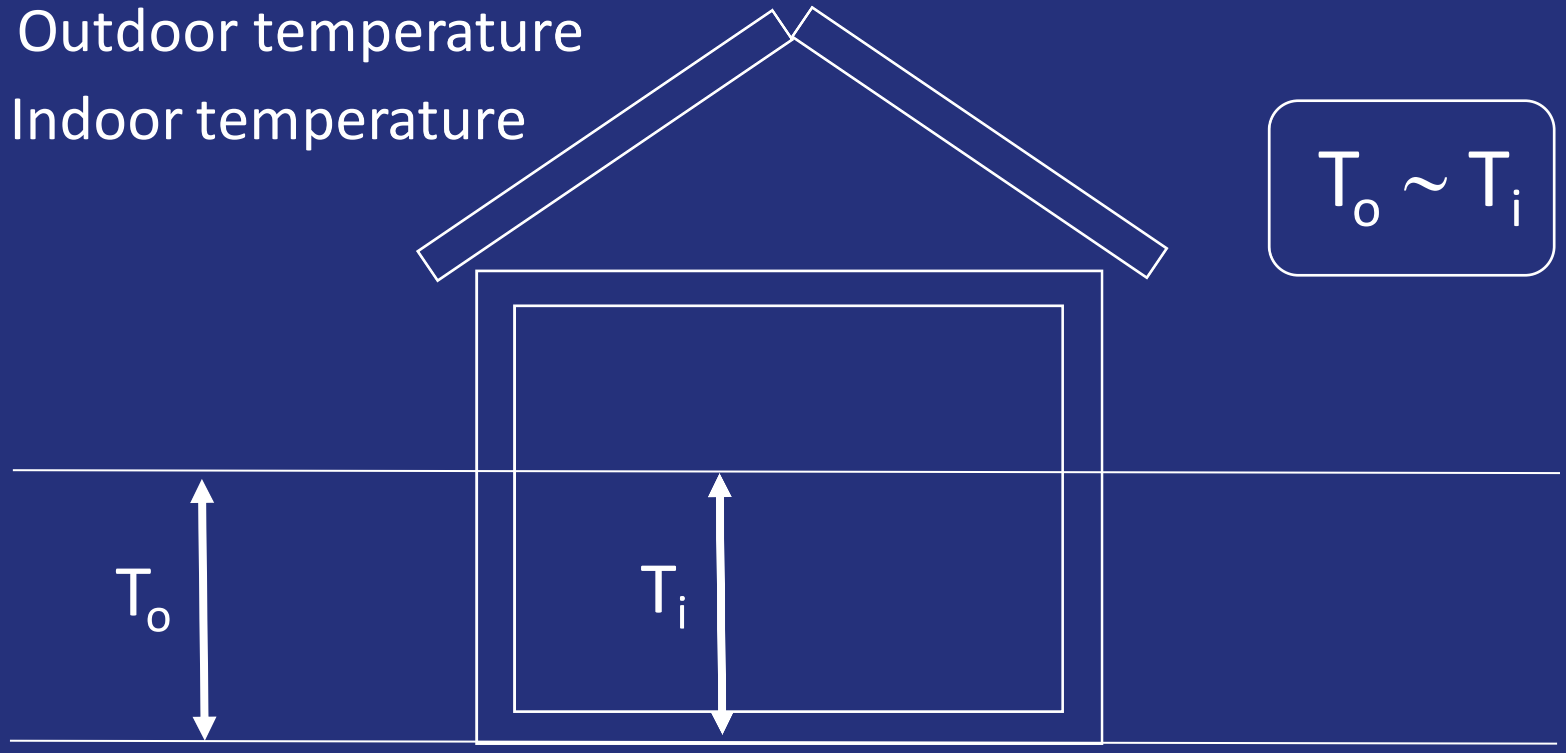
COLD LOAD

Didactic Material

STEADY STATE (Equilibrium)

