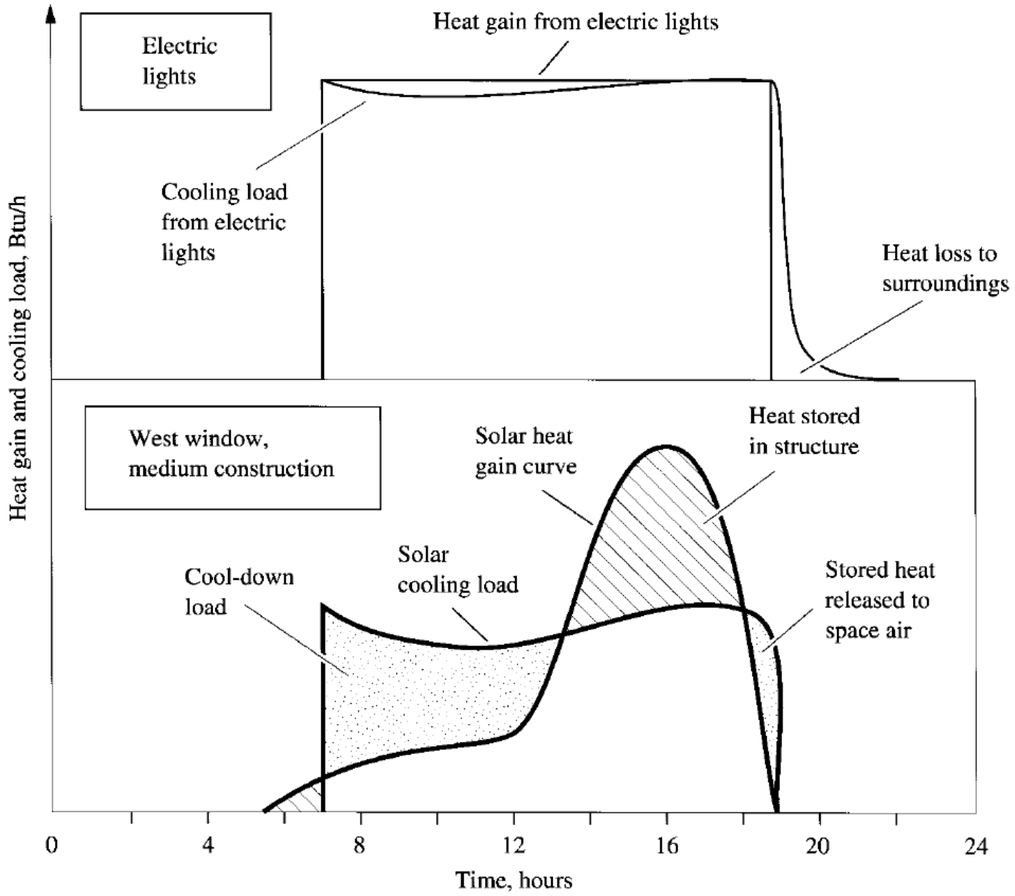
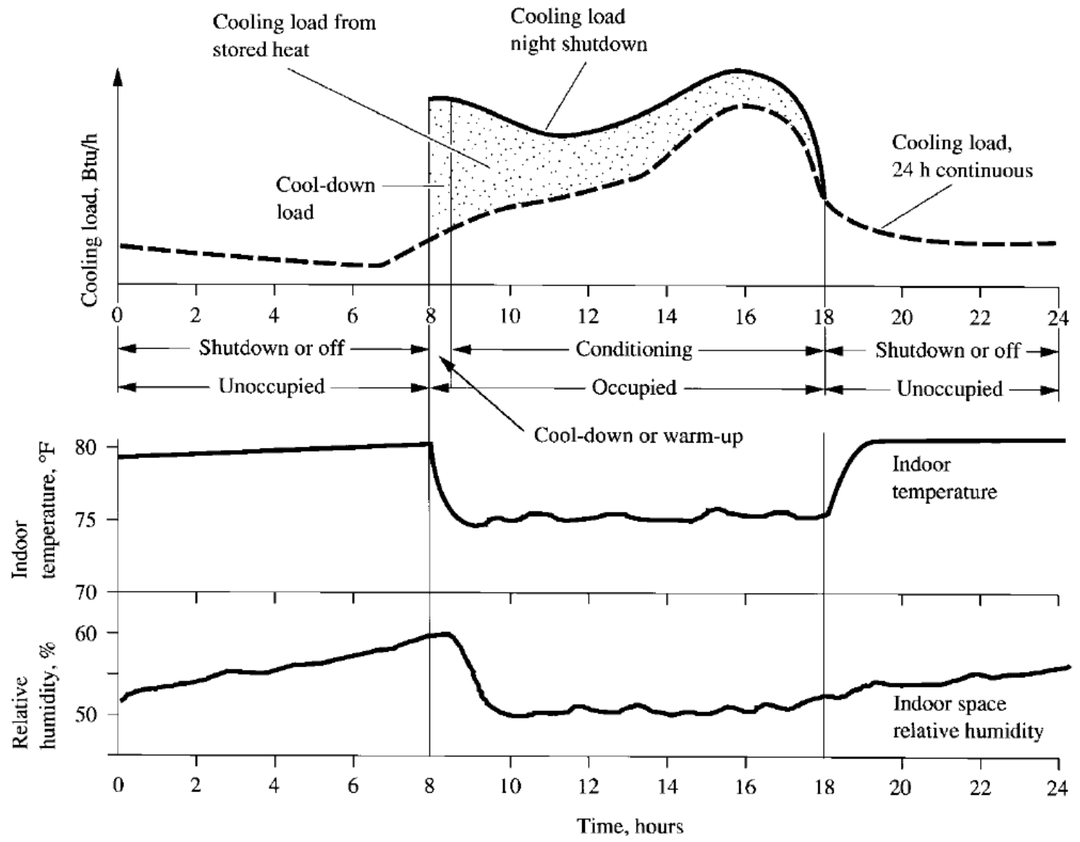
BUILDINGS HVAC SYSTEM
Cooling loads

