Advanced Building Science

- Cooling Load Calculations
  - Principles & considerations
  - Heat flow rates and design conditions
  - Generalized procedures
  - Residential (simplified approach)

- Readings
  - HF - Chapter 17 => primary focus
  - HF - Chapter 18 => (review for procedures and tables)

Cooling Load Calculations

Principles and Considerations

- "Worst case" design loads for the equipment
  - may be different than "worst case" for a specific space
  - room by room calculation is strongly recommended
  - however, peak load may or may not coincide with the largest heat gain for a specific space or the whole house

Cooling Load Calculations

Principles and Considerations

- Far more complicated than heating design loads
  - additional gains
  - solar gain is extremely dynamic and time dependent
  - latent effects probably can't be ignored
  - radiant gains are significant and not always instantaneous
- Timing is everything

Heat Flow/Gain Rates – The Big Picture

- Space heat gain
  - mode of entry
  - sensible or latent heat gain
- Space cooling load
  - radiant heat gain
- Space heat extraction rate
- Distribution gains
- Cooling coil load

Initial Design Conditions

- Building characteristics
- Configuration
  - orientation will be important
- Outdoor design conditions
- Indoor design conditions
- Operating schedules
- Date and time of peak conditions
  - may require a several iterations

Heat Sources and Heat Gain Concepts

- Time delay
- People
- Lighting
- Motors
- Appliances
- Fenestration
- Exterior (and interior) surfaces
- Infiltration & ventilation
- Miscellaneous

It’s All About the Heat Balance

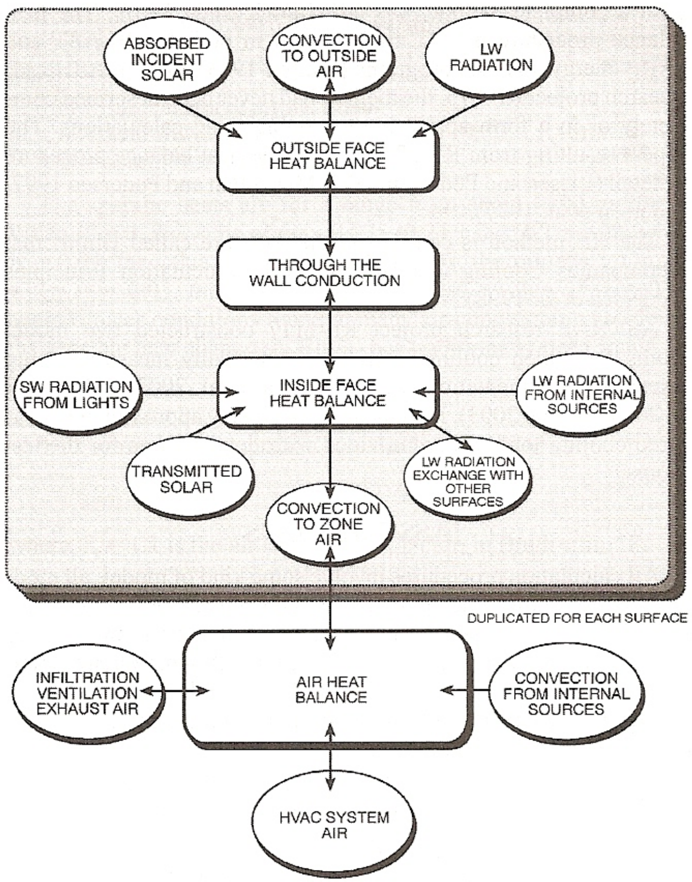

Fig. 5 Schematic of Heat Balance Processes in Zone

Source: ASHRAE Handbook Fundamentals 2013, Chapter 18.15

Overall Cooling Load Methods

Heat Balance (HB) Method

- Assumes well mixed
- Uniform surface temperatures and radiation

- Residential => Residential Load Factor (RLF) Method
  - Basis is ResHB
  - Functionally driven with Cooling Factors
  - See Table 1
- Commercial => Radiant Time Series (RTS) Method
  - Replaces earlier approaches such as
    - transfer function
    - total equivalent temperature difference / time averaging
    - cooling load temperature difference / cooling load factor