T_o = Outdoor temperature

T_i = Indoor temperature

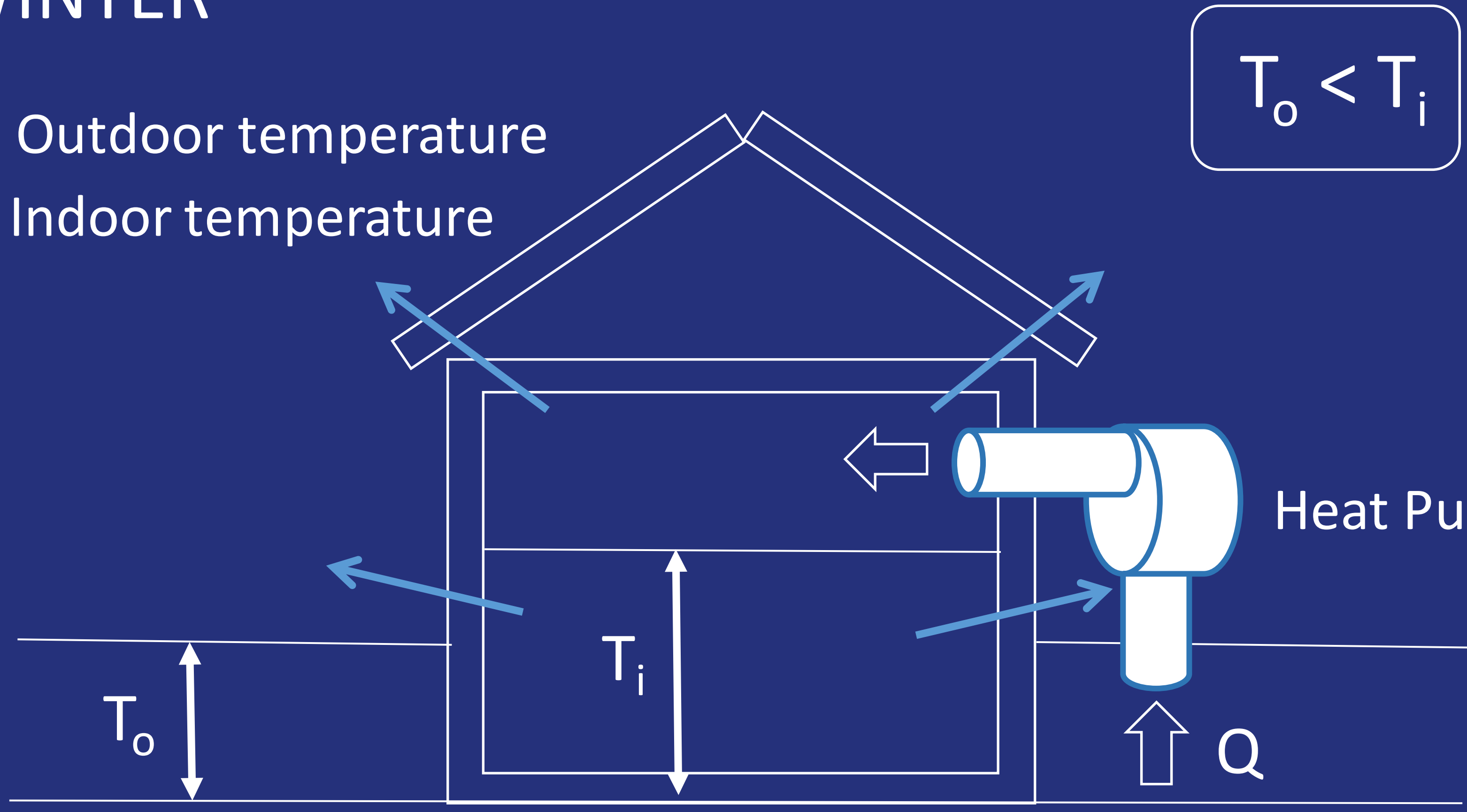


$T_o \sim T_i$

WINTER

T_o = Outdoor temperature

T_i = Indoor temperature

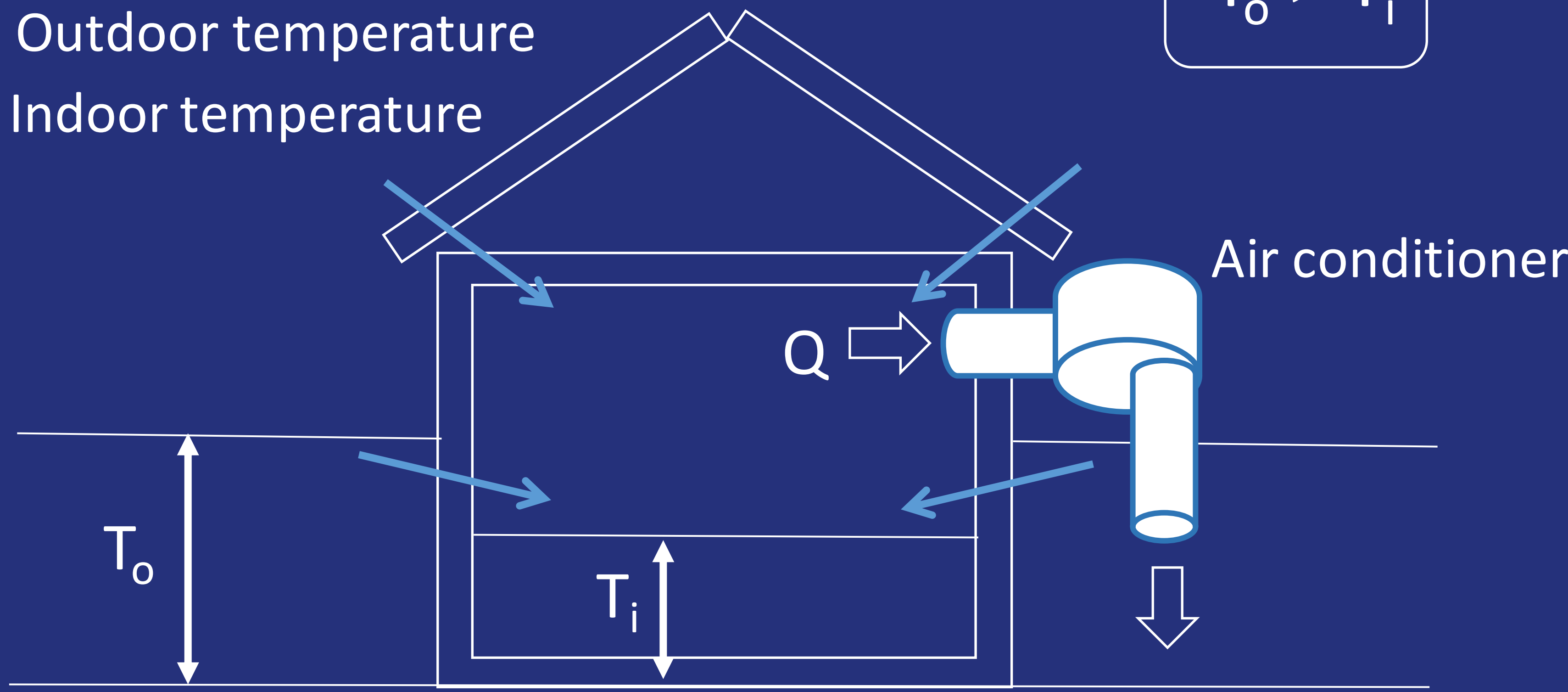


SUMMER

T_o = Outdoor temperature

T_i = Indoor temperature

$T_o > T_i$



COLD LOAD

It is the amount of thermal energy per unit of time that an enclosed space exchanges with the outside due to different climatic conditions

COLD LOAD

Depends on:

- Indoor temperature (Thermal comfort conditions)
- Outdoor temperature (External climate conditions)
- Thermal isolation of walls and roof (heat gains and losses)

THERMAL COMFORT CONDITIONS

Thermal comfort is defined as the state of mind that expresses satisfaction with the environment

The values of indoor temperatures and relative humidities for thermal comfort conditions are given by different local and International regulations:

- ISO 7730:2005
- CEN CR 1752: 1999
- SPAIN: RITE 2007

THERMAL COMFORT CONDITIONS

- ISO 7730:2005

Season	Indoor Temperature ºC	Air velocity m/s	Relative Humidity %
Summer	23-25	0.18-0.24	40-60
Winter	20-23	0.15-0.20	40-60

