Swegon air academy

CIT Energy Management AB
A Chalmers Industriteknik Company

Healthy IEQ and energy efficiency

Ideas and concepts from research and reality

Lars Ekberg

Examples of IEQ factors

Illustration: SP The Swedish Technical Research Institute

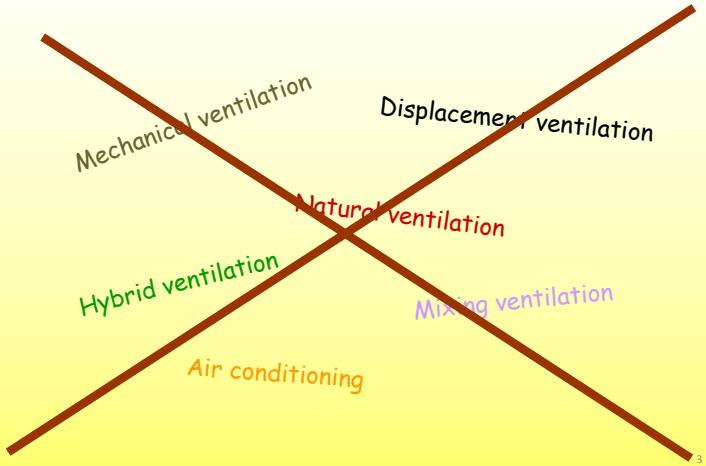
Thermal climate

- -operative temp.
- -surface temp.
- -air movements
- -…

Air Quality

- -formaldehyde
- -nitrogen dioxide
- -particles
- -…

What type of system is the best ?



What type of system is the best ?

A system suited for its purpose

Designed with respect to the building, the activities and the requirements

Correctly dimensioned and designed with respect to service och maintenance

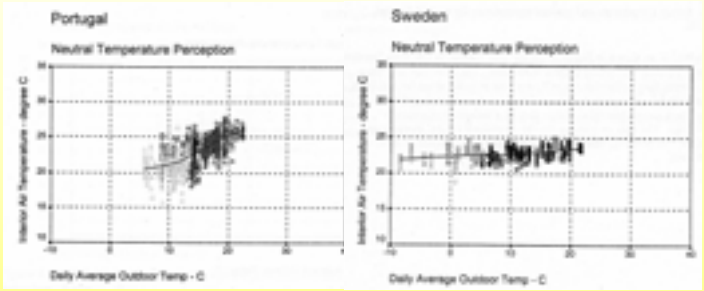
Designed so that it does not cause disturbance (draught and noise)

Indoor Environment Guidelines

- Thermal Climate (EN ISO 7730)
  - Desired operative temperature, air velocity etc.
  - PMV & PPD indices
- Indoor Air Quality (EN 15251, WHO, ISIAQ…)
  - Mainly specification of airflow rates required
  - Limited guidelines regarding specific air pollutants

Thermal climate

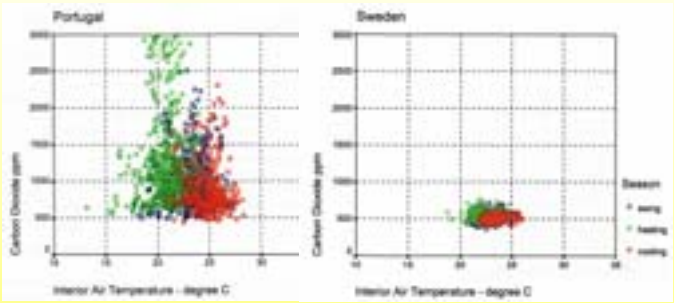
Portugese offices Swedish offices



Reference: Stoops , J. (2001)

Air Quality – CO_2

Portugese offices Swedish offices

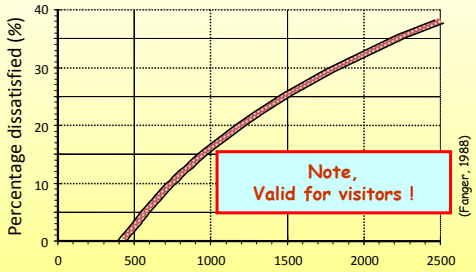


Your experiences ?

