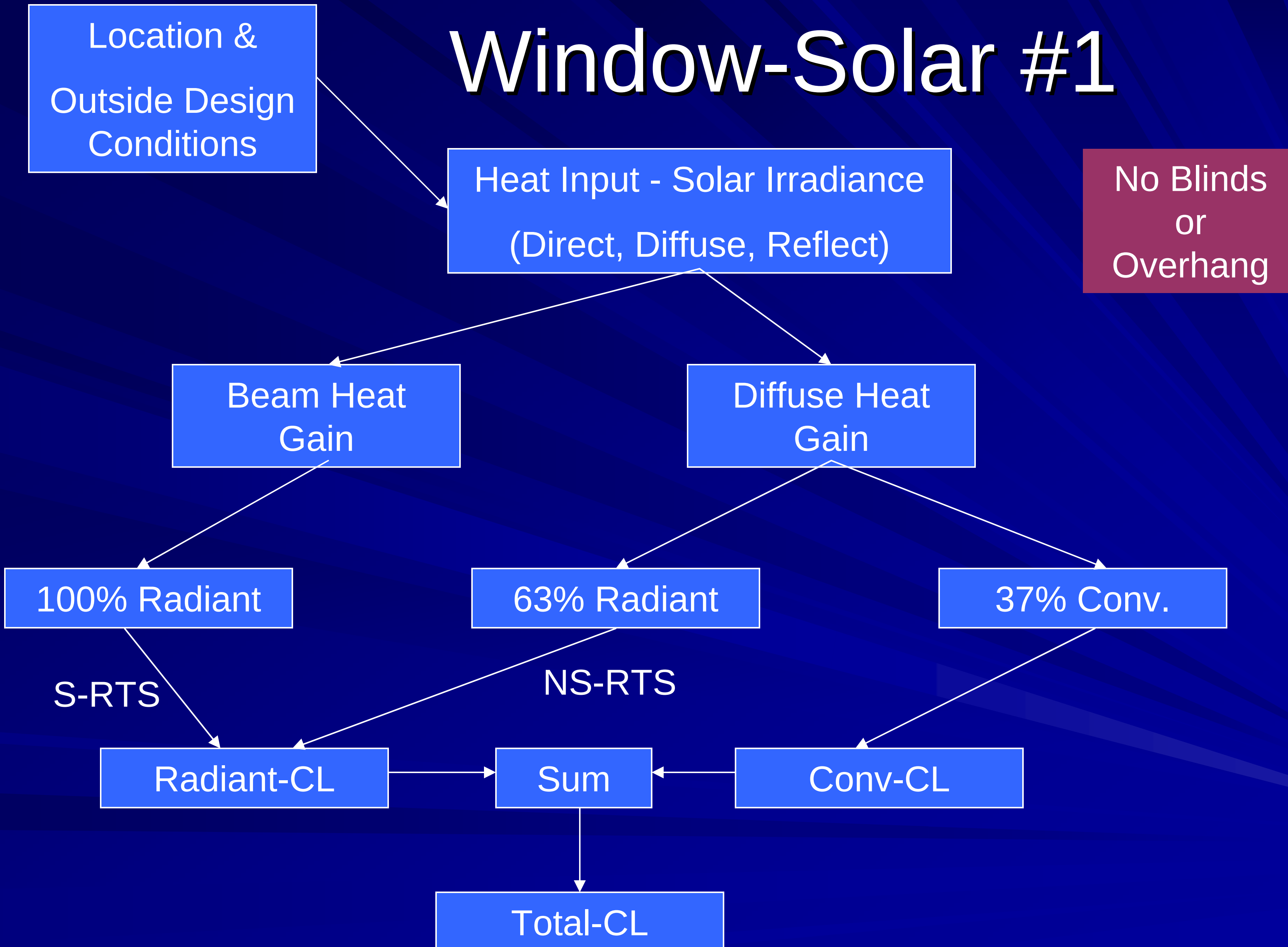
1. Cooling with adjacent unconditioned room. Select for computation a temperature equal to $t_i + 0.667(t_o - t_i)$ in the unconditioned space.
2. Heating with adjacent room unheated. Select for computation a temperature equal to $t_i - 0.50(t_i - t_o)$ in the unconditioned space.

WINDOW HEAT GAIN

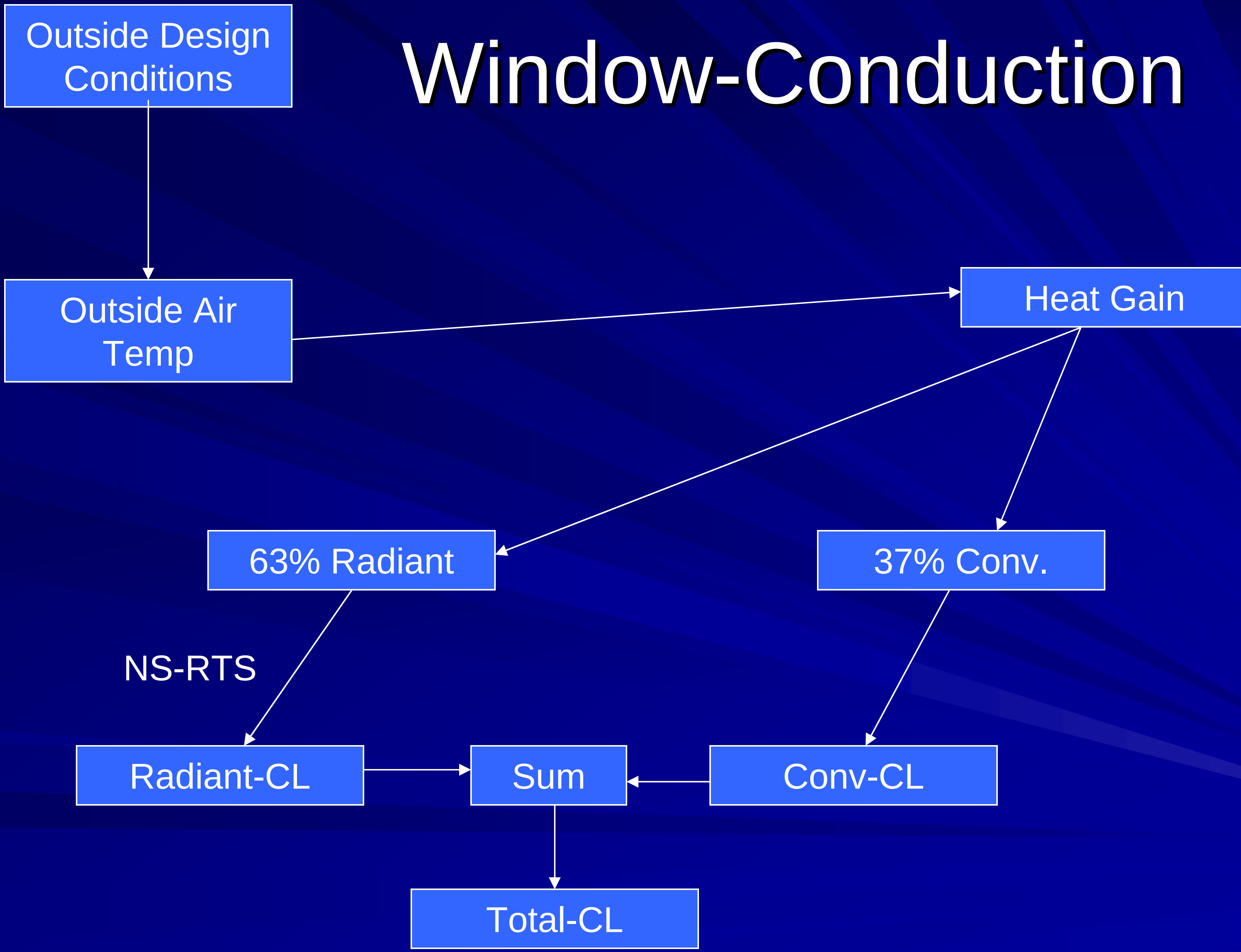
1) Window Conduction Heat Gain

2) Window Solar Heat Gain

Window-Solar #1



Window-Conduction



W-Window Heat Gain

ตารางที่ 12: Window Component of Heat Gain (No Blinds or Overhang)

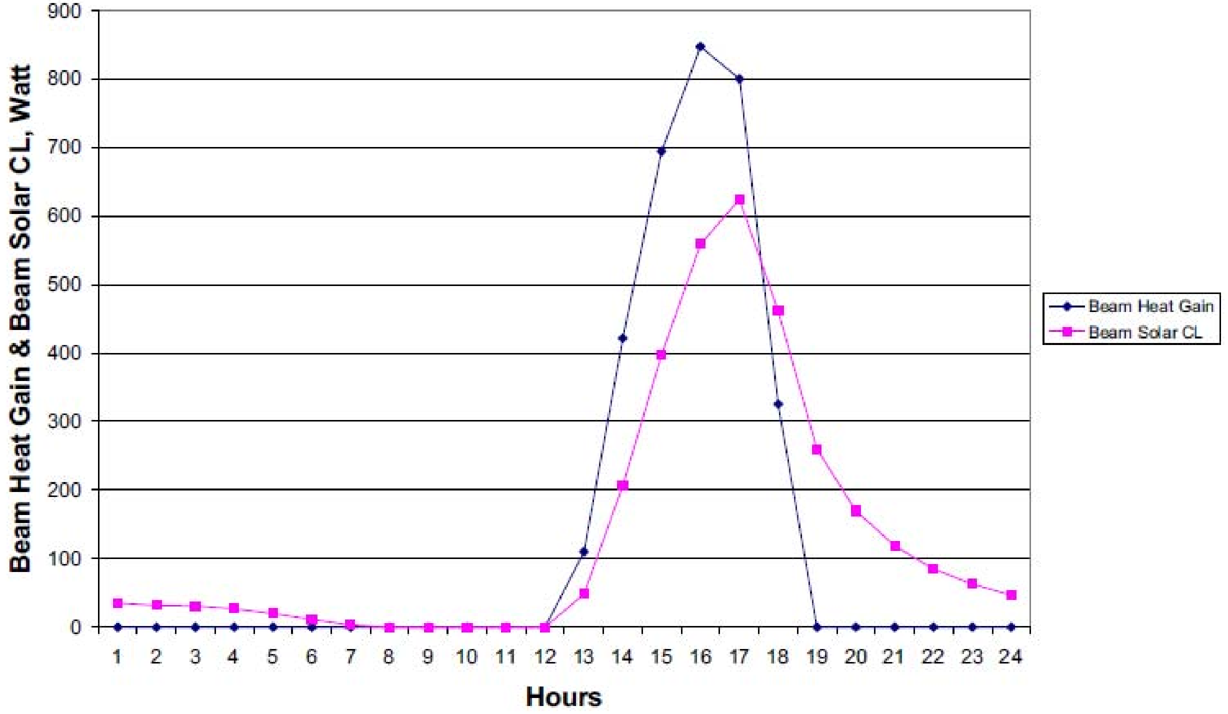
	Direct Solar				Diffuse Solar						Conduction		
Local Standard Time *LST* Hour	Surface Incident Angle θ Degree	Surface Direct E_D W/m^2	Direct *SHGC*	Direct Solar Heat Gain Watt	Ground Reflected E_r W/m^2	Ratio *Y*	Sky Diffuse E_d W/m^2	Surface Diffuse E_d+E_r W/m^2	Hemis. *SHGC*	Diffuse Solar Heat Gain Watt	Outside Temp. t_o °C	Conduction Heat Gain Watt	Total Window Heat Gain Watt
1	100.6	0	0	0	0	0.48	0	0	0.63	0	30.5	89.9	89.9
2	115.3	0	0	0	0	0.45	0	0	0.63	0	30.2	85	85
3	129.8	0	0	0	0	0.45	0	0	0.63	0	29.9	81.1	81.1
4	144.2	0	0	0	0	0.45	0	0	0.63	0	29.7	78.2	78.2
5	157.7	0	0	0	0	0.45	0	0	0.63	0	29.6	77.2	77.2
6	167.7	0	0	0	0	0.45	0	0	0.63	0	29.7	79.2	79.2
7	164.2	0	0	0	19	0.45	29.6	48.6	0.63	55.2	30.1	84.1	139.2
8	151.8	0	0	0	46.2	0.45	42.8	89	0.63	101	30.7	92.9	193.9
9	137.8	0	0	0	69.9	0.45	47.8	117.7	0.63	133.6	31.7	105.6	239.2
10	123.4	0	0	0	88.7	0.45	50.1	138.8	0.63	157.6	32.7	120.3	277.9
11	108.7	0	0	0	101.4	0.45	51.3	152.7	0.63	173.3	33.9	136.9	310.2
12	94.1	0	0	0	107.1	0.52	59.9	166.9	0.63	189.5	35.1	152.6	342.1
13	79.4	176.2	0.346	110	105.4	0.64	73.6	179	0.63	203.2	35.9	164.3	477.5
14	64.7	402.5	0.581	421.5	96.5	0.79	89.8	186.3	0.63	211.5	36.5	172.2	805.1
15	50.2	584.7	0.659	694.7	81	0.96	105	186	0.63	211.1	36.7	175.1	1080.8
16	35.8	691.1	0.681	847.5	59.8	1.11	113.5	173.4	0.63	196.8	36.5	172.2	1216.4
17	22.3	663	0.67	800.3	34.4	1.22	105.1	139.5	0.63	158.3	36	165.3	1123.9
18	12.3	270.7	0.668	325.8	6.6	1.28	42.4	49	0.63	55.6	35.2	154.5	535.9
19	15.8	0	0	0	0	1.26	0	0	0.63	0	34.3	141.8	141.8
20	28.2	0	0	0	0	1.18	0	0	0.63	0	33.4	129.1	129.1
21	42.2	0	0	0	0	1.05	0	0	0.63	0	32.6	118.3	118.3
22	56.6	0	0	0	0	0.89	0	0	0.63	0	31.9	108.5	108.5
23	71.3	0	0	0	0	0.72	0	0	0.63	0	31.3	100.7	100.7
24	85.9	0	0	0	0	0.58	0	0	0.63	0	30.9	94.8	94.8
Column Number													
1	2	3	4	5	6	7	8	9	10	11	12	13	14

