CHAPTER 3.

BUILDING THERMAL LOAD ESTIMATION

3.1 Purpose of Thermal Load Estimation

To estimate energy consumption amount.

To determine capacity of the HVAC equipment.

To estimate the operation cost of the building.

To improve building energy performance during design phase.

3.2 Cooling Load vs Heating Load

Great solar radiation
T_o = 30-35℃ (in temperate weather zone)
T_i = 26 ℃
RH= high or low

Little solar radiation
T_o = -10℃(in temperate weather zone)
T_i = 20 ℃
RH= usually low

3.3 Critical Conditions for Design

The designer must select an appropriate set of conditions for the load calculation: outside weather, solar effects, inside temperature and humidity, the status of building operations, and many other factors

For heating, the critical design condition occurs during cold weather when there is little or no heating assistance from radiant solar energy or internal heat gains from lights, appliances, or people.

For cooling load conditions, the critical design condition is the peak coincident occurrence of heat, humidity, solar effects, and internal heat gains from equipment, lights, and people.

Several estimates must be performed for different times to determine the highest combination of individual loads.

3.3.1 Outdoor Design Temperature

Outdoor weather conditions affect heating and air-conditioning loads.

Historic extremes of temperature and humidity are the basis for design load calculations.

Statistical data compiled for locations throughout the world are used by HVAC designers.

Outdoor design temperatures are selected on the basis of a percent concept.

Climatic Conditions for the United States

						Winter,[b] °C		Summer,[c] °C							Prevailing Wind			Temp., °C	
Col. 1	Col. 2		Col. 3		Col. 4	Col. 5		Col. 6			Col. 7	Col. 8			Col. 9			Col. 10	
State and Station[a]	Lat.		Long.		Elev.	Design Dry-Bulb		Design Dry-Bulb and Mean Coincident Wet-Bulb			Mean Daily Range	Design Wet-Bulb			Winter		Summer	Median of Annual Extr.	
	°	′N	°	′W	m	99%	97.5%	1%	2.5%	5%		1%	2.5%	5%		m/s[d]		Max.	Min.
ALABAMA																			
Alexander City	32	57	85	57	201	−8	−6	36/25	34/24	33/24	12	26	26	26					
Anniston AP	33	35	85	51	183	−8	−6	36/25	34/24	33/24	12	26	26	26	SW	3	SW	36.9	−10.9
Auburn	32	36	85	30	199	−8	−6	36/25	34/24	33/24	12	26	26	26				37.7	−9.7
Birmingham AP	33	34	86	45	189	−8	−6	36/23	34/24	33/23	12	26	25	24	NNW	4	WNW	36.9	−10.6
Decatur	34	37	86	59	177	−12	−9	35/24	34/23	33/23	12	26	25	24					
Dothan AP	31	19	85	27	114	−5	−3	34/24	33/24	33/24	11	27	26	26					
Florence AP	34	48	87	40	177	−8	−6	36/23	34/23	33/23	12	26	25	24	NW	4	NW		
Gadsden	34	01	86	00	169	−9	−7	36/24	34/24	33/23	12	26	25	24	NNW	4	WNW		
Huntsville AP	34	42	86	35	185	−12	−9	35/24	34/23	33/23	13	26	25	24	N	5	SW		
Mobile AP	30	41	88	15	64	−4	−2	35/25	34/25	33/24	10	27	26	26	N	5	N		
Mobile Co	30	40	88	15	64	−4	−2	35/25	34/25	33/24	9	27	26	26				36.6	−5.4
Montgomery AP	32	23	86	22	52	−6	−4	36/24	35/24	34/24	12	26	26	26	NW	4	W	37.2	−7.7
Selma, Craig AFB	32	20	87	59	51	−6	−3	36/26	35/25	34/25	12	27	27	26	N	5	SW	37.8	−8.0
Talladega	33	27	86	06	172	−8	−6	36/25	34/24	33/24	12	26	26	26				37.6	−11.6
Tuscaloosa AP	33	13	87	37	52	−7	−5	37/24	36/24	34/24	12	26	26	25	N	3	WNW		

Percent concept

1) Heating load calculations:

The percent concept assumes a heating season of December through February, which equals 2160 hours per year.

It imply the weather will be at or above the listed condition only for the specified percentage of 2160 hours per year.

Percentage values: 99% and 97.5%

2) Cooling load calculations:

Summer is defined as June through September, which equals 2928 hours

Percentage values: 1%, 2.5%, and 5%

3.3.2 Indoor Design Temperature

ASHRAE Standard 55 specifies summer and winter comfort zones appropriate for clothing insulation levels of 0.5 and 0.9 clo [0.078 and 0.14 (m^2K/W), respectively.

Summer comfort operative temperature:

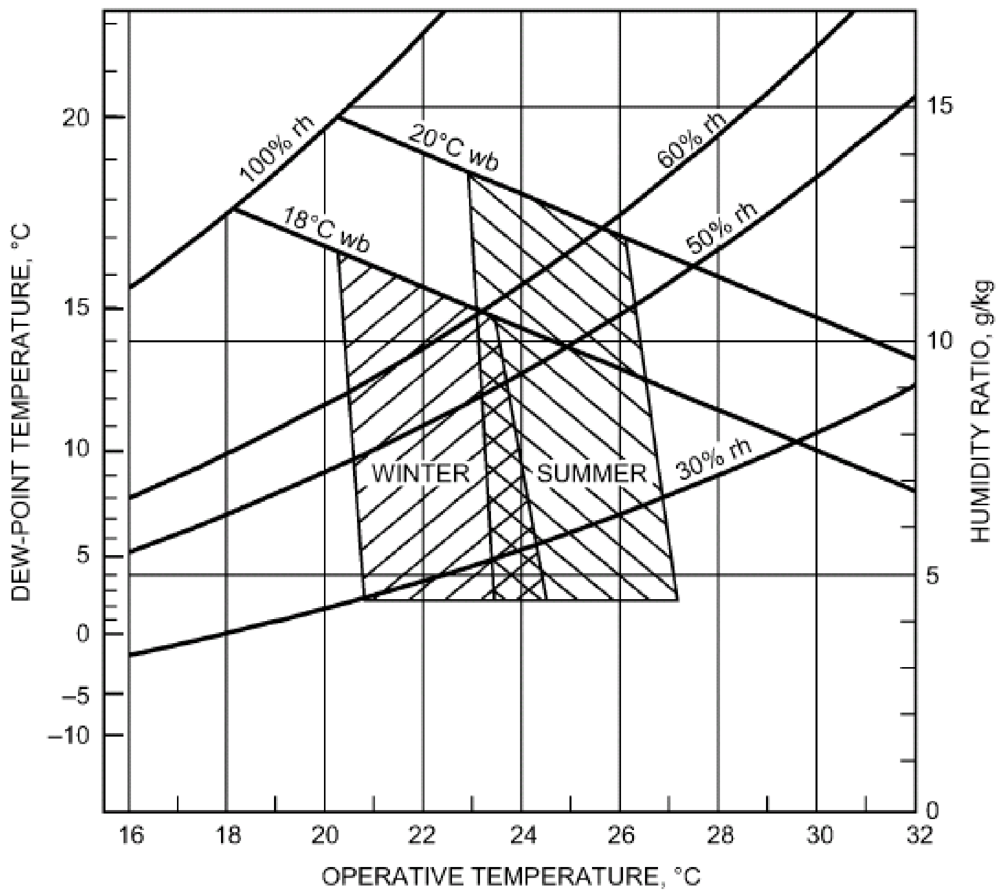
23 – 27 ℃

Winter comfort operative temperature:

21 – 25 ℃

Comfort relative humidity:

30 – 60%



ASHRAE Summer and Winter Comfort Zones

(Acceptable ranges of operative temperature and humidity for people in typical summer and winter clothing during primarily sedentary activity.)

ASHRAE : *American Society of Heating, Refrigerating and Air-Conditioning Engineers*

3.4 Manual vs Computer Calculations

Manual Calculation:

To determine maximum heating and cooling loads to size HVAC equipment.

Computer Calculation (Simulation):

To estimate annual energy consumption by calculating hour-by-hour building heat gain/loss and HVAC operations.

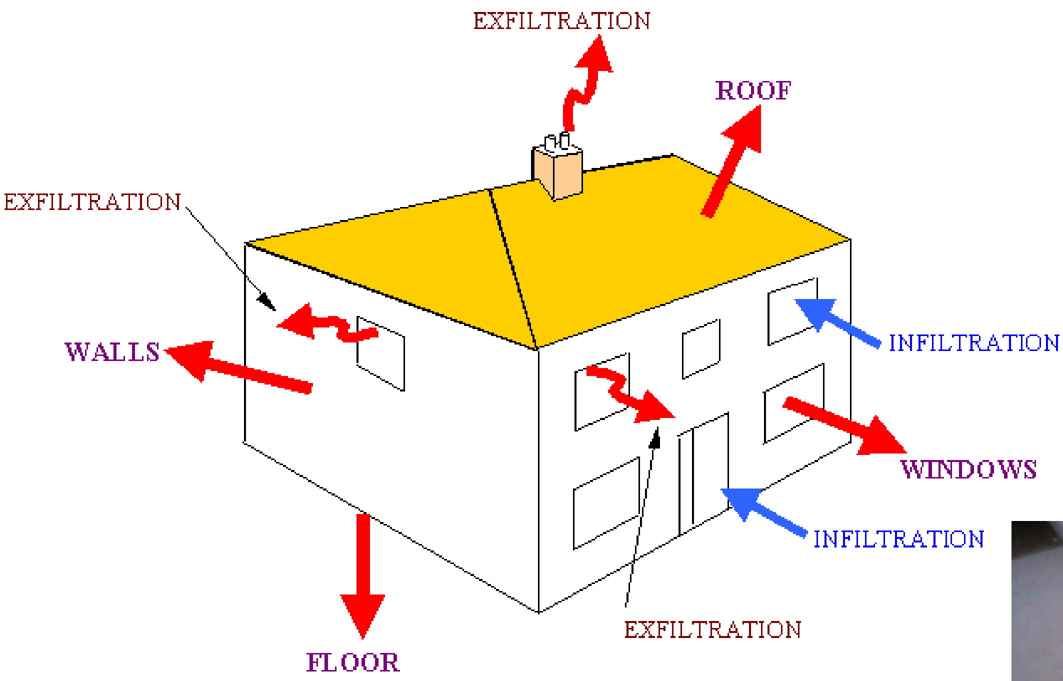
To improve building design and HVAC operation schemes by comparing thermal performances of several design alternatives.