Residential Cooling Load Procedure

Unique features

- considered occupied 24 hours per day, every day
- loads are primarily through the structural components
  - comparatively the internal gains are small
- most residences are a single zone
- greater distribution losses (as fraction of total)
- residential cooling units are generally small
- dehumidification only occurs during cooling

Note: Multifamily buildings may or may not fit single family methods depending on exposures and systems used.

General Guidelines

- Design for Typical Building Use
  - Meet representative maximum conditions, not extreme conditions
- Building Codes and Standards
  - Codes and local regulations take precedence
- Design Judgment

General Guidelines

- Verification
  - Post-construction commissioning and verification is important
- Uncertainty & Safety Allowances
  - Due to the general and approximate nature, it may be tempting to add safety allowances for each aspect of the calculation
  - This can be compounding, so allowances (if applied, at all) should be added to final results

Total Sensible Cooling Load

- Heat gain through structural components
  - Below grade is ignored (or considered highly insulated)
- Heat gain through windows
  - transmission
  - solar radiation
- Heat gain caused by air infiltration and ventilation
- Heat gain due to occupancy
- Heat gain due to household equipment
- Heat gain in air distribution system

Latent Cooling Load

- Usually are evaluated separately
- However, for residential buildings they are frequently estimated as a percentage of sensible loads
  - This is clearly flawed, but better than nothing at all
  - Momentum is building to address latent loads more intentionally

Loads Through Opaque Surfaces

- RLF Method uses:

  $$q_{opq} = A \times CF_{opq}$$

  $$CF_{opq} = U(OF_t \times \Delta T + OF_b + OF_r \times DR)$$

- For ceilings/roof, walls, floors over ambient
  - use "opaque surface cooling factor coefficients"
  - see Table 7 & 8

May reduce load slightly using slab floor procedure

Source: ASHRAE Handbook Fundamentals 2013, Chapter 17.2

Table 7 Opaque Surface Cooling Factor Coefficients

Surface Type	OF_t	OF_b, °F	OF_r
Ceiling or wall adjacent to vented attic	0.62	$25.7\ \alpha_{roof} - 8.1$	–0.19
Ceiling/roof assembly	1	$68.9\ \alpha_{roof} - 12.6$	–0.36
Wall (wood frame) or door with solar exposure	1	14.8	–0.36
Wall (wood frame) or door (shaded)	1	0	–0.36
Floor over ambient	1	0	–0.06
Floor over crawlspace	0.33	0	–0.28
Slab floor (see Slab Floor section)			

α_{roof} = roof solar absorptance (see Table 8)

Source: ASHRAE Handbook Fundamentals 2013, Chapter 17.9

Table 8 Roof Solar Absorptance α_{roof}

Material	Color: White	Light	Medium	Dark
Asphalt shingles	0.75	0.75	0.85	0.92
Tile	0.30	0.40	0.80	0.80
Metal	0.35	0.50	0.70	0.90
Elastomeric coating	0.30			

Source: Summarized from Parker et al. 2000

Source: ASHRAE Handbook Fundamentals 2013, Chapter 17.8

Loads Through Transparent Surfaces

- RLF Method Uses:

$$q_{fen} = A \times CF_{fen}$$

$$CF_{fen} = U(\Delta T - 0.46DR) + PXI \times SHGC \times IAC \times FF$$

$$PXI = T_x \times E_t \qquad \text{(if unshaded)}$$

$$PXI = T\,[E_d + (1 - F_{shd})\,E_D\,] \qquad \text{(if shaded)}$$

  - PXI = Peak Exterior Irradiance [see Table 10, 11, & 12]
  - SHGC = solar heat gain coefficient see [Tables or NFRC value]
  - IAC = Interior shading attenuation coefficient [see Table 14]
  - FF = fenestration solar load factor [see Table 13]