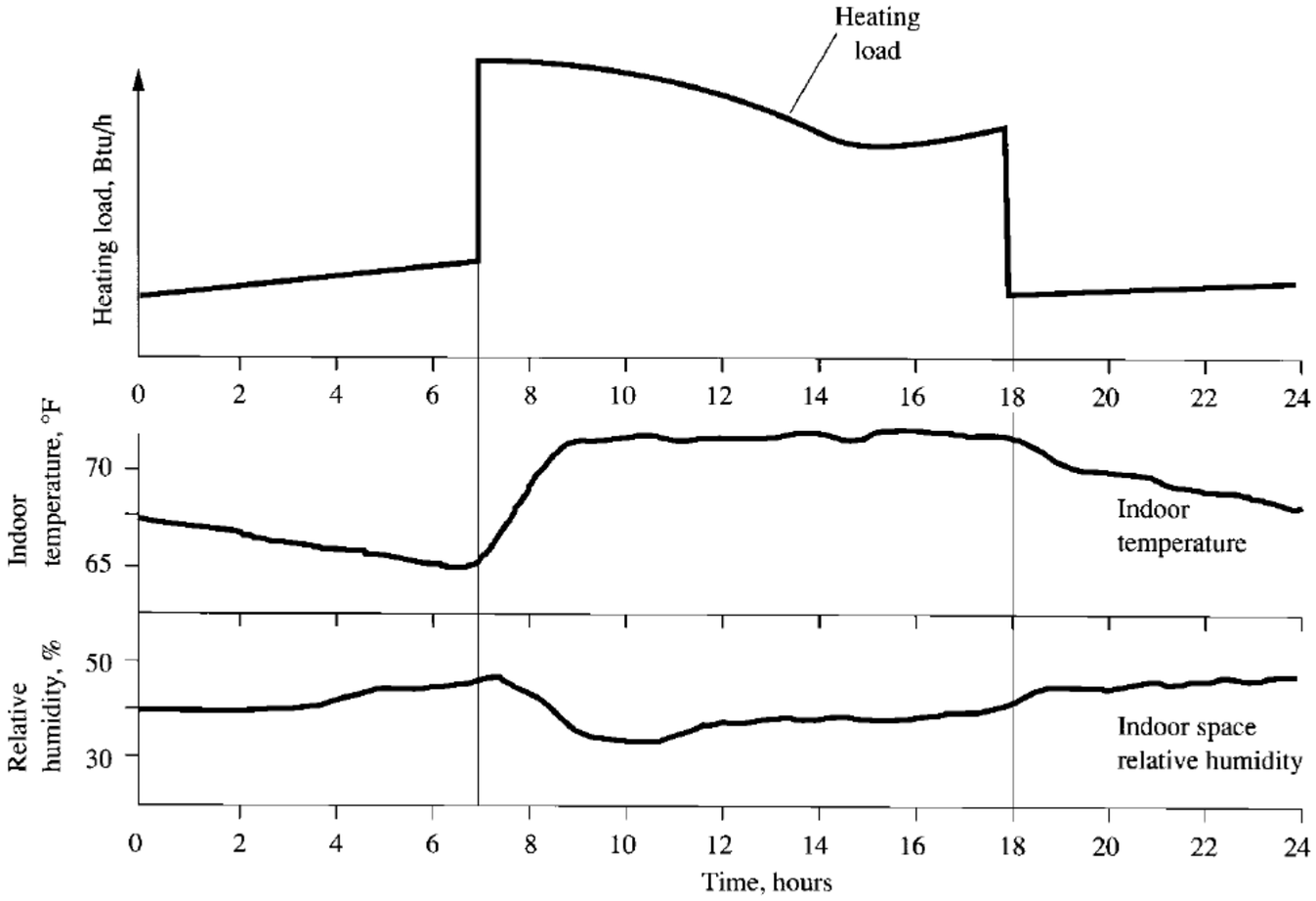
Heat Gains and Cooling Loads



Summer operation



Winter operation



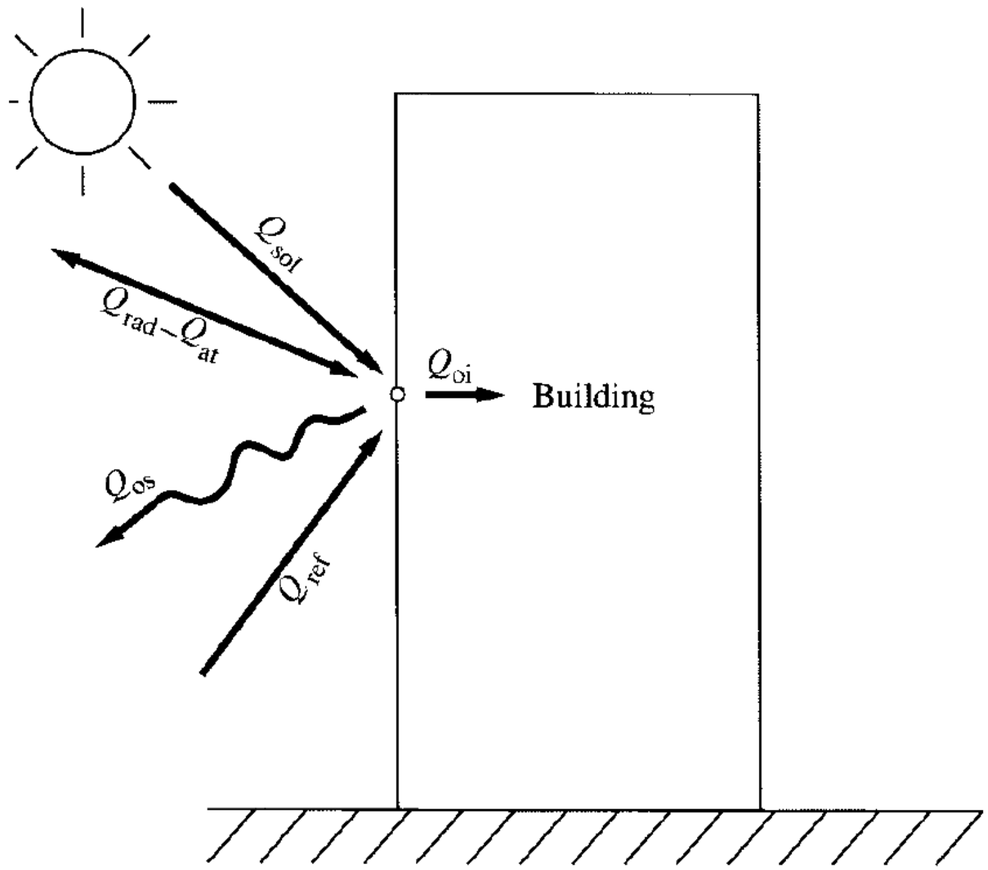
Surface Balance

$$Q_{sol} + Q_{ref} = Q_{os} + (Q_{rad} - Q_{at}) + Q_{oi}$$

$$Q_{sol} = \alpha \cdot [A_s \cdot (I_D + I_d) + A_{sh} \cdot I_d]$$

$$Q_{ref} = A \cdot \alpha_{os} \cdot I_{ref}$$

$$Q_{os} = h_c \cdot A \cdot (T_{os} - T_o)$$



Sol-Air Temperature

- Q_{ref} offset by $Q_{rad} - Q_{at}$

$$Q_{sol} + \cancel{Q_{ref}} = Q_{os} + \cancel{(Q_{rad} - Q_{at})} + Q_{oi}$$

$$Q_{sol} = Q_{os} + Q_{oi}$$

$$Q_{oi} = h_o \cdot A \cdot (T_{sol} - T_{os})$$

$$\alpha_{os} \cdot I_t \cdot A = h_o \cdot A \cdot (T_{os} - T_o) + h_o \cdot A \cdot (T_{sol} - T_{os})$$

$$\alpha_{os} \cdot I_t = h_o \cdot (T_{os} - T_o) + h_o \cdot (T_{sol} - T_{os})$$

$$\alpha_{os} \cdot I_t = h_o \cdot [\cancel{(T_{os} - T_o)} + \cancel{(T_{sol} - T_{os})}]$$

- Sol-air temperature

$$T_{sol} = T_o + \frac{\alpha_{os} \cdot I_t}{h_o}$$