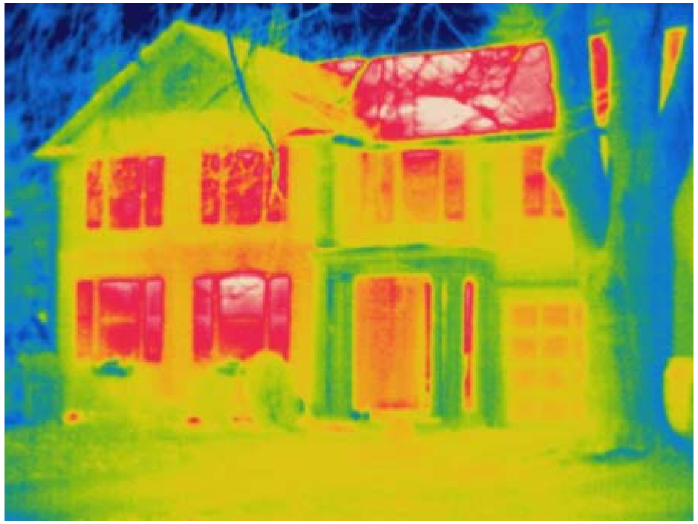
3.5 Heating Load Estimation

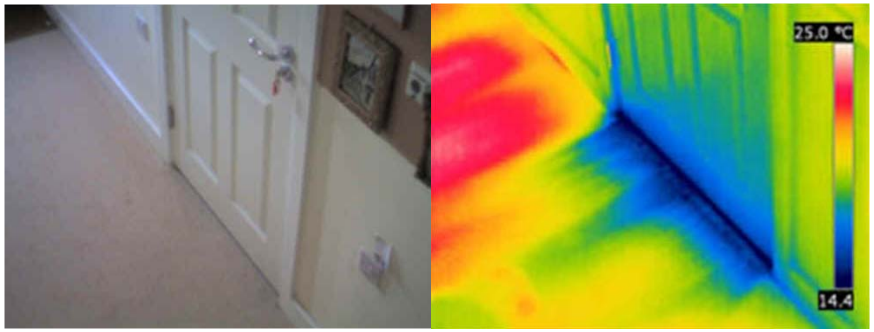
Heating loads are due to heat losses by:

1) Conductive heat loss through envelope (walls, windows, doors, floors, roof, etc.).

2) Infiltration, exfiltration and ventilation air.





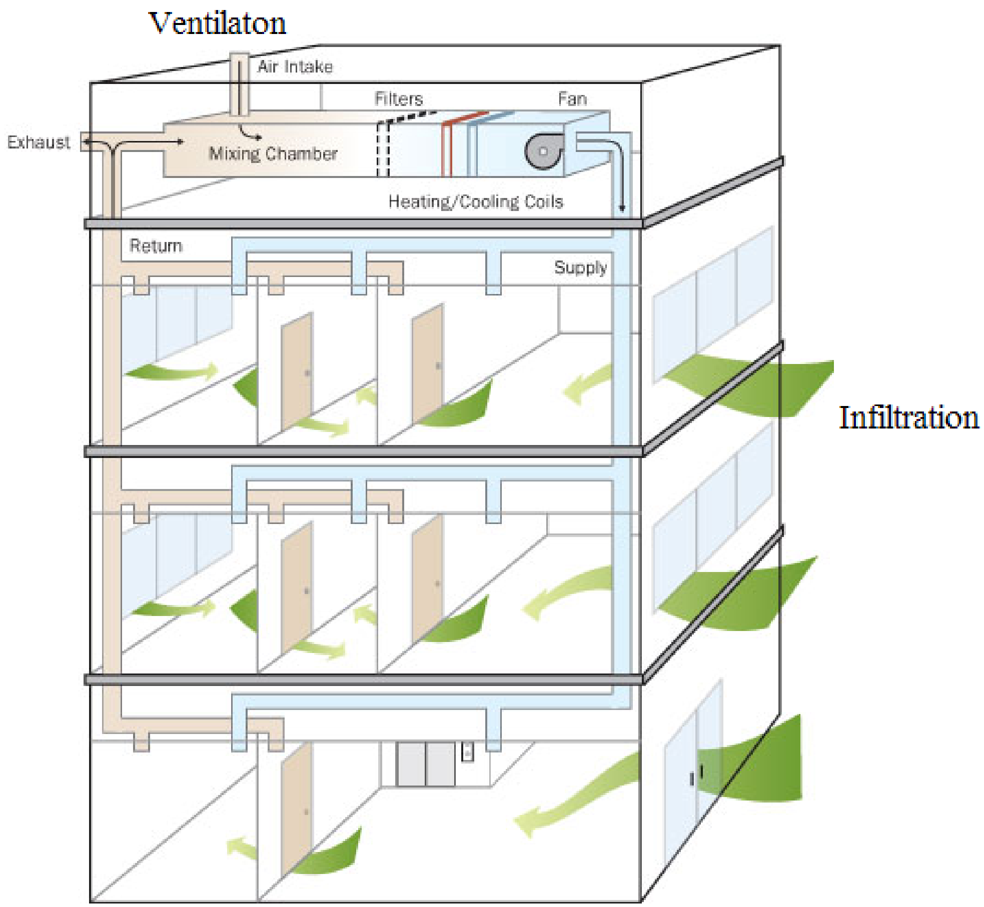


Infiltration, Exfiltration and Ventilation

Infiltration is the uncontrolled passage of outdoor air into a building through unintended leaks in the building envelope (e.g., cracks between wall sections, wall-floor connections, corners, the roof-wall interface, around windows and doors).

Exfiltration is the opposite process.

Infiltration and exfiltration are driven by air pressure differences that exist between the inside of a building relative to the outside of a building across the building envelope. These air pressure differences are the result of natural forces (e.g., wind and temperature) and a building's geometry, HVAC system design, and envelope tightness.



Ventilation is the process of "changing" or replacing air in any space to provide high indoor air quality (i.e. to control temperature, replenish oxygen, or remove moisture, odors, smoke, heat, dust, airborne bacteria, and carbon dioxide).

Ventilation is used to remove unpleasant smells and excessive moisture, introduce outside air, to keep interior building air circulating, and to prevent stagnation of the interior air.

Ventilation includes both the exchange of air to the outside as well as circulation of air within the building. It is one of the most important factors for maintaining acceptable indoor air quality in buildings. Methods for ventilating a building may be divided into mechanical/forced and natural types.

3.5.1 Conductive Heating Load

$$Q = UA\Delta t \qquad\qquad Q = \sum_{j=1}^{n} U_j A_j (t_i - t_o)$$

Q = heating load (W) (kcal/h)

A_j = area of each envelope element (m^2)

U = overall heat transfer coefficient (W/m^2K) ($kcal/m^2h$℃)

t_i = indoor design air temperature (K) (℃)

t_o = outdoor design air temperature (K) (℃)

U-Factor (Overall Heat Transfer Coefficient)

