Measurement & Verification Pte Ltd

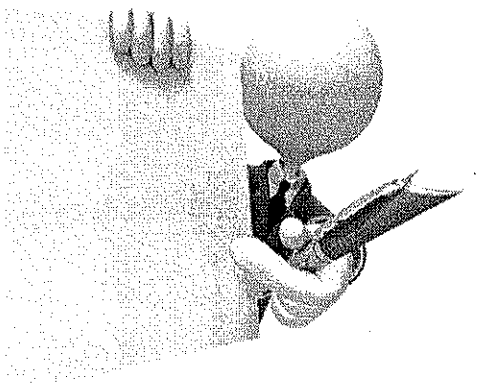
Cooling Load Calculation

Steven Kang
Steven.kang@mnv.com.sg

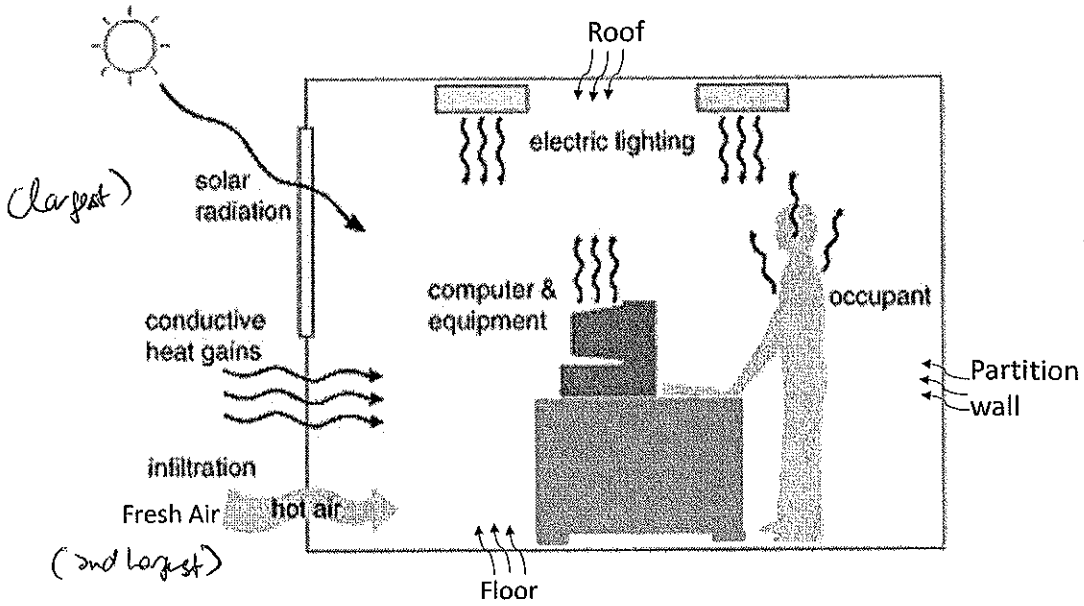
Agenda

Measurement & Verification Pte Ltd

1. Components of cooling load
2. Sensible and latent cooling load
3. Basic principles of cooling load calculation
4. Cooling load component breakdown
5. Cooling load profile
6. Cooling load benchmarking data
7. Softwares for cooling load calculation



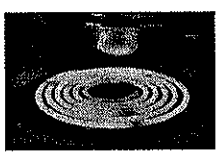
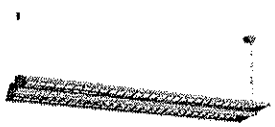
Components of Cooling Loads

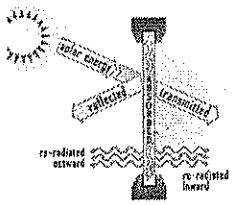


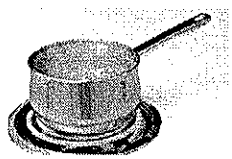
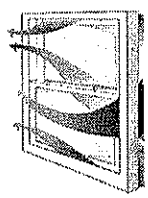
Sensible and Latent Cooling Loads