Work places: Indoor temperatures between 17ºC and 25ºC and relative humidities between 30% and 70%

THERMAL COMFORT CONDITIONS

- CEN CR 1752: 1999

Table 1 — Design criteria for spaces in different types of buildings[a)]

Type of building/ space	Activity met	Occupancy person/ m^2	Category	Operative temperature[b)] °C Summer (cooling season)	Operative temperature[b)] °C Winter (heating season)	Maximum mean air velocity m/s Summer (cooling season)	Maximum mean air velocity m/s Winter (heating season)	Sound pressure dB (A)	Ventilation rate l/s × m^2	Additional ventilation when smoking is allowed[c),d)] l/s × m^2
Single office (cellular office)	1,2	0,1	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	30	2,0	—
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	35	1,4	—
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	40	0,8	—
Landscaped office	1,2	0,07	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	35	1,7	0,7
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	40	1,2	0,5
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	45	0,7	0,3
Conference room	1,2	0,5	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	30	6,0	5,0
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	35	4,2	3,6
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	40	2,4	2,0
Auditorium	1,2	1,5	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	30	16[(e)]	—
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	33	11,2	—
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	35	6,4	—
Cafeteria or restaurant	1,2	0,7	A	24,5 ± 1,0	22,0 ± 1,0	0,18	0,15	35	8,0	—
			B	24,5 ± 2,0	22,0 ± 2,5	0,22	0,18	45	5,6	5,0
			C	24,5 ± 2,5	22,0 ± 3,5	0,25	0,21	50	3,2	2,8
Classroom	1,2	0,5	A	24,5 ± 0,5	22,0 ± 1,0	0,18	0,15	30	6,0	—
			B	24,5 ± 1,5	22,0 ± 2,0	0,22	0,18	35	4,2	—
			C	24,5 ± 2,5	22,0 ± 3,0	0,25	0,21	40	2,4	—
Kindergarten	1,4	0,5	A	23,5 ± 1,0	20,0 ± 1,0	0,16	0,13	30	7,1	—
			B	23,5 ± 2,0	20,0 ± 2,5	0,20	0,16	40	4,9	—
			C	23,5 ± 2,5	20,0 ± 3,5	0,24	0,19	45	2,8	—
Department store	1,6	0,15	A	23,0 ± 1,0	19,0 ± 1,5	0,16	0,13	40	4,2	—
			B	23,0 ± 2,0	19,0 ± 3,0	0,20	0,15	45	3,0	—
			C	23,0 ± 3,0	19,0 ± 4,0	0,23	0,18	50	1,6	—

NOTES

OUTDOOR CONDITIONS

In Spain the dry and wet temperature in summer season for different cities are given in the regulations UNE 100-014-84, 100-001-85, 100-002-88

Example:

	Dry Temp / Wet Temp	Dry Temp / Wet Temp	Dry Temp / Wet Temp	MAO (ºC)
	1%	2,5%	5%	
Albacete	34,6 / 20,4	33,1 / 20,3	31,7 / 19,6	39,3
Alicante	31,5 / 20,8	30,2 / 21,5	29,2 / 21,6	29,0
Barcelona	28,7 / 23,0	27,8 / 22,6	27,0 / 22,6	27,5
Bilbao	29,8 / 21,1	27,5 / 20,0	25,7 / 19,3	30,5
Burgos	30,8 / 19,3	29,2 / 18,6	27,2 / 18,0	38,0
Cáceres	36,3 / 18,9	35,2 / 18,7	33,8 /18,0	35,8

OUTDOOR CONDITIONS

Percentile level: Annual percentage of time that the dry temperature of the locality surpasses a certain level

- 1%: Hospital, clinique
- 2.5%: Building of special consideration
- 5%: other buildings

Mean Annual Oscilation (MAO): Difference between summer and winter temperature

SENSIBLE AND LATENT HEAT

When the air is cooled, the water is condensed and the relative humidity of the air is increased. Then we can distinguish:

- Sensible heat: heat to change the air temperature
- Latent heat: heat to change the state of water

In small cooling units the latent heat is not important but, with a big ones, we have to calculate both types of heat