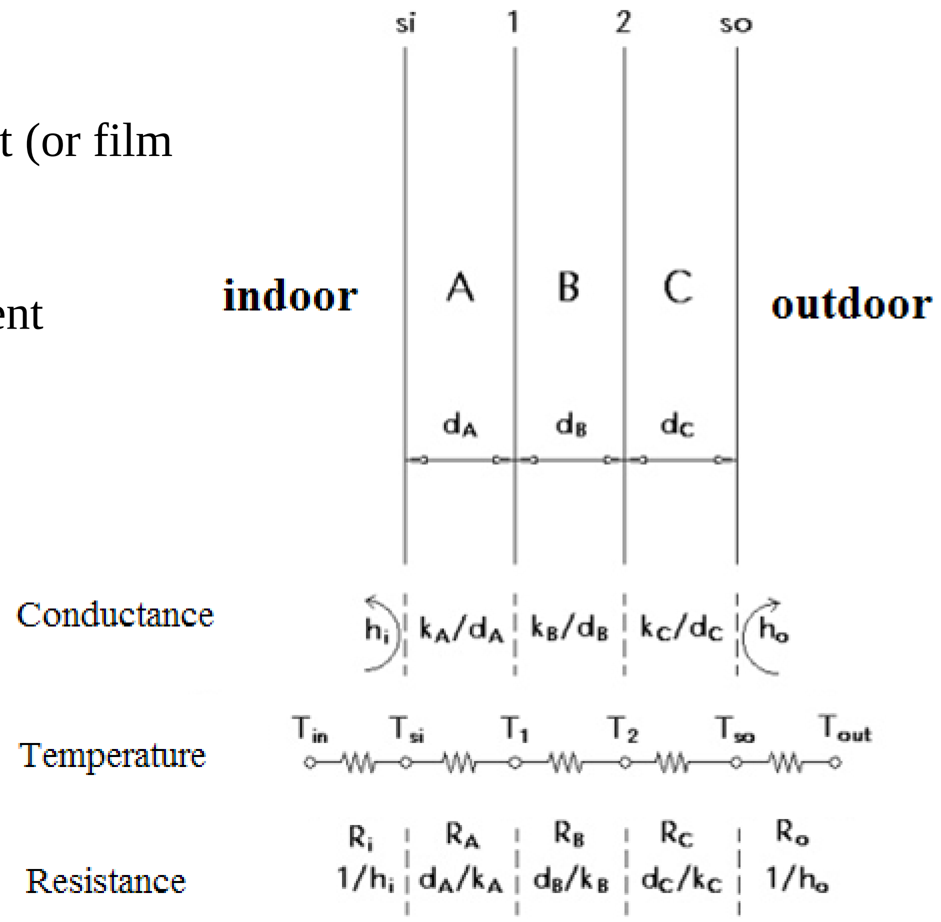
$$R_{tot} = \frac{1}{h_i} + \sum \frac{d_i}{k_i} + R_{air} + \frac{1}{h_o}$$ (m^{2}K/W) (m^{2}h°C/kcal)

Where,

h_i = indoor surface heat transfer coefficient (or film conductance) (kcal/m^{2}h°C)

h_o = outdoor surface heat transfer coefficient (kcal/m^{2}h°C)

$$U = \frac{1}{R_{tot}}$$ (W/m^{2}K) (kcal/m^{2}h°C)



Surface Conductances and Resistances for Air

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	9.26	0.11	5.17	0.19	4.32	0.23
Sloping—45°	Upward	9.09	0.11	5.00	0.20	4.15	0.24
Vertical	Horizontal	8.29	0.12	4.20	0.24	3.35	0.30
Sloping—45°	Downward	7.50	0.13	3.41	0.29	2.56	0.39
Horizontal	Downward	6.13	0.16	2.10	0.48	1.25	0.80
MOVING AIR (Any position)		h_o	R				
Wind (for winter) 6.7 m/s (24 km/h)	Any	34.0	0.030	—	—	—	—
Wind (for summer) 3.4 m/s (12 km/h)	Any	22.7	0.044	—	—	—	—

Notes:
1. Surface conductance h_i and h_o measured in W/(m$^2 \cdot$K); resistance R in (m$^2 \cdot$K)/W.
2. No surface has both an air space resistance value and a surface resistance value.
3. Conductances are for surfaces of the stated emittance facing virtual blackbody surroundings at the same temperature as the ambient air. Values are based on a surface-air temperature difference of 5.5 °C and for surface temperatures of 21 °C.

Table 2 Indoor Surface Heat Transfer Coefficient h_i in W/(m²·K), Vertical Orientation (Still Air Conditions)

Glazing ID	Glazing Type	Glazing Height m	Winter Conditions			Summer Conditions		
			Glass Temp. °C	Temp. Diff. °C	h_i W/(m²·K)	Glass Temp. °C	Temp. Diff. °C	h_i W/(m²·K)
1	Single glazing	0.6	–9	30	8.04	33	9	4.12
		1.2	–9	30	7.42	33	9	3.66
		1.8	–9	30	7.10	33	9	3.43
5	Double glazing with 12.7 mm airspace	0.6	7	14	7.72	35	11	4.28
		1.2	7	14	7.21	35	11	3.80
		1.8	7	14	6.95	35	11	3.55
23	Double glazing with e = 0.1 on surface 2 and 12.7 mm argon space	0.6	13	8	7.44	34	10	4.20
		1.2	13	8	7.00	34	10	3.73
		1.8	13	8	6.77	34	10	3.49
43	Triple Glazing with e = 0.1 on surfaces 2 and 5 and 12.7 mm argon spaces	0.6	17	4	7.09	40	16	4.61
		1.2	17	4	6.72	40	16	4.08
		1.8	17	4	6.53	40	16	3.81

Notes:
Glazing ID refers to fenestration assemblies in Table 4.
Winter conditions: room air temperature t_i = 21°C, outdoor air temperature t_o = –18°C, no solar radiation
Summer conditions: room air temperature t_i = 24°C, outdoor air temperature t_o = 32°C, direct solar irradiance E_D = 748 W/m²
$h_i = h_{ic} + h_{iR} = 1.46(\Delta T/L)^{0.25} + e\Gamma(T_g^4 - T_i^4)/\Delta T$
where $\Delta T = T_g - T_i$, K; L = glazing height, m; T_g = glass temperature, K

Table 3 Thermal Resistances of Plane Air Spaces[a,b,c], (m²·K)/W

Position of Air Space	Direction of Heat Flow	Air Space: Mean Temp.[d], °C	Air Space: Temp. Diff.[d], °C	13 mm Air Space[c] Effective Emittance ε_{eff}[d,e] 0.03	0.05	0.2	0.5	0.82	20 mm Air Space[c] Effective Emittance ε_{eff}[d,e] 0.03	0.05	0.2	0.5	0.82
Horiz.	Up	32.2	5.6	0.37	0.36	0.27	0.17	0.13	0.41	0.39	0.28	0.18	0.13
		10.0	16.7	0.29	0.28	0.23	0.17	0.13	0.30	0.29	0.24	0.17	0.14
		10.0	5.6	0.37	0.36	0.28	0.20	0.15	0.40	0.39	0.30	0.20	0.15
		−17.8	11.1	0.30	0.30	0.26	0.20	0.16	0.32	0.32	0.27	0.20	0.16
		−17.8	5.6	0.37	0.36	0.30	0.22	0.18	0.39	0.38	0.31	0.23	0.18
		−45.6	11.1	0.30	0.29	0.26	0.22	0.18	0.31	0.31	0.27	0.22	0.19
		−45.6	5.6	0.36	0.35	0.31	0.25	0.20	0.38	0.37	0.32	0.26	0.21
45° Slope	Up	32.2	5.6	0.43	0.41	0.29	0.19	0.13	0.52	0.49	0.33	0.20	0.14
		10.0	16.7	0.36	0.35	0.27	0.19	0.15	0.35	0.34	0.27	0.19	0.14
		10.0	5.6	0.45	0.43	0.32	0.21	0.16	0.51	0.48	0.35	0.23	0.17
		−17.8	11.1	0.39	0.38	0.31	0.23	0.18	0.37	0.36	0.30	0.23	0.18
		−17.8	5.6	0.46	0.45	0.36	0.25	0.19	0.48	0.46	0.37	0.26	0.20
		−45.6	11.1	0.37	0.36	0.31	0.25	0.21	0.36	0.35	0.31	0.25	0.20
		−45.6	5.6	0.46	0.45	0.38	0.29	0.23	0.45	0.43	0.37	0.29	0.23
Vertical	Horiz.	32.2	5.6	0.43	0.41	0.29	0.19	0.14	0.62	0.57	0.37	0.21	0.15
		10.0	16.7	0.45	0.43	0.32	0.22	0.16	0.51	0.49	0.35	0.23	0.17
		10.0	5.6	0.47	0.45	0.33	0.22	0.16	0.65	0.61	0.41	0.25	0.18
		−17.8	11.1	0.50	0.48	0.38	0.26	0.20	0.55	0.53	0.41	0.28	0.21
		−17.8	5.6	0.52	0.50	0.39	0.27	0.20	0.66	0.63	0.46	0.30	0.22
		−45.6	11.1	0.51	0.50	0.41	0.31	0.24	0.51	0.50	0.42	0.31	0.24
		−45.6	5.6	0.56	0.55	0.45	0.33	0.26	0.65	0.63	0.51	0.36	0.27
45° Slope	Down	32.2	5.6	0.44	0.41	0.29	0.19	0.14	0.62	0.58	0.37	0.21	0.15
		10.0	16.7	0.46	0.44	0.33	0.22	0.16	0.60	0.57	0.39	0.24	0.17
		10.0	5.6	0.47	0.45	0.33	0.22	0.16	0.67	0.63	0.42	0.26	0.18
		−17.8	11.1	0.51	0.49	0.39	0.27	0.20	0.66	0.63	0.46	0.30	0.22
		−17.8	5.6	0.52	0.50	0.39	0.27	0.20	0.73	0.69	0.49	0.32	0.23
		−45.6	11.1	0.56	0.54	0.44	0.33	0.25	0.67	0.64	0.51	0.36	0.28
		−45.6	5.6	0.57	0.56	0.45	0.33	0.26	0.77	0.74	0.57	0.39	0.29
Horiz.	Down	32.2	5.6	0.44	0.41	0.29	0.19	0.14	0.62	0.58	0.37	0.21	0.15
		10.0	16.7	0.47	0.45	0.33	0.22	0.16	0.66	0.62	0.42	0.25	0.18
		10.0	5.6	0.47	0.45	0.33	0.22	0.16	0.68	0.63	0.42	0.26	0.18
		−17.8	11.1	0.52	0.50	0.39	0.27	0.20	0.74	0.70	0.50	0.32	0.23
		−17.8	5.6	0.52	0.50	0.39	0.27	0.20	0.75	0.71	0.51	0.32	0.23
		−45.6	11.1	0.57	0.55	0.45	0.33	0.26	0.81	0.78	0.59	0.40	0.30
		−45.6	5.6	0.58	0.56	0.46	0.33	0.26	0.83	0.79	0.60	0.40	0.30
		Air Space		40 mm Air Space[c]					90 mm Air Space[c]				

The complete table is available from the class website.