Heat Balance Equation

- For a surface a heat balancing equation can be written as

$$q_{i,t} = \left[h_{ci}(T_{r,t} - T_{i,t}) + \sum_{j=1}^{k} h_{ij}(T_{j,t} - T_{i,t}) \right] \cdot A_i + S_{ir,t} + L_{ir,t} + E_{ir,t} + O_{ir,t}$$

- h_{ci}convective heat transfer surface *i*
- h_{ij} radiative heat transfer
- $T_{r,t}$ room temperature
- $T_{i,t}$ *i*th surface temperature
- $T_{j,t}$ *j*th surface temperature
- $S_{ir,t}$ solar radiation
- $L_{ir,t}$ electric lights
- $E_{ir,t}$ radiative energy from equipment absorbed *ith surface*
- $O_{ir,t}$ radiation from occupants absorbed on the surface

sensible cooling load

$$Q_{rs,t} = \sum_{i}^{m} h_{ci}\left(T_{r,t} - T_{i,t}\right)A_i \; + \dot{V}_{if}\rho c_{pa}\left(T_{o,t} - T_{r,t}\right) + S_{c,t} \; + L_{c,t} + E_{c,t} + O_{c,t}$$

- h_{ci}convective heat transfer surface *i*
- $\dot{V}_{if}$ volumetric flow rate infiltration
- $T_{o,t}$ outdoor temperature at time *t*
- $T_{r,t}$ room air temperature at time *t*
- $S_{c,t}$ solar radiation from windows
- $L_{c,t}$ electric lights
- $E_{c,t}$ convective energy from equipment absorbed *ith surface*
- $O_{c,t}$ sensible heat from occupants

Heat Balance Method

- Impossible to solve equations without computer codes
- Different methods developed
  - Transfer function method
  - Radiant time series
  - Finite difference
  - CLTD/SCL/CLF Method, cooling load temperature difference
  - TETD/TA Method total eqivalent temperature difference
- CLTD/SCL/CLF Method
  - CLTD: Cooling Load Temperature Difference
  - SCL: Solar Cooling Load
  - CLF: Cooling Load Factor

CLTD/SCL/CLF Method

- The method add three terms to compute the overall cooling load
- CLTD using transfer function method computes the sensible cooling load due to exterior walls and roofs
- SCL computes the effect of solar heat gain taking into account the heat storage effect of room construction and floor coverings
- CLF computes the effect of interior sensible cooling loads

