

ME 425

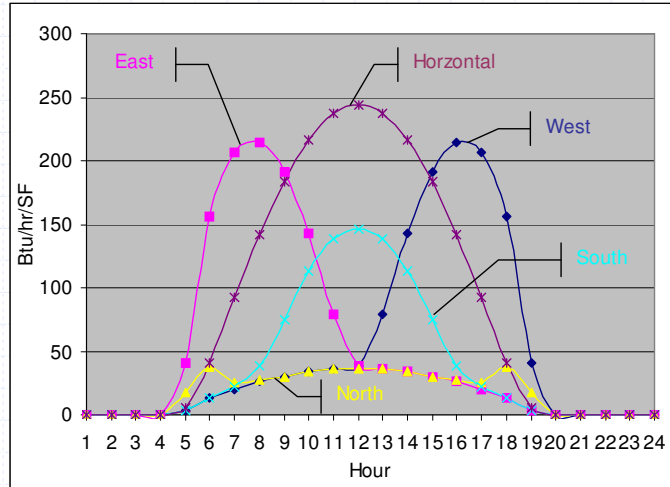
Space Cooling Load Calculations

Keith E. Elder, P.E.

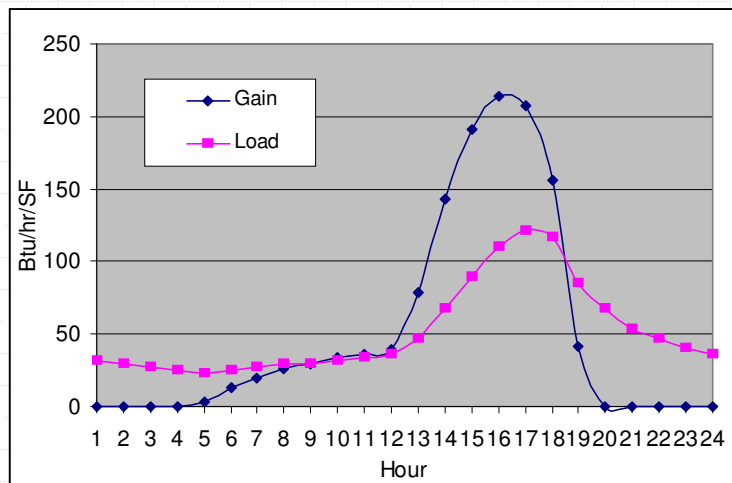
Cooling Load vs. Heat Gain

- ◆ **Space Heat Gain**
 - The instantaneous rate at which heat enters into and/or is generated within a space at a given instant.
- ◆ **Space Cooling Load**
 - The rate at which heat must be removed from the space to maintain a constant space air temperature.
- ◆ **Heat Extraction**
 - The actual heat removed from the space taking account that space air temperature does not remain constant, but experiences minor, cyclic variations.

Solar Heat Gain (July)



Solar Cooling Load vs. Heat Gain July oriented West – 48° N. Lat.



Calculation Techniques

- ◆ TETD/TA Method
 - Originally Developed by Willis Carrier
 - Widely used but sources not well-documented
- ◆ Transfer Function Method (TFM)
 - Rigorous & Complex
 - Requires Computer
- ◆ 1989 CLTD/CLF Method
 - Hand Calculation Method
 - Simplified Factors based on TFM (above)
- ◆ Radiant Time Series (RTS) Method
 - Based on Heat Balance Method (exact solution)
 - Requires Computer-Based Solution Techniques

CLTD/CLF Method Formulas

- ◆ Glass cooling load is calculated:
 - $q = A(SC)(SHGF)(CLF)$ for radiation
 - $q = UA(CLTD)$ for conduction
- ◆ Opaque surface cooling load is calculated:
 - $q = UA(CLTD)$
- ◆ Internal loads are calculated:
 - $q_{\text{cooling load}} = q_{\text{heat gain}} \times CLF$

Opaque Surface Cooling Load

$$q = UA(\text{CLTD}_{\text{corrected}})$$

- U = Assembly U-factor
- A = Opaque Surface Area
- CLTD = Cooling Load Temperature Difference
 - ◆ Based on latitude
 - ◆ Time-of-day
 - ◆ Thermal storage in materials used
 - ◆ R-value of component
 - ◆ Presence of suspended ceiling (for roofs only)

Opaque Surface Calculation

- ◆ Use Table 31 (89F26.36) for Wall Calculations
- ◆ Use Table 29 (89F26.34) for Roof Calculations
 - Select Wall/Roof Type
 - Look up uncorrected CLTD
 - Correct CLTD

$$\text{CLTD}_{\text{corrected}} = (\text{CLTD} + \text{LM})k + (78 - t_{\text{room}}) + (t_m - 85)$$

LM = Latitude/Month Correction Factor (Table 32 - 89F26.37)

k = Color Correction (Dark = 1.0, Med = 0.83, Light = 0.65)

t_{room} = design indoor space temperature

t_m = average temperature on the design day

= max.outdoor temperature - (daily range) / 2

Wall CLTD Tables

Table 31 Cooling Load Temperature Differences for Calculating Cooling Load from Sun