Table 4 Typical Thermal Properties of Common Building and Insulating Materials—Design Values[a]

Description	Density, kg/m^3	Conductivity[b] (k), $W/(m \cdot K)$	Conductance (C), $W/(m^2 \cdot K)$	Resistance[c] (R)		Specific Heat, $kJ/(kg \cdot K)$
				$1/k$, $(m \cdot K)/W$	For Thickness Listed ($1/C$), $(m^2 \cdot K)/W$	
BUILDING BOARD						
Asbestos-cement board	1900	0.58	—	1.73	—	1.00
Asbestos-cement board 3.2 mm	1900	—	187.4	—	0.005	—
Asbestos-cement board 6.4 mm	1900	—	93.7	—	0.011	—
Gypsum or plaster board 9.5 mm	800	—	17.6	—	0.056	1.09
Gypsum or plaster board 12.7 mm	800	—	12.6	—	0.079	—
Gypsum or plaster board 15.9 mm	800	—	10.1	—	0.099	—
Plywood (Douglas Fir)[d]	540	0.12	—	8.66	—	1.21
Plywood (Douglas Fir) 6.4 mm	540	—	18.2	—	0.055	—
Plywood (Douglas Fir) 9.5 mm	540	—	12.1	—	0.083	—
Plywood (Douglas Fir) 12.7 mm	540	—	9.1	—	0.11	—
Plywood (Douglas Fir) 15.9 mm	540	—	7.3	—	0.14	—
Plywood or wood panels 19.0 mm	540	—	6.1	—	0.16	1.21
Vegetable fiber board						
Sheathing, regular density[e] 12.7 mm	290	—	4.3	—	0.23	1.30
19.8 mm	290	—	2.8	—	0.36	—
Sheathing intermediate density[e] 12.7 mm	350	—	5.2	—	0.19	1.30
Nail-base sheathing[e] 12.7 mm	400	—	5.3	—	0.19	1.30
Shingle backer 9.5 mm	290	—	6.0	—	0.17	1.30
Shingle backer 7.9 mm	290	—	7.3	—	0.14	—
Sound deadening board 12.7 mm	240	—	4.2	—	0.24	1.26
Tile and lay-in panels, plain or acoustic	290	0.058	—	17.	—	0.59
12.7 mm	290	—	4.5	—	0.22	—
19.0 mm	290	—	3.0	—	0.33	—

The complete table is available from the class website.

Table 4 U-Factors for Various Fenestration Products in W/($m^2 \cdot K$)

Product Type / Frame Type / ID Glazing Type	Glass Only: Center of Glass	Glass Only: Edge of Glass	Vertical Installation, Operable (including sliding and swinging glass doors): Aluminum without Thermal Break	Operable: Aluminum with Thermal Break	Operable: Reinforced Vinyl/ Aluminum Clad Wood	Operable: Wood/ Vinyl	Operable: Insulated Fiberglass/ Vinyl	Vertical Installation, Fixed: Aluminum without Thermal Break	Fixed: Aluminum with Thermal Break	Fixed: Reinforced Vinyl/ Aluminum Clad Wood	Fixed: Wood/ Vinyl	Fixed: Insulated Fiberglass/ Vinyl
Single Glazing												
1 3.2 mm glass	*5.91*	*5.91*	7.24	6.12	5.14	5.05	4.61	6.42	6.07	5.55	5.55	5.35
2 6.4 mm acrylic/polycarb	*5.00*	*5.00*	6.49	5.43	4.51	4.42	4.01	5.60	5.25	4.75	4.75	4.58
3 3.2 mm acrylic/polycarb	*5.45*	*5.45*	6.87	5.77	4.82	4.73	4.31	6.01	5.66	5.15	5.15	4.97
Double Glazing												
4 6.4 mm airspace	*3.12*	*3.63*	4.93	3.70	3.25	3.13	2.77	3.94	3.56	3.19	3.17	3.04
5 12.7 mm airspace	*2.73*	*3.36*	4.62	3.42	3.00	2.87	2.53	3.61	3.22	2.86	2.84	2.72
6 6.4 mm argon space	*2.90*	*3.48*	4.75	3.54	3.11	2.98	2.63	3.75	3.37	3.00	2.98	2.85
7 12.7 mm argon space	*2.56*	*3.24*	4.49	3.30	2.89	2.76	2.42	3.47	3.08	2.73	2.70	2.58
Double Glazing, e = 0.60 on surface 2 or 3												
8 6.4 mm airspace	*2.95*	*3.52*	4.80	3.58	3.14	3.02	2.67	3.80	3.41	3.05	3.03	2.90
9 12.7 mm airspace	*2.50*	*3.20*	4.45	3.26	2.85	2.73	2.39	3.42	3.03	2.68	2.66	2.54
10 6.4 mm argon space	*2.67*	*3.32*	4.58	3.38	2.96	2.84	2.49	3.56	3.17	2.82	2.80	2.67
11 12.7 mm argon space	*2.33*	*3.08*	4.31	3.13	2.74	2.62	2.28	3.28	2.89	2.54	2.52	2.40

The complete table is available from the class website.

Table 1 Representative Fenestration Frame U-Factors in W/(m²·K), Vertical Orientation

		Product Type/Number of Glazing Layers																
		Operable			Fixed			Garden Window		Plant-Assembled Skylight			Curtainwall[e]			Sloped/Overhead Glazing[e]		
Frame Material	Type of Spacer	Single[b]	Double[c]	Triple[d]	Single[b]	Double[c]	Triple[d]	Single[b]	Double[c]	Single[b]	Double[c]	Triple[d]	Single[f]	Double[g]	Triple[h]	Single[f]	Double[g]	Triple[h]
Aluminum without thermal break	All	13.51	12.89	12.49	10.90	10.22	9.88	10.67	10.39	44.57	39.86	39.01	17.09	16.81	16.07	17.32	17.03	16.30
Aluminum with thermal break[a]	Metal	6.81	5.22	4.71	7.49	6.42	6.30			39.46	28.67	26.01	10.22	9.94	9.37	10.33	9.99	9.43
	Insulated	n/a	5.00	4.37	n/a	5.91	5.79			n/a	26.97	23.39	n/a	9.26	8.57	n/a	9.31	8.63
Aluminum-clad wood/ reinforced vinyl	Metal	3.41	3.29	2.90	3.12	2.90	2.73			27.60	22.31	20.78						
	Insulated	n/a	3.12	2.73	n/a	2.73	2.50			n/a	21.29	19.48						
Wood /vinyl	Metal	3.12	2.90	2.73	3.12	2.73	2.38	5.11	4.83	14.20	11.81	10.11						
	Insulated	n/a	2.78	2.27	n/a	2.38	1.99	n/a	4.71	n/a	11.47	9.71						
Insulated fiberglass/ vinyl	Metal	2.10	1.87	1.82	2.10	1.87	1.82											
	Insulated	n/a	1.82	1.48	n/a	1.82	1.48											
Structural glazing	Metal												10.22	7.21	5.91	10.33	7.27	5.96
	Insulated												n/a	5.79	4.26	n/a	5.79	4.26

Note: This table should only be used as an estimating tool for early phases of design.
[a]Depends strongly on width of thermal break. Value given is for 9.5 mm.
[b]Single glazing corresponds to individual glazing unit thickness of 3 mm. (nominal).
[c]Double glazing corresponds to individual glazing unit thickness of 19 mm. (nominal).
[d]Triple glazing corresponds to individual glazing unit thickness of 34.9 mm. (nominal).
[e]Glass thickness in curtainwall and sloped/overhead glazing is 6.4 mm.
[f]Single glazing corresponds to individual glazing unit thickness of 6.4 mm. (nominal).
[g]Double glazing corresponds to individual glazing unit thickness of 25.4 mm. (nominal).
[h]Triple glazing corresponds to individual glazing unit thickness of 44.4 mm. (nominal).
n/a Not applicable

Table 6 U-Factors of Doors in W/(m²·K)

Door Type	No Glazing	Single Glazing	Double Glazing with 12.7 mm Airspace	Double Glazing with $e = 0.10$, 12.7 mm Argon
SWINGING DOORS (Rough Opening, 970 × 2080 mm)				
Slab Doors				
Wood slab in wood frame[a]	2.61			
6% glazing (560 × 200 lite)	—	2.73	2.61	2.50
25% glazing (560 × 910 lite)	—	3.29	2.61	2.38
45% glazing (560 × 1620 lite)	—	3.92	2.61	2.21
More than 50% glazing		Use Table 4 (operable)		
Insulated steel slab with wood edge in wood frame[a]	0.91			
6% glazing (560 × 200 lite)	—	1.19	1.08	1.02
25% glazing (560 × 910 lite)	—	2.21	1.48	1.31
45% glazing (560 × 1630 lite)	—	3.29	1.99	1.48
More than 50% glazing		Use Table 4 (operable)		
Foam insulated steel slab with metal edge in steel frame[b]	2.10			
6% glazing (560 × 200 lite)	—	2.50	2.33	2.21
25% glazing (560 × 910 lite)	—	3.12	2.73	2.50
45% glazing (560 × 1630 lite)	—	4.03	3.18	2.73
More than 50% glazing		Use Table 4 (operable)		
Cardboard honeycomb slab with metal edge in steel frame	3.46			
Style and Rail Doors				
Sliding glass doors/ French doors		Use Table 4 (operable)		
Site-Assembled Style and Rail Doors				
Aluminum in Aluminum Frame	—	7.49	5.28	4.49
Aluminum in Aluminum Frame with Thermal Break	—	6.42	4.20	3.58

The complete table is available from the class website.