W-Window CL

ตารางที่ 13: Window Component of Cooling Load (No Blinds or Overhang)

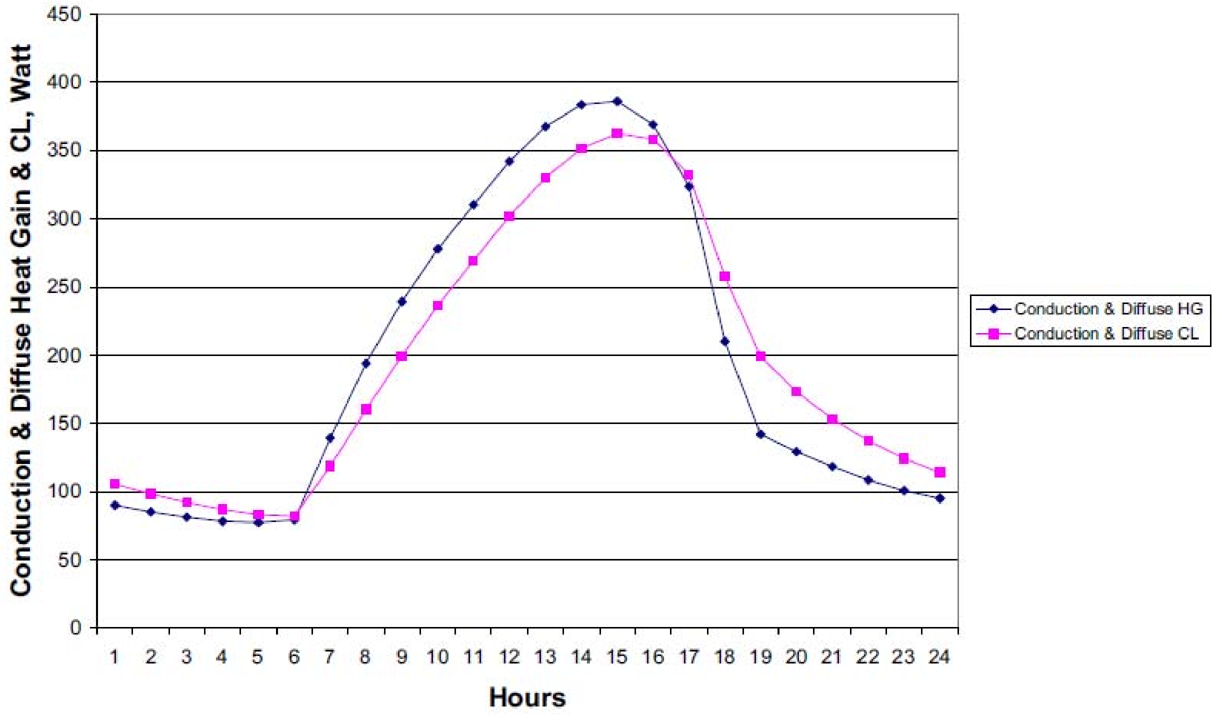
Local Standard Time LST Hour	Direct Solar					Diffuse Solar and Conduction Through Glass								Total Window Cooling Load Watt
								Heat Gain						
	Beam Heat Gain Watt	Heat Gain Radiant 100% Watt	Solar RTS Zone Type 4 %	Radiant Cooling Load Watt	Direct Solar Cooling Load Watt	Diffuse Heat Gain Watt	Conduction Heat Gain Watt	Total 100% Watt	Convective 37% Watt	Radiant 63% Watt	Nonsolar RTS Zone Type 4 %	Radiant Cooling Load Watt	Diff. & Conduc. Cooling Load Watt	
1	0	0	44	35.3	35.3	0	89.9	89.9	33.3	56.7	41	72.1	105.4	140.6
2	0	0	19	32	32	0	85	85	31.5	53.6	20	66.7	98.2	130.2
3	0	0	11	30.9	30.9	0	81.1	81.1	30	51.1	12	62	92	122.9
4	0	0	7	26.7	26.7	0	78.2	78.2	28.9	49.3	8	57.8	86.8	113.4
5	0	0	5	19.7	19.7	0	77.2	77.2	28.6	48.6	5	54.5	83.1	102.8
6	0	0	3	11.3	11.3	0	79.2	79.2	29.3	49.9	4	52.6	81.9	93.2
7	0	0	3	3.3	3.3	55.2	84.1	139.2	51.5	87.7	3	67.1	118.6	121.9
8	0	0	2	0	0	101	92.9	193.9	71.7	122.1	2	88.2	160	160
9	0	0	1	0	0	133.6	105.6	239.2	88.5	150.7	1	111	199.4	199.4
10	0	0	1	0	0	157.6	120.3	277.9	102.8	175.1	1	133.5	236.3	236.3
11	0	0	1	0	0	173.3	136.9	310.2	114.8	195.4	1	154.7	269.4	269.4
12	0	0	1	0	0	189.5	152.6	342.1	126.6	215.5	1	175.3	301.9	301.9
13	110	110	1	48.4	48.4	203.2	164.3	367.5	136	231.5	1	194.1	330.1	378.5
14	421.5	421.5	1	206.3	206.3	211.5	172.2	383.6	141.9	241.7	0	209.6	351.6	557.9
15	694.7	694.7	0	397.8	397.8	211.1	175.1	386.2	142.9	243.3	0	219.7	362.6	760.4
16	847.5	847.5	0	558.9	558.9	196.8	172.2	369	136.5	232.5	0	221.9	358.4	917.4
17	800.3	800.3	0	624.6	624.6	158.3	165.3	323.6	119.7	203.9	0	212.8	332.5	957.1
18	325.8	325.8	0	461.6	461.6	55.6	154.5	210.1	77.7	132.4	0	180	257.7	719.4
19	0	0	0	259.9	259.9	0	141.8	141.8	52.5	89.3	0	146.6	199	459
20	0	0	0	169.9	169.9	0	129.1	129.1	47.8	81.3	0	125.2	173	342.9
21	0	0	0	118.6	118.6	0	118.3	118.3	43.8	74.5	0	109.4	153.2	271.8
22	0	0	0	84.9	84.9	0	108.5	108.5	40.2	68.4	0	97.1	137.2	222.1
23	0	0	0	63	63	0	100.7	100.7	37.3	63.4	0	86.9	124.2	187.2
24	0	0	0	46.5	46.5	0	94.8	94.8	35.1	59.7	0	78.7	113.8	160.3
Column Number														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Beam Solar Time-delay Effect



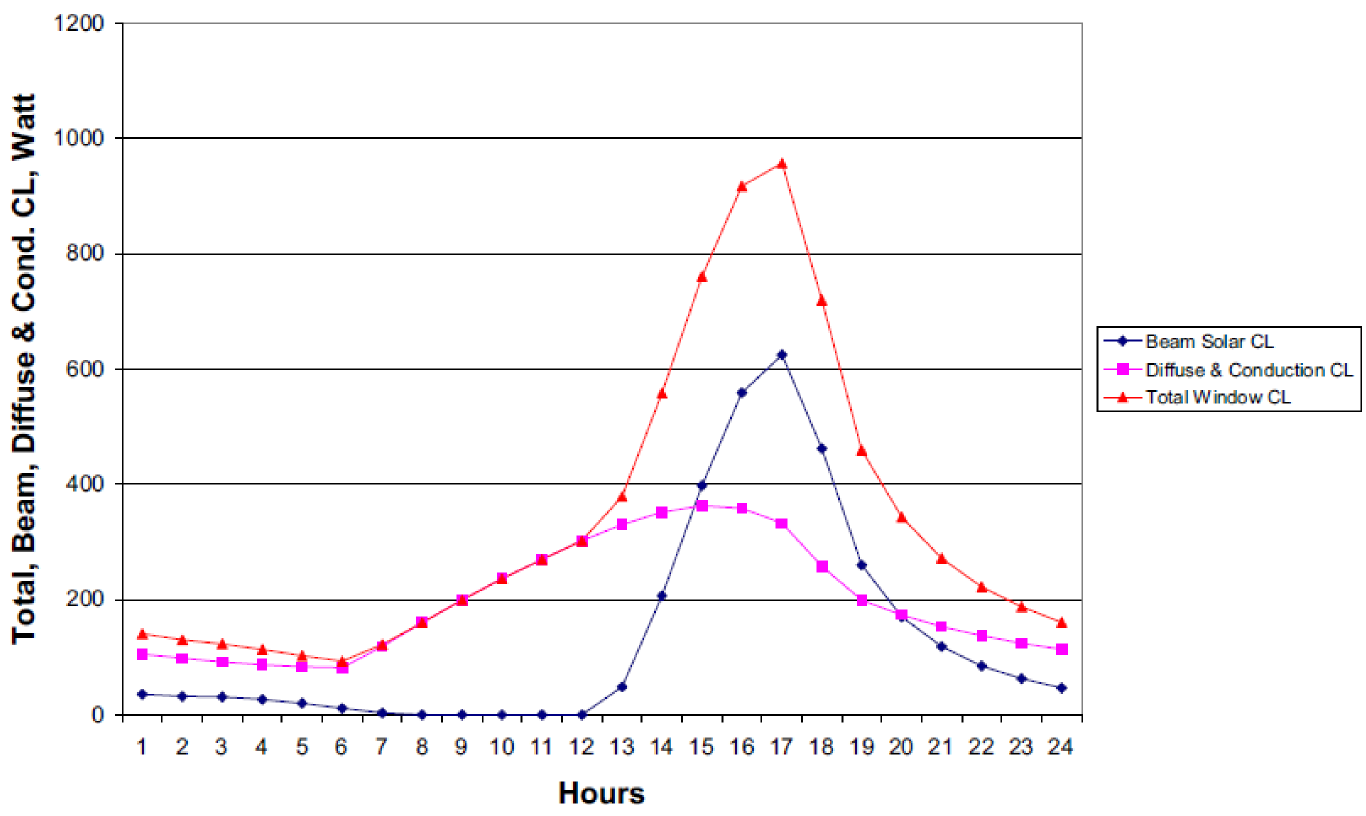
รูปที่ 11: Time-delay Effect จาก Solar RTS Values ที่มีต่อ Beam Heat Gain ผ่านกระจกหน้าต่างด้านตะวันตก

Diff. Solar Time-delay Effect



รูปที่ 12: Time-delay Effect จาก NonSolar RTS Values ที่มีต่อ Conduction และ Diffuse Heat Gain ผ่านกระจกหน้าต่างด้านตะวันตก

W-Window CL Components



รูปที่ 13: องค์ประกอบของ Total Cooling Load ของกระจกหน้าต่างที่ติดตั้งอยู่บนผนังด้านตะวันตก