Reference: Stoops , J. (2001)

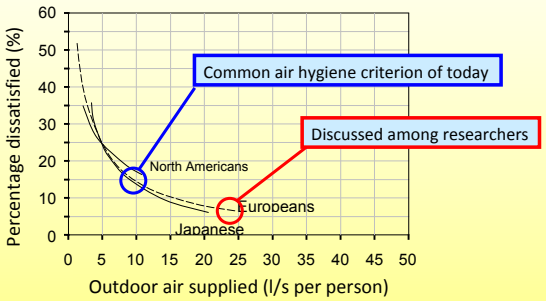
The CO_2 requirement

CO_2 - indicator for the perception of pollutants from people



CO_2-concentration (*ppm*)

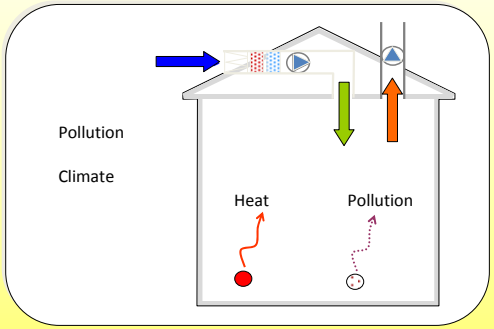
The CO_2 requirement



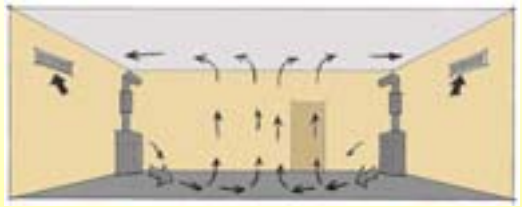
…and the technical solution

To make the technical solution work…

The air distribution system



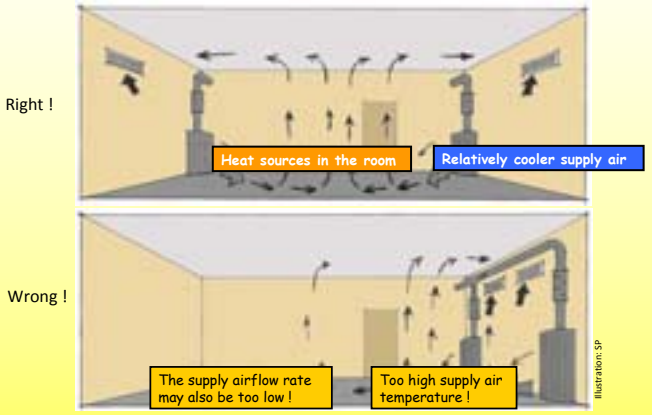
How to ensure efficient ventilation?



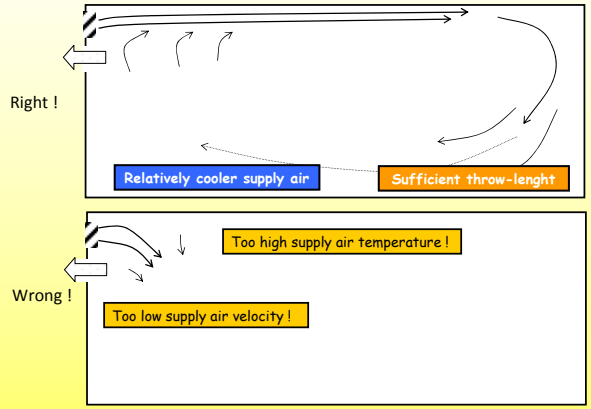
- Correct placement of air terminal units
- Appropriate supply air temperature
- Correct adjustment of the throw length
- Sufficient airflow rates

Two main principles – displacement and mixing ventilation…

Displacement ventilation

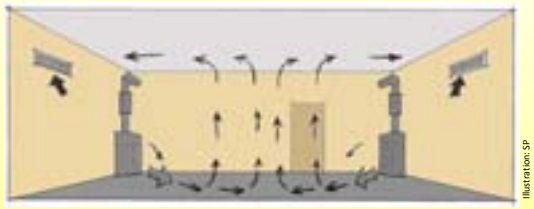


Mixing ventilation



Risk of annoyance !