3.5.2 Infiltration Heating Load

1) Sensible Heating Load

$$Q = 0.24 \times 1.2 \times CMH \times (t_i - t_o)$$

Where,

Q = heating load (W) (kcal/h)

0.24 = specific heat of dry air (kJ/kgK) (kcal/kg℃)

1.2 = specific weight of air (kg/m^3)

CMH = airflow (m^3/h)

t_i = indoor air temperature (K) (℃)

t_o = outdoor air temperature (K) (℃)

2) Latent Heating Load

$$Q = 597 \times 1.2 \times CMH \times (x_i - x_o)$$

Where,

Q = heating load (W) (kcal/h)

597= latent heat of vaporization of water at 0℃ (kJ/kg) (kcal/kg)

1.2 = specific weight of air (kg/m^3)

CMH = airflow (m^3/h)

x_i = room humidity ratio of indoor air (kg/kg$_{da}$)

x_o = outdoor air humidity ratio of outdoor air (kg/kg$_{da}$)

Airflow Estimation

Airflow is estimated by using *crack method* and *air change method*

1) Crack method

- The crack method is more accurate than air change method.
- Outdoor air infiltrates the indoor space through cracks around doors, windows, and joints between walls and floors and even through the building material itself.
- The amount depends on the total area of the cracks, the type of crack and the pressure difference between the inside and outside.
- Airflow is calculated by :

$$\boxed{\text{CMH} = \text{CMH per meter} \times \text{meter of crack}}$$

2) Air change method

Most Designers prefer to use simpler air change method

Airflow into a space can be measured in air changes per hour

$$\mathrm{CMH} = \mathrm{ACH} \times \mathrm{Volume}$$

Where,

CMH = airflow(m^3/h)

ACH = Air changes per hour

$Volume$ = space volume(m^3)

Infiltration air changes per hour occurring under average conditions in residences

Kind of room	***Single glass, No Weather-strip***	***Storm Sash or Weather-stripped***
No windows or exterior doors	0.5	0.3
Windows or exterior doors on 1 side	1	0.7
Windows or exterior doors on 2 sides	1.5	1
Windows or exterior doors on 3 sides	2	1.3
Entrance halls	2	1.3

3.5.3 Ventilation Heating Load

Outside air is introduced by the HVAC system to dilute air contaminants and to make up for exhaust.

The ventilation load is calculated by the same equations used for infiltration.

Ventilation is determined according to *ASHRAE Standard 62*.

OUTDOOR AIR REQUIREMENTS FOR VENTILATION*

2.1 COMMERCIAL FACILITIES (offices, stores, shops, hotels, sports facilities)

Application	Estimated Maximum** Occupancy P/1000 ft^2 or 100 m^2	Outdoor Air Requirements				Comments
		cfm/ person	L/s· person	cfm/ft^2	L/s·m^2	
Dry Cleaners, Laundries						Dry-cleaning processes may require more air.
Commercial laundry	10	25	13			
Commercial dry cleaner	30	30	15			
Storage, pick up	30	35	18			
Coin-operated laundries	20	15	8			
Coin-operated dry cleaner	20	15	8			
Food and Beverage Service						
Dining rooms	70	20	10			
Cafeteria, fast food	100	20	10			
Bars, cocktail lounges	100	30	15			Supplementary smoke-removal equipment may be required.
Kitchens (cooking)	20	15	8			Makeup air for hood exhaust may require more ventilating air. The sum of the outdoor air and transfer air of acceptable quality from adjacent spaces shall be sufficient to provide an exhaust rate of not less than 1.5 cfm/ft^2 (7.5 L/s·m^2).

The complete table is available from the class website.

3.5.4 Miscellaneous Loads

In addition to conduction, infiltration, and ventilation, heating loads should take into account miscellaneous factors such as losses through walls below grade and slabs on grade.

Table 14 Heat Loss Below Grade in Basement Walls

Depth, m	Path Length Through Soil, m	Heat Loss Coefficient, W/(m²·K)[a] Un-insulated		R = 0.73 m²·K/W		R = 1.47 m²·K/W		R = 2.20 m²·K/W	
0 to 0.3	0.2	2.33	Σ[b]	0.86	3.53	0.53	Σ[b]	0.38	Σ[b]
0.3 to 0.6	0.69	1.26	3.59	0.66	1.52	0.45	0.98	0.36	0.74
0.6 to 0.9	1.18	0.88	4.47	0.53	2.05	0.38	1.36	0.30	1.04
0.9 to 1.2	1.68	0.67	5.14	0.45	2.50	0.34	1.70	0.27	1.31
1.2 to 1.5	2.15	0.54	5.68	0.39	2.89	0.30	2.00	0.25	1.56
1.5 to 1.8	2.64	0.45	6.13	0.34	3.23	0.27	2.27	0.23	1.79
1.8 to 2.1	3.13	0.39	6.52	0.30	3.53	0.25	2.52	0.21	2.00

Source: Latta and Boileau (1969).
[a]Soil conductivity was assumed to be 1.38 W/(m·K).
[b]Σ = heat loss to current depth.

Table 15 Heat Loss Through Basement Floors

Depth of Foundation Wall below Grade, m	Heat Loss Coefficient, W/(m²·K) Shortest Width of House, m 6	7.3	8.5	9.7
1.5	0.18	0.16	0.15	0.13
1.8	0.17	0.15	0.14	0.12
2.1	0.16	0.15	0.13	0.12

Note: $\Delta t = (t_a - A)$

Residential Cooling and Heating Load Calculations

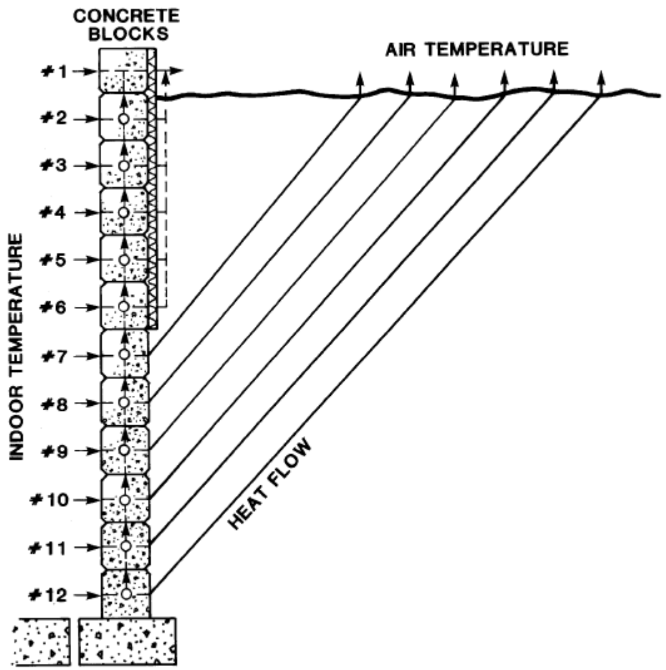


Fig. 5 Heat Flow Path for Partially Insulated Basement Wall

Table 5 Typical Apparent Thermal Conductivity Values for Soils, $W/(m^2 \cdot K)$

	Normal Range	Recommended Values for Design[a]	
		Low[b]	High[c]
Sands	0.6 to 2.5	0.78	2.25
Silts	0.9 to 2.5	1.64	2.25
Clays	0.9 to 1.6	1.12	1.56
Loams	0.9 to 2.5	0.95	2.25

[a]Reasonable values for use when no site- or soil-specific data are available.

[b]Moderately conservative values for minimum heat loss through soil (e.g., use in soil heat exchanger or earth-contact cooling calculations). Values are from Salomone and Marlowe (1989).

[c]Moderately conservative values for maximum heat loss through soil (e.g., use in peak winter heat loss calculations). Values are from Salomone and Marlowe (1989).