Source: ASHRAE Handbook Fundamentals 2013, Chapter 17.9-11

Table 10 Peak Irradiance, Btu/h·ft²

Exposure		Latitude								
		20°	25°	30°	35°	40°	45°	50°	55°	60°
North	E_D	40	34	29	26	26	27	30	36	43
	E_d	41	36	33	30	27	24	22	20	18
	E_t	80	70	62	56	53	51	52	55	61
Northeast/Northwest	E_D	146	142	139	135	131	127	122	118	114
	E_d	56	54	51	50	48	47	45	44	43
	E_t	202	196	190	184	179	173	168	163	158
East/West	E_D	168	172	175	177	178	177	176	173	170
	E_d	63	62	61	60	60	60	59	59	59
	E_t	231	234	236	237	237	237	235	233	230
Southeast/Southwest	E_D	89	104	117	128	138	147	154	160	164
	E_d	65	64	64	65	65	66	66	67	68
	E_t	154	168	181	193	203	213	220	227	232
South	E_D	0	19	44	68	90	110	129	147	163
	E_d	53	61	62	63	65	66	68	70	71
	E_t	53	80	106	131	155	177	197	217	235
Horizontal	E_D	268	266	262	255	246	234	219	202	182
	E_d	54	54	54	54	54	54	54	54	54
	E_t	322	320	316	309	300	288	273	256	236

Source: ASHRAE Handbook Fundamentals 2013 Chapter 17.9

Table 11 Exterior Attachment Transmission

Attachment	T_x
None	1.0
Exterior insect screen	0.64 (see Chapter 15, Table 13G)
Shade screen	Manufacturer shading coefficient (SC) value, typically 0.4 to 0.6

Source: ASHRAE Handbook Fundamentals 2013, Chapter 17.10

Table 14 Interior Attenuation Coefficients (IAC_{cl})

Glazing Layers	Glazing Type (ID*)	Drapes: Open-Weave Light	Drapes: Closed-Weave Dark	Drapes: Closed-Weave Light	Roller Shades: Opaque Dark	Roller Shades: Opaque White	Roller Shades: Translucent Light	Blinds: Medium	Blinds: White
1	Clear (1a)	0.64	0.71	0.45	0.64	0.34	0.44	0.74	0.66
	Heat absorbing (1c)	0.68	0.72	0.50	0.67	0.40	0.49	0.76	0.69
2	Clear (5a)	0.72	0.81	0.57	0.76	0.48	0.55	0.82	0.74
	Low-e high-solar (17c)	0.76	0.86	0.64	0.82	0.57	0.62	0.86	0.79
	Low-e low-solar (25a)	0.79	0.88	0.68	0.85	0.60	0.66	0.88	0.82
	Heat absorbing (5c)	0.73	0.82	0.59	0.77	0.51	0.58	0.83	0.76

*Chapter 15 glazing identifier

Source: ASHRAE Handbook Fundamentals 2013, Chapter 17.11

Loads Due to Infiltration & Ventilation

- Find air flow and use equations:

$$q_s = C_s \times Q \times \Delta T$$

$$q_l = C_l \times Q \times \Delta W$$

- Air flow
  - use procedures Chapter 16 or
  - use simplified methods based on effective leakage area and infiltration driving force [see Tables 3, 4, & 5]

$$Q_i = A_l \times IDF$$

Source: ASHRAE Handbook Fundamentals 2013, Chapter 16

Loads Due to Internal Gains

- Use equations:

$$q_{ig,s} = 464 + 0.7A_{cf} + 75N_{oc}$$

$$q_{ig,l} = 68 + 0.7A_{cf} + 41N_{oc}$$

  - A_{cf} = conditioned floor area
  - N_{oc} = number of occupants

Source: ASHRAE Handbook Fundamentals 2013, Chapter 16

Loads Due to Air Distribution System

- Use equation:

$$q_d = F_{dl} \times q_{bl}$$

  - F_{dl} = duct gain factor [see Table 6]
  - q_{bl} = total building load (sensible)