Sensible cooling loads
1. Dry heat
2. Increase dry bulb temperature only

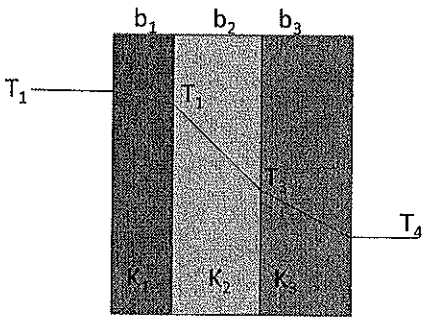
Latent cooling loads
1. Moisture to space which needs to be removed
2. Cooling load is manifested when the moisture condense on the cooling coil



Conduction load (Thro' internal wall / floor and external glass)



Q = U x A x ΔT

Where

U: Thermal transmittance ($W/m^2.K$)

ΔT: Delta Temperature (C)

A: Area

$U = 1 / R_t$

$R_t = R_o + b_1/k_1 + ... Ra + ...b_n/k_n + R_i$

Where

Rt: Total thermal resistance (m^2K/W)

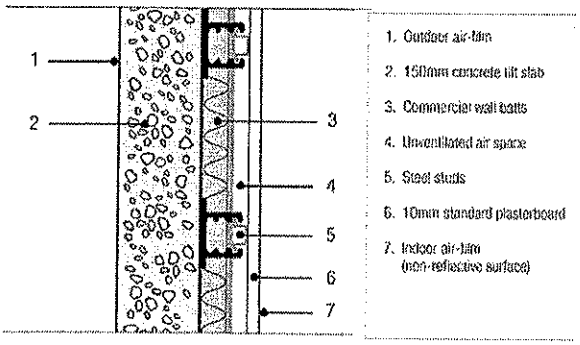
R_o & R_i: Outside and inside air film resistance

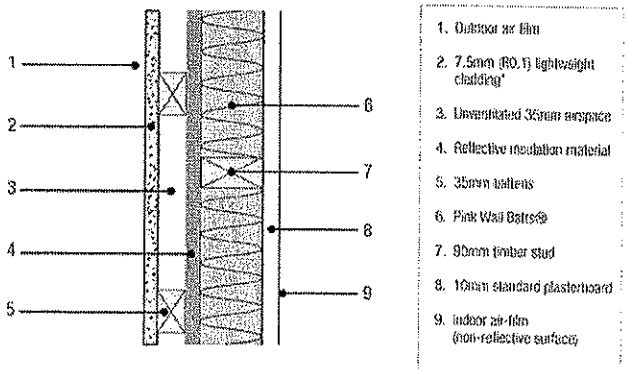
Ra: Thermal resistance of air space

k: Thermal conductivity (W/m.K)

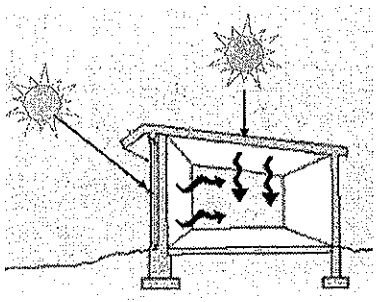
b: Thickness (m)

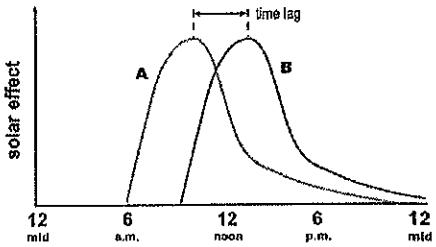
Example of external wall components





Sun lit walls





Curve **A** shows the magnitude of the solar effect on the exterior wall.