Solar RTS Values

ตารางที่ 5: Solar RTS Values

% Glass	Light						Medium						Heavy					
	With Carpet			No Carpet			With Carpet			No Carpet			With Carpet			No Carpet		
	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%	10%	50%	90%
Zone Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Hour	Radiant Time Factor,%																	
0	53	55	56	44	45	46	52	54	55	28	29	29	47	49	51	26	27	28
1	17	17	17	19	20	20	16	16	15	15	15	15	11	12	12	12	13	13
2	9	9	9	11	11	11	8	8	8	10	10	10	6	6	6	7	7	7
3	5	5	5	7	7	7	5	4	4	7	7	7	4	4	3	5	5	5
4	3	3	3	5	5	5	3	3	3	6	6	6	3	3	3	4	4	4
5	2	2	2	3	3	3	2	2	2	5	5	5	2	2	2	4	4	4
6	2	2	2	3	2	2	2	1	1	4	4	4	2	2	2	3	3	3
7	1	1	1	2	2	2	1	1	1	4	3	3	2	2	2	3	3	3
8	1	1	1	1	1	1	1	1	1	3	3	3	2	2	2	3	3	3
9	1	1	1	1	1	1	1	1	1	3	3	3	2	2	2	3	3	3
10	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	3	3	3
11	1	1	1	1	1	1	1	1	1	2	2	2	2	2	1	3	3	2
12	1	1	1	1	1	0	1	1	1	2	2	2	2	1	1	2	2	2
13	1	1	0	1	0	0	1	1	1	2	2	2	2	1	1	2	2	2
14	1	0	0	0	0	0	1	1	1	1	1	1	2	1	1	2	2	2
15	1	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2
16	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2
17	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2
18	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2
19	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2
20	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2
21	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	2	2
22	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	1	1
23	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	2	1	1
	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

SHGC

Table 7-4 Visible Transmission (VT), Shading Coefficients (SC), and Solar Heat Gain Coefficient (SHGC) at Normal Incidence for Single Pane Glass and Insulating Glass

Glazing System: ID	Glazing System: Glass Thick, in.	Center Glazing VT	Center Glazing SC	Glazing SHGC at Specified Incidence Angles: Normal 0°	Normal 40°	50°	60°	70°	Hemis. (Diffuse)	Total Window SHGC at Normal Incidence: Aluminum Operable	Aluminum Fixed	Other Frames Operable	Other Frames Fixed	Total Window VT at Normal Incidence: All Frames Operable	All Frames Fixed
	Uncoated Single Glazing														
1a	1/8 Clear	0.90	1.00	0.86	0.85	0.83	0.78	0.67	0.78	0.75	0.78	0.63	0.75	0.65	0.78
1b	1/4 Clear	0.89	0.94	0.81	0.80	0.77	0.73	0.62	0.73	0.71	0.74	0.60	0.71	0.65	0.78
1c	1/8 Bronze	0.68	0.85	0.73	0.71	0.69	0.64	0.55	0.65	0.64	0.67	0.54	0.64	0.49	0.59
1d	1/4 Bronze	0.55	0.73	0.62	0.60	0.58	0.54	0.46	0.55	0.55	0.57	0.46	0.54	0.40	0.48
1e	1/8 Green	0.82	0.82	0.71	0.68	0.66	0.62	0.53	0.63	0.62	0.65	0.53	0.62	0.60	0.71
1f	1/4 Green	0.74	0.68	0.58	0.56	0.54	0.51	0.44	0.52	0.51	0.53	0.43	0.51	0.54	0.64
1g	1/8 Gray	0.62	0.82	0.70	0.68	0.66	0.61	0.53	0.63	0.61	0.64	0.52	0.61	0.45	0.54
1h	1/4 Gray	0.43	0.65	0.56	0.53	0.51	0.48	0.41	0.49	0.50	0.51	0.42	0.49	0.31	0.37
1i	1/4 Bluegreen	0.75	0.72	0.62	0.59	0.57	0.54	0.46	0.55	0.55	0.57	0.46	0.54	0.54	0.65
	Reflective Single Glazing														
1j	1/4 SS on CLR 8%	0.08	0.22	0.19	0.19	0.18	0.17	0.15	0.17	0.18	0.18	0.15	0.17	0.06	0.07
1k	1/4 SS on CLR 14%	0.14	0.29	0.25	0.25	0.24	0.23	0.20	0.23	0.23	0.24	0.19	0.22	0.10	0.12
1l	1/4 SS on CLR 20%	0.20	0.36	0.31	0.30	0.30	0.28	0.24	0.28	0.28	0.29	0.24	0.27	0.15	0.17
1m	1/4 SS on GRN 14%	0.12	0.29	0.25	0.25	0.24	0.23	0.20	0.23	0.23	0.24	0.19	0.22	0.09	0.10
1n	1/4 TI on CLR 20%	0.20	0.34	0.29	0.29	0.28	0.26	0.23	0.27	0.27	0.27	0.22	0.26	0.15	0.17
1o	1/4 TI on CLR 30%	0.30	0.45	0.39	0.38	0.37	0.35	0.30	0.35	0.35	0.36	0.29	0.34	0.22	0.26
	Uncoated Double Glazing														
5a	1/8 CLR CLR	0.81	0.87	0.75	0.73	0.70	0.63	0.49	0.65	0.66	0.68	0.55	0.66	0.59	0.71
5b	1/4 CLR CLR	0.78	0.81	0.70	0.68	0.65	0.58	0.45	0.60	0.61	0.64	0.52	0.61	0.57	0.68
5c	1/8 BRZ CLR	0.62	0.72	0.62	0.59	0.57	0.51	0.39	0.53	0.55	0.57	0.46	0.54	0.45	0.54
5d	1/4 BRZ CLR	0.48	0.59	0.50	0.47	0.45	0.40	0.31	0.42	0.45	0.46	0.37	0.44	0.35	0.42
5e	1/8 GRN CLR	0.74	0.70	0.60	0.57	0.55	0.49	0.38	0.51	0.53	0.55	0.45	0.53	0.54	0.64
5f	1/4 GRN CLR	0.66	0.54	0.47	0.44	0.42	0.38	0.30	0.40	0.42	0.43	0.35	0.41	0.48	0.57
5g	1/8 GRY CLR	0.56	0.69	0.59	0.57	0.54	0.48	0.37	0.50	0.52	0.54	0.44	0.52	0.41	0.49
5h	1/4 GRY CLR	0.40	0.51	0.44	0.42	0.40	0.35	0.28	0.38	0.39	0.41	0.33	0.39	0.29	0.35
5i	1/4 BLUGRN CLR	0.67	0.58	0.50	0.47	0.45	0.40	0.32	0.43	0.45	0.46	0.37	0.44	0.49	0.58
5j	1/4 HI-P GRN CLR	0.59	0.46	0.39	0.37	0.35	0.31	0.25	0.33	0.35	0.36	0.29	0.34	0.43	0.51

U-Factors for Glass

Table 4 U-Factors for Various Fenestration Products in Btu/h·ft^2·°F

Product Type		Glass Only		Vertical Installation									
				Operable (including sliding and swinging glass doors)					Fixed				
Frame Type													
ID	Glazing Type	Center of Glass	Edge of Glass	Aluminum Without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Insulated Fiberglass/ Vinyl	Aluminum Without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Insulated Fiberglass/ Vinyl
	Single Glazing												
1	1/8 in. glass	*1.04*	*1.04*	1.27	1.08	0.90	0.89	0.81	1.13	1.07	0.98	0.98	0.94
2	1/4 in. acrylic/polycarbonate	*0.88*	*0.88*	1.14	0.96	0.79	0.78	0.71	0.99	0.92	0.84	0.84	0.81
3	1/8 in. acrylic/polycarbonate	*0.96*	*0.96*	1.21	1.02	0.85	0.83	0.76	1.06	1.00	0.91	0.91	0.87
	Double Glazing												
4	1/4 in. air space	*0.55*	*0.64*	0.87	0.65	0.57	0.55	0.49	0.69	0.63	0.56	0.56	0.53
5	1/2 in. air space	*0.48*	*0.59*	0.81	0.60	0.53	0.51	0.44	0.64	0.57	0.50	0.50	0.48
6	1/4 in. argon space	*0.51*	*0.61*	0.84	0.62	0.55	0.53	0.46	0.66	0.59	0.53	0.52	0.50
7	1/2 in. argon space	*0.45*	*0.57*	0.79	0.58	0.51	0.49	0.43	0.61	0.54	0.48	0.48	0.45
	Double Glazing, e = 0.60 on surface 2 or 3												
8	1/4 in. air space	*0.52*	*0.62*	0.84	0.63	0.55	0.53	0.47	0.67	0.60	0.54	0.53	0.51
9	1/2 in. air space	*0.44*	*0.56*	0.78	0.57	0.50	0.48	0.42	0.60	0.53	0.47	0.47	0.45
10	1/4 in. argon space	*0.47*	*0.58*	0.81	0.59	0.52	0.50	0.44	0.63	0.56	0.50	0.49	0.47
11	1/2 in. argon space	*0.41*	*0.54*	0.76	0.55	0.48	0.46	0.40	0.58	0.51	0.45	0.44	0.42
	Double Glazing, e = 0.40 on surface 2 or 3												
12	1/4 in. air space	*0.49*	*0.60*	0.82	0.61	0.53	0.51	0.45	0.64	0.58	0.51	0.51	0.49
13	1/2 in. air space	*0.40*	*0.54*	0.75	0.54	0.48	0.45	0.40	0.57	0.50	0.44	0.44	0.41
14	1/4 in. argon space	*0.43*	*0.56*	0.78	0.57	0.50	0.47	0.41	0.59	0.53	0.46	0.46	0.44
15	1/2 in. argon space	*0.36*	*0.51*	0.72	0.52	0.45	0.43	0.37	0.53	0.47	0.41	0.40	0.38
	Double Glazing, e = 0.20 on surface 2 or 3												
16	1/4 in. air space	*0.45*	*0.57*	0.79	0.58	0.51	0.49	0.43	0.61	0.54	0.48	0.48	0.45
17	1/2 in. air space	*0.35*	*0.50*	0.71	0.51	0.44	0.42	0.36	0.53	0.46	0.40	0.39	0.37
18	1/4 in. argon space	*0.38*	*0.52*	0.74	0.53	0.46	0.44	0.38	0.55	0.48	0.42	0.42	0.40
19	1/2 in. argon space	*0.30*	*0.46*	0.67	0.47	0.41	0.39	0.33	0.48	0.41	0.36	0.35	0.33

Insulating Glass Unit (IGU)