표 2-32 난방설계용 지중온도 (일본의 예, 단위 : ℃)

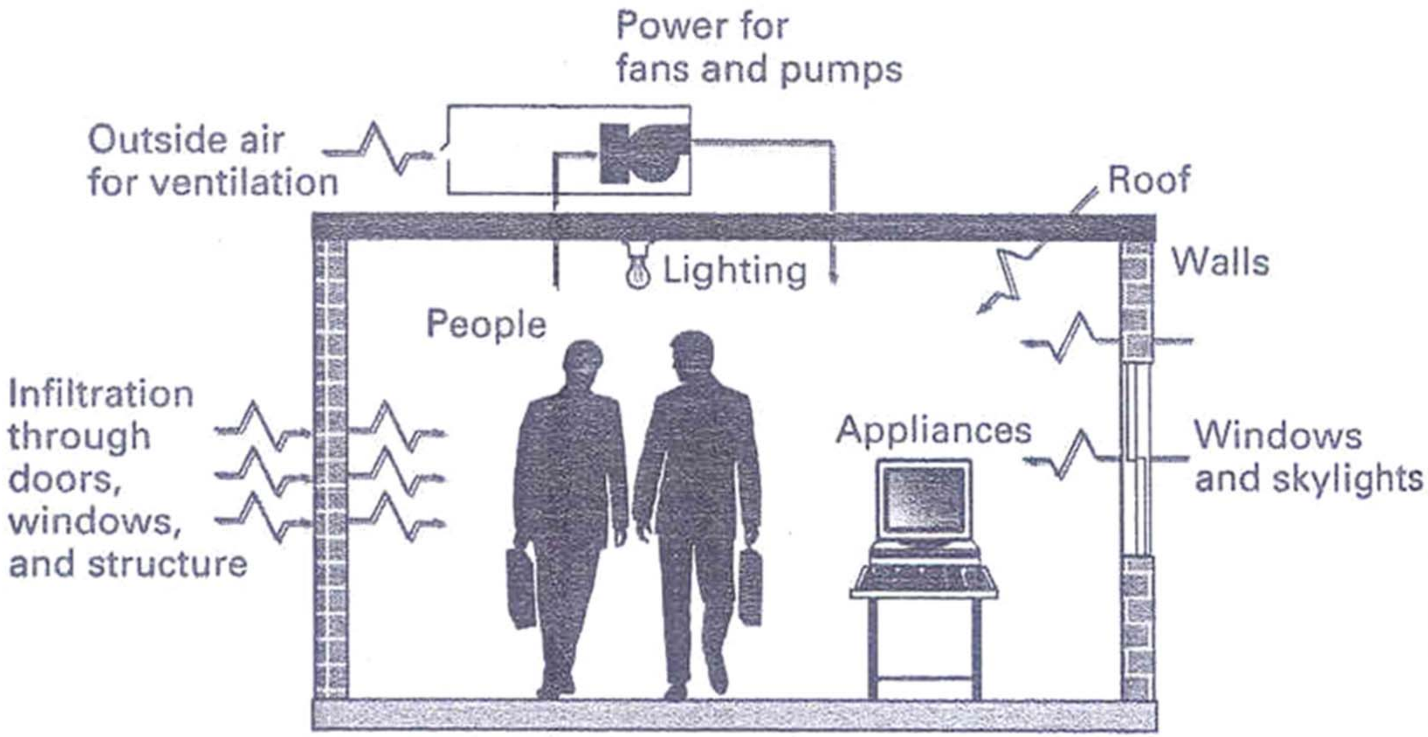
지 명	지 중 깊 이 [m]								
	1	2	3	4	5	6	8	10	15
삽 뽀 로	-4.7	-0.5	2.3	4.2	5.4	6.3	7.2	7.7	8.0
센 다 이	1.2	4.8	7.2	8.7	9.8	10.5	11.3	11.7	12.0
동 경	3.8	7.4	9.8	11.3	12.4	13.1	13.9	14.3	14.6
나 고 야	3.9	7.7	10.2	11.9	13.0	13.8	14.6	15.0	15.3
오 사 까	5.6	9.2	11.6	13.2	14.3	15.0	15.8	16.2	16.4
후꾸오까	5.5	9.0	11.4	12.9	14.0	14.7	15.5	15.9	16.1

표 2-33 난방설계용 지중온도 (단위 : ℃)

지 역	월평균 지표온도		동결심도 [cm]	깊이에 따른 지중온도(1월)		
	최 저	최 고		0.5 [m]	2 [m]	3 [m]
속 초	-0.4	25.9	47	0.19	6.5	8.60
춘 천	-0.9	26.7	157	-5.3	2.8	5.50
강 릉	-0.1	26.4	44	0.4	3.9	9.40
서 울	-2.5	27.0	77	-0.2	5.6	8.10
인 천	-1.3	27.0	65	-1.0	6.0	8.30
울릉도	1.4	26.1	14	2.2	8.1	10.1
수 원	-1.5	26.7	117	-4.3	3.7	6.40
서 산	-0.6	27.3	75	-1.7	5.8	8.30
청 주	-1.7	27.8	98	-3.2	4.8	7.40
대 전	-0.7	27.2	87	-2.1	5.6	8.20
추풍령	-1.2	27.1	79	1.9	5.5	8.00
포 항	0.8	28.3	37	0.9	7.8	13.0
군 산	0.7	28.6	43	0.5	7.5	9.90
대 구	-0.1	28.9	59	-0.7	6.9	9.40
전 주	0.6	28.7	58	-0.6	6.7	9.20
울 산	2.4	28.4	37	0.9	7.9	11.0
광 주	1.3	28.7	42	0.6	7.8	10.2
부 산	3.0	28.4	7	2.8	9.1	11.2
충 무	2.3	27.4	22	1.9	8.5	10.7
목 포	2.1	28.0	15	3.5	9.4	11.5
여 수	1.6	26.8	11	2.7	9.0	11.1

3.6 Cooling Load Estimation

Heat gains include conduction, solar effects, outdoor air loads, and internal heat loads.



Components of building cooling load

3.6.1 Heat Gain through Walls and Roofs (Opaque)

A simple temperature difference between indoor and outdoor air will not account for solar heat. The outside surface is much warmer than the surrounding air, due to the solar radiation effect.

Conduction calculating use TETD*(Total equivalent temperature difference)*

TETD include solar effects as well as temperature difference

TETD vary with the orientation, time of day, absorption property of the surface, and thermal mass of the building assembly

$$Q = UA(\mathrm{TETD}) \qquad Q = \sum_{j=1}^{n} U_j A_j (\mathrm{TETD})$$

Where,

Q = cooling load (W) (kcal/h)

U = overall heat transfer coefficient (W) (kcal/m^{2}h℃)

A = area of each envelope element (m^2)

$TETD$ = total equivalent temperature difference(℃)

TABLE 2–12
Total equivalent temperature differentials for calculating heat gain through flat roofs

			Sun Time																	
			A.M						P.M.											
		U-value	8		10		12		2		4		6		8		10		12	
Description of Roof Construction	Wt, lb per sq ft	Btu/(hr)(ft²)(F°)	D	L	D	L	D	L	D	L	D	L	D	L	D	L	D	L	D	L
Light Construction Roofs—Exposed to Sun																				
1″ Insulation + steel siding	7.4	0.213	28	11	65	31	90	48	95	53	78	45	43	27	8	6	1	1	−3	−3
2″ Insulation + steel siding	7.8	0.125	24	8	61	29	88	46	96	53	81	46	48	30	10	8	2	2	−3	−3
1″ Insulation + 1″ wood	8.4	0.206	12	2	47	21	77	39	92	50	86	48	61	36	25	16	7	5	0	−1
2″ Insulation + 1″ wood	8.5	0.122	8	0	41	18	72	36	90	48	88	40	65	38	30	19	9	7	1	0
1″ Insulation + 2.5″ wood	12.7	0.193	2	−2	23	8	48	23	70	36	79	42	71	40	50	29	29	17	15	9
2″ Insulation + 2.5″ wood	13.1	0.117	1	−2	19	6	43	20	65	33	76	41	72	40	53	31	33	20	18	11
Medium Construction Roofs—Exposed to Sun																				
1″ Insulation + 4″ wood	17.3	0.183	5	0	14	5	31	14	49	24	62	32	65	35	56	31	41	24	29	17
2″ Insulation + 4″ wood	17.8	0.113	6	1	13	4	28	12	45	22	58	30	63	34	56	31	43	25	32	18
1″ Insulation + 2″ h.w. concrete	28.3	0.206	4	−1	27	11	54	26	74	39	81	44	70	40	45	27	24	15	12	7
2″ Insulation + 2″ h.w. concrete	28.8	0.122	2	−2	23	9	49	23	70	36	79	43	71	40	49	29	28	17	15	9
4″ l.w. concrete	17.8	0.213	1	−3	28	11	59	28	82	43	88	48	74	42	44	27	19	12	6	4
6″ l.w. concrete	24.5	0.157	−2	−4	9	2	31	13	55	27	72	38	76	41	64	36	42	25	25	15
8″ l.w. concrete	31.2	0.125	6	2	6	1	16	6	32	14	49	24	61	32	63	34	55	31	41	24
Heavy Construction Roofs—Exposed to Sun																				
1″ Insulation + 4″ h.w. concrete	51.6	0.199	7	1	17	6	33	15	50	25	61	32	63	34	53	30	40	23	28	16
2″ Insulation + 4″ h.w. concrete	52.1	1.120	7	2	15	6	30	13	46	23	58	30	61	33	54	30	41	23	31	17
1″ Insulation + 6″ h.w. concrete	75.0	0.193	13	6	17	7	26	12	38	18	48	25	53	28	51	27	43	24	35	19
2″ Insulation + 6″ h.w. concrete	75.4	0.117	15	7	17	7	25	11	36	17	46	23	51	27	50	27	43	24	36	20

1. *Application.* These values may be used for all normal air-conditioning estimates, usually without correction in latitude 0° to 50° north or south when the load is calculated for the hottest weather.
2. *Corrections.* The values in the table were calculated for an inside temperature of 75°F and an outdoor maximum temperature of 95°F with an outdoor daily range of 21°F. The table remains approximately correct for other outdoor maximums (93–102°F) and other outdoor daily ranges (16–34°F), provided that the outdoor daily average temperature remains approximately 85°F.
3. *Attics or other spaces between the roof and ceiling.* If the ceiling is insulated and a fan is used for positive ventilation in the space between the ceiling and roof, the total temperature differential for calculating the room load may be decreased by 25 percent. If the attic space contains a return duct or other air plenum, care should be taken in determining the portion of the heat gain that reaches the ceiling.
4. *Light Colors.* Credit should not be taken for light-colored roofs, except where the permanence of light color is established by experience, as in rural areas or where there is little smoke.