		Solar Time, h																								
		0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	
North Latitude	Wall Facing	Group A Walls																								
N	N	14	14	14	13	13	12	12	11	11	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
NE	NE	19	19	19	18	17	17	16	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
E	E	24	24	24	23	22	21	20	19	19	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
SE	SE	24	23	23	22	21	20	20	19	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
S	S	20	20	19	19	18	18	17	16	16	15	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
SW	SW	23	23	23	24	24	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
W	W	27	27	26	26	25	24	24	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
NW	NW	21	21	21	20	20	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
		Group B Walls																								
N	N	15	14	14	13	13	12	12	11	11	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
NE	NE	20	20	19	18	18	17	17	16	16	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
E	E	23	23	22	21	20	19	19	18	18	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
SE	SE	23	22	22	21	20	19	19	18	18	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
S	S	21	20	19	19	18	18	17	16	16	15	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
SW	SW	25	25	25	26	26	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
W	W	29	29	28	28	27	27	26	26	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
NW	NW	23	23	23	22	22	21	21	20	20	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
		Group C Walls																								
N	N	15	14	13	12	11	10	9	8	8	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
NE	NE	19	17	16	14	13	13	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
E	E	22	21	19	17	15	14	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
SE	SE	22	21	19	17	15	14	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
S	S	21	19	18	16	15	13	12	10	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
SW	SW	26	27	25	23	20	18	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
W	W	31	29	27	25	22	20	18	16	14	13	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
NW	NW	25	23	21	20	18	16	14	13	13	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

Roof CLTD Tables

Table 29 Cooling Load Temperature Differences (CLTD) for Calculating Cooling Load from Floor

Roof No	Description of Construction	Weight, lb/ft ²	U-value, Btu/h·ft ² ·°F	Solar Time																							
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Without Suspended Ceiling																											
1	Steel sheet with 1-in. (or 2-in.) insulation	7 (8)	0.213 (0.124)	1	-2	-3	-3	-3	-3	6	19	34	49	61	71	78	79	77	70	59	45	30	18	12	8	5	3
2	1-in. wood with 1-in. insulation	8	0.170	6	3	0	-1	-3	-3	-2	4	14	27	39	52	62	70	74	74	70	62	51	38	28	20	14	9
3	4-in. lightweight concrete	18	0.213	9	5	2	0	-2	-3	-3	1	9	20	32	44	55	64	70	73	71	66	57	45	34	25	18	13
4	2-in. heavyweight concrete with 1-in. (or 2-in.) insulation	29 (0.122)	0.206 (0.122)	12	8	5	3	0	-1	-1	3	11	20	30	41	51	59	65	66	66	62	54	45	36	29	22	17
5	1-in. wood with 2-in. insulation	9	0.109	3	0	-3	-4	-5	-7	-6	-3	5	16	27	39	49	57	63	64	62	57	48	37	26	18	11	7
6	6-in. lightweight concrete	24	0.158	22	17	13	9	6	3	1	3	7	15	23	33	43	51	58	62	64	62	57	50	42	35	28	
7	2.5-in. wood with 1-in. ins.	13	0.130	29	24	20	16	13	10	7	6	6	9	13	20	27	34	42	48	53	55	56	54	49	44	39	34
8	8-in. lightweight concrete	31	0.126	35	30	26	22	18	14	11	9	7	7	9	13	19	25	33	39	46	50	53	54	53	49	45	40
9	4-in. heavyweight concrete with 1-in. (or 2-in.) insulation	52 (52)	0.200 (0.120)	25	22	18	15	12	9	8	8	10	14	20	26	33	40	46	50	53	53	52	48	43	38	34	30
10	2.5-in. wood with 2-in. ins.	13	0.093	30	26	23	19	16	13	10	9	8	9	13	17	23	29	36	41	46	49	51	50	47	43	39	35
11	Roof terrace system	75	0.106	34	31	28	25	22	19	16	14	13	13	15	18	22	26	31	36	40	44	45	46	45	43	40	37
12	6-in. heavyweight concrete with 1-in. (or 2-in.) insulation	75 (75)	0.192 (0.117)	31	28	25	22	20	17	15	14	14	16	18	22	26	31	36	40	43	45	45	44	42	40	37	34
13	4-in. wood with 1-in. (or 2-in.) insulation	17 (18)	0.106 (0.078)	38	36	33	30	28	25	22	20	18	17	16	17	18	21	24	28	32	36	39	41	43	43	42	40

Opaque Adjustment Factors

Table 32 CLTD Correction For Latitude and Month Applied to Walls and Roofs, North Latitudes

Lat.	Month	N	NNE NNW	NE NW	ENE WNW	E W	ESE WSW	SE SW	SSE SSW	S	HOR
0	Dec	-3	-5	-5	-5	-2	0	3	6	9	-1
	Jan/Nov	-3	-5	-4	-4	-1	0	2	4	7	-1
	Feb/Oct	-3	-2	-2	-2	-1	-1	0	-1	0	0
	Mar/Sept	-3	0	1	-1	-1	-3	-3	-5	-8	0
	Apr/Aug	5	4	3	0	-2	-5	-6	-8	-8	-2
	May/Jul	10	7	5	0	-3	-7	-8	-9	-8	-4
8	Dec	-4	-6	-6	-6	-3	0	4	8	12	-5
	Jan/Nov	-3	-5	-6	-5	-2	0	3	6	10	-4
	Feb/Oct	-3	-4	-3	-3	-1	-1	1	2	4	-1
	Mar/Sept	-3	-2	-1	-1	-1	-2	-2	-3	-4	0
	Apr/Aug	2	2	2	0	-1	-4	-5	-7	-7	-1
	May/Jul	7	5	4	0	-2	-5	-7	-9	-7	-2
16	Dec	-4	-6	-8	-8	-4	-1	4	9	13	-9
	Jan/Nov	-4	-6	-7	-7	-4	-1	4	8	12	-7
	Feb/Oct	-3	-5	-5	-4	-2	0	2	5	7	-4
	Mar/Sept	-3	-3	-2	-2	-1	-1	0	0	0	-1
	Apr/Aug	-1	0	-1	-1	-1	-3	-3	-5	-6	0
	May/Jul	4	3	3	0	-1	-4	-5	-7	-7	0
	Jun	6	4	4	1	-1	-4	-6	-8	0	-7