Curve **B** shows the resulting heat that is transferred through the wall into the space.

$$Q = U \times A \times CLTD$$

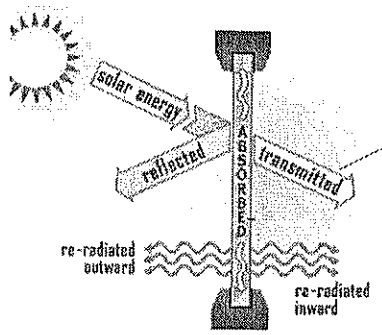
A factor called the cooling load temperature difference (CLTD) is used to account for the added heat transfer due to the sun shining on exterior walls, roofs, and windows, and the capacity of the wall and roof to store heat. The CLTD is substituted for ΔT in the equation to estimate heat transfer by conduction.

Example of CLTD from ASHRAE Fundamental Handbook

Table 32 July Cooling Load Temperature Differences for Calculating Cooling Load from Sunlit Walls 40°North Latitude

Wall Face	Hour 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Wall Number 1																								
N	1	0	−1	−1	−2	−1	4	6	6	7	9	12	14	15	16	16	16	16	15	9	6	4	3	2
NE	1	0	−1	−1	−2	1	13	23	26	24	19	16	15	16	16	16	15	13	11	8	6	4	3	2
E	1	0	−1	−1	−1	1	16	28	34	36	33	27	20	17	17	17	16	14	11	8	6	4	3	2
SE	1	0	−1	−1	−2	0	8	18	26	31	32	31	27	22	18	17	16	14	11	8	6	4	3	2
S	1	0	−1	−1	−2	−1	0	2	6	12	18	24	28	29	28	24	19	15	11	8	6	4	3	2
SW	1	0	−1	−1	−1	−1	0	2	4	7	9	14	22	29	36	39	38	34	25	13	7	4	3	2
W	1	1	−1	−1	−1	−1	1	2	4	7	9	12	15	23	33	41	44	44	34	18	9	5	3	2
NW	1	0	−1	−1	−1	−1	0	2	4	7	9	12	14	16	21	28	34	36	31	16	8	5	3	2
Wall Number 2																								
N	3	2	1	0	−1	−1	−1	2	4	5	6	8	10	12	13	14	15	16	16	15	12	9	7	4
NE	3	2	1	0	−1	−1	1	7	14	20	22	21	18	17	16	16	16	16	14	13	10	8	6	4
E	3	2	1	0	−1	−1	1	8	18	26	31	32	29	24	21	19	18	17	15	13	11	8	6	4
SE	3	2	1	0	−1	−1	0	4	11	18	24	28	29	28	25	22	19	17	16	13	11	8	6	4
S	3	2	1	0	−1	−1	−1	−1	1	4	8	13	18	23	26	27	26	22	18	15	12	8	6	4
SW	4	2	1	1	0	−1	−1	0	1	3	5	7	11	17	23	29	34	36	34	29	22	15	9	6
W	4	3	2	1	0	−1	−1	0	1	3	5	7	9	13	18	26	33	38	41	37	28	19	12	8
NW	4	2	1	1	−1	−1	−1	−1	1	3	5	7	9	12	14	18	23	28	32	30	23	16	11	7

Solar Radiation Thro' Glass



$Q = SF \times CF \times A \times SC_1 \times SC_2$

Where
SF: Solar factor
CF: Solar correction factor
(Depends on direction and wall pitch angle)
A: Window area
SC1: Shading coeff of glass
SC2: Shading coeff of external shading devices



Prof SK Chou

ETTV methodology
SF for Singapore has been experimentally determined to be 211 W/m²

ETTV

3.1 The ETTV formula is given as follows:

$$ETTV = 12(1-WWR)U_w + 3.4(WWR)U_f + 211(WWR)(CF)(SC)$$

where

ETTV	:	envelope thermal transfer value (W/m^2)
WWR	:	window-to-wall ratio (fenestration area / gross area of exterior wall)
U_w	:	thermal transmittance of opaque wall ($W/m^2{}^\circ K$)
U_f	:	thermal transmittance of fenestration ($W/m^2{}^\circ K$)
CF	:	correction factor for solar heat gain through fenestration
SC	:	shading coefficients of fenestration