Note: h.w. = heavy weight
l.w. = light weight

3.6.2 Heat Gain through Glazing (Transparent or Translucent)

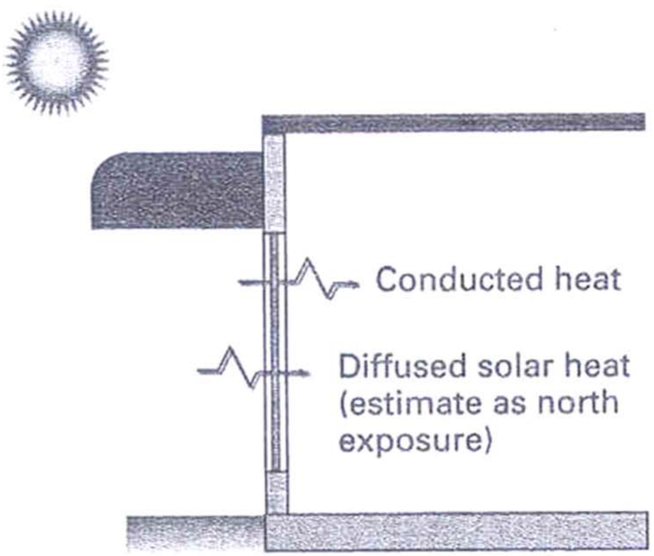
Glazing materials usually have lower thermal resistance than the opaque building materials and they also admit solar radiation into the space.

These heat loads are considered in two parts, simple conductive heat transfer due to the temperature differences between indoor air and outdoor air, and solar heat gain.

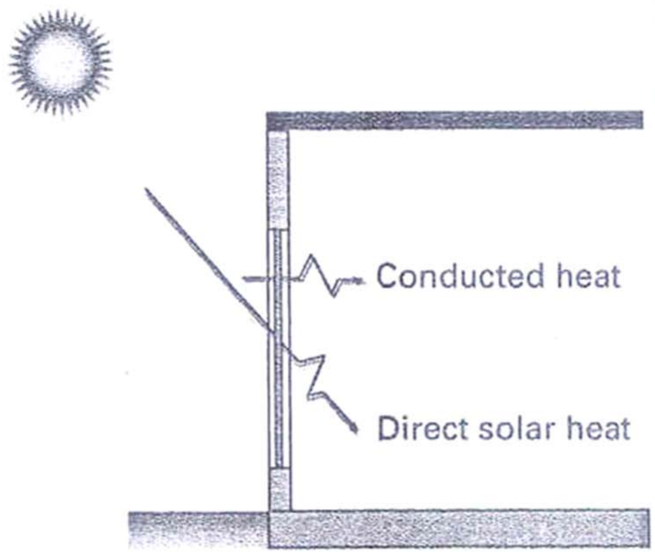
$$\boxed{Q = A\ U\ (t_i - t_o) + (SC)(A)(SHGF)}$$

$SHGF$ = solar heat gain factor (W/m^2)

SC = shading coefficient(dimensionless)



Shaded glass



Glass in sun

SHGF(solar heat gain factor)

The amount of solar heat that will enter a clear single-pane window at a given time of year and time of day, facing the specified orientation.

Table 15 Solar Irradiance (E_{DN}) and Solar Heat Gain Factors (SHGF) for 16° North Latitude

Date	Solar Time	Direct Normal W/m²	Solar Heat Gain Factors, W/m² N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Hor.	Solar Time
Jan	7	445	17	19	138	291	390	424	396	303	155	19	17	17	17	17	17	17	43	5
	8	827	45	48	174	463	662	756	734	596	359	79	45	45	45	45	45	45	249	4
	9	948	67	67	102	384	630	770	791	690	481	183	69	67	67	67	67	67	472	3
	10	1001	82	82	86	209	474	658	736	704	563	321	97	82	82	82	82	82	640	2
	11	1025	91	91	91	96	242	467	614	663	611	462	236	96	91	91	91	91	745	1
	12	1032	95	95	95	95	100	228	438	580	628	580	438	228	100	95	95	95	781	12
HALF DAY TOTALS			348	352	618	1452	2398	3153	3457	3216	2465	1344	666	401	350	348	348	348	2539	
Feb	7	575	24	55	265	435	531	544	474	326	113	26	24	24	24	24	24	24	80	5
	8	862	53	60	304	567	729	778	706	524	244	56	53	53	53	53	53	53	319	4
	9	961	74	77	202	482	675	763	733	592	347	96	74	74	74	74	74	74	549	3
	10	1006	90	91	104	291	508	636	664	593	423	193	93	90	90	90	90	90	721	2
	11	1027	99	99	102	118	262	428	527	542	471	323	154	103	99	99	99	99	831	1
	12	1033	103	103	103	104	108	189	336	448	487	448	336	189	108	104	103	103	868	12
HALF DAY TOTALS			390	431	1013	1922	2728	3226	3262	2790	1835	906	547	417	392	390	390	390	2932	
Mar	7	633	35	167	392	543	605	578	457	259	46	33	33	33	33	33	33	33	126	5
	8	857	63	157	441	647	752	740	614	389	111	61	61	61	61	61	61	61	380	4
	9	942	83	110	342	564	688	708	622	435	180	85	82	82	82	82	82	82	605	3
	10	983	98	103	191	378	519	575	542	424	240	106	99	98	98	98	98	98	777	2
	11	1002	107	110	113	166	273	361	394	365	280	173	113	110	107	107	107	107	884	1
	12	1007	111	111	112	114	117	149	215	273	294	273	215	149	117	114	112	111	918	12
HALF DAY TOTALS			443	712	1556	2381	2924	3074	2771	2026	1005	588	483	447	440	438	437	437	3230	
Apr	6	44	7	24	37	43	43	37	24	7	2	2	2	2	2	2	2	2	4	6
	7	622	75	297	482	589	604	528	369	141	45	42	42	42	42	42	42	42	169	5
	8	806	85	312	543	681	717	644	473	217	74	70	70	70	70	70	70	70	412	4
	9	884	97	248	468	609	657	608	465	244	97	90	90	90	90	90	90	90	622	3
	10	923	111	171	320	444	498	476	380	231	118	108	105	105	105	105	105	105	784	2
	11	942	120	126	169	228	270	276	245	188	136	121	118	115	115	115	115	118	881	1
	12	948	123	123	124	125	125	129	135	141	143	141	135	129	125	125	124	123	910	12
HALF DAY TOTALS			565	1271	2126	2709	2907	2682	2058	1111	547	583	494	491	489	489	489	491	3331	
May	6	138	43	94	128	141	134	106	59	11	9	9	9	9	9	9	9	10	17	6
	7	607	157	378	531	602	583	474	289	76	49	49	49	49	49	49	49	52	195	5
	8	770	165	415	597	689	677	564	362	121	78	76	76	76	76	76	76	80	424	4
	9	844	156	365	539	625	621	525	344	141	100	96	96	96	96	96	96	100	620	3
	10	882	149	281	409	477	473	397	264	139	116	111	111	111	111	111	111	116	771	2
	11	901	147	198	248	273	262	220	165	130	126	123	120	120	120	122	124	128	861	1
	12	906	146	144	139	134	132	131	130	129	129	129	130	131	132	134	139	144	889	12
HALF DAY TOTALS			892	1811	2534	2888	2826	2358	1553	684	541	528	526	526	526	528	532	556	3335	
Jun	6	168	64	124	163	175	162	123	64	13	12	12	12	12	12	12	12	13	24	6
	7	593	194	403	542	598	565	445	252	63	52	52	52	52	52	52	52	57	203	5
	8	750	209	449	611	683	653	526	313	98	79	79	79	79	79	79	79	84	425	4
	9	823	199	408	560	626	601	487	294	118	98	98	98	98	98	98	98	105	613	3
	10	860	187	329	440	486	459	363	222	124	116	113	113	113	113	113	113	121	759	2
	11	879	181	241	283	290	258	200	146	130	126	121	121	121	121	125	128	136	846	1
	12	885	179	173	158	142	134	132	130	129	129	129	130	132	134	142	158	173	873	12
HALF DAY TOTALS			1122	2042	2682	2930	2762	2207	1356	612	548	540	539	540	542	545	555	599	3307	