ASHRAE Table 1B-Cooling

Design conditions for SEATTLE/TACOMA, WA, USA

Station Information															
Station name	WMO#	Lat	Long	Elev	StdP	Hours +/- UTC	Time zone code	Period							
<i>t_a</i>	<i>t_b</i>	<i>t_c</i>	<i>t_d</i>	<i>t_e</i>	<i>t_f</i>	<i>t_g</i>	<i>t_h</i>	<i>t_i</i>							
SEATTLE/TACOMA	727930	47.45N	122.30W	400	14.485	-8.00	NAP	7201							
Annual Heating and Humidification Design Conditions															
Coldest month	Heating DB				Humidification DP/MCDB and HR				Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB		
	99.6%	99%	DP	HR	99.6%	99%	DP	HR	MCDB	WS	0.4%	1%	MCDB	MCWS	PCWD
2	3a	3b	4a	4b	4c	4d	4e	4f	5a	5b	5c	5d	6a	6b	
12	23.8	28.4	5.8	7.5	28.5	13.0	10.8	32.6	26.2	44.4	23.9	45.8	9.3	20	
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%	0.4%	1%	2%	0.4%	1%	2%	MCWS	PCWD
7	8	9a	9b	9c	9d	9e	9f	10a	10b	10c	10d	10e	10f	11a	11b
	18.2	84.9	65.2	81.2	63.7	77.6	62.3	66.5	82.5	64.7	78.9	63.1	75.8	9.7	0

Daily Range

Glass Cooling Load, Radiation

$$q=A(SC)(SHGF)(CLF)$$

- A = glass area
- SC = Shading Coefficient
- SHGF = Solar Heat Gain Factor, tabulated by
 - ◆ Latitude
 - ◆ Month
 - ◆ Orientation
- CLF = Cooling Load Factor, tabulated by
 - ◆ Time-of-day
 - ◆ Building Mass
 - ◆ Floor Treatment (Optional)

Solar Heat Gain Factors (Table 34-89F26.40)

48° N. Lat										
	N (Shade)	NNE/ NNW	NE/ NW	ENE/ WNW	E/ W	ESE/ WSW	SE/ SW	SSE/ SSW	S	HOR
Jan.	15	15	15	53	118	175	216	239	245	85
Feb.	20	20	36	103	168	216	242	249	250	138
Mar.	26	26	80	154	204	234	239	232	228	188
Apr.	31	61	132	180	219	225	215	194	186	226
May	35	97	158	200	218	214	192	163	150	247
June	46	110	165	204	215	206	180	148	134	252
July	37	96	156	196	214	209	187	158	146	244
Aug.	33	61	128	174	211	216	208	188	180	223
Sep.	27	27	72	144	191	223	228	223	220	182
Oct.	21	21	35	96	161	207	233	241	242	136
Nov.	15	15	15	52	115	172	212	234	240	85
Dec.	13	13	13	36	91	156	195	225	233	65

Shading Coefficient

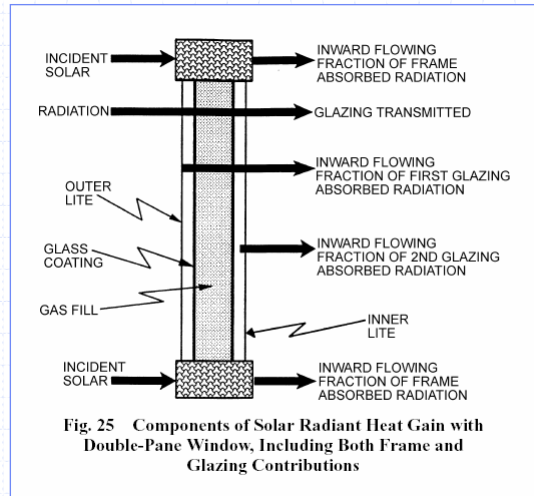


Fig. 25 Components of Solar Radiant Heat Gain with Double-Pane Window, Including Both Frame and Glazing Contributions

Shading Coefficients

(Table 11- '97F29.25-26)

Table 11 Visible Transmission (VT), Shading Coefficient (SC), and Solar Heat Gain Coefficient (SHGC) at Normal Incidence for Single Pane Glass and Insulating Glass

Glazing System	Glass Thick ID in.	Center Glazing VT	Center Glazing SC	Glazing SHGC at Specified Incidence Angles							Total Window SHGC at Normal Incidence					
				Normal							Aluminum		Other Frames		All Frames	
				0°	40°	50°	60°	70°	Hemis. (Diffuse)	Operable	Fixed	Operable	Fixed	Operable	Fixed	
<i>Uncoated Single Glazing</i>																
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	
<i>Reflective Single Glazing</i>																
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	
<i>Uncoated Double Glazing</i>																
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 GRV 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	