COLD LOAD CALCULATION

Three methods:

- Simplified method: depends only on room size and occupancy level (approximation, very poor accuracy)
- Simple Cold Load Calculation: without outdoor conditions and without latent heat calculation (intermediate accuracy)
- Full Cold Load Calculation: including sensible and latent heat (high accuracy)

COLD LOAD CALCULATION

Simplified method:

Valid for poor accuracy requirements: Rooms, shops and offices with the area below 100 m^2

$$Q = A \times k$$

Cold load

A: Area of the rooms

k: Coefficient in W/m^2 units

Type of local	k Coefficient (W/m^2)
House	
New and isolated room	100
Partially isolated room	125
Hot room and attic	150
Hotel	
Hall	140
Room	100
Office	
Small	115
Big	140

Type of local	k Coefficient (W/m^2)
Shops	
Small shops	120
Busy shops	180
Supermarkets	120
Hypermarkets	160
Public locals	
Cinema, Theater	180
Hall	230
Restaurant	230
Bar, Coffee shop	290
Discotheque	300

COLD LOAD CALCULATION

Simplified method:

The method is not valid in the following cases:

- Viewing terrace
- Doors open permanently to the street
- Direct solar radiation in the facade
- A lot of open spaces, stairs, etc.
- Very high illumination
- High air currents

COLD LOAD CALCULATION

Simple cold load calculation:

Valid for intermediate accuracy requirements: Shops and public places with areas below 300 m^2

It is does not consider latent heat calculation

It is not necessary to know outdoor temperatures

VALID ONLY FOR SMALL AND INTERMEDIATE EQUIPMENT

COLD LOAD CALCULATION

Simple cold load calculation:

Factors considered:

- Isolation in windows: effects of solar insolation depends of windows orientation
- Transmission: heat gains through windows, walls and floors
- Electrical devices and appliances: sensible heat produced by these devices

COLD LOAD CALCULATION

Simple cold load calculation:

Factors considered:

- Occupants: includes the maxima occupancy of the building
- Ventilation: for houses and small offices, it depends on the number of rooms and, for big public places, it depends on the number of occupants

COLD LOAD CALCULATION

<u>Simple cold load calculation:</u>

Correction factor:

The final cold load calculated is multiplied by a security factor according to:

- Very hot localisation: 1.2.
- High oscillation of occupancy: 1.2.
- Comfort requirements: 1.3.
- Main use time: afternoon 0.8, night 0.7.

COLD LOAD CALCULATION

Full cold load calculation:

Valid for accuracy requirements: Public places, local buildings with special conditions: heat sources, big windows, etc.

It considers sensible and latent heat calsulations.

It is neccesery for the cooling unit selection.

The thermal transmittance of the walls and the rest of envelope is taken into consideration.

The outdoor condictions have to be fixed.

COLD LOAD CALCULATION

Full cold load calculation:

The total cold load is calculated by:

$$Q = Q_S + Q_L$$

- Q_S: Sensible heat gains
- Q_L: Latent heat gains

COLD LOAD CALCULATION

Full cold load calculation:

Sensible heat gains:

$$Q_S = Q_{SR} + Q_{ST} + Q_{SV} + Q_{SI}$$

- Q_{SR}: Solar Radiation gains
- Q_{ST}: Heat transfer through enclosure surfaces
- Q_{SV}: Ventilation and infiltration of the surrounding air
- Q_{SI}: Internal heat sources: people and electrical devices

COLD LOAD CALCULATION

Full cold load calculation:

Solar Radiation Gains, Q_{SR} :

$$Q_{SR} = A \times R \times f$$

- **A:** Area of windows or transparent surface in m^2
- **R:** Unitary Solar Radiation
- **f:** Correction factor

COLD LOAD CALCULATION

Full cold load calculation:

Unitary Solar Radiation, **R**, depends on the orientation of surface, latitude, day and time

For calculations, the days **13th July** or **24th August** and solar times from 12 to 16 are used