Source: ASHRAE Handbook Fundamentals Chapter 17.8

Table 6 Typical Duct Loss/Gain Factors

		1 Story						2 or More Stories					
	Supply/Return Leakage	**11%/11%**			**5%/5%**			**11%/11%**			**5%/5%**		
Duct Location	**Insulation ft²·h·°F/Btu**	**R-0**	**R-4**	**R-8**	**R-0**	**R-4**	**R-8**	**R-0**	**R-4**	**R-8**	**R-0**	**R-4**	**R-8**
Conditioned space		No loss (F_{dl} = 0)											
Attic	C	1.26	0.71	0.63	0.68	0.33	0.27	1.02	0.66	0.60	0.53	0.29	0.25
	H/F	0.49	0.29	0.25	0.34	0.16	0.13	0.41	0.26	0.24	0.27	0.14	0.12
	H/HP	0.56	0.37	0.34	0.34	0.19	0.16	0.49	0.35	0.33	0.28	0.17	0.15
Basement	C	0.12	0.09	0.09	0.07	0.05	0.04	0.11	0.09	0.09	0.06	0.04	0.04
	H/F	0.28	0.18	0.16	0.19	0.10	0.08	0.24	0.17	0.15	0.16	0.09	0.08
	H/HP	0.23	0.17	0.16	0.14	0.09	0.08	0.20	0.16	0.15	0.12	0.08	0.07
Crawlspace	C	0.16	0.12	0.11	0.10	0.06	0.05	0.14	0.12	0.11	0.08	0.06	0.05
	H/F	0.49	0.29	0.25	0.34	0.16	0.13	0.41	0.26	0.24	0.27	0.14	0.12
	H/HP	0.56	0.37	0.34	0.34	0.19	0.16	0.49	0.35	0.33	0.28	0.17	0.15

Values calculated for ASHRAE *Standard* 152 default duct system surface area using model of Francisco and Palmiter (1999). Values are provided as guidance only; losses can differ substantially for other conditions and configurations. Assumed surrounding temperatures:

Cooling (C): t_o = 95°F, t_{attic} = 120°F, t_b = 68°F, t_{crawl} = 72°F   Heating/furnace (H/F) and heating/heating pump (H/HP): t_o = 32°F, t_{attic} = 32°F, t_b = 64°F, t_{crawl} = 32°F

Source: ASHRAE Handbook Fundamentals 2013, Chapter 17.8

Loads Due to Latent Gains

- Use equation (32):

$$q_l = q_{vi,l} \text{ x } q_{ig,l}$$

- Usually added at the end
  – Sometimes as a percentage of total sensible gain, but that is not the preferred method

Source: ASHRAE Handbook Fundamentals 2013, Chapter 17.10

Cooling Load Summary

Table 15 Summary of RLF Cooling Load Equations

Load Source	Equation	Tables and Notes
Exterior opaque surfaces	$q_{opq} = A \times \text{CF}$	
	$\text{CF} = U(\text{OF}_t \Delta t + \text{OF}_b + \text{OF}_r \text{DR})$	OF factors from Table 7
Exterior transparent surfaces	$q_{fen} = A \times \text{CF}$	PXI from Table 9 plus adjustments
	$\text{CF} = U(\Delta t - 0.46\text{DR}) + \text{PXI} \times \text{SHGC} \times \text{IAC} \times \text{FF}_s$	FF_s from Table 13
Partitions to unconditioned space	$q = AU\Delta t$	Δt = temperature difference across partition
Ventilation/infiltration	$q_s = C_s Q \Delta t$	See Common Data and Procedures section
Occupants and appliances	$q_{ig,s} = 464 + 0.7A_{cf} + 75N_{oc}$	
Distribution	$q_d = F_{dl} \Sigma q$	F_{dl} from Table 6
Total sensible load	$q_s = q_d + \Sigma q$	
Latent load	$q_l = q_{vi,l} + q_{ig,}$	
Ventilation/infiltration	$q_{vi,l} = C_l Q \Delta W$	
Internal gain	$q_{ig,l} = 68 + 0.07A_{cf} + 41N_{oc}$	