Shading Coefficients (Table 19-05F31.48) (SC=1.15 x SHGC)

Table 19 Interior Solar Attenuation Coefficients (IAC) for Single or Double Glazings Shaded by Interior Venetian Blinds or Roller Shades

Glazing System ^a	Nominal Thickness ^b Each Pane, in.	Glazing Solar Transmittance ^b		IAC					
		Outer Pane	Single or Inner Pane	Glazing SHGC ^b	Venetian Blinds		Roller Shades		
					Medium	Light	Opaque Dark	Opaque White	Translucent Light
<i>Single Glazing Systems</i>									
Clear, residential	1/8 ^c		0.87 to 0.80	0.86	0.75 ^d	0.68 ^d	0.82	0.40	0.45
Clear, commercial	1/4 to 1/2		0.80 to 0.71	0.82					
Clear, pattern	1/8 to 1/2		0.87 to 0.79						
Heat absorbing, pattern	1/8			0.59					
Tinted	3/16, 7/32		0.74, 0.71						
<i>Above glazings, automated blinds^e</i>									
Above glazings, tightly closed vertical blinds				0.86	0.44	0.59			
Heat absorbing ^f	1/4		0.46	0.59	0.30	0.26			
Heat absorbing, pattern	1/4				0.84	0.78	0.66	0.44	0.47
Tinted	1/8, 1/4		0.51, 0.45						
Heat absorbing or pattern			0.44 to 0.30	0.59	0.79	0.76	0.59	0.41	0.47
Heat absorbing	3/8		0.34						
Heat absorbing or pattern			0.29 to 0.15						
Reflective coated glass			0.24	0.37	0.99	0.94	0.85	0.66	0.73
			0.26 to 0.52	0.83	0.75				
<i>Double Glazing Systems^g</i>									
Clear double, residential	1/8	0.87	0.87	0.76	0.71 ^d	0.66 ^d	0.81	0.40	0.46
Clear double, commercial	1/4	0.80	0.80	0.70					
Heat absorbing double ^h	1/4	0.46	0.8	0.47	0.72	0.66	0.74	0.41	0.55
Reflective double				0.17 to 0.35	0.90	0.86			

Cooling Load Factors (CLF) (Table 36-89F26.41)

Air-Conditioning Cooling Load

26.41

Table 36 Cooling Load Factors (CLF) for Glass Without Interior Shading, North Latitudes, General