CLTD

- Space sensible cooling load

$$Q_{rs,w} = U \cdot A \cdot CLTD$$

- *U* overall heat-transfer coefficient
- *A* area of exterior wall, roof, or window
- *CLTD* cooling load temperature difference (usually in °F)
- *CLTD* tables reported for specific conditions
  - T_r=70 °F (25.6 °C)
  - T_o=85 °F (29.4 °C)
  - Solar radiation 40° N latitude July 21

- Possible correction for different temperatures

$$CLTD_{corr} = CLTD + 78 - T_r + T_{om} - 85$$

Space Cooling due to Fenestration

- The data is split according to the exposition of the window

$$Q_{rs,s} = Q_{sun} + Q_{sh} = A_s \cdot SCL_s \cdot SC + A_{sh} \cdot SCL_{sh} \cdot SC$$

Q_{sun} space cooling load from solar heat gain through sunlit area of window glass

Q_{sh} space cooling load from solar heat gain through shaded area of window glass

A_s, A_sh sunlit and shaded area

SC shading coefficient

SCL_s solar cooling load for sunlit glass facing specific direction

SCL_{sh} solar cooling load for shaded area as if glass is facing north

Internal Cooling Loads

- Sensible internal heat contains the radiative component is multiplied by a factor

$$Q_{int,s} = q_{int,s} \cdot CLF_{int}$$

- Convective internal heat components are considered directly as loads
- Latent heat gains are considered directly as load

$$Q_{int,l} = q_{int,l}$$

Zone types

TABLE 6.5 Zone Types for Use with SCL and CLF Tables, Single-Story Building

Zone parameters				Zone type			Error band	
No. walls	Floor covering	Partition type	Inside shade	Glass solar	People and equipment	Lights	Plus	Minus
1 or 2	Carpet	Gypsum	*	A	B	B	9	2
1 or 2	Carpet	Concrete block	*	B	C	C	9	0
1 or 2	Vinyl	Gypsum	Full	B	C	C	9	0
1 or 2	Vinyl	Gypsum	Half to none	C	C	C	16	0
1 or 2	Vinyl	Concrete block	Full	C	D	D	8	0
1 or 2	Vinyl	Concrete block	Half to none	D	D	D	10	6
3	Carpet	Gypsum	*	A	B	B	9	2
3	Carpet	Concrete block	Full	A	B	B	9	2
3	Carpet	Concrete block	Half to none	B	B	B	9	0
3	Vinyl	Gypsum	Full	B	C	C	9	0
3	Vinyl	Gypsum	Half to none	C	C	C	16	0
3	Vinyl	Concrete block	Full	B	C	C	9	0
3	Vinyl	Concrete block	Half to none	C	C	C	16	0
4	Carpet	Gypsum	*	A	B	B	6	3
4	Vinyl	Gypsum	Full	B	C	C	11	6
4	Vinyl	Gypsum	Half to none	C	C	C	19	−1

A total of 14 zone parameters are defined. Those not shown in this were selected to achieve the minimum error band shown in the right-hand column for solar cooling load.

*The effect of inside shade is negligible in this case.

Source: Adapted from *ASHRAE Handbook 1997, Fundamentals*. Reprinted with permission.

Solar Cooling Loads

Glass face	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
	Zone type A																							
N	0	0	0	0	1	25	27	28	32	35	38	40	40	39	36	31	31	36	12	6	3	1	1	0
NE	0	0	0	0	2	85	129	134	112	75	55	48	44	40	37	32	26	18	7	3	2	1	0	0
E	0	0	0	0	2	93	157	185	183	154	106	67	53	45	39	33	26	18	7	3	2	1	0	0
SE	0	0	0	0	1	47	95	131	150	150	131	97	63	49	41	34	27	18	7	3	2	1	0	0
S	0	0	0	0	0	9	17	25	41	64	85	97	96	84	63	42	31	20	8	4	2	1	0	0
SW	0	0	0	0	0	9	17	24	30	35	39	64	101	133	151	152	133	93	35	17	8	4	2	1
W	1	0	0	0	0	9	17	24	30	35	38	40	65	114	158	187	192	156	57	27	13	6	3	2
NW	1	0	0	0	0	9	17	24	30	35	38	40	40	50	84	121	143	130	46	22	11	5	3	1
Horiz.	0	0	0	0	0	24	69	120	169	211	241	257	259	245	217	176	125	70	29	14	7	3	2	1