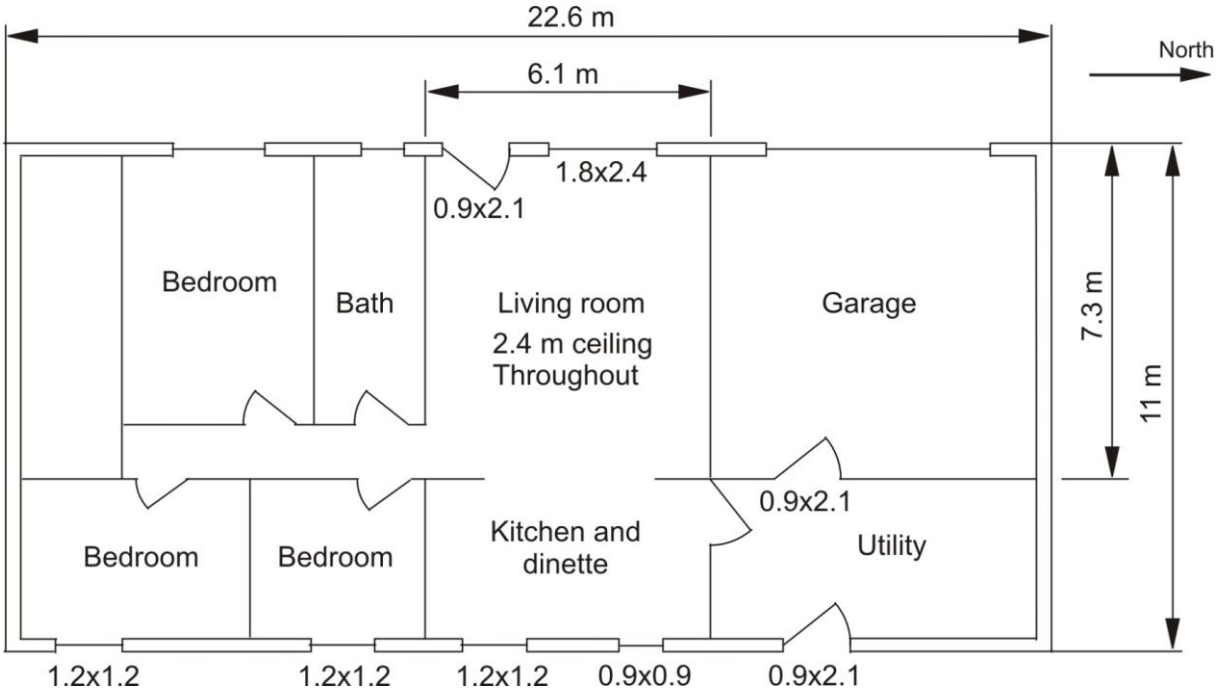
Cooling load calculation of a single family house using CLTD/GLF method

Floor Plan of the Single Family House



Roof construction

Conventional roof-attic-ceiling combination U = 0.28 W/(m2·K)

Wall construction

Brick, insulation, gypsum wallboard U = 0.34 W/(m2·K)

Partition wall U = 0. 4 W/(m2·K)

Doors

Wood, solid core U = 1.82 W/(m2·K)

Windows

Clear double-pane glass in wood frames

3 mm thick. U = 2.84 W/(m2·K)

The window glass has a 600 mm overhang at the top.

Assume closed, medium-color venetian blinds.

Outdoor design conditions

Temperature of 35°C dry bulb with a 13 K daily range

Relative humidity ratio of 0.0136 kg vapour/kg dry air (23.7 °C wet bulb)

Indoor design conditions

Temperature of 24 °C dry bulb

Relative humidity ratio of 50%

Occupancy

Four persons

Appliances and lights

470 W for the kitchen and 50% in the living room

Find the sensible, latent and total cooling load!

Solution

The cooling load must be made on a room-by-room basis to determine the proper distribution of air.