Fenestration Facing	Room Construction	Solar Time, h																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
		N (Shaded)	L	0.17	0.14	0.11	0.09	0.08	0.33	0.42	0.48	0.56	0.63	0.71	0.76	0.80	0.82	0.82	0.79	0.75	0.84	0.61	0.48	0.38	0.31
	M	0.23	0.20	0.18	0.16	0.14	0.34	0.41	0.46	0.53	0.59	0.65	0.70	0.73	0.75	0.76	0.74	0.75	0.79	0.61	0.50	0.42	0.36	0.31	0.27
	H	0.25	0.23	0.21	0.20	0.19	0.38	0.45	0.49	0.55	0.60	0.65	0.69	0.72	0.72	0.72	0.70	0.70	0.75	0.57	0.46	0.39	0.34	0.31	0.28
	L	0.36	0.32	0.28	0.23	0.17	0.26	0.43	0.47	0.44	0.41	0.40	0.39	0.38	0.36	0.33	0.30	0.26	0.20	0.16	0.13	0.10	0.08	0.07	0.07
	M	0.09	0.08	0.07	0.06	0.06	0.24	0.38	0.42	0.39	0.37	0.37	0.36	0.36	0.34	0.33	0.30	0.27	0.22	0.18	0.16	0.14	0.13	0.12	0.10
	H	0.11	0.10	0.09	0.08	0.08	0.26	0.39	0.42	0.39	0.38	0.35	0.34	0.34	0.33	0.32	0.31	0.28	0.25	0.21	0.18	0.16	0.14	0.13	0.12
NE	L	0.04	0.04	0.03	0.02	0.02	0.23	0.41	0.51	0.51	0.45	0.39	0.38	0.35	0.31	0.28	0.26	0.23	0.19	0.15	0.12	0.10	0.08	0.06	0.05
	M	0.07	0.06	0.06	0.05	0.04	0.21	0.36	0.44	0.45	0.40	0.36	0.33	0.31	0.30	0.28	0.26	0.23	0.21	0.17	0.15	0.13	0.11	0.09	0.08
	H	0.09	0.08	0.08	0.07	0.07	0.23	0.37	0.44	0.44	0.39	0.34	0.31	0.29	0.27	0.26	0.24	0.22	0.20	0.17	0.14	0.13	0.12	0.11	0.10
ENE	L	0.04	0.03	0.03	0.02	0.02	0.21	0.40	0.52	0.57	0.53	0.45	0.39	0.34	0.31	0.28	0.25	0.22	0.18	0.14	0.12	0.09	0.08	0.06	0.05
	M	0.07	0.06	0.05	0.05	0.04	0.20	0.35	0.45	0.49	0.47	0.41	0.36	0.33	0.30	0.28	0.26	0.23	0.20	0.17	0.14	0.12	0.11	0.09	0.08
	H	0.09	0.09	0.08	0.07	0.07	0.25	0.36	0.46	0.49	0.45	0.38	0.35	0.30	0.27	0.25	0.23	0.21	0.19	0.16	0.14	0.13	0.12	0.11	0.10
E	L	0.04	0.03	0.03	0.02	0.02	0.19	0.37	0.51	0.57	0.57	0.50	0.42	0.37	0.32	0.29	0.25	0.22	0.19	0.15	0.12	0.10	0.08	0.06	0.05
	M	0.07	0.06	0.06	0.05	0.05	0.18	0.33	0.44	0.50	0.51	0.46	0.39	0.35	0.31	0.29	0.26	0.23	0.21	0.17	0.15	0.13	0.11	0.09	0.08
	H	0.09	0.09	0.08	0.08	0.07	0.20	0.34	0.45	0.49	0.49	0.43	0.36	0.32	0.29	0.26	0.24	0.22	0.19	0.17	0.15	0.13	0.12	0.11	0.10
ESE	L	0.05	0.04	0.03	0.03	0.02	0.17	0.34	0.49	0.58	0.61	0.57	0.48	0.41	0.36	0.32	0.28	0.24	0.20	0.16	0.13	0.10	0.09	0.07	0.06
	M	0.08	0.07	0.06	0.05	0.05	0.16	0.31	0.43	0.51	0.54	0.51	0.40	0.39	0.35	0.32	0.29	0.26	0.22	0.19	0.16	0.14	0.12	0.11	0.09
	H	0.10	0.09	0.09	0.08	0.08	0.19	0.32	0.43	0.50	0.52	0.49	0.41	0.36	0.32	0.29	0.26	0.24	0.21	0.18	0.16	0.14	0.13	0.12	0.11
SE	L	0.05	0.04	0.04	0.03	0.03	0.13	0.28	0.43	0.55	0.62	0.63	0.57	0.48	0.42	0.37	0.33	0.28	0.24	0.19	0.15	0.12	0.10	0.08	0.07
	M	0.09	0.08	0.07	0.06	0.05	0.14	0.26	0.38	0.48	0.54	0.56	0.51	0.43	0.40	0.36	0.33	0.29	0.25	0.21	0.18	0.16	0.14	0.12	0.10
	H	0.11	0.10	0.10	0.09	0.08	0.17	0.28	0.40	0.49	0.53	0.53	0.48	0.41	0.36	0.33	0.30	0.27	0.23	0.20	0.18	0.16	0.14	0.13	0.12
SEI	L	0.07	0.06	0.06	0.04	0.03	0.06	0.15	0.28	0.43	0.55	0.63	0.64	0.60	0.52	0.45	0.40	0.35	0.29	0.23	0.18	0.15	0.12	0.10	0.08
	M	0.11	0.09	0.08	0.07	0.06	0.08	0.16	0.26	0.38	0.48	0.55	0.57	0.54	0.48	0.43	0.39	0.35	0.30	0.25	0.21	0.18	0.16	0.14	0.12
	H	0.12	0.11	0.11	0.10	0.09	0.12	0.19	0.29	0.40	0.49	0.54	0.53	0.51	0.44	0.39	0.35	0.31	0.27	0.23	0.20	0.18	0.16	0.15	0.13
S	L	0.08	0.07	0.05	0.04	0.04	0.08	0.09	0.14	0.22	0.34	0.48	0.59	0.65	0.65	0.59	0.50	0.43	0.36	0.28	0.22	0.18	0.15	0.12	0.10
	M	0.12	0.11	0.09	0.08	0.07	0.08	0.11	0.14	0.21	0.31	0.42	0.52	0.57	0.58	0.53	0.47	0.41	0.36	0.29	0.25	0.21	0.18	0.16	0.14
	H	0.13	0.12	0.12	0.11	0.10	0.11	0.14	0.17	0.24	0.33	0.43	0.51	0.56	0.55	0.50	0.43	0.37	0.32	0.26	0.22	0.20	0.18	0.16	0.15
SSW	L	0.10	0.08	0.07	0.06	0.05	0.06	0.09	0.11	0.15	0.19	0.27	0.39	0.52	0.62	0.67	0.65	0.58	0.46	0.36	0.28	0.23	0.19	0.15	0.12
	M	0.14	0.12	0.11	0.09	0.08	0.09	0.11	0.13	0.15	0.18	0.25	0.36	0.49	0.55	0.59	0.59	0.52	0.44	0.35	0.30	0.25	0.22	0.19	0.16
	H	0.15	0.14	0.13	0.12	0.11	0.12	0.13	0.14	0.16	0.17	0.19	0.25	0.34	0.44	0.52	0.56	0.56	0.49	0.37	0.30	0.25	0.21	0.19	0.17
SW	L	0.12	0.10	0.08	0.06	0.05	0.06	0.08	0.10	0.12	0.14	0.16	0.24	0.36	0.49	0.60	0.66	0.66	0.58	0.43	0.33	0.27	0.22	0.18	0.14
	M	0.15	0.14	0.12	0.10	0.09	0.09	0.10	0.12	0.13	0.15	0.17	0.23	0.33	0.44	0.53	0.58	0.59	0.53	0.41	0.33	0.28	0.24	0.21	0.18
	H	0.15	0.14	0.13	0.12	0.11	0.12	0.13	0.14	0.16	0.17	0.19	0.25	0.34	0.44	0.52	0.56	0.56	0.49	0.37	0.30	0.25	0.21	0.19	0.17
WSW	L	0.12	0.10	0.08	0.07	0.05	0.06	0.07	0.09	0.10	0.12	0.13	0.17	0.26	0.40	0.52	0.62	0.66	0.61	0.44	0.34	0.27	0.22	0.18	0.15
	M	0.15	0.13	0.12	0.10	0.09	0.09	0.10	0.11	0.12	0.13	0.14	0.17	0.24	0.35	0.46	0.54	0.58	0.55	0.42	0.34	0.28	0.24	0.21	0.18