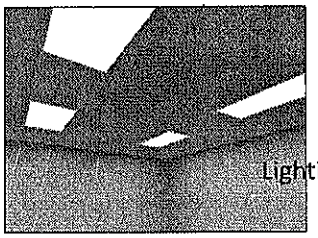
3.2 Where more than one type of material and/or fenestration is used, the respective term or terms shall be expanded into sub-elements as shown:

$$ETTV = \frac{12(A_{w1} \times U_{w1} + A_{w2} \times U_{w2} + \ldots + A_{wn} \times U_{wn})}{A_o} + \frac{3.4(A_{f1} \times U_{f1} + A_{f2} \times U_{f2} + \ldots + A_{fn} \times U_{fn})}{A_o} + \frac{211(A_{f1} \times SC_{f1} + A_{f2} \times SC_{f2} + \ldots + A_{fn} \times SC_{fn})(CF)}{A_o}$$

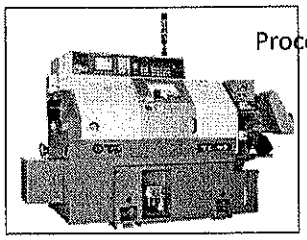
where

Internal Cooling Loads

Measurement & Verification Pte Ltd

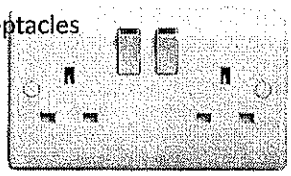


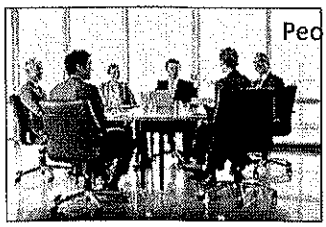
Lighting



Process

Receptacles





People

Internal loads guidelines

Measurement & Verification Pte Ltd

2. For receptacle loads, Table A below is for reference.

Table A: Receptacle Loads	Standard	Nominal Values
a. Computer intensive offices	Source:-	22.0 W/m^2
b. General office areas	ASHRAE STD	16.0 W/m^2
c. Large conference areas	90.1:2010	11.0 W/m^2
d. Server/Computer rooms		540.0 W/m^2

Source: http://www.bca.gov.sg/Envsuslegislation/others/GM_Certification_Std2012.pdf

Table 3 Rates of Heat Gain from Occupants of Conditioned Spaces

Degree of Activity		Total Heat, W: Adult Male	Total Heat, W: Adjusted, M/F[a]	Sensible Heat, W	Latent Heat, W
Seated at theater	Theater, matinee	115	95	65	30
Seated at theater, night	Theater, night	115	105	70	35
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
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
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
Heavy machine work; lifting	Factory	470	470	185	285
Athletics	Gymnasium	585	525	210	315

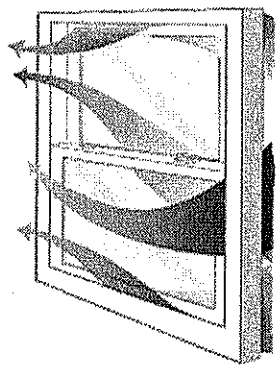
Source: Ashrae 1997 Handbook

Table 7 – Maximum lighting power budget (including ballast loss)

Type of usage	Maximum lighting power budget (Watts / m^2)
Offices	15
Classrooms	15
Lecture theatres	15
Auditoriums / Concert halls	10
Shops / Supermarkets / Departmental stores (including general, accent and display lighting)	25
Restaurants	15
Lobbies / Atriums / Concourses	10
Stairs	6
Corridors	10
Car parks	5
Electronic manufacturing and fine detail / Assembly industries	20
Medium and heavy industries	15
Warehouses / Storage areas	10

Source: SS530-2006

Infiltration Cooling Loads



Estimates of Infiltration Airflow, air changes/hr

Neutral pressure, poor construction	1.0
Neutral pressure, average construction	0.6
Neutral pressure, tight construction	0.3
Pressurized, poor construction	0.5
Pressurized, average construction	0.3
Pressurized, tight construction	0.0