Source: ASHRAE Handbook Fundamentals 2013, Chapter 17.11

In Summary

Questions and Discussion

Next Class

- Energy Estimating
  - General considerations
  - Component modeling and loads
  - System modeling
    - Degree-day methods (primarily heating)
    - Bin method (heating & cooling)

- Readings
  - HF Chapter 19.1 to 19.8
  - HF Chapter 19.16 to 19.33

Supplemental Slide

FENESTRATION DIRECT SOLAR, DIFFUSE SOLAR, AND CONDUCTIVE HEAT GAINS

For fenestration heat gain, use the following equations:

Direct beam solar heat gain q_b:

$$q_b = AE_{t,b}\,\mathrm{SHGC}(\theta)\mathrm{IAC}(\theta,\Omega) \qquad (13)$$

Diffuse solar heat gain q_d:

$$q_d = A(E_{t,d} + E_{t,r})\langle \mathrm{SHGC} \rangle_D\, \mathrm{IAC}_D \qquad (14)$$

Conductive heat gain q_c:

$$q_c = UA(T_{out} - T_{in}) \qquad (15)$$

Total fenestration heat gain Q:

$$Q = q_b + q_d + q_c \qquad (16)$$

Source: ASHRAE Handbook Fundamentals Chapter 18

Supplemental Slide

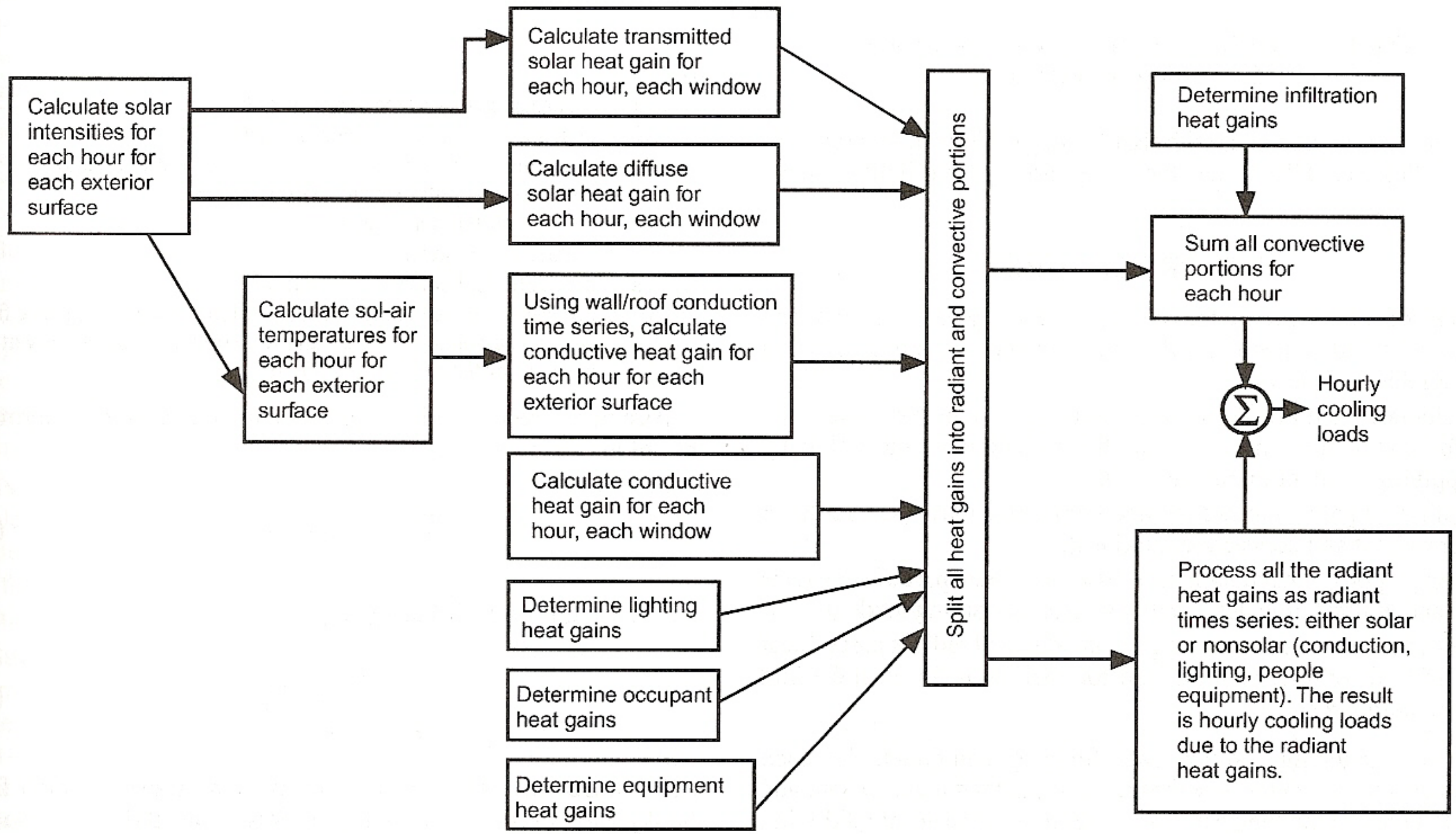

Fig. 8 Overview of Radiant Time Series Method

Source: ASHRAE Handbook Fundamentals Chapter 18

Supplemental Slide

Table 14 Recommended Radiative/Convective Splits for Internal Heat Gains