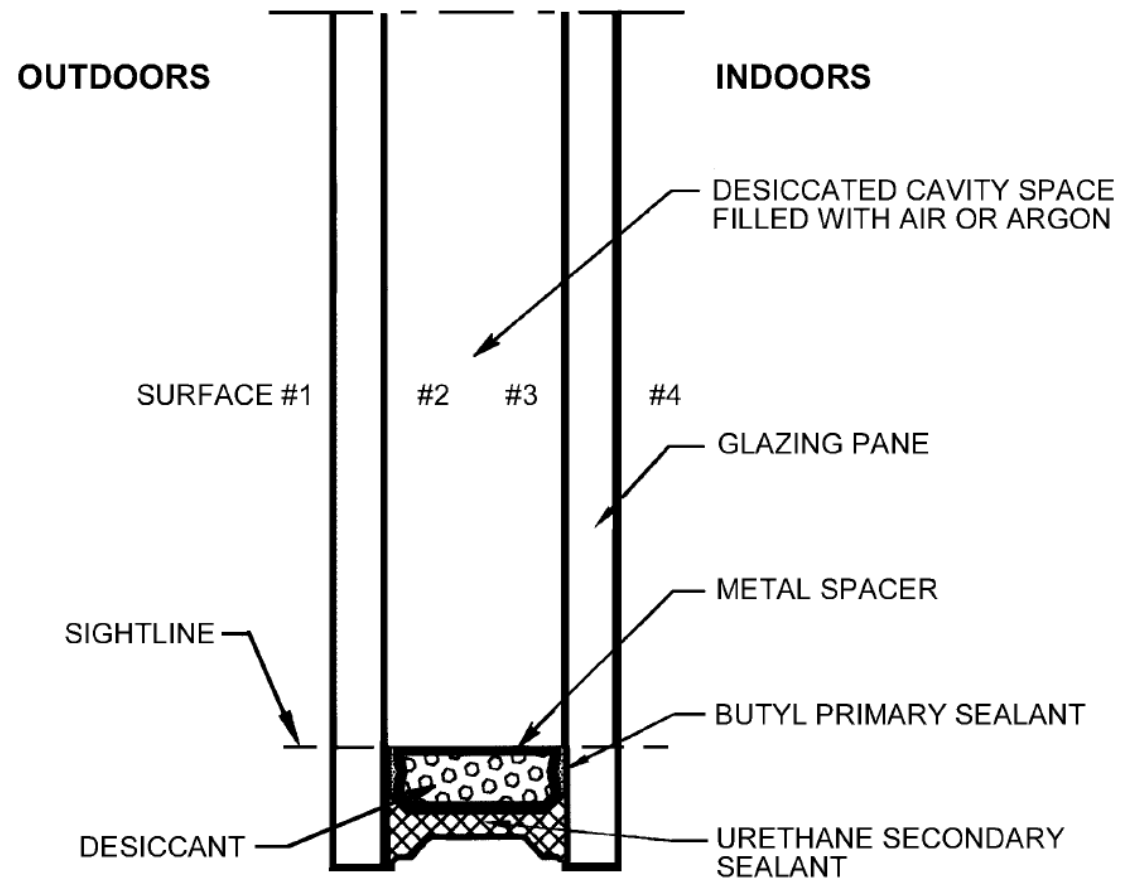
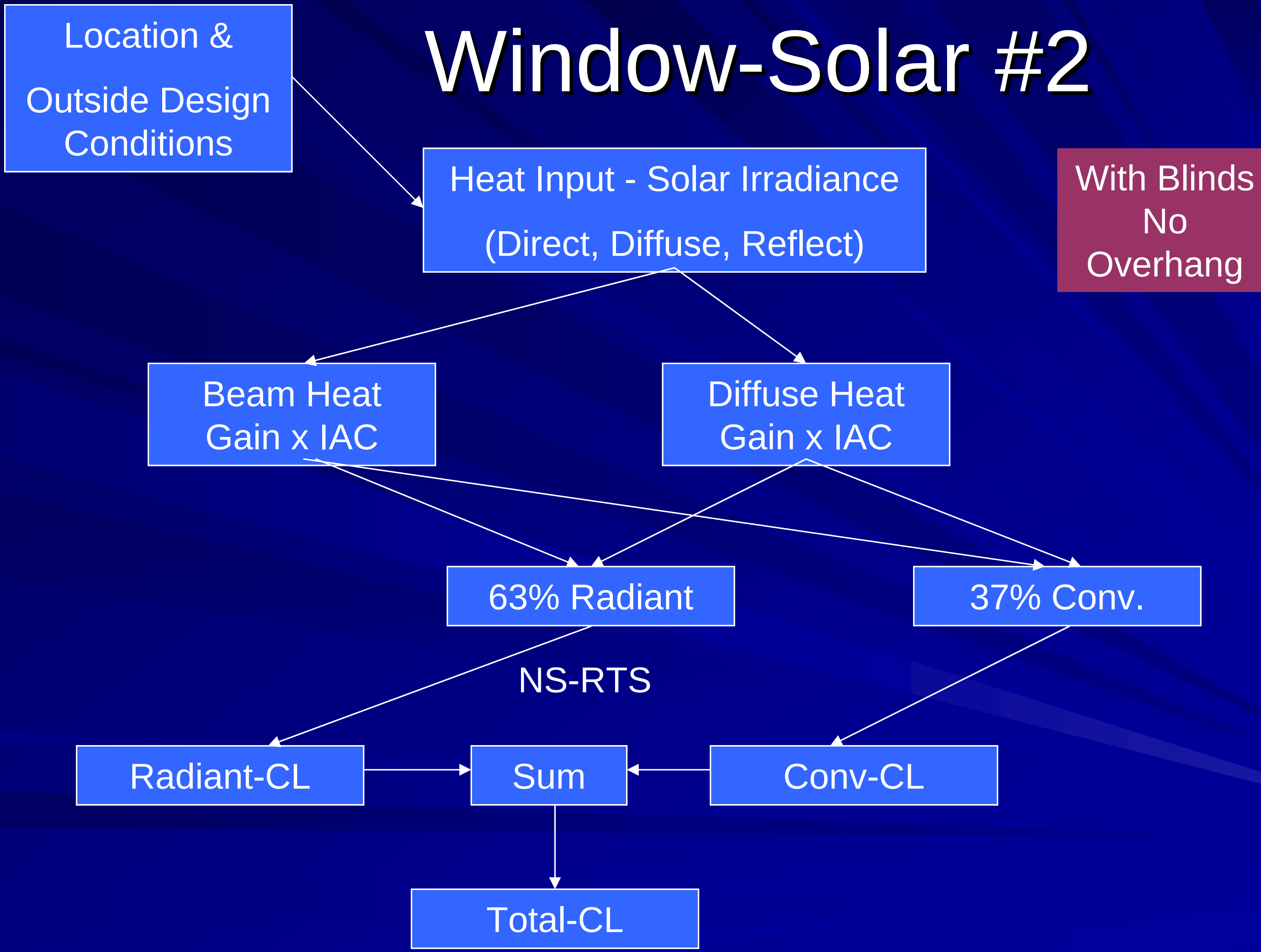
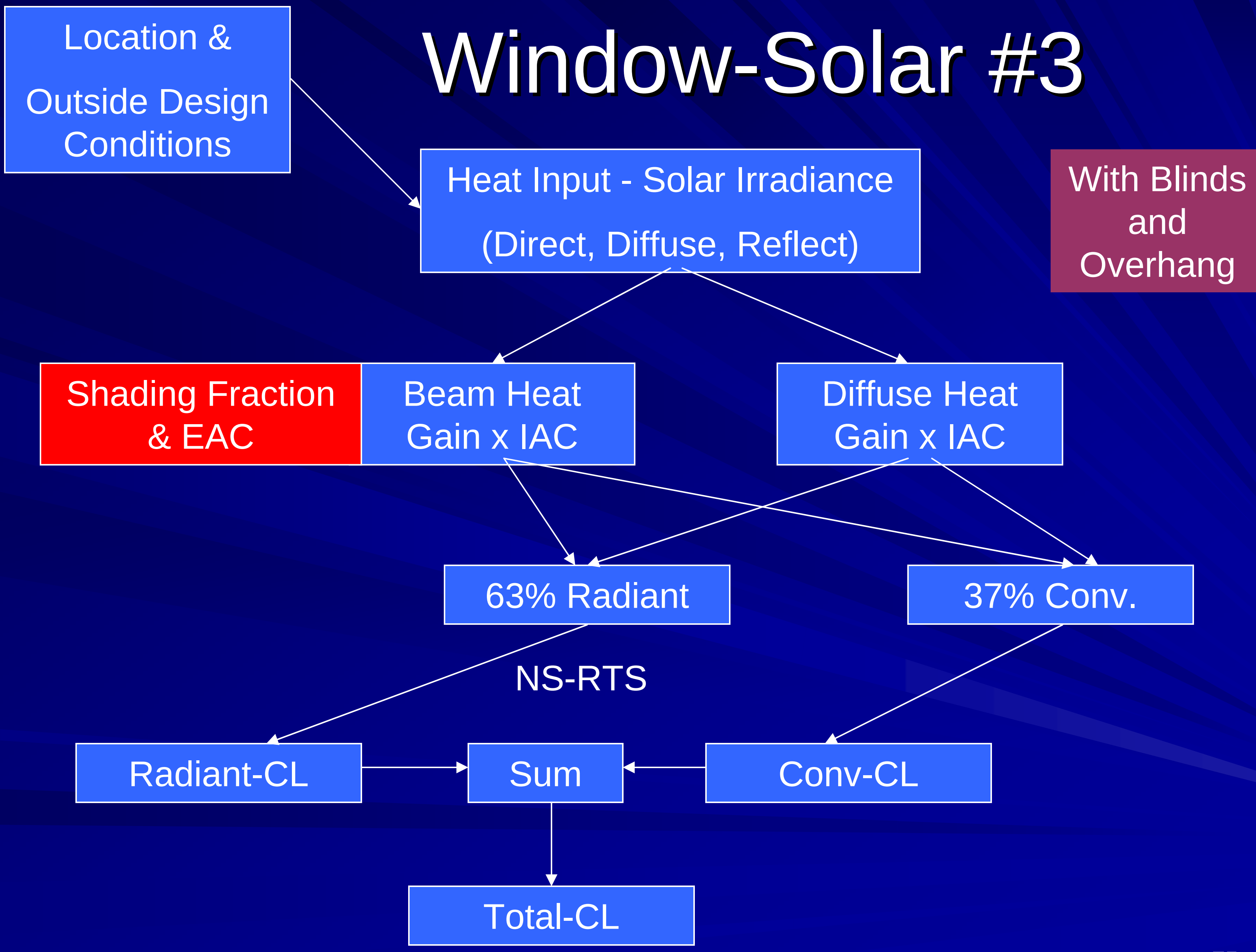


Fig. 1 Insulating Glazing Unit (IGU) Construction Detail

Window-Solar #2



Window-Solar #3



Venetian Blinds
Shading Coefficients (IAC)

Table 7-8 Shading Coefficients for Single Glass with Indoor Shading by Venetian Blinds or Roller Shades

			Type of Shading				
					Roller Shade		
	Nominal	Solar	Venetian Blinds		Opaque		Translucent
Type of Glass	Thickness,[a] in.	Transmittance[b]	Medium	Light	Dark	White	Light
Clear	3/32[c]	0.87 to 0.80	0.74[d] (0.63)[e]	0.67[d] (0.58)[e]	0.81	0.39	0.44
Clear	1/4 to 1/2	0.80 to 0.71					
Clear pattern	1/8 to 1/2	0.87 to 0.79					
Heat-absorbing pattern	1/8	—					
Tinted	3/16, 7/32	0.74, 0.71					
Heat-absorbing[f]	3/16, 1/4	0.46					
Heat-absorbing pattern	3/16, 1/4	—	0.57	0.53	0.45	0.30	0.36
Tinted	1/8, 7/32	0.59, 0.45					
Heat-absorbing or pattern	—	0.44 to 0.30	0.54	0.52	0.40	0.28	0.32
Heat-absorbing[f]	3/8	0.34					
Heat-absorbing or pattern		0.29 to 0.15					
	—	0.24	0.42	0.40	0.36	0.28	0.31
Reflective coated glass	S.C. = 0.30[g]		0.25	0.23			
	= 0.40		0.33	0.29			
	= 0.50		0.42	0.38			
	= 0.60		0.50	0.44			

[a]Refer to manufacturers' literature for values.
[b]For vertical blinds with opaque white and beige louvers in the tightly closed position, SC is 0.25 and 0.29 when used with glass of 0.71 to 0.80 transmittance.
[c]Typical residential glass thickness.
[d]From Van Dyck and Konen (1982), for 45° open venetian blinds, 35° solar incidence, and 35° profile angle.
[e]Values for closed venetian blinds. Use these values only when operation is automated for solar gain reduction (as opposed to daylight use).
[f]Refers to gray, bronze, and green tinted heat-absorbing glass.
[g]SC for glass with no shading device.

Venetian Blinds

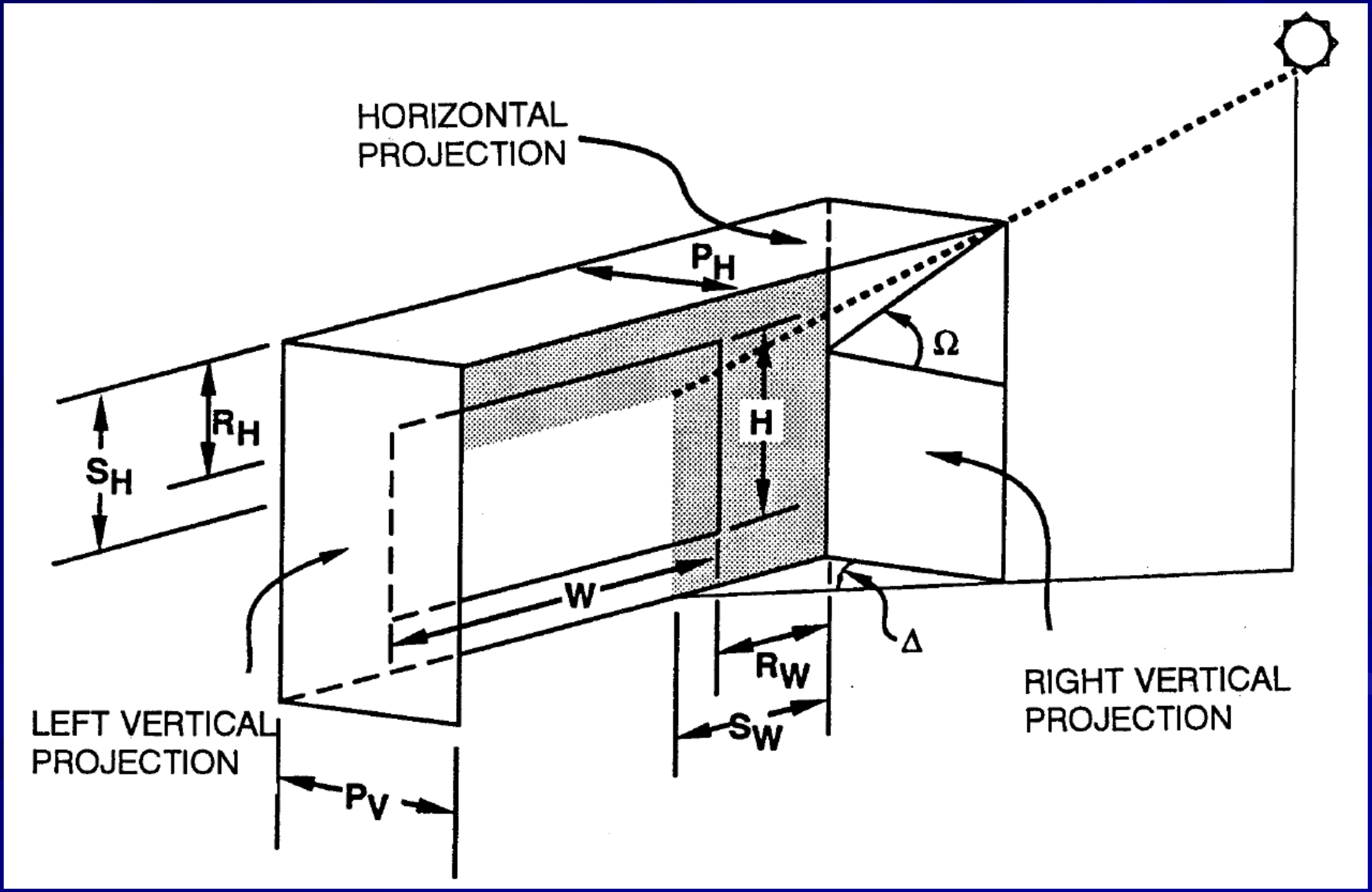
Draperies IAC

Table 22 Interior Solar Attenuation Coefficients for Single and Insulating Glass with Draperies