COLD LOAD CALCULATION

Solar time

Orientation

	8	10	12	13	14	15	16	18	20
N	37.2	44.2	44.2	44.2	44.2	40.7	37.2	75.6	0.0
NE	330.2	81.4	44.2	44.2	44.2	40.7	37.2	15.1	0.0
E	516.3	308.1	44.2	44.2	44.2	40.7	37.2	15.1	0.0
SE	374.4	346.5	131.4	46.5	44.2	40.7	37.2	15.1	0.0
S	40.7	138.4	217.4	197.7	138.4	81.4	40.7	15.1	0.0
S0	37.2	44.2	131.4	258.1	346.5	394.2	374.4	169.8	8.1
0	37.2	44.2	44.2	134.9	308.1	453.5	516.3	372.1	29.1
NO	37.2	44.2	44.2	44.2	81.4	208.1	330.2	333.7	29.1
Hor.	396.5	639.5	733.7	709.3	639.5	538.4	396.5	75.6	29.1

R factor for Latitude = 40º on the day of 13th July, in kcal/hm²

COLD LOAD CALCULATION

Full cold load calculation:

Correction factor, **f**: considering type of glass, system of darkening

Type of glass:

Normal Glass	Glass 6mm	Double Glass	Triple Glass	Blue Glass	Red Glass	Green Glass	Absorbance Glass (40%-70%)
1	0.94	0.90	0.83	0.60	0.58	0.32	0.80-0.62

COLD LOAD CALCULATION

Full cold load calculation:

Correction factor **f**: considering type of glass, darkening systems

Darkening systems:

Awning	Clear Blind	Dark Blind	Clear Curtain	Dark Curtain	External wooden blind
0.24	0.56	0.75	0.41	0.80	0.24

COLD LOAD CALCULATION

Full cold load calculation:

Heat transfer through envelope, Q_{ST} :

$$Q_{ST} = U \times A \times (T_o - T_i)$$

- **A:** Area of envelope surface in m^2
- **T_0:** Outdoor Temperature
- **T_i:** Indoor Temperature of design
- **U:** Coefficient of heat transfer of envelope surface

COLD LOAD CALCULATION

<u>Full cold load calculation:</u>

Heat transfer through envelope, Q_{ST} :

$$Q_{ST} = U \times A \times (T_o - T_i)$$

U coefficient: can be calculated based on the composition and width of the envelope surface

If it is not possible to do it, estimations can be used

COLD LOAD CALCULATION

Full cold load calculation:

U coefficient estimation for external walls

Surface	U(W/m²K)
Simple Brick 9	3.5
Concrete block	2
Brick12 + chamber + Brick4	1.5
Brick12 + chamber + Brick7	1.7
Brick12 + Isolation4+ Brick4	0.7

COLD LOAD CALCULATION

Full cold load calculation:

U coefficient estimation for internal partition

Surface	$U (W/m^2K)$
Brick 4	3.5
Brick 7	3.4
Plasteboard without isolation	4.6
Plasteboard with isolation	1.4

COLD LOAD CALCULATION

Full cold load calculation:

U coefficient estimation for roofs

Surface	U(W/m²K)
Terrace	1.3
Roof tile without chamber	1.7
Roof tile with chamber	1.3
Roof sheet without isolation	8.1
Roof sheet with isolaiton	2.3

COLD LOAD CALCULATION

Full cold load calculation:

U coefficient estimation for floors

Surface	$U (W/m^2K)$
About soil	1.1
Ceramic slab 15	1.4
Ceramic slab 20	1.3
Concrete slab 20	1.3

COLD LOAD CALCULATION

Full cold load calculation:

U coefficient estimation for windows

Surface	U(W/m²K)
Simple glass 6mm	6.5
Double glass 6+6	3.4
Double glass with chamber	3

COLD LOAD CALCULATION

Full cold load calculation:

U coefficient estimation for doors

Surface	$U(W/m^2K)$
Blind wooden door	3.5
Wooden door with glass	3.9
Blind metalic door	5.8
Metalic door with glass	4.6

COLD LOAD CALCULATION

Full cold load calculation:

Heat gains from infiltration of surrounding air, Q_{SV} :

$$Q_{SV} = V \times \rho \times C_p \times (T_o - T_i)$$

- **V:** Air flow in m^3/s
- **ρ:** Air density, 1.18 kg/m^3
- **C_p:** Thermal capacity of Air: 1012 J/Kg K
- **(T_o-T_i):** Difference between outdoor and indoor temperatures

COLD LOAD CALCULATION

Full cold load calculation:

	Per Person	Per m^2	Per room
Storehouse		0.75 -3	
Parking		5	
Public WC			25
Particular WC			15
Classroom	8		
Bars	12	12	
Coffee shop	15	15	

Air flow in L/s

COLD LOAD CALCULATION

Full cold load calculation:

	Per Person	Per m^2	Per room
Sport Hall	12	4	
Casino	12	10	
Dinner Room	10	6	
Kitchen	8	2	
Rest room	20	15	
Bedroom	8	1,5	
School, Library	5	3	

Air flow in L/s

COLD LOAD CALCULATION

Full cold load calculation:

	Per Person	Per m^2	Per room
Teachers' room	5	1.5	
Waiting room	8	4	
Photo studio		2.5	
Museum	8	4	
Discotheque	15	13	
Physiotherapy room	10	1.5	

Air flow in L/s

COLD LOAD CALCULATION

Full cold load calculation:

Heat gains from Internal sources, Q_{SI}:

$$Q_{SI} = Q_{SIL} + Q_{SIE} + Q_{SIO}$$

- Q_{SIL} : Heat from lighting
- Q_{SIE} : Heat from electrical devices
- Q_{SIO} : Heat from occupants

COLD LOAD CALCULATION

Full cold load calculation:

Heat gains from Internal sources, Q_I:

Lighting

- **Incandescent light:** $Q_{SIL} = nP_L$

n = number of lights

P_L = power of lights

- **Fluorescent light:** $Q_{SIL} = 1.25\ nP_L$

COLD LOAD CALCULATION

Full cold load calculation:

Heat gains from Internal sources, Q_I:

Occupants

$$Q_{SI0} = n \times Q_{SIP}$$

- n = number of persons
- Q_{SIP} = sensible heat by a person, depends on their activity and the temperature of room

COLD LOAD CALCULATION

Full cold load calculation:

Activity	28ºC	27ºC	26ºC	24ºC
Sitting Person	52	58	64	70
Standing Person	52	58	64	76
Light work	58	64	70	87
Walking	64	70	81	99
Dancing	81	87	99	110
Hard Work	134	140	145	151

Sensible heat in W per person

COLD LOAD CALCULATION

Full cold load calculation:

Latent heat gains:

$$Q_L = Q_{LV} + Q_{LO}$$

- Q_{LV} : Gains of Latent heat by ventilation and infiltration of surrounding air.
- Q_{LO} : Gains of Latent heat by occupancy

COLD LOAD CALCULATION

Full cold load calculation:

Latent Heat gains from infiltration of surrounding air, Q_{LV} :

$$Q_{LV} = V \times \rho \times C_p \times (H_o - H_i)$$

- **V:** Air flow in m^3/s
- **ρ:** Air density, 1.18 kg/m^3
- **C_p:** Latent Heat of water: 2257 kJ/kg
- **$(H_o - H_i)$:** Difference of outdoor and indoor absolute humidity

COLD LOAD CALCULATION

Full cold load calculation:

Latent Heat gains from occupancy, Q_{SO} :

Occupants

$$Q_{L0} = n \times Q_{LP}$$

- n = number of persons
- Q_{LP} = Latent heat by person, depends of its activity and the temperature of room

COLD LOAD CALCULATION

Full cold load calculation:

Latent heat in W/person

Activity	28ºC	27ºC	26ºC	24ºC
Sitting Person	52	47	41	30
Standing Person	81	87	81	70
Light work	163	157	151	134
Walking	186	180	169	151
Dancing	215	204	198	180
Hard Work	291	291	285	268

COLD LOAD CALCULATION

Full cold load calculation:

Correction factor:

The final cold load calculated is multiplied by a security factor according to:

- Very hot localisation: 1.2.
- High oscillation of occupancy: 1.2.
- Comfort requirements: 1.3.
- Main use time: Afternoon 0.8, night 0.7.

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