Displacement ventilation



- Cold air and air movements close to the air terminal unit
- Always high risk of draught within about 1-2 m

Risk of annoyance !

Mixing ventilation

- "Downdraught" if supply air velocity is too low
- Risk of draught if incorrect design or operation

The room air distribution can be checked by tracer gas measurements

- Air change efficiency
- Ventilation efficiency
- Local air change index
- Local air quality index
- .....

Caution ! This may be time consuming and expensive !

The air change efficiency, ε_a

- Mixing ventilation

  ε y0.45

- Displacement ventilation

  ε y0.65

- "Piston flow"

  ε y1.0

40 % higher efficiency with displacement ventilation?

Ventilation effectiveness

Local ventilation index

Contaminant removal effectiveness

$$\frac{C_{exhaust}}{C_{breath}}$$

Illustration: Skistad

Ventilation effectiveness

Local ventilation index

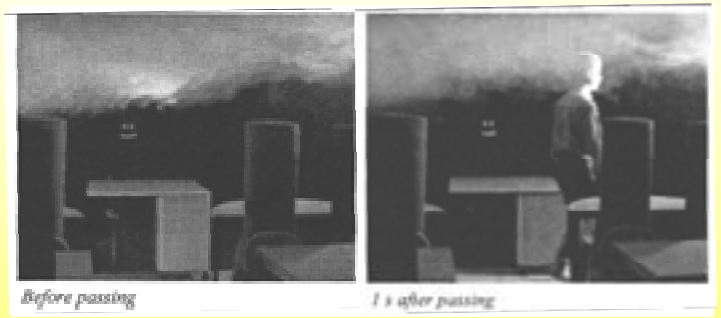
Contaminant removal effectiveness

	When cooling
Mixing ventilation	*0.9-1.0*
Displacement ventilation	*1.2-1.4*

Reference: CEN CR 1752

40 % higher efficiency with displacement ventilation?

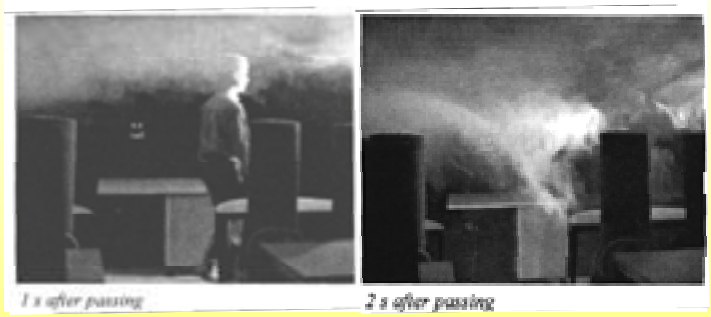
The Stratification



Supply airflow rate 8 l/s per person **Walking speed 0.7 m/s**

Reference: Mattsson , M. (1999)

People moving



Supply airflow rate 8 l/s per person **Walking speed 1.3 m/s**

Reference: Mattsson , M. (1999)

Classroom experiments

Figure 6-17 Set-up and walking path in the classroom.

Reference: Mattsson , M. (1999)

The classroom IAQ

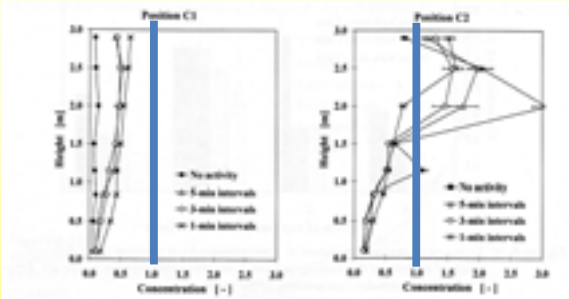


Figure 6-19 Vertical concentration profiles in positions C1 (left) and C2 (right) at different levels of activity. Contaminant source in position D. Concentrations relative to extract. Error bars indicate standard uncertainty of the mean (N=12).