Sensible heat gains

For walls, roof and doors

$$Q = U \cdot A \cdot (CLTD)$$

where

CLTD – Cooling Load Temperature Difference, K

Table 1 CLTD Values for Single-Family Detached Residences[a]

Daily Temperature Range[b]	Design Temperature, °C											
	29		32			35			38		41	43
	L	M	L	M	H	L	M	H	M	H	M	H
All walls and doors												
North	4	2	7	4	2	10	7	4	10	7	10	13
NE and NW	8	5	11	8	5	13	11	8	13	11	13	16
East and West	10	7	13	10	7	16	13	10	16	13	16	18
SE and SW	9	6	12	9	6	14	12	9	14	12	14	17
South	6	3	9	6	3	12	9	6	12	9	12	14
Roofs and ceilings												
Attic or flat built-up	23	21	26	23	21	28	26	23	28	26	28	31
Floors and ceilings												
Under conditioned space, over unconditioned room, or over crawl space	5	2	7	5	2	8	7	5	8	7	8	11
Partitions												
Inside or shaded	5	2	7	5	2	8	7	5	8	7	8	11

[a]Cooling load temperature differences (CLTDs) for single-family detached houses, duplexes, or multifamily, with both east and west exposed walls or only north and south exposed walls, K.

[b]L denotes low daily range, less than 9 K; M denotes medium daily range, 9 to 14 K; and H denotes high daily range, greater than 14 K.

ASHRAE Fundamentals 2001, Ch. 28, Table 1

For windows

$$Q = A \cdot (GLF)$$

where GLF – Glass Load Factor, W/m^2

Table 3 Window Glass Load Factors (GLFs) for Single-Family Detached Residences[a]

Design Temperature, °C	Regular Single Glass						Regular Double Glass						Heat-Absorbing Double Glass						Clear Triple Glass		
	29	32	35	38	41	43	29	32	35	38	41	43	29	32	35	38	41	43	29	32	35
No inside shading																					
North	107	114	129	148	151	158	95	95	107	117	120	129	63	63	73	79	82	88	85	85	95
NE and NW	199	205	221	237	243	262	173	177	186	196	199	208	114	117	123	132	139	139	158	158	167
East and West	278	284	300	315	322	337	243	246	255	265	268	278	161	161	170	177	186	186	221	221	230
SE and SW[b]	249	255	271	287	290	309	218	221	230	240	243	252	142	145	155	161	170	170	196	199	205
South[b]	167	173	189	205	211	227	145	148	158	167	170	180	98	98	107	114	123	123	132	132	142
Horizontal skylight	492	492	508	524	527	539	432	435	442	451	454	464	284	287	293	300	303	309	391	394	401
Draperies, venetian blinds, translucent roller shades, fully drawn																					
North	57	60	73	85	91	104	50	50	60	69	73	82	41	44	50	57	60	66	47	50	57
NE and NW	101	104	120	132	136	148	91	95	101	110	114	123	76	76	85	91	91	101	88	88	95
East and West	142	145	158	170	173	186	126	129	139	145	148	158	104	104	114	120	120	129	123	123	129
SE and SW[b]	126	129	145	155	161	173	114	117	123	132	136	145	91	95	101	107	110	117	110	114	120
South[b]	85	88	104	117	120	132	76	79	88	98	98	107	63	66	73	79	82	88	73	76	82
Horizontal skylight	246	249	262	271	274	284	224	224	233	240	243	249	183	186	192	199	199	205	218	218	224
Opaque roller shades, fully drawn																					
North	44	47	63	73	79	91	41	44	54	60	63	73	38	38	47	54	54	63	41	41	47
NE and NW	79	82	98	107	114	126	73	76	85	95	95	104	66	69	76	82	85	91	73	73	82
East and West	107	114	126	139	142	155	101	104	114	120	123	132	91	95	101	107	110	117	101	101	110
SE and SW[b]	98	101	114	126	132	145	91	95	104	110	114	123	82	85	91	98	101	107	91	91	98
South[b]	66	69	85	95	101	114	63	63	73	82	85	95	57	60	66	73	76	82	60	63	69
Horizontal skylight	189	192	202	214	218	227	180	180	189	196	199	205	164	164	173	180	180	186	177	180	186

[a]Glass load factors (GLFs) for single-family detached houses, duplexes, or multifamily residences, with both east and west exposed walls or only north and south exposed walls, W/m^2.