Sensible KW = CMH_{IA} x DT / 3000
DT: Delta T (C) between IA & RA

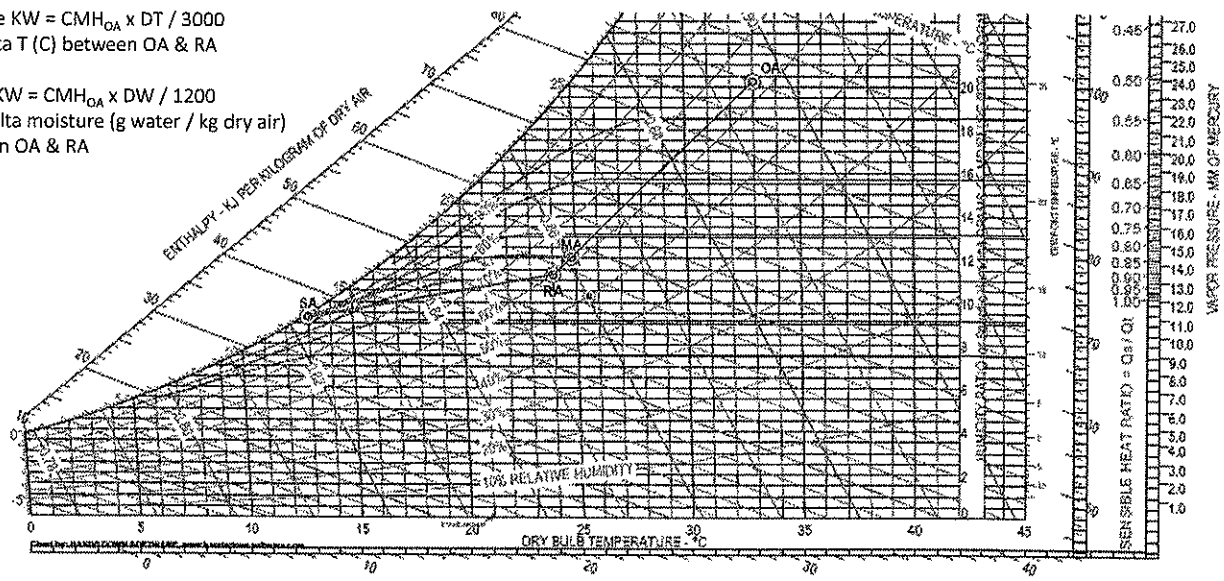
Latent KW = CMH_{IA} x DW / 1200
DW: Delta moisture (g water / kg dry air) between IA & RA

Source: Trane clinic

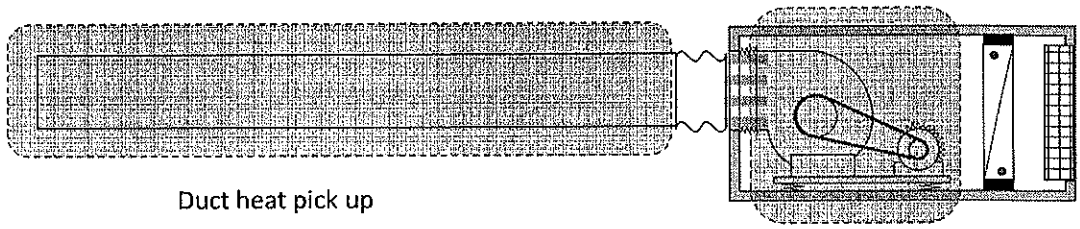
Ventilation Cooling Loads

Sensible KW = CMH_{OA} x DT / 3000
DT: Delta T (C) between OA & RA

Latent KW = CMH_{OA} x DW / 1200
DW: Delta moisture (g water / kg dry air) between OA & RA