Reference: Mattsson , M. (1999)

A simulated office

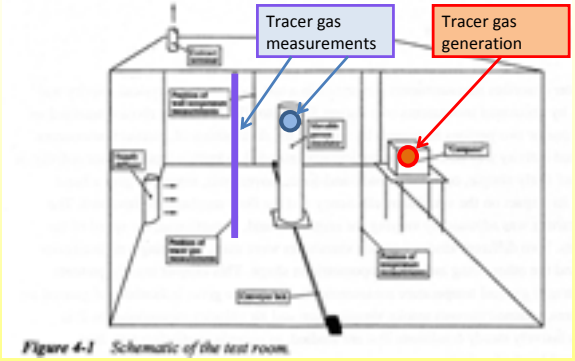
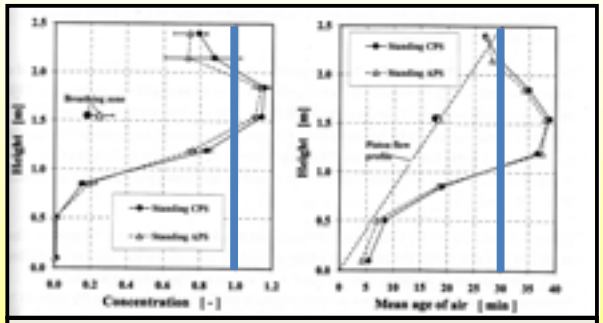


Figure 4-1 Schematic of the test room.

Reference: Mattsson , M. (1999)

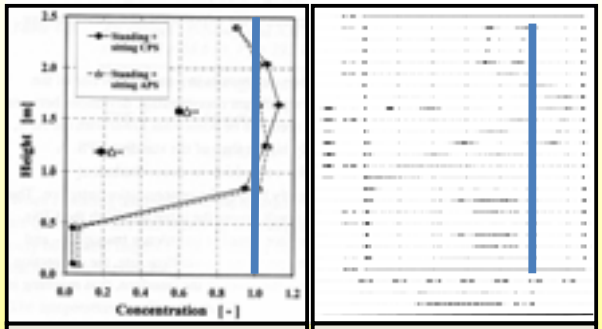
The office IAQ



21 l/s and heat generation 295 W
No disturbance by movements

Reference: Mattsson , M. (1999)

The office IAQ

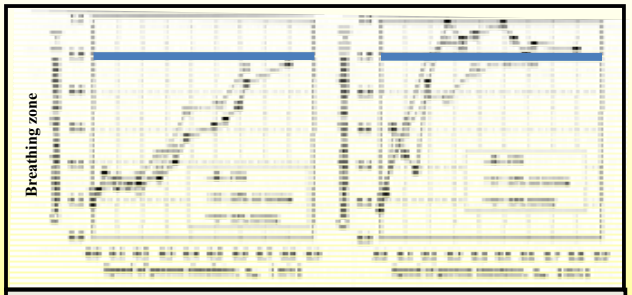


21 l/s and heat gen. 395 W	37 l/s and heat gen. 395 W

No movements by person simulator

Reference: Mattsson , M. (1999)

People moving in the office



Pollution spread to the breathing zone

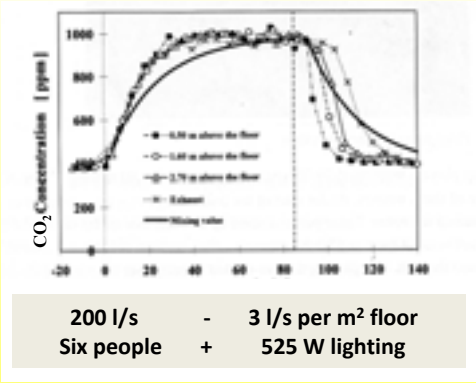
The computer was the only source of contamination

Reference: Mattsson , M. (1999)

A sportshall

Reference: Matson , M. (1999)

The sportshall IAQ



200 l/s - 3 l/s per m² floor
Six people + 525 W lighting

Reference: Matson , M. (1999)

The examples indicate that displacement ventilation works:

- without disturbance from movements
- if the supply airflow rate is high enough

Typical applications are found in the industry

- High rooms
- Large airflows required for removal of heat

… and that displacement ventilation does not work:

- If the supply airflow rate is too low…
- …even with moderate disturbances

Why not displacement in offices?