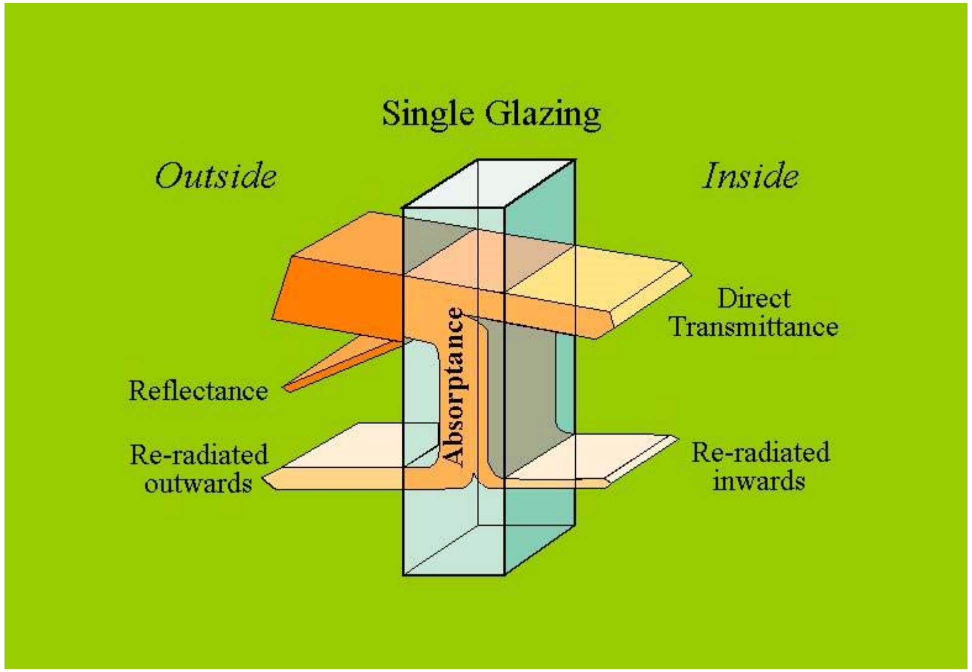
Table 9 Peak Irradiance, W/m^2

Exposure		Latitude								
		20°	25°	30°	35°	40°	45°	50°	55°	60°
North	E_D	132	117	106	101	103	110	124	145	172
	E_d	136	122	109	98	88	79	70	63	55
	E_t	269	238	215	199	190	189	194	207	227
Northeast/Northwest	E_D	541	532	522	511	501	490	480	470	461
	E_d	163	154	147	140	135	130	126	123	120
	E_t	704	686	668	652	636	621	606	593	580
East/West	E_D	627	640	650	657	662	663	662	659	653
	E_d	173	169	166	163	162	161	161	161	162
	E_t	800	809	816	821	824	825	823	820	815
Southeast/Southwest	E_D	334	380	422	460	494	525	553	557	598
	E_d	174	173	174	175	177	180	183	187	191
	E_t	508	553	595	635	672	705	736	764	788
South	E_D	0	65	146	223	297	368	436	501	563
	E_d	149	171	175	180	186	192	198	205	212
	E_t	149	236	321	403	482	559	634	705	774
Horizontal	E_D	906	901	888	867	838	801	756	703	642
	E_d	124	124	124	124	124	124	124	124	124
	E_t	1030	1025	1012	991	962	925	880	827	776

SC(shading coefficient)

The SC is the ratio of solar gain (due to direct sunlight) passing through a glass unit to the solar energy which passes through 3mm Clear Float Glass.

It is referred to as an indicator to how the glass is thermally insulating (shading) the interior when there is direct sunlight on the panel or window.

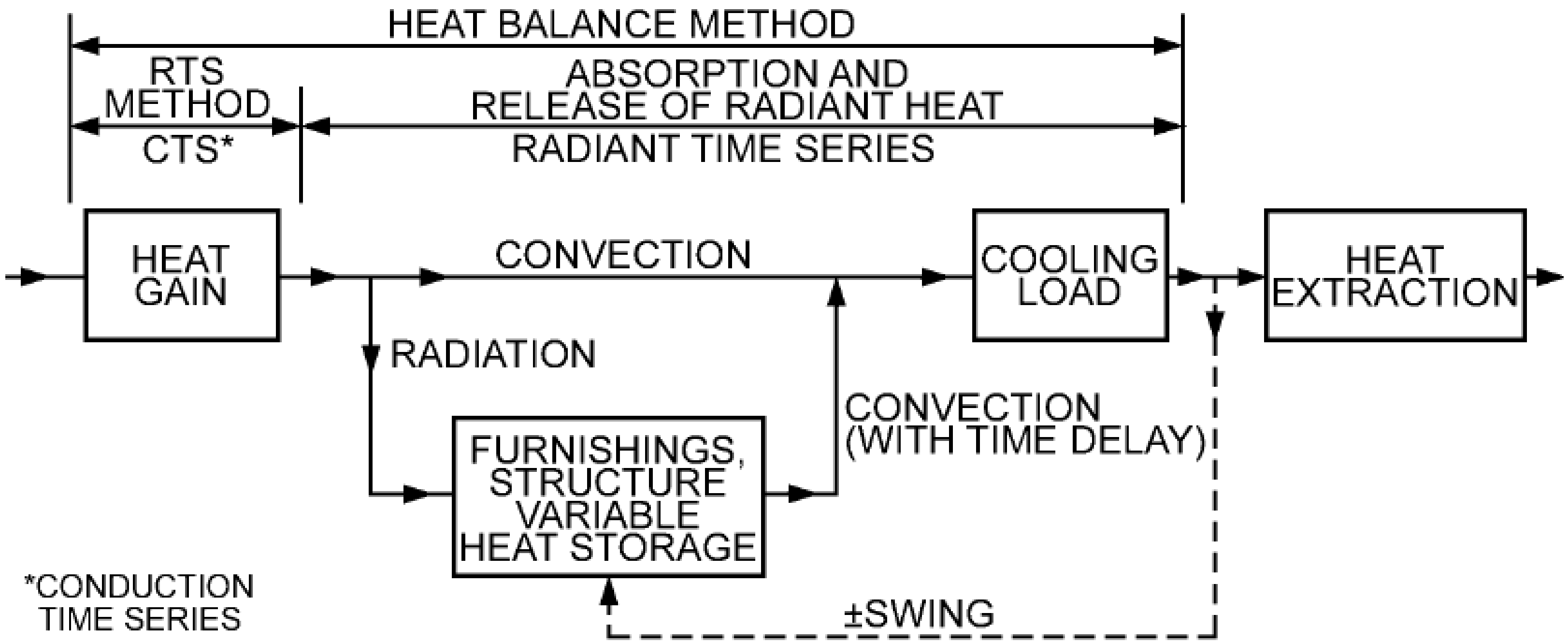


Shading coefficient for single glass and insulating glass

Type of Glass	Normal Thickness	Shading Coefficient[a]
Single Glass		
Regular sheet	1/8	1.00
Regular plate/float	1/4	0.95
	3/8	0.91
	1/2	0.88
Grey sheet	1/8	0.78
	1/4	0.86
Heat-absorbing plate/float	3/16	0.72
	1/4	0.70
Insulating Glass		
Regular sheet out, regular sheet in	1/8	0.90
Regular plate/float out, regular plate/float in	1/4	0.83
Heat-absorbing plate/float out, regular plate/float In	1/4	0.06

[a]Wind velocity 7.5 mph.
Source: Reprinted with permission from ASHRAE.

Origin of Difference Between Magnitude of Instantaneous Heat Gain and Instantaneous Cooling Load



3.6.3 Infiltration and Ventilation

The infiltration is much lower during hot weather than cold weather especially in high-rise buildings. In winter, stack effect due to great temperature difference between indoor and outdoor airs cause more infiltration.

Sensible heat and latent heat loads due to infiltration can be calculated by :

$$Q_{sensible} = 0.24 \times 1.2 \times CMH \times (t_i - t_o)$$

$$Q_{latent} = 597 \times 1.2 \times CMH \times (x_i - x_o)$$

Total heat, *enthalpy (h)* is the sum of sensible and latent heat. The *enthalpy* can be taken from a psychrometric chart or tables.

$$Q = 1.2 \times CMH \times \Delta h$$

Δh = change in enthalpy (kcal/kg_{da})

Outside air introduced for ventilation by the air-conditioning equipment result in sensible and latent loads calculated by the same equations as in the infiltration cooling load calculations.

3.6.4 Internal Heat Gains

Heat is generated inside buildings by lights, appliances, and occupants.

People liberate both sensible and latent heat. Latent heat results from exhaled moisture and evaporation of perspiration. The latent het loads depend on the level of activity.

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

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

Notes:

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

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

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

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

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

Heat from lights and appliances can be calculated using the factor for conversion of electrical to thermal energy:

$$Q = 3.41 \times P$$

P = power input to light fixture or appliance(W)

Heat from building lighting and appliances may not be estimated precisely. Usually, the wattage per unit area (W/m2) is used.

Table 10 Recommended Heat Gain from Miscellaneous Office 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 3300	390 to 2150
Labeling machine, 1,500 to 30,000 pieces/h	600 to 6600	390 to 4300
Postage meter	230	150
Vending machines		
Cigarette	72	72
Cold food/beverage	1150 to 1920	575 to 960
Hot beverage	1725	862
Snack	240 to 275	240 to 275
Other		
Bar code printer	440	370
Cash registers	60	48
Check processing workstation, 12 pockets	4800	2470
Coffee maker, 10 cups	1500	1050 sens., 450 latent
Microfiche reader	85	85
Microfilm reader	520	520
Microfilm reader/printer	1150	1150
Microwave oven, 28 L	600	400
Paper shredder	250 to 3000	200 to 2420
Water cooler, 30 L/h	700	350

Table 8 Recommended Heat Gain from Typical Computer Equipment

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

Sources: Hosni et al. (1999), Wilkins and McGaffin (1994).

[a]Based on 386, 486, and Pentium grade.

[b]Typical values for monitors displaying Windows environment.

Table 13 Summary of Radiant-Convective Split for Office Equipment

Device	Fan	Radiant	Convective
Computer	Yes	10 to 15%	85 to 90%
Monitor	No	35 to 40%	60 to 65%
Computer and monitor	–	20 to 30%	70 to 80%
Laser printer	Yes	10 to 20%	80 to 90%
Copier	Yes	20 to 25%	75 to 80%
Fax machine	No	30 to 35%	65 to 70%

Source: Hosni et al. (1999).