Glazing	Glass Trans-mission	Glazing SHGC (No Drapes)	IAC									
			A	B	C	D	E	F	G	H	I	J
Single glass												
1/8 in. clear	0.86	0.87	0.87	0.82	0.74	0.69	0.64	0.59	0.53	0.48	0.42	0.37
1/4 in. clear	0.8	0.83	0.84	0.79	0.74	0.68	0.63	0.58	0.53	0.47	0.42	0.37
1/2 in. clear	0.71	0.77	0.84	0.80	0.75	0.69	0.64	0.59	0.55	0.49	0.44	0.40
1/4 in. heat absorbing	0.46	0.58	0.85	0.81	0.78	0.73	0.69	0.66	0.61	0.57	0.54	0.49
1/2 in. heat absorbing	0.24	0.44	0.86	0.84	0.80	0.78	0.76	0.72	0.68	0.66	0.64	0.60
Reflective coated	—	0.52	0.95	0.90	0.85	0.82	0.77	0.72	0.68	0.63	0.60	0.55
	—	0.44	0.92	0.88	0.84	0.82	0.78	0.76	0.72	0.68	0.66	0.62
	—	0.35	0.90	0.88	0.85	0.83	0.80	0.75	0.73	0.70	0.68	0.65
	—	0.26	0.83	0.80	0.80	0.77	0.77	0.77	0.73	0.70	0.70	0.67
Insulating glass, 1/4-in. air space												
(1/8 in. out and 1/8 in. in)	0.76	0.77	0.84	0.80	0.73	0.71	0.64	0.60	0.54	0.51	0.43	0.40
Insulating glass 1/2-in. air space												
Clear out and clear in	0.64	0.72	0.80	0.75	0.70	0.67	0.63	0.58	0.54	0.51	0.45	0.42
Heat absorbing out and clear in	0.37	0.48	0.89	0.85	0.82	0.78	0.75	0.71	0.67	0.64	0.60	0.58
Reflective coated	—	0.35	0.95	0.93	0.93	0.90	0.85	0.80	0.78	0.73	0.70	0.70
	—	0.26	0.97	0.93	0.90	0.90	0.87	0.87	0.83	0.83	0.80	0.80
	—	0.17	0.95	0.95	0.90	0.90	0.85	0.85	0.80	0.80	0.75	0.75

Draperies

External Shading



External Shading

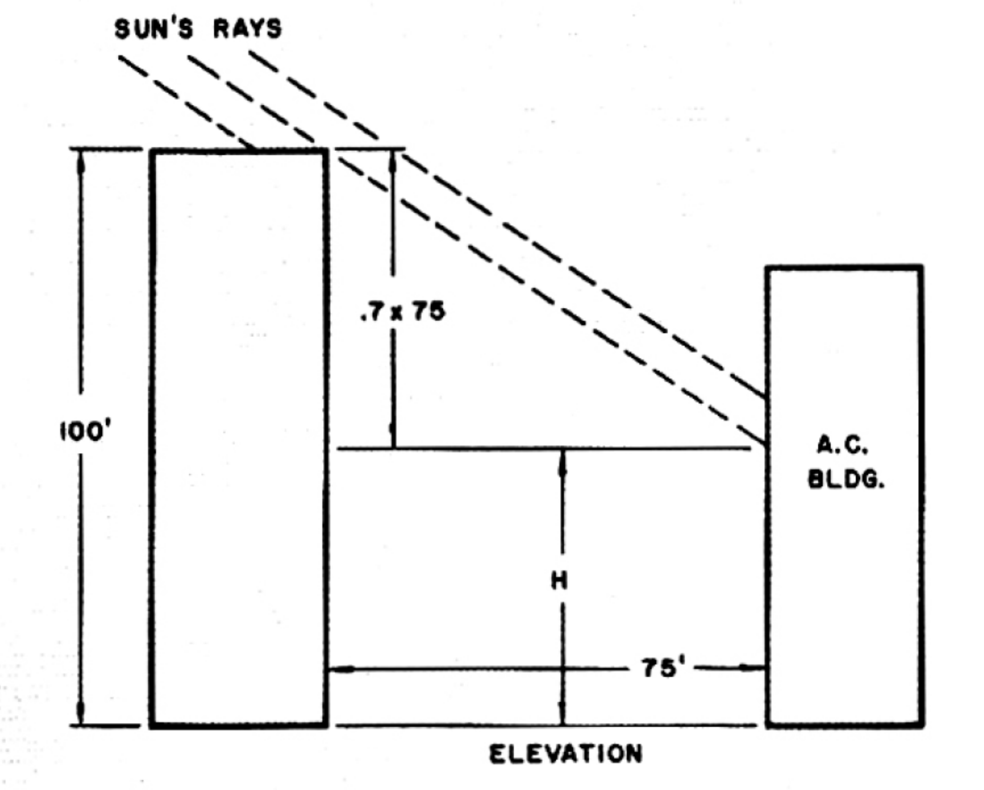
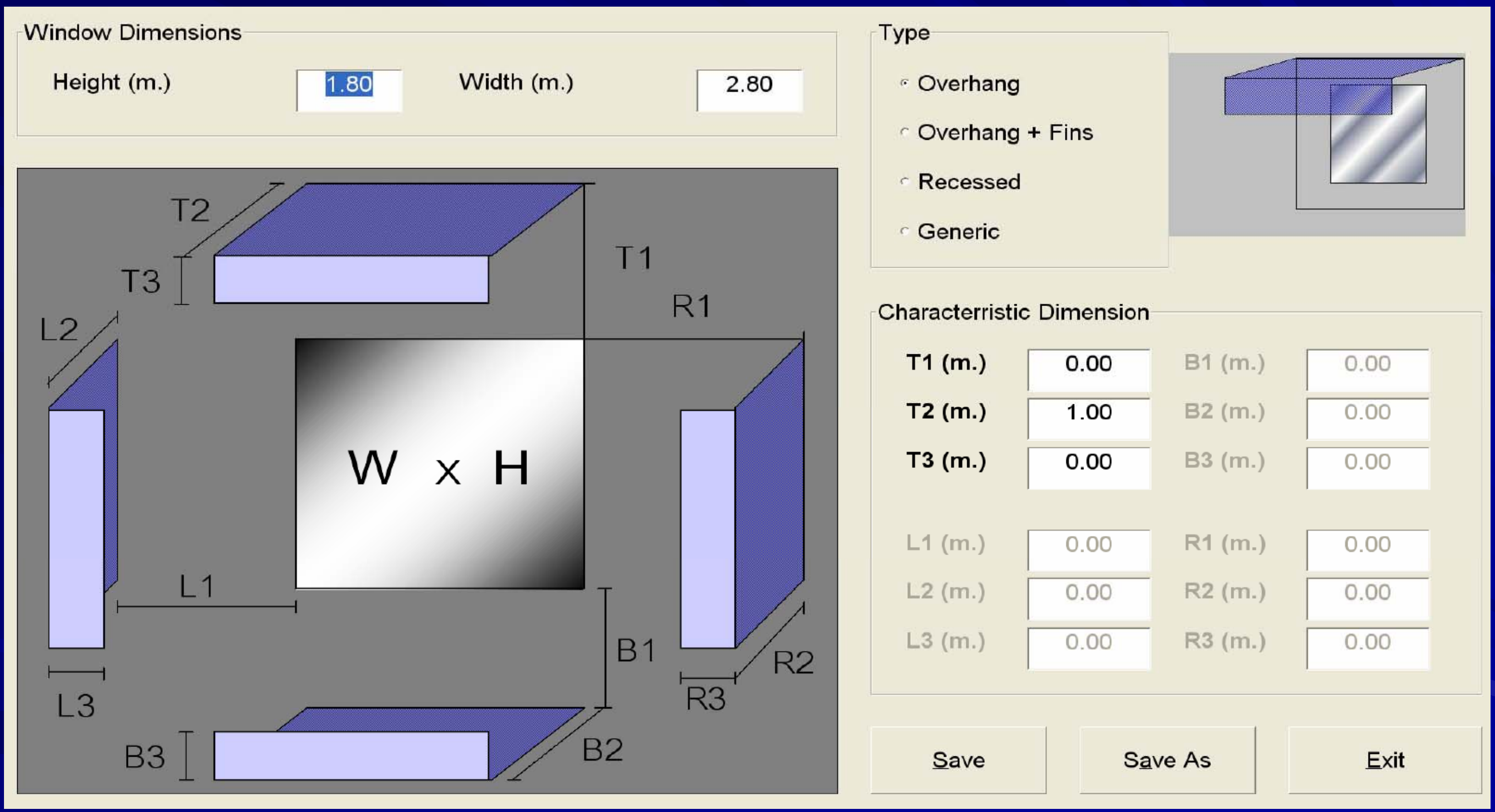


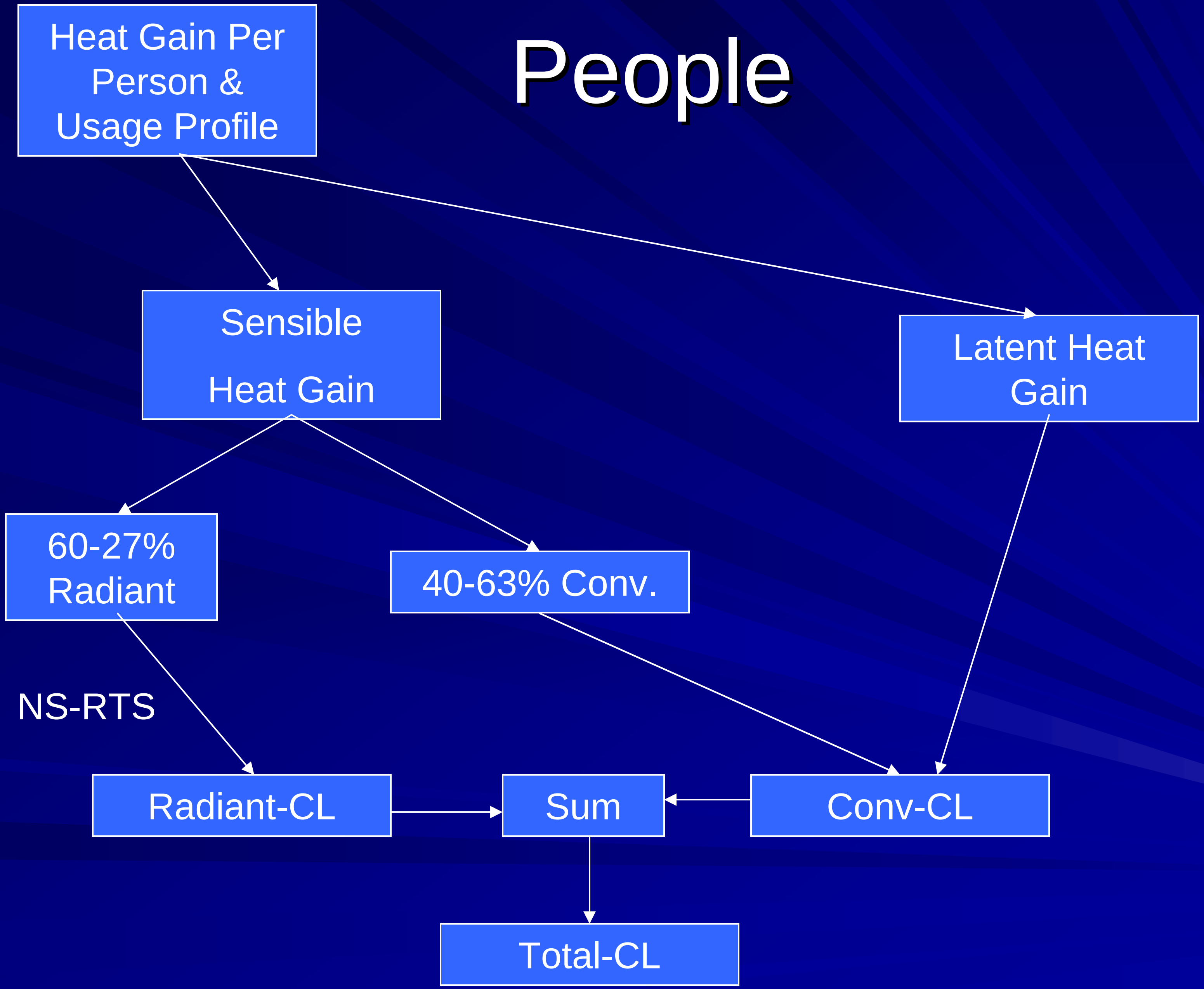
FIG. 20-SHADING OF BUILDING BY ADJACENT BUILDING

External Shading



People Heat Gain

People



Heat Gain Per Person & Usage Profile
Sensible Heat Gain
Latent Heat Gain
60-27% Radiant
40-63% Conv.
NS-RTS
Radiant-CL
Sum
Conv-CL
Total-CL