Heat Gain Type	Recommended Radiative Fraction	Recommended Convective Fraction	Comments
Occupants, typical office conditions	0.6	0.4	See Table 1 for other conditions.
Equipment	0.1 to 0.8	0.9 to 0.2	See Tables 6 to 12 for details of equipment heat gain and recommended radiative/convective splits for motors, cooking appliances, laboratory equipment, medical equipment, office equipment, etc.
Office, with fan	0.10	0.9	
Without fan	0.3	0.7	
Lighting			Varies; see Table 3.
Conduction heat gain			
Through walls and floors	0.46	0.54	
Through roof	0.60	0.40	
Through windows	0.33 (SHGC > 0.5) 0.46 (SHGC < 0.5)	0.67 (SHGC > 0.5) 0.54 (SHGC < 0.5)	
Solar heat gain through fenestration			
Without interior shading	1.0	0.0	
With interior shading			Varies; see Tables 13A to 13G in Chapter 15.
Infiltration	0.0	1.0	

Source: Nigusse (2007).

Source: ASHRAE Handbook Fundamentals Chapter 18

Supplemental Slide

Table 15 Solar Absorptance Values of Various Surfaces

Surface	Absorptance
Brick, red (Purdue) [a]	0.63
Paint	
Red[b]	0.63
Black, matte[b]	0.94
Sandstone[b]	0.50
White acrylic[a]	0.26
Sheet metal, galvanized	
New[a]	0.65
Weathered[a]	0.80
Shingles	0.82
Gray[b]	
Brown[b]	0.91
Black[b]	0.97
White[b]	0.75
Concrete[a,c]	0.60 to 0.83