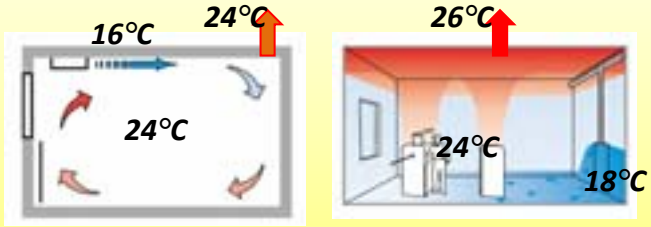
- Major risk of discomfort due to draught
- Reduced useable floor area
- Because it may need 3-4 times higher airflow rate than required for air hygiene

- Displacement ventilation requires 30-40 l/s per person
- Air hygiene requirement is about 10 l/s per person

The energy aspect

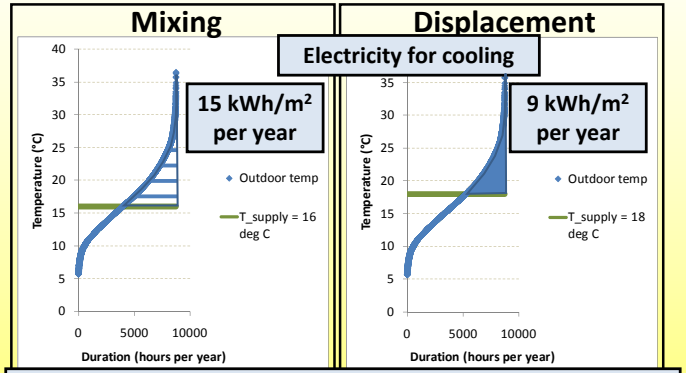
-Some calculated examples

Mixing **Displacement**



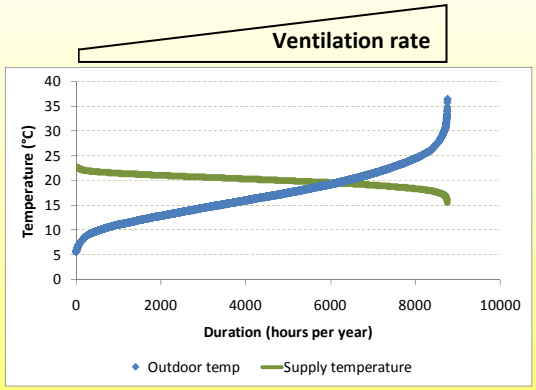
Assume correct function

Energy for air handling



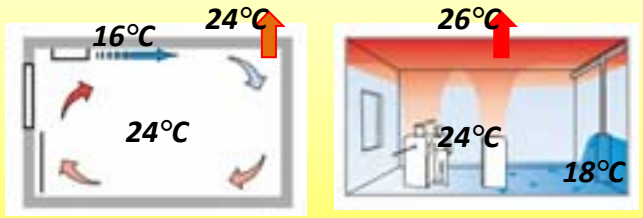
Flow rate = 3 l/s per m² -> Fan electricity = 27 kWh/m², year in both cases

If we add demand control:



Demand control

Min flow rate	Max flow rate	t_{sup}	t_{room}	t_{exh}	Electricity (kWh/m² per y) Fans	Cooling	Total
1 l/s, m²	3 l/s, m²	16°C	24°C	24°C	16	16	32
~~1 l/s, m²~~	~~3 l/s, m²~~	~~18°C~~	~~24°C~~	~~26°C~~	~~16~~	~~9~~	~~25~~
2 l/s, m²	3 l/s, m²	18°C	24°C	26°C	22	9	31
3 l/s, m²	3 l/s, m²	18°C	24°C	26°C	27	9	36