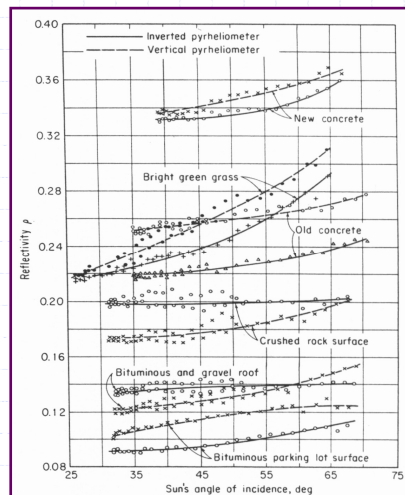
Cooling Load Factors (CLF) (Table 39-89F26.43)

Table 39 Cooling Load Factors (CLF) for Glass with Interior Shading, North Latitudes (All Room Constructions)

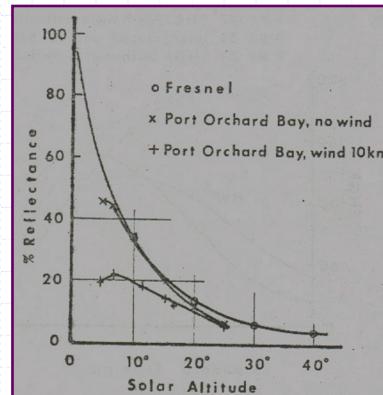
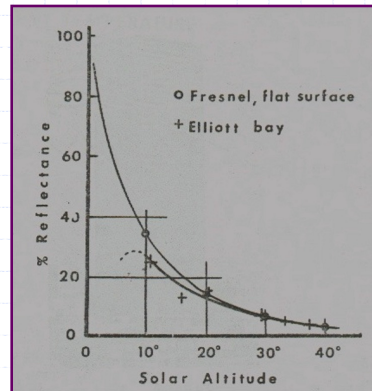
Fenestration Facing	Solar Time, h																							
	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
N	0.08	0.07	0.06	0.06	0.07	0.73	0.66	0.65	0.73	0.80	0.86	0.89	0.89	0.86	0.82	0.75	0.78	0.91	0.24	0.18	0.15	0.13	0.11	0.10
NNE	0.05	0.03	0.02	0.02	0.03	0.54	0.77	0.62	0.42	0.37	0.37	0.37	0.36	0.35	0.32	0.28	0.23	0.17	0.08	0.07	0.06	0.05	0.04	0.04
NE	0.03	0.02	0.02	0.02	0.02	0.56	0.76	0.74	0.58	0.37	0.29	0.27	0.26	0.24	0.22	0.20	0.16	0.12	0.06	0.05	0.04	0.04	0.03	0.03
ENE	0.03	0.02	0.02	0.02	0.02	0.52	0.76	0.80	0.71	0.52	0.31	0.26	0.24	0.22	0.20	0.18	0.15	0.11	0.06	0.05	0.04	0.04	0.03	0.03
E	0.03	0.02	0.02	0.02	0.02	0.47	0.72	0.80	0.76	0.62	0.41	0.27	0.24	0.22	0.20	0.17	0.14	0.11	0.06	0.05	0.05	0.04	0.03	0.03
ESE	0.03	0.03	0.02	0.02	0.02	0.41	0.67	0.79	0.80	0.72	0.54	0.34	0.27	0.24	0.21	0.19	0.15	0.12	0.07	0.05	0.05	0.04	0.04	0.03
SE	0.03	0.03	0.02	0.02	0.02	0.30	0.57	0.74	0.81	0.79	0.68	0.49	0.33	0.28	0.25	0.22	0.18	0.13	0.08	0.07	0.06	0.05	0.04	0.04
SSE	0.04	0.03	0.03	0.03	0.02	0.12	0.31	0.54	0.72	0.81	0.81	0.71	0.54	0.38	0.32	0.27	0.22	0.16	0.09	0.08	0.07	0.06	0.05	0.04
S	0.04	0.04	0.03	0.03	0.03	0.09	0.16	0.23	0.38	0.58	0.75	0.83	0.80	0.68	0.50	0.35	0.27	0.19	0.11	0.09	0.08	0.07	0.06	0.05
SSW	0.05	0.04	0.04	0.03	0.03	0.09	0.14	0.18	0.22	0.27	0.43	0.63	0.78	0.84	0.80	0.66	0.46	0.25	0.13	0.11	0.09	0.08	0.07	0.06
SW	0.05	0.05	0.04	0.04	0.03	0.07	0.11	0.14	0.16	0.19	0.22	0.38	0.59	0.75	0.83	0.81	0.69	0.45	0.16	0.12	0.10	0.09	0.07	0.06
WSW	0.05	0.05	0.04	0.04	0.03	0.07	0.10	0.12	0.14	0.15	0.17	0.23	0.44	0.64	0.78	0.84	0.78	0.55	0.16	0.12	0.10	0.09	0.07	0.06
W	0.05	0.05	0.04	0.04	0.03	0.06	0.09	0.11	0.13	0.15	0.16	0.17	0.31	0.53	0.72	0.82	0.81	0.61	0.16	0.12	0.10	0.08	0.07	0.06
WNW	0.05	0.05	0.04	0.03	0.03	0.07	0.10	0.12	0.14	0.16	0.17	0.18	0.22	0.43	0.65	0.80	0.84	0.66	0.16	0.12	0.10	0.08	0.07	0.06
NW	0.05	0.04	0.04	0.03	0.03	0.07	0.11	0.14	0.17	0.19	0.20	0.21	0.22	0.30	0.52	0.73	0.82	0.69	0.16	0.12	0.10	0.08	0.07	0.06
NNW	0.05	0.05	0.04	0.03	0.03	0.11	0.17	0.22	0.26	0.30	0.32	0.33	0.34	0.34	0.39	0.61	0.82	0.76	0.17	0.12	0.10	0.08	0.07	0.06