Source: ASHRAE Handbook Fundamentals Chapter 18

Supplemental Slide

Table 16 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, Btu/h·ft²·°F	0.075	0.076	0.075	0.074	0.074	0.071	0.073	0.118	0.054	0.092	0.101	0.066	0.050	0.102	0.061	0.111	0.124	0.091	0.102	0.068
Total *R*	13.3	13.2	13.3	13.6	13.6	14.0	13.8	8.5	18.6	10.8	9.9	15.1	20.1	9.8	16.3	9.0	8.1	11.0	9.8	14.6
Mass, lb/ft²	6.3	4.3	16.4	5.2	17.3	5.2	13.7	7.5	7.8	26.8	42.9	44.0	44.2	59.6	62.3	76.2	80.2	96.2	182.8	136.3
Thermal Capacity, Btu/ft²·°F	1.5	1.0	3.3	1.2	3.6	1.6	3.0	1.8	1.9	5.9	8.7	8.7	8.7	11.7	12.4	15.7	15.3	19.0	38.4	28.4
Hour	**Conduction Time Factors, %**																			
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	44	41	50	25	2	5	4	1	1	2	2	1	3	4	3
2	20	15	32	18	33	32	34	26	31	6	14	13	7	2	2	2	3	3	4	3
3	4	3	11	3	13	12	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
Layer ID from outside to inside (see Table 18)	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01
	F09	F08	F10	F08	F10	F11	F07	F06	F06	F06	M01	M01	M01	M01	M01	M01	M01	M01	M01	M01
	F04	F04	F04	G03	G03	G02	G03	I01	I01	I01	F04	F04	F04	F04	F04	F04	F04	F04	F04	F04
	I02	I02	I02	I04	I04	I04	I04	G03	G03	G03	I01	G03	I01	I01	M03	I01	I01	I01	I01	M15
	F04	F04	F04	G01	G01	G04	G01	F04	I04	M03	G03	I04	G03	M03	I04	M05	M01	M13	M16	I04
	G01	G01	G01	F02	F02	F02	F02	G01	G01	F04	F04	G01	I04	F02	G01	G01	F02	F04	F04	G01
	F02	F02	F02	—	—	—	—	F02	F02	G01	G01	F02	G01	—	F02	F02	—	G01	G01	F02
	—	—	—	—	—	—	—	—	—	F02	F02	—	F02	—	—	—	—	F02	F02	—

Source: ASHRAE Handbook Fundamentals Chapter 18

Supplemental Slide

Table 17 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, Btu/h·ft²·°F	0.044	0.040	0.045	0.041	0.042	0.041	0.069	0.058	0.080	0.065	0.057	0.036	0.052	0.054	0.052	0.051	0.056	0.055	0.042
Total *R*	22.8	25.0	22.2	24.1	23.7	24.6	14.5	17.2	12.6	15.4	17.6	27.6	19.1	18.6	19.2	19.7	18.0	18.2	23.7
Mass, lb/ft²	5.5	4.3	2.9	7.1	11.4	7.1	10.0	11.5	4.9	6.3	5.1	5.6	11.8	30.6	43.9	57.2	73.9	97.2	74.2
Thermal Capacity, Btu/ft²·°F	1.3	0.8	0.6	2.3	3.6	2.3	3.7	3.9	1.4	1.6	1.4	1.6	2.8	6.6	9.3	12.0	16.3	21.4	16.2
Hour	**Conduction Time Factors, %**																		
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	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
Layer ID from outside to inside (see Table 18)	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01	F01
	F08	F08	F08	F12	F14	F15	F13	F13	F13	F13	F13	F13	M17	F13	F13	F13	F13	F13	F13
	G03	G03	G03	G05	G05	G05	G03	G03	G03	G03	G03	G03	F13	G03	G03	G03	G03	G03	M14
	F05	F05	F05	F05	F05	F05	I02	I02	I02	I02	I03	I02	G03	I03	I03	I03	I03	I03	F05
	I05	I05	I05	I05	I05	I05	G06	G06	F08	F08	F08	I03	I03	M11	M12	M13	M14	M15	I05
	G01	F05	F03	F05	F05	F05	F03	F05	F03	F05	F03	F08	F08	F03	F03	F03	F03	F03	F16
	F03	F16	—	G01	G01	G01	—	F16	—	F16	—	—	F03	—	—	—	—	—	F03
	—	F03	—	F03	F03	F03	—	F03	—	F03	—	—	—	—	—	—	—	—	—