Further examples

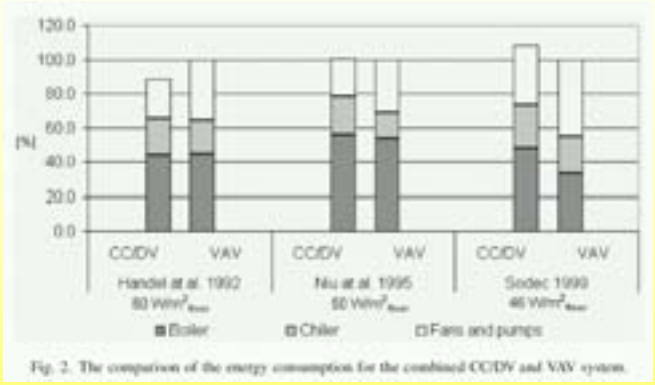


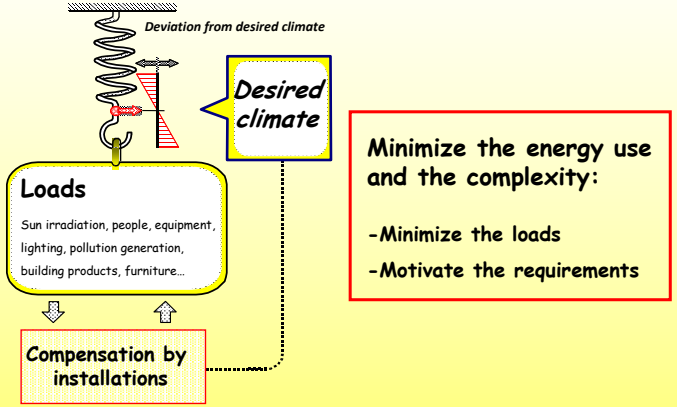
Fig. 2. The comparison of the energy consumption for the combined CC/DV and VAV system.

Source: Novoselac and Srebric (2001)

Literature

- Im, P. (2005) Literature review on underfloor air distribution (UFAD) system, Energy Systems Laboratory, Texas A&M University System
- Mattsson, M. (1999) On the efficiency of displacement ventilation – with particular reference to the influence of human activity, Royal Institute of Technology, Stockholm
- Novoselac and Srebric (2001) A critical review on the performance and design of combined cooled ceiling and displacement ventilation systems, Energy and Buildings, 34, 497-509
- Matsumoto,H. and Ohba, Y. (2004)The influence of a moving object on air distribution in displacement ventilated rooms, Jour. Asian Arcitecture and Bldg Eng.
- Fitzner,K. (1996) Displacement ventilation and cooled ceilings, Results of laboratory tests and practical installations, Proceedings of the Conference Indoor Air ´96, Nagoya
- Lau, J. And Chen, Q. (2006) Energy analysis for workshops with floor-supply displacement ventilation under the U.S. climates, Energy and Buildings, 38, 1212-1219
- Kim, I.G., Homma, H. (1992) Distribution and ventilation efficiency of CO2 produced by occupants in upward and downward ventilated rooms. ASHRAE Technical Data Bulletin, Vol. 8, No. 2.
- Mattsson, M. (2002) Vertical distribution of occupant-generated particles in a room with displacement ventilation, Proceedings of the Indoor Air 2002 Conference, Vol. 1, pp 509-514, Monterey, California
- Nielsen, P.V. (1993) Displacement Ventilation – Theory and design, Dept. Of Building Technology and Structural Engineering, Aalborg University, Denmark
- REHVA Design Guidebook No. 1, Displacement Ventilation in non-industrial Premises, 2° endition, 2002, Federation of European HVAC Assoc

Healthy IEQ and energy efficiency



Minimize the energy use and the complexity:

-Minimize the loads

-Motivate the requirements

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Thank you !

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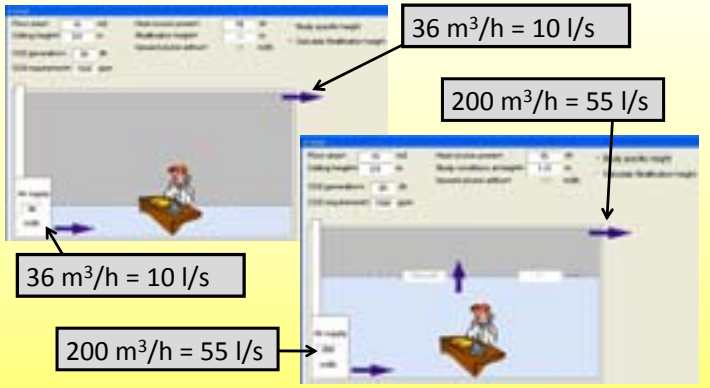
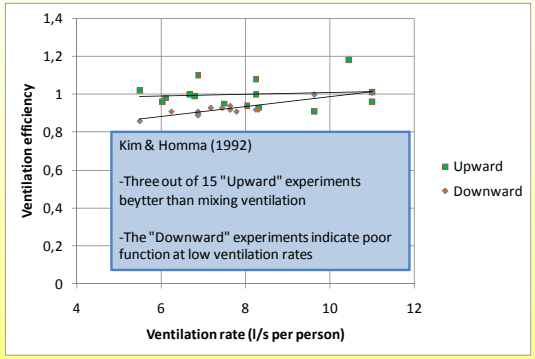
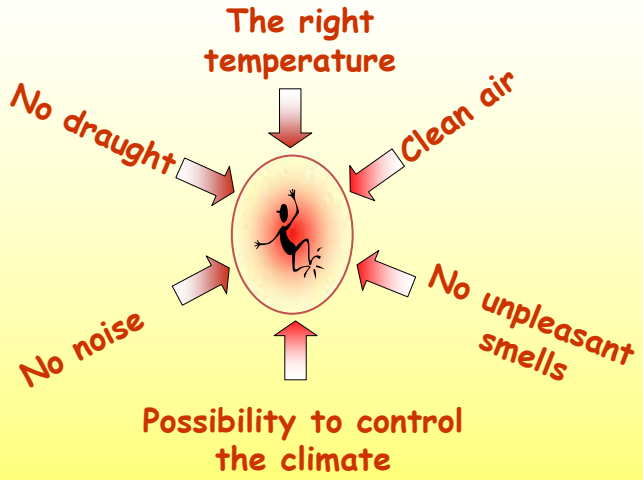
Extra material

The supply airflow rate will match the thermal plume



Experiments by Kim & Homma 1992





Air change rates (ACH = air changes per hour)

Control of air quality by removal of <u>air pollutants</u>

Residential buildings	0.5-1 ACH
Office rooms with hydronic cooling	1.5-2 ACH
Operating theatres in hospitals	17-30 ACH
Clean rooms	>200 ACH

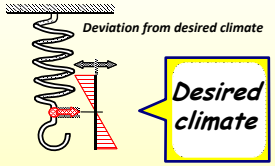
Control of temperature by removal of <u>heat surplus</u>

Office rooms with an all air system	3-6 ACH
Supermarkets, department stores	6-10 ACH
Auditoriums, lecture rooms, theatres	5-12 ACH

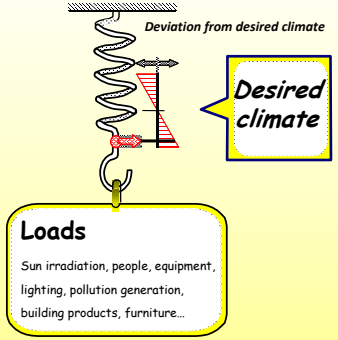
Compensation of air exhaust required for safety ventilation, "<u>process air flows</u>"

Laboratory rooms with fume hoods	15-30 ACH
Restaurant kitchens	10-20 ACH

How the indoor climate occurs



How the indoor climate occurs



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