Factors Affecting Reflectivity

All Solar radiation values in all tables and software have a “surrounding reflectivity” assumption built in to them.



"Elliott Bay Phenomenon"

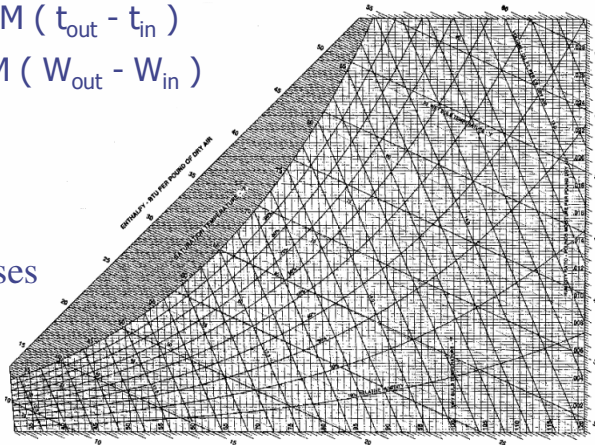


Infiltration Load

$$q_{\text{sensible}} = 1.10 \text{ CFM} (t_{\text{out}} - t_{\text{in}})$$

$$q_{\text{latent}} = 4840 \text{ CFM} (W_{\text{out}} - W_{\text{in}})$$

Requires
psychrometric
chart in most cases



Internal Loads

$$Q_{\text{people-sensible}} = \text{No.} \times \text{Heat Gain} \times \text{CLF}$$

$$Q_{\text{people-latent}} = \text{No.} \times \text{Heat Gain}$$

$$Q_{\text{lighting}} = \text{Heat Gain} \times \text{CLF}$$

$$Q_{\text{equipment}} = \text{Heat Gain} \times \text{CLF}$$

Use CLF = 1.0 unless HVAC runs 24 hours

Lighting Gain (Use Energy Code)

TABLE 15-1
Unit Lighting Power Allowance (LPA)

Use ¹	LPA ² (W/R ³)		LPA ² (W/R ³)
Painting, welding, carpentry, machine shops	2.30	Police and fire stations ⁸	1.20
Barber shops, beauty shops	2.00	Atria (atriums)	1.00
Hotel banquet/conference/exhibition hall ^{3,4}	2.00	Assembly spaces ⁹ , auditoriums, gymnasias ⁹ , theaters	1.00
Laboratories	2.00	Group R-1 common areas	1.00
Aircraft repair hangars	1.50	Process plants	1.00
Cafeterias, fast food establishments ⁵	1.50	Restaurants/bars ⁸	1.00
Factories, workshops, handling areas	1.50	Locker and/or shower facilities	0.80
Gas stations, auto repair shops ⁶	1.50	Warehouses ¹¹ , storage areas	0.50
Institutions	1.50	Aircraft storage hangars	0.40
Libraries ⁵	1.50	Parking garages	See Section 1532
Nursing homes and hotel/motel guest rooms	1.50		
Retail ¹⁰ , retail banking	1.50	Plans Submitted for Common Areas Only⁷	
Wholesale stores (pallet rack shelving)	1.50	Main floor building lobbies ⁹ (except mall concourses)	1.20
Mall concourses	1.40	Common areas, corridors, toilet facilities and washrooms, elevator lobbies	0.80
School buildings (Group E occupancy only, school classrooms, day care centers)	1.35		
Laundries	1.30		
Office buildings, office/administrative areas in facilities of other use types (including but not limited to schools, hospitals, institutions, museums, banks, churches) ^{5,7,11}	1.20		