People Heat Gain

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

Degree of Activity	Location	Total Heat, Btu/h Adult Male	Total Heat, Btu/h Adjusted, M/F[a]	Sensible Heat, Btu/h	Latent Heat, Btu/h	% Sensible Heat that is Radiant[b] Low V	% Sensible Heat that is Radiant[b] High V
Seated at theater	Theater, matinee	390	330	225	105		
Seated at theater, night	Theater, night	390	350	245	105	60	27
Seated, very light work	Offices, hotels, apartments	450	400	245	155		
Moderately active office work	Offices, hotels, apartments	475	450	250	200		
Standing, light work; walking	Department store; retail store	550	450	250	200	58	38
Walking, standing	Drug store, bank	550	500	250	250		
Sedentary work	Restaurant[c]	490	550	275	275		
Light bench work	Factory	800	750	275	475		
Moderate dancing	Dance hall	900	850	305	545	49	35
Walking 3 mph; light machine work	Factory	1000	1000	375	625		
Bowling[d]	Bowling alley	1500	1450	580	870		
Heavy work	Factory	1500	1450	580	870	54	19
Heavy machine work; lifting	Factory	1600	1600	635	965		
Athletics	Gymnasium	2000	1800	710	1090		

Notes:
1. Tabulated values are based on 75°F room dry-bulb temperature. For 80°F 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 Btu/h.

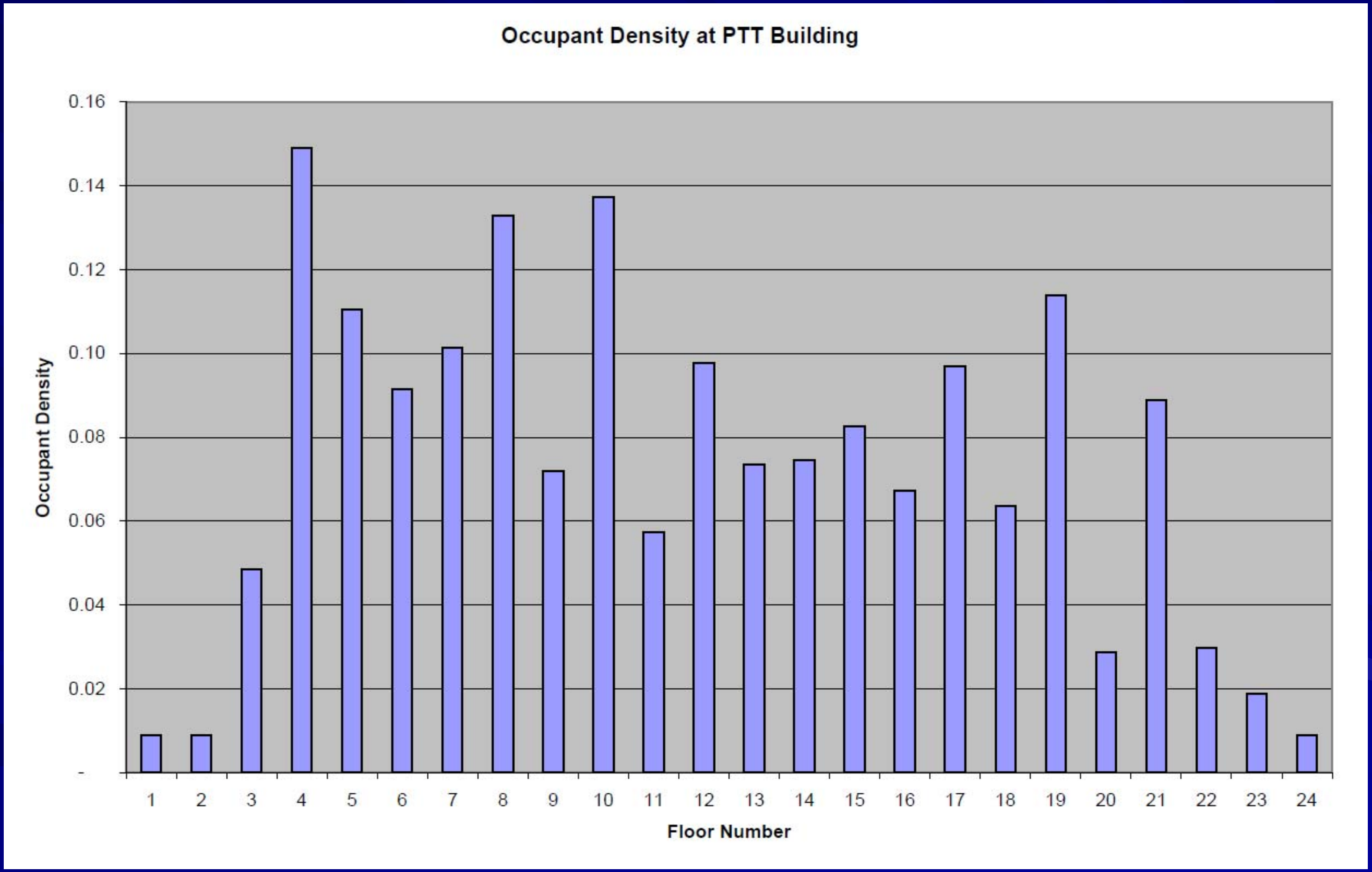
[a] Adjusted heat gain is based on normal percentage of men, women, and children for the application listed, with the postulate that the gain from an adult female is 85% of that for an adult male, and that the gain from a child is 75% of that for an adult male.

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

[c] Adjusted heat gain includes 60 Btu/h for food per individual (30 Btu/h sensible and 30 Btu/h latent).

[d] Figure one person per alley actually bowling, and all others as sitting (400 Btu/h) or standing or walking slowly (550 Btu/h).

Occupant Density (PTT Bld.)



Motor Heat Gain (Power)

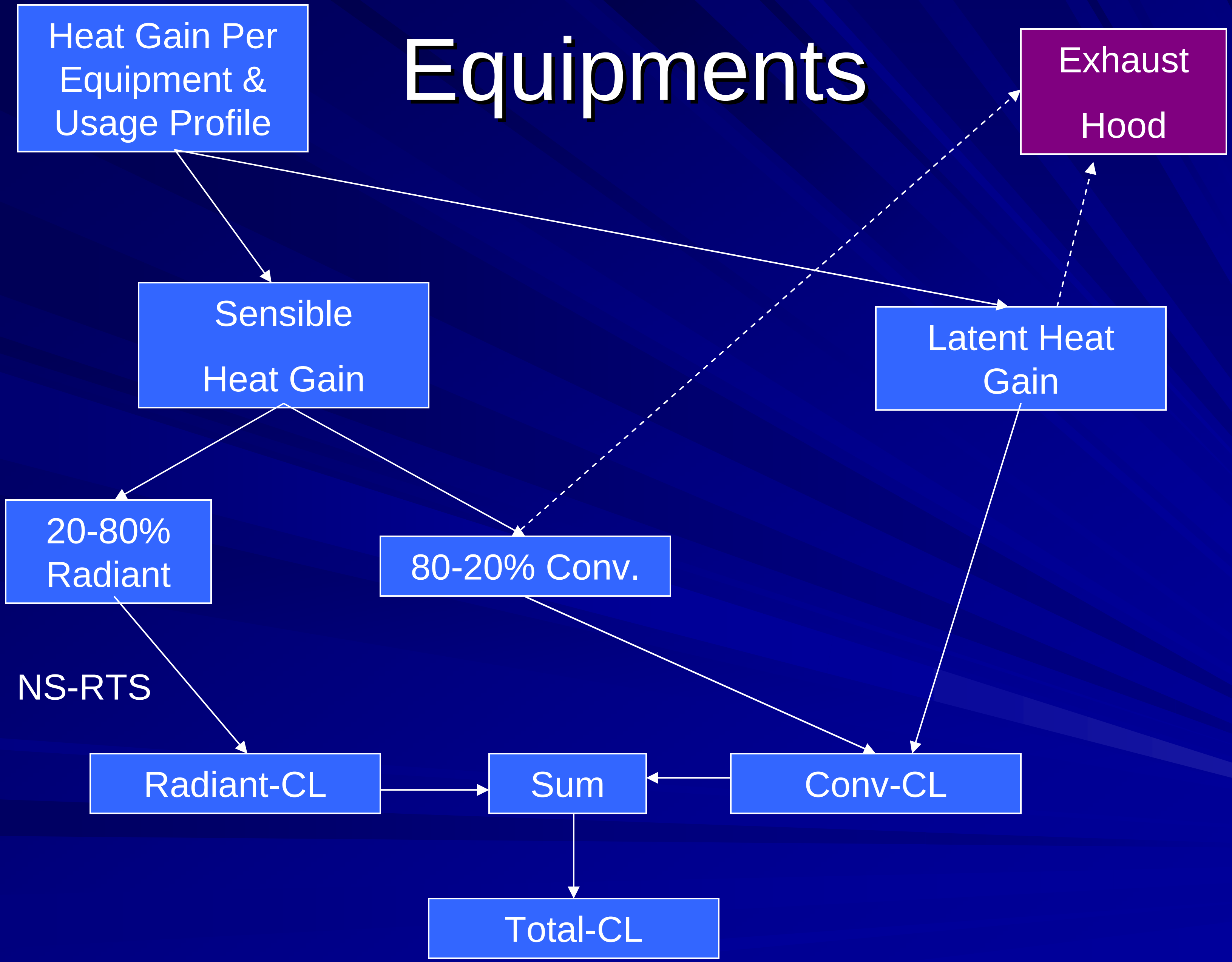
Motor Heat Gain

Table 3A Average Efficiencies and Related Data Representative of Typical Electric Motors

Motor Name-plate or Rated Horse-power	Motor Type	Nominal rpm	Full Load Motor Effi-ciency, %	Location of Motor and Driven Equipment with Respect to Conditioned Space or Airstream: A — Motor in, Driven Equip-ment in, Btu/h	B — Motor out, Driven Equip-ment in, Btu/h	C — Motor in, Driven Equip-ment out, Btu/h
0.05	Shaded pole	1500	35	360	130	240
0.08	Shaded pole	1500	35	580	200	380
0.125	Shaded pole	1500	35	900	320	590
0.16	Shaded pole	1500	35	1,160	400	760
0.25	Split phase	1750	54	1,180	640	540
0.33	Split phase	1750	56	1,500	840	660
0.50	Split phase	1750	60	2,120	1,270	850
0.75	3-phase	1750	72	2,650	1,900	740
1	3-phase	1750	75	3,390	2,550	850
1.5	3-phase	1750	77	4,960	3,820	1,140
2	3-phase	1750	79	6,440	5,090	1,350
3	3-phase	1750	81	9,430	7,640	1,790
5	3-phase	1750	82	15,500	12,700	2,790
7.5	3-phase	1750	84	22,700	19,100	3,640

Appliances Heat Gain

Equipments



Heat Gain Per Equipment & Usage Profile
Exhaust Hood
Sensible Heat Gain
Latent Heat Gain
20-80% Radiant
80-20% Conv.
NS-RTS
Radiant-CL
Sum
Conv-CL
Total-CL

Heat Gain from Equipments

Table 7-18 Heat Gain from Selected Office and Hospital Equipment

Appliance	Size	Maximum Input Rating, Btu/h	Standby Input Rating, Btu/h	Recommended Rate of Heat Gain, Btu/h
Check processing workstation	12 pockets	16400	8410	8410
Computer devices				
Card puncher	—	2730 to 6140	2200 to 4800	2200 to 4800
Card reader	—	7510	5200	5200
Communication/transmission	—	6140 to 15700	5600 to 9600	5600 to 9600
Disk drives/mass storage	—	3410 to 34100	3412 to 22420	3412 to 22420
Magnetic ink reader	—	3280 to 16000	2600 to 14400	2600 to 14400
Microcomputer	16 to 640 Kbyte[a]	340 to 2050	300 to 1800	300 to 1800
Minicomputer	—	7500 to 15000	7500 to 15000	7500 to 15000
Optical reader	—	10240 to 20470	8000 to 17000	8000 to 17000
Plotters	—	256	128	214
Printers				
Letter quality	30 to 45 char/min	1200	600	1000
Line, high speed	5000 or more lines/min	4300 to 18100	2160 to 9040	2500 to 13000
Line, low speed	300 to 600 lines/min	1540	770	1280
Tape drives	—	4090 to 22200	3500 to 15000	3500 to 15000
Terminal	—	310 to 680	270 to 600	270 to 600
Copiers/Duplicators				
Blue print	—	3930 to 42700	1710 to 17100	3930 to 42700
Copiers (large)	30 to 67[a] copies/min	5800 to 22500	3070	5800 to 22500
Copiers (small)	6 to 30[a] copies/min	1570 to 5800	1020 to 3070	1570 to 5800
Feeder	—	100	—	100
Microfilm printer	—	1540	—	1540
Sorter/collator	—	200 to 2050	—	200 to 2050

Hood Load Factor

Table 4A Hooded Electric Appliance Usage Factors, Radiation Factors, and Load Factors

Appliance	Usage Factor F_U	Radiation Factor F_R	Load Factor $F_L = F_U F_R$ Elec/Steam
Griddle	0.16	0.45	0.07
Fryer	0.06	0.43	0.03
Convection oven	0.42	0.17	0.07
Charbroiler	0.83	0.29	0.24
Open-top range			
without oven	0.34	0.46	0.16
Hot-top range			
without oven	0.79	0.47	0.37
with oven	0.59	0.48	0.28
Steam cooker	0.13	0.30	0.04

Sources: Alereza and Breen (1984), Fisher (1998).