[b]Correct by +30% for latitude of 48° and by −30% for latitude of 32°. Use linear interpolation for latitude from 40 to 48 and from 40 to 32°.

To obtain GLF for other combinations of glass and/or inside shading: $GLF_a = (SC_a/SC_t)(GLF_t - U_tD_t) + U_aD_t$, where the subscripts a and t refer to the alternate and table values, respectively. SC_t and U_t are given in Table 5. $D_t = (t_a - 24)$, where $t_a = t_o - (DR/2)$; t_o is the outdoor design temperature and DR is the daily range.

ASHRAE Fundamentals 2001, Ch. 28, Table 3

The effects of permanent outside shading devices should be considered separately. Shaded glass is considered the same as north-facing glass. The shade line factor (SLF) is the ratio of the distance a shadow falls beneath the edge of an overhang to the width of the overhang (Table 5 and 6). Therefore, assuming the overhang is at the top of the window, the shade line (H) equals the SLF times the overhang width (W). The shaded and sunlit glass areas have to be computed separately. NE and NW facing windows should not be considered shaded.

Table 5 Shading Coefficients and U-Factors for Residential Windows

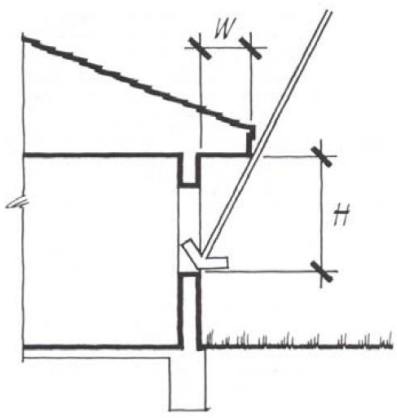
	Inside Shade					
	None		Drapery, Venetian Blind, or Translucent Roller Shade		Opaque Roller Shade	
Glass Type	SC	*U*	SC	*U*	SC	*U*
Single	1.00	5.91	0.50	4.60	0.38	4.60
Double	0.88	3.46	0.45	3.12	0.36	3.12
Heat-absorbing	0.58	2.56	0.37	2.50	0.33	2.50
Triple	0.80	2.50	0.44	2.27	0.36	2.27

Note: *U* is in W/(m^2 · K).

Table 6 Shade Line Factors (SLFs)

Direction Window Faces	Latitude, Degrees N						
	24	32	36	40	44	48	52
East	0.8	0.8	0.8	0.8	0.8	0.8	0.8
SE	1.8	1.6	1.4	1.3	1.1	1.0	0.9
South	9.2	5.0	3.4	2.6	2.1	1.8	1.5
SW	1.8	1.6	1.4	1.3	1.1	1.0	0.9
West	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Note: Shadow length below the overhang equals the shade line factor times the overhang width. Values are averages for the 5 h of greatest solar intensity on August 1.



For occupancy

Plan 67 W per person. Divide occupants evenly among rooms not! used as bedrooms. If number of occupants is not known, assume two people for first bedroom and one person for each additional bedroom.

For appliances and light

Appliance loads are concentrated mainly in the kitchen and laundry areas. In single-family houses a sensible load of 470 W should be divided between the kitchen and/o laundry and the adjoining rooms.

Infiltration

For summer sensible heat is:

$$Q = 1.2 \cdot \dot{V} \cdot \Delta t$$

$$\dot{V} = ACH \cdot V \cdot 1000/3600$$

Where

$\dot{V}$ - volumetric airflow rate l/s

V - volume of room

ACH - summer air change rate 1/h (see Table 8.)