System heat gains



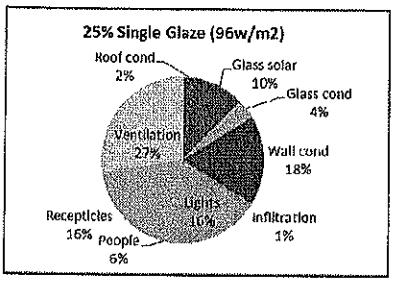
Duct heat pick up

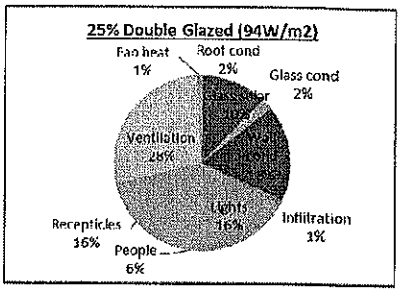
Motor & fan pick up

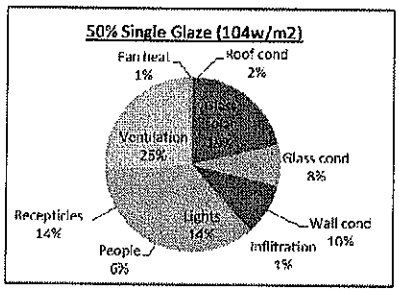
Sensible and Latent Cooling Loads

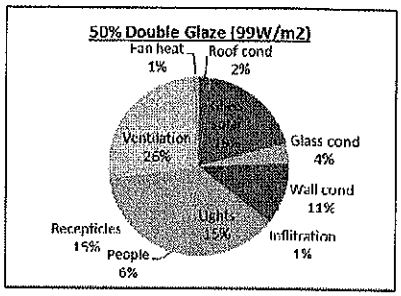
cooling load components	sensible load	latent load	space load	coil load
conduction through roof, walls, windows, and skylights	✓		✓	✓
solar radiation through windows, skylights	✓		✓	✓
conduction through ceiling, interior partition walls, and floor	✓		✓	✓
people	✓	✓	✓	✓
lights	✓		✓	✓
equipment/appliances	✓	✓	✓	✓
infiltration	✓	✓	✓	✓
ventilation	✓	✓		✓
system heat gains	✓			✓

Cooling Load Component Breakdown





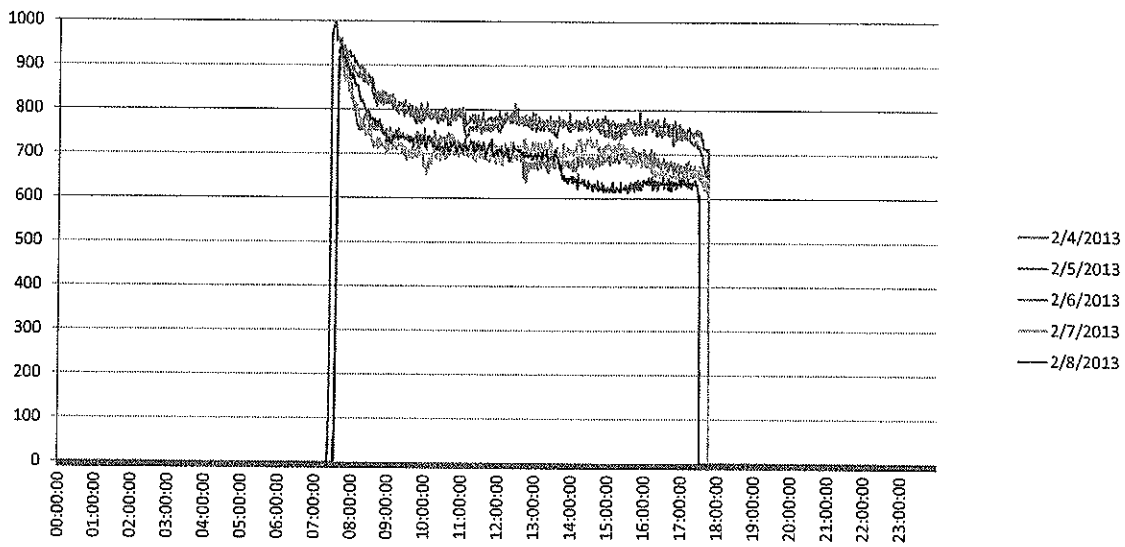




Top 2: Solar + Ventilation.