Source: ASHRAE Handbook Fundamentals Chapter 18

Supplemental Slide

Table 30 Window Component of Cooling Load (No Blinds or Overhang)

Local Standard Hour	Unshaded Direct Beam Solar (if AC = 1): Beam Heat Gain, Btu/h	Convective 0%, Btu/h	Radiant 100%, Btu/h	Solar RTS, Zone Type 8, %	Radiant Btu/h	Cooling Load, Btu/h	Shaded Direct Beam (AC < 1.0) + Diffuse + Conduction: Beam Heat Gain, Btu/h	Diffuse Heat Gain, Btu/h	Conduction Heat Gain, Btu/h	Total Heat Gain, Btu/h	Convective 54%, Btu/h	Radiant 46%, Btu/h	Nonsolar RTS, Zone Type 8	Radiant Btu/h	Cooling Load, Btu/h	Window Cooling Load, Btu/h
1	0	0	0	54	196	196	0	0	–54	–54	–29	–25	49	138	109	305
2	0	0	0	16	196	196	0	0	–90	–90	–48	–41	17	118	70	266
3	0	0	0	8	196	196	0	0	–121	–121	–65	–56	9	101	36	232
4	0	0	0	4	196	196	0	0	–148	–148	–80	–68	5	84	4	200
5	0	0	0	3	196	196	0	0	–166	–166	–90	–76	3	67	–23	174
6	0	0	0	2	196	196	0	106	–148	–42	–23	–19	2	81	58	254
7	0	0	0	1	196	196	0	569	–81	488	263	224	2	196	460	656
8	0	0	0	1	191	191	0	1002	76	1078	582	496	1	361	943	1134
9	0	0	0	1	169	169	0	1371	251	1622	876	746	1	539	1415	1583
10	0	0	0	1	132	132	0	1665	408	2073	1119	953	1	705	1824	1956
11	0	0	0	1	86	86	0	1887	547	2434	1314	1119	1	849	2164	2249
12	0	0	0	1	42	42	0	2177	641	2818	1522	1296	1	994	2516	2558
13	537	0	537	1	300	300	0	2436	717	3153	1703	1450	1	1130	2833	3133
14	2183	0	2183	1	1265	1265	0	2614	762	3376	1823	1553	1	1241	3064	4329
15	3722	0	3722	1	2402	2402	0	2648	762	3410	1841	1569	1	1303	3144	5547
16	4583	0	4583	1	3266	3266	0	2479	708	3187	1721	1466	1	1291	3012	6278
17	4392	0	4392	1	3506	3506	0	2072	632	2703	1460	1243	1	1191	2651	6157
18	3177	0	3177	1	3010	3010	0	1429	538	1967	1062	905	1	999	2061	5071
19	1017	0	1017	1	1753	1753	0	599	399	998	539	459	1	717	1256	3008
20	0	0	0	0	832	832	0	0	300	300	162	138	1	456	618	1449
21	0	0	0	0	496	496	0	0	215	215	116	99	0	332	448	945
22	0	0	0	0	334	334	0	0	130	130	70	60	0	255	325	659
23	0	0	0	0	248	248	0	0	58	58	31	27	0	203	234	483
24	0	0	0	0	206	206	0	0	0	0	0	0	0	167	167	373

Source: ASHRAE Handbook Fundamentals Chapter 18