Table 8 Summer Air Exchange Rates (ACH) as Function of Airtightness

	Outdoor Design Temperature, °C					
Class	**29**	**32**	**35**	**38**	**41**	**43**
Tight	0.33	0.34	0.35	0.36	0.37	0.38
Medium	0.46	0.48	0.50	0.52	0.54	0.56
Loose	0.68	0.70	0.72	0.74	0.76	0.78

Note: Values are for 3.4 m/s (12 km/h) wind and indoor temperature of 24°C.

Latent heat gains

Latent cooling load has three main sources: outdoor air, occupants and other sources (cooking, laundry, bathing etc.). A latent factor LF of 1.3 matches the performance of typical residential vapour compression cooling systems. Latent factor is usually less than 1.3.

Figure 1 may be used to estimate the total cooling load by reading LF as a function of the design humidity ratio and air tightness.

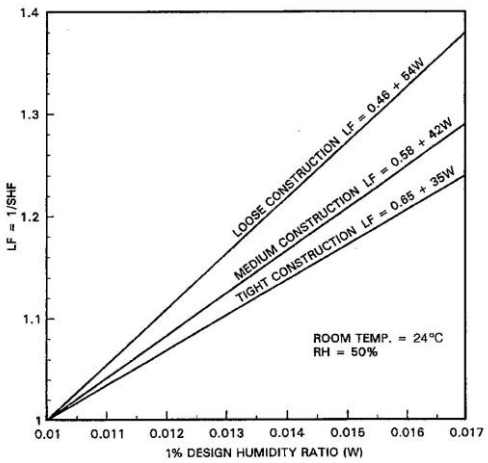


Fig. 1 Effect of Infiltration on Latent Load Factor

Total heat gain

$$Q = LF \cdot \sum Q_{sensible}$$

Example for the living room: (sensible heat gains only)

West wall

$$Q = U \cdot A \cdot (CLTD) = 0.34 \cdot (14.6 - 1.9 - 4.3) \cdot 14 = 40W$$

Partition

$$Q = U \cdot A \cdot (CLTD) = 0.4 \cdot 17.5 \cdot 7 = 49W$$

Roof

$$Q = U \cdot A \cdot (CLTD) = 0.28 \cdot 44.5 \cdot 27 = 336W$$

West door

$$Q = U \cdot A \cdot (CLTD) = 1.82 \cdot 1.9 \cdot 14 = 48W$$

West window - taking into account 600 mm overhang and closed venetian blind (H=0.5m)

$$Q = A \cdot (GLF) = (1.8 - 0.5) \cdot 2.4 \cdot 141 = 437W$$

Shaded glass (as if facing North)

$$Q = A \cdot (GLF) = 0.5 \cdot 2.4 \cdot 63 = 76W$$

Item	Net Area, m^2	GLF, W/m^2	U-Factor, $W/(m^2 \cdot K)$	CLTD, K	Cooling Load, kW	Reference
Living Room						
West wall	8.4		0.34	14	0.040	Table 1
Partition (garage)	17.5		0.40	7	0.049	Table 1
Roof	44.5		0.28	27	0.336	Table 1
West door	1.9		1.82	14	0.048	Table 1
West glass	3.1	141			0.437	Table 3
Shaded glass	1.2	63			0.076	Table 3

Occupancy

$$Q = 67W \cdot n = 67 \cdot 4 = 268W$$

Appliances (assuming that 50% of the kitchen load is picked up in the living room)

$$Q = 470W \cdot 0.5 = 235W$$

Infiltration

$$Q = 1.2 \cdot \dot{V} \cdot \Delta t = 1.2 \cdot 14.85 \cdot (36 - 24) = 214W$$

$$\dot{V} = ACH \cdot V \cdot 1000/3600 = 0.5 \cdot 106.9 \cdot 1000 / 3600 = 14.85 l / s$$

After calculating sensible heat gains for each room, the latent heat gain has to be obtained. If we find LF in Figure 1 the total cooling load can be calculated for the family house.

Source: ASHRAE Fundamentals 2001 Chapter 28.