Office Equipment Load Factor

Table 11 Recommended Load Factors for Various Types of Offices

Load Density of Office	Load Factor, W/m^2	Description
Light	5.4	Assumes 15.5 m^2/workstation (6.5 workstations per 100 m^2) with computer and monitor at each plus printer and fax. Computer, monitor, and fax diversity 0.67, printer diversity 0.33.
Medium	10.8	Assumes 11.6 m^2/workstation (8.5 workstations per 100 m^2) with computer and monitor at each plus printer and fax. Computer, monitor, and fax diversity 0.75, printer diversity 0.50.
Medium/ Heavy	16.1	Assumes 9.3 m^2/workstation (11 workstations per 100 m^2) with computer and monitor at each plus printer and fax. Computer and monitor diversity 0.75, printer and fax diversity 0.50.
Heavy	21.5	Assumes 7.8 m^2/workstation (13 workstations per 100 m^2) with computer and monitor at each plus printer and fax. Computer and monitor diversity 1.0, printer and fax diversity 0.50.

Actual Load Factor

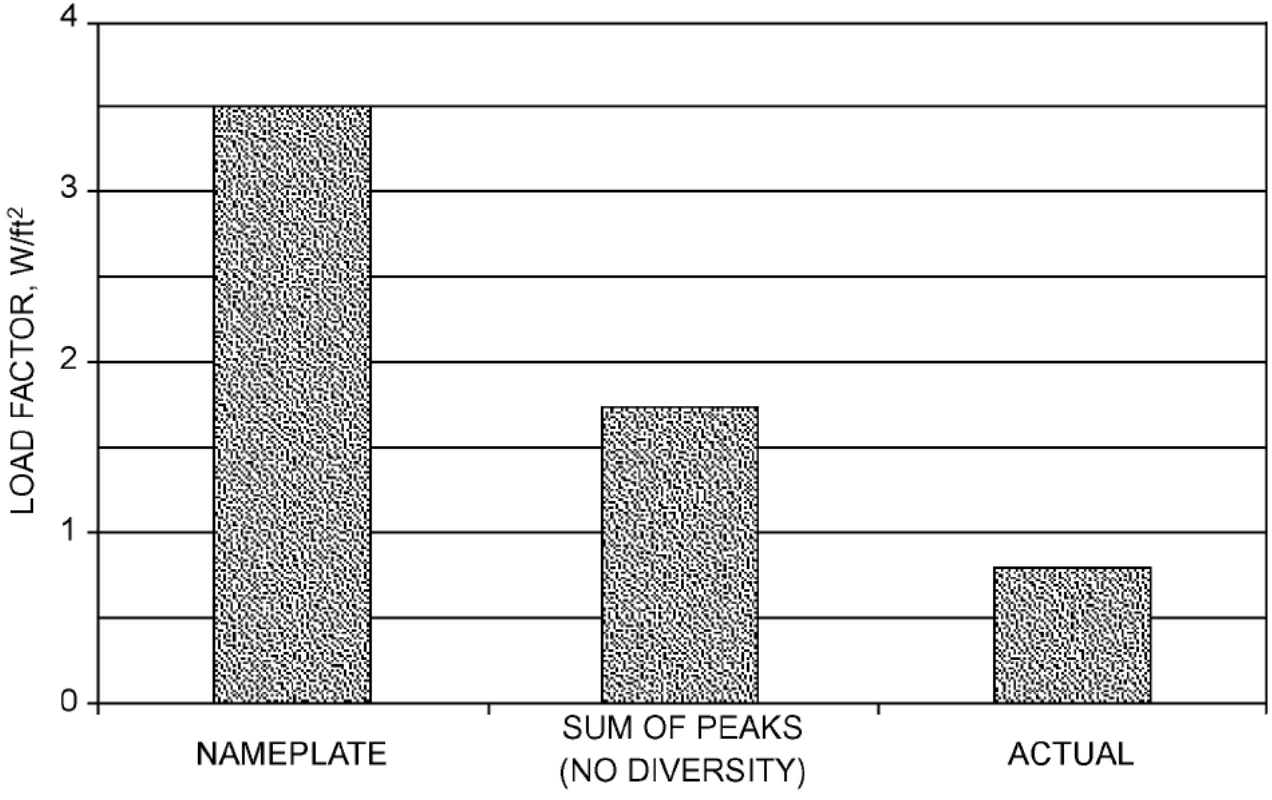
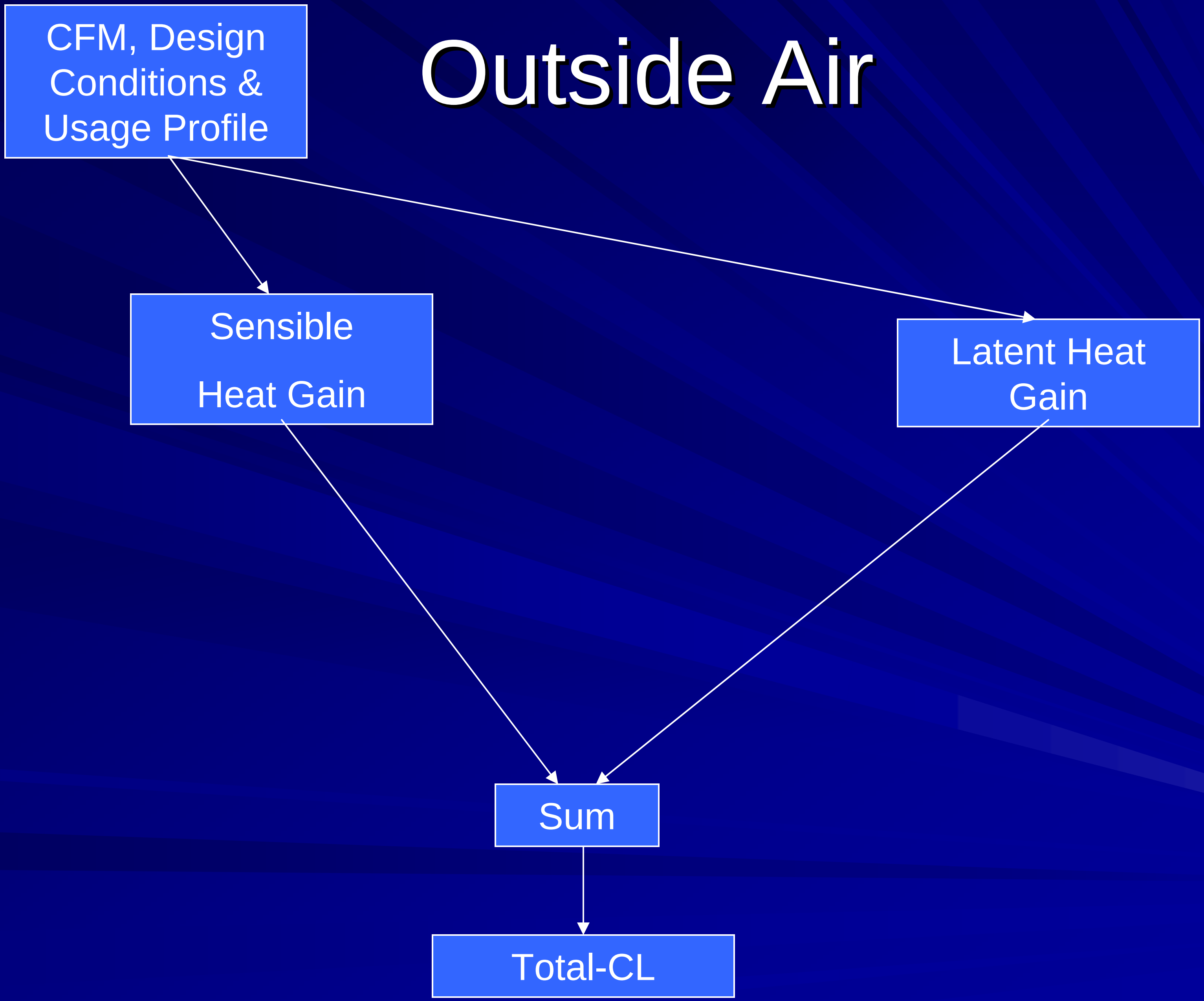


Fig. 4 Office Equipment Load Factor Comparison
(Wilkins and McGaffin 1994)

Ventilation/Infiltration Heat Gain

Outside Air


CFM, Design Conditions & Usage Profile
Sensible Heat Gain
Latent Heat Gain
Sum
Total-CL

Outdoor Air Load

Ventilation and Infiltration Air

$$q_{sensible} = 1.10\,Q\,(t_o - t_i)$$

$$q_{latent} = 4840\,Q\,(W_o - W_i)$$

$$q_{total} = 4.5\,Q\,(h_o - h_i)$$

Q = ventilation cfm from ASHRAE *Standard* 62; infiltration from Chapter 5

t_o, t_i = outside, inside air temperature, °F

W_o, W_i = outside, inside air humidity ratio, lb (water)/lb (dry air)

h_o, h_i = outside, inside air enthalpy, Btu/lb (dry air)

Ventilation CFM: ASHRAE Standard 62-2007

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE *(continued)*
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values: Occupant Density (see Note 4)	Default Values: Combined Outdoor Air Rate (see Note 5)		Air Class
	cfm/person	L/s·person	cfm/ft^2	L/s·m^2		#/1000 ft^2 or #/100 m^2	cfm/person	L/s·person	
Office Buildings									
Office space	5	2.5	0.06	0.3		5	17	8.5	1
Reception areas	5	2.5	0.06	0.3		30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1
Miscellaneous Spaces									
Bank vaults/safe deposit	5	2.5	0.06	0.3		5	17	8.5	2
Computer (not printing)	5	2.5	0.06	0.3		4	20	10.0	1
Electrical equipment rooms	–	–	0.06	0.3	B	–			1

Example: Calculation of Ventilation Rate

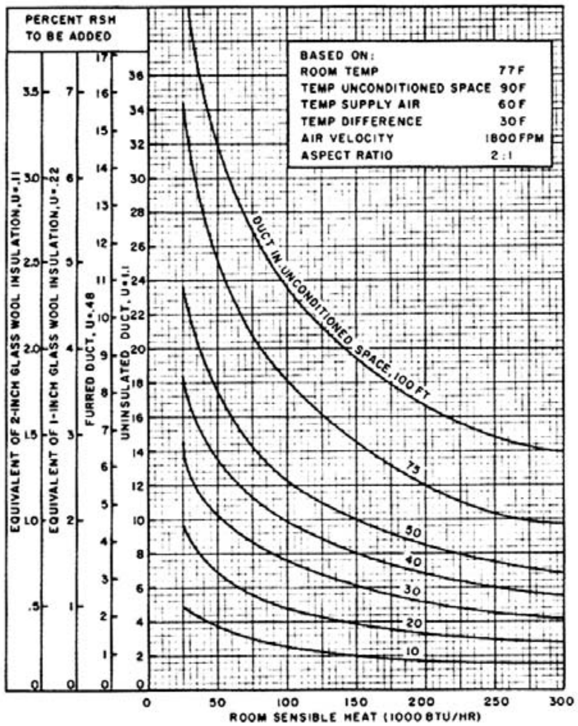
1) Floor Space = 2,000 Sq.m (Az)
2) Number of Occupant = 0.1 x 2 000 = 200 (Pz)
3) People Outdoor Air Rate = 5 cfm/person (Rp)
4) Aera Outdoor Air Rate = 0.06 cfm/Sq.ft (Ra)
5) Ventilation Rate (Vbz) = Rp x Pz + Ra x Az
   = 5 x 200 + 0.06 x 2,000 x 10.76
   = 1,000 + 1291
   = 2,291 cfm
   = 11.46 cfm/person
6) Use 2,400 cfm = 12 cfm/person