Gain vs. Load - Lighting Example

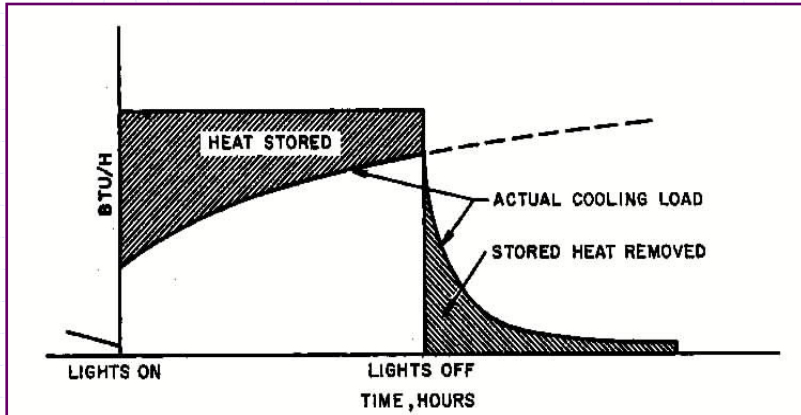


Fig. 2 Thermal Storage Effect in Cooling Load from Lights

Lighting - Load Not in Space

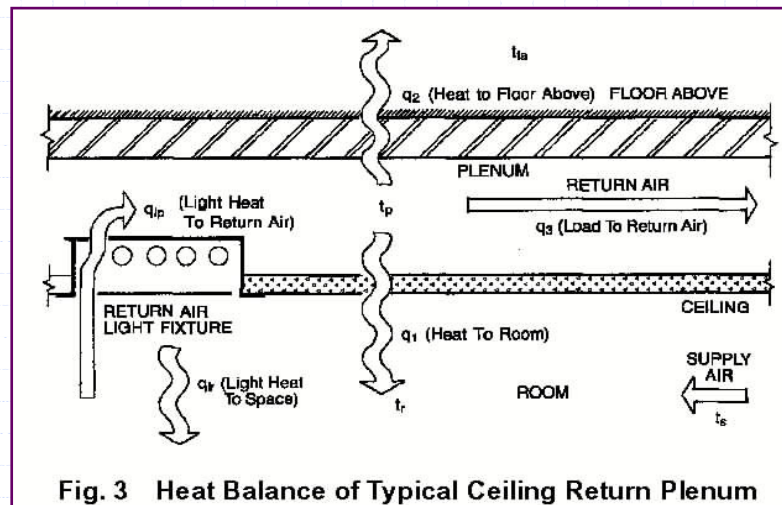


Fig. 3 Heat Balance of Typical Ceiling Return Plenum

People Heat Gain

29.4

2001 ASHRAE Fundamentals Handbook

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		Sensible Heat, Btu/h	Latent Heat, Btu/h	% Sensible Heat that is Radiant ^b	
		Adult Male	Adjusted, M/E ^a			Low V	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		

Office Equipment Heat Gain

Table 8 Recommended Heat Gain from Typical Computer Equipment

Appliance	Maximum Input Rating, W	Recommended Rate of Heat Gain, W
Mail-processing equipment		
Folding machine	125	80
Inserting machine, 3,600 to 6,800 pieces/h	600 to 3,300	390 to 2,150
Labeling machine, 1,500 to 30,000 pieces/h	600 to 6,600	390 to 4,300
Postage meter	240	150
Vending machines		
Cigarette	72	72
Cold food/beverage	1,150 to 1,920	575 to 960
Hot beverage	1,725	862
Snack	240 to 275	240 to 275
Other		
Bar code printer	440	370
Cash registers	60	48
Check processing workstation, 12 pockets	4,800	2,470
Coffee maker, 10 cups	1,500	1,050 W sens., 1,540 Btu/h latent
Microfiche reader	85	85
Microfilm reader	520	520
Microfilm reader/printer	1,150	1,150
Microwave oven, 1 ft ³	600	400
Paper shredder	250 to 3,000	200 to 2,420
Water cooler,	700	350

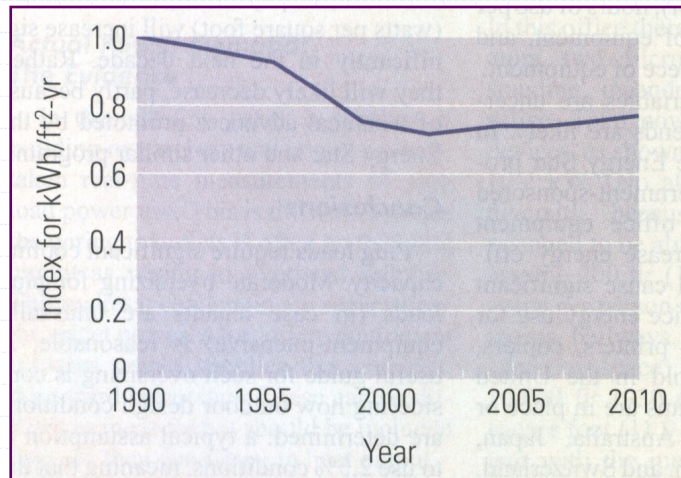
	Continuous, W	Energy Saver Mode, W
Computers^a		
Average value	55	20
Conservative value	65	25
Highly conservative value	75	30
Monitors^b		
Small monitor (13 to 15 in.)	55	0
Medium monitor (16 to 18 in.)	70	0
Large monitor (19 to 20 in.)	80	0

Sources: Hosni et al. (1999), Wilkins and McGaffin (1994).
^aBased on 386, 486, and Pentium grade.
^bTypical values for monitors displaying Windows environment.

	Continuous, W	1 page per min., W	Idle, W
Laser Printers			
Small desktop	130	75	10
Desktop	215	100	35
Small office	320	160	70
Large office	550	275	125
Copiers			
Desktop copier	400	85	20
Office copier	1,100	400	300

Source: Hosni et al. (1999).

Projected Office Equip. Wattage



In-Class Cooling Load Exercise

What is the July cooling load at 5:00 pm for the Seattle office space described in the heat loss example. Assume an indoor design condition of 78°F and 40% Relative Humidity.