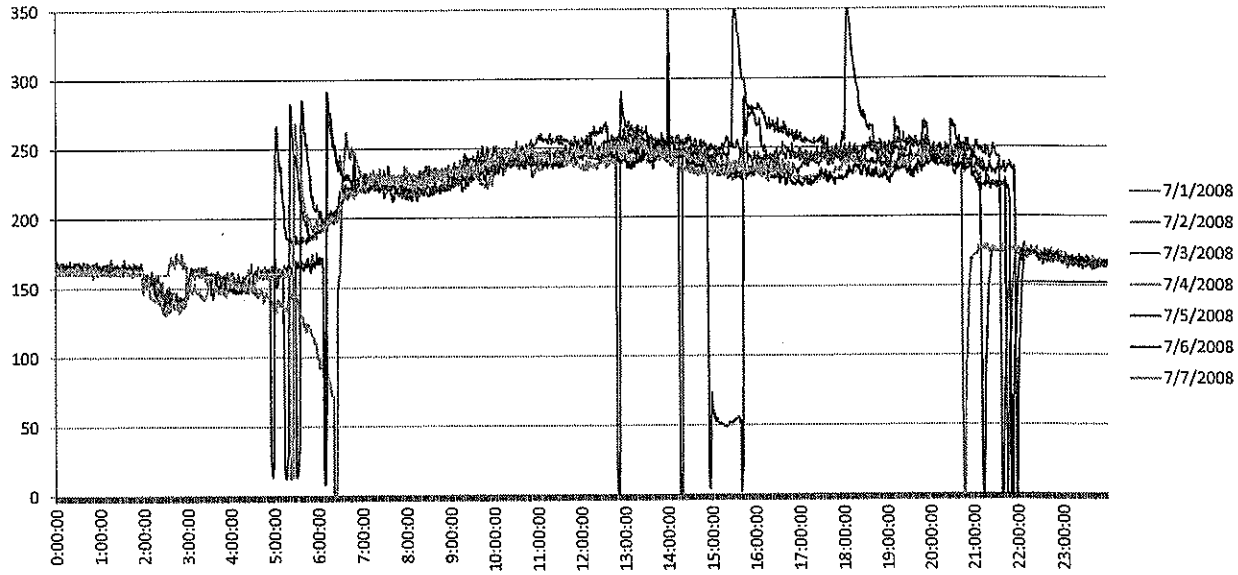
reduce glass occupancy sensor — CO_2

Cooling Load Profile (Office)