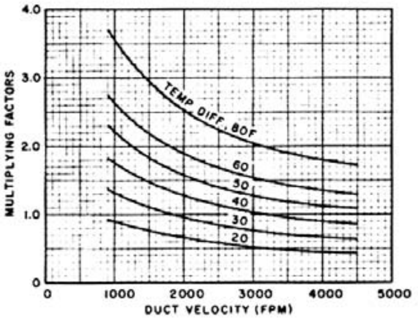
Miscellaneous

Duct Heat Gain

CHART 3- HEAT GAIN TO SUPPLY DUCT

Percent of Room Sensible Heat





MULTIPLYING FACTORS FOR OTHER ROOM TEMPERATURES

Room Temp	Multiplying Factor
75	1.10
76	1.06
77	1.00
78	0.97
79	0.94
80	0.92

$$Q = UPl \times \frac{2.165 \times AV}{(2.165 \times AV) + UPl} (t_3 - t_1)$$

where:

- Q = duct heat gain (Btu/hr)
- U = duct heat transmission factor (Btu/hr-sq ft-F)
- P = rectangular duct perimeter (ft)
- l = duct length (ft)
- A = duct area (sq ft)
- V = duct velocity (fpm)
- t_1 = temperature of supply air entering duct (F)
- t_3 = temperature of surrounding air (F)

Based on formulas in ASHRAE Guide 1963, p. 184, 185.

Duct Leak Loss

Table 9 Leakage as Percentage of Airflow[a,b]

Leakage Class	System cfm per ft^2 Duct Surface[c]	Static Pressure, in. of water					
		0.5	1	2	3	4	6
48	2	15	24	38	49	59	77
	2.5	12	19	30	39	47	62
	3	10	16	25	33	39	51
	4	7.7	12	19	25	30	38
	5	6.1	9.6	15	20	24	31
24	2	7.7	12	19	25	30	38
	2.5	6.1	9.6	15	20	24	31
	3	5.1	8.0	13	16	20	26
	4	3.8	6.0	9.4	12	15	19
	5	3.1	4.8	7.5	9.8	12	15
12	2	3.8	6	9.4	12	15	19
	2.5	3.1	4.8	7.5	9.8	12	15
	3	2.6	4.0	6.3	8.2	9.8	13
	4	1.9	3.0	4.7	6.1	7.4	9.6
	5	1.5	2.4	3.8	4.9	5.9	7.7
6	2	1.9	3	4.7	6.1	7.4	9.6
	2.5	1.5	2.4	3.8	4.9	5.9	7.7
	3	1.3	2.0	3.1	4.1	4.9	6.4
	4	1.0	1.5	2.4	3.1	3.7	4.8
	5	0.8	1.2	1.9	2.4	3.0	3.8
3	2	1.0	1.5	2.4	3.1	3.7	4.8
	2.5	0.8	1.2	1.9	2.4	3.0	3.8
	3	0.6	1.0	1.6	2.0	2.5	3.2
	4	0.5	0.8	1.3	1.6	2.0	2.6
	5	0.4	0.6	0.9	1.2	1.5	1.9

Duct Leakage Class

Table 6 Duct Leakage Classification[a]

Duct Type	Predicted Leakage Class C_L [Eq. (43)] Sealed[b,c]	Unsealed[c]
Metal (flexible excluded)		
Round and flat oval	3	30 (6 to 70)
Rectangular		
≤ 2 in. of water (both positive and negative pressures)	12	48 (12 to 110)
> 2 and ≤ 10 in. of water (both positive and negative pressures)	6	48 (12 to 110)[c]
Flexible		
Metal, aluminum	8	30 (12 to 54)
Nonmetal	12	30 (4 to 54)
Fibrous glass		
Round	3	na
Rectangular	6	na

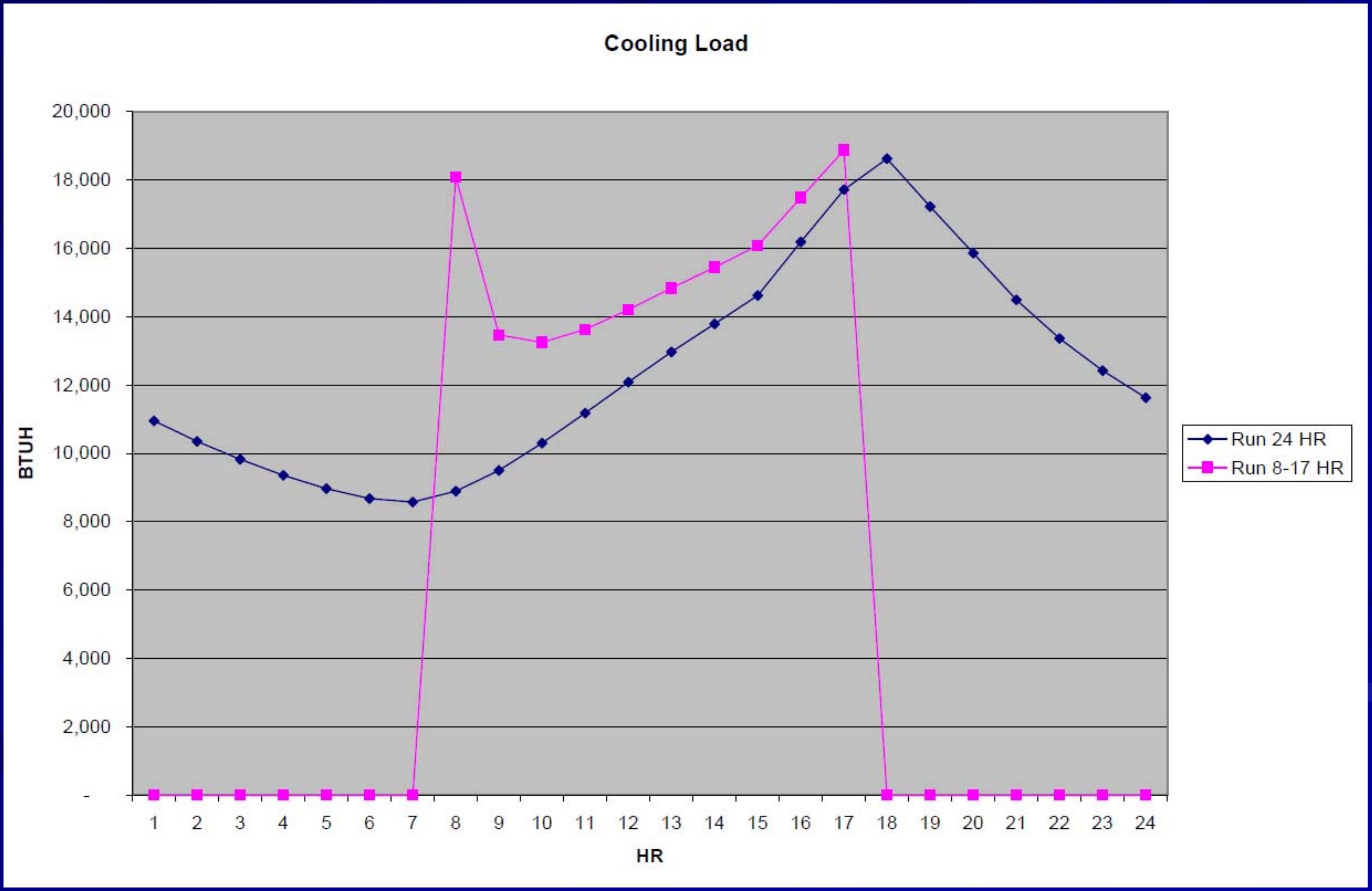
Duct Heat Gain & Leak Loss

Duct Heat Gain in % of RSH
-Supply Duct 1.5% (Typical Value)
-Return Duct 1.5% (Typical Value)

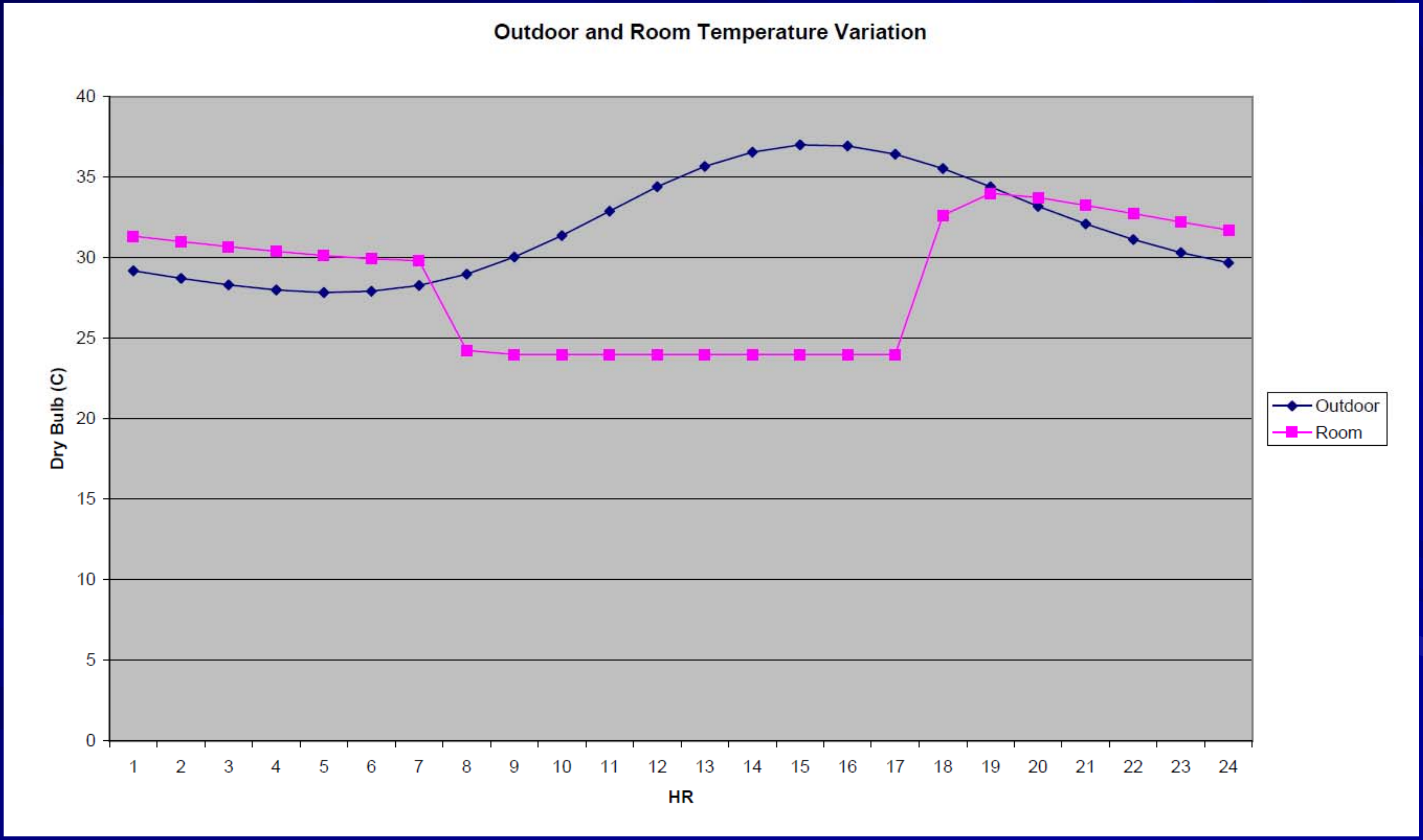
Duct Leakage in % of Total Air Supply
-Supply Duct 3% (Typical Value)
-Return Duct 0% (Typical Value)

Note that these value are only approximated.

Effect of Internal Mass



Room Temperature Variation



Diversity Factor & Block Load

TABLE 14-TYPICAL DIVERSITY FACTORS
FOR LARGE BUILDINGS
(Apply to Refrigeration Capacity)

TYPE OF APPLICATION	DIVERSITY FACTOR	
	People	Lights
Office	.75 to .90	.70 to .85
Apartment, Hotel	.40 to .60	.30 to .50
Department Store	.80 to .90	.90 to 1.0
Industrial*	.85 to .95	.80 to .90