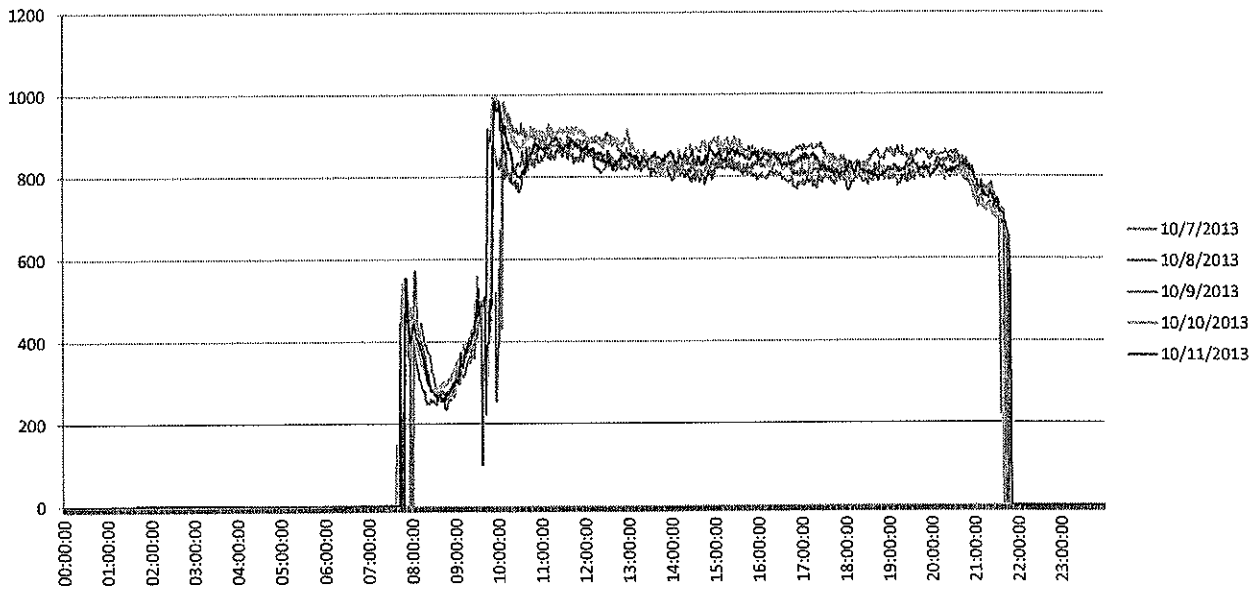
Peak throughout.
Many peak due to pull down load.

Cooling Load Profile (Hotel)



night about 50-60% of day

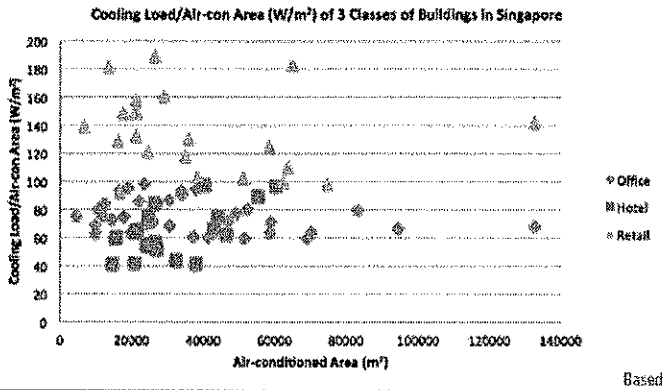
Cooling Load Profile (Malls)



① Morning pull down load spike
② Breakfast FB operation
③ Flat throughout rest of day

Cooling Load Benchmarking Data

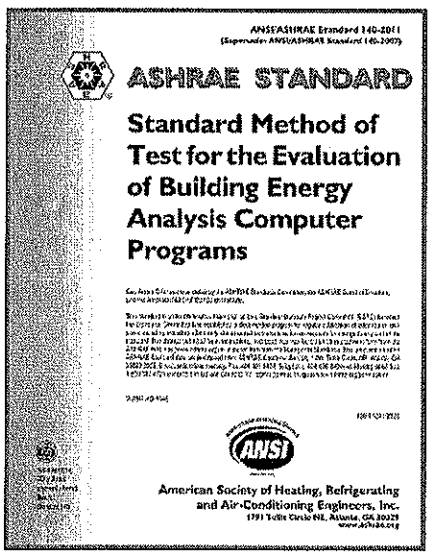
	Measured Cooling Load/Air-con Area (W/m²)	
	Range	Average
Office (35 projects)	60 – 98	76
Hotel (20 projects)	42 – 98	64
Retail (21 projects)	93 – 190	135



Based on data from BCA and NEA

Software For Calculating Cooling Load

- Ashrae standard 140



- DOE2
- eQUEST
- EnergyPlus
- EnergyPro
- IES (Integrated environmental solutions)
- HAP (Carrier HAP)
- TRACE 700 (Trane TRACE)
- Visual DOE

Measurement & Verification Pte Ltd

Thank you for your attention

Discussion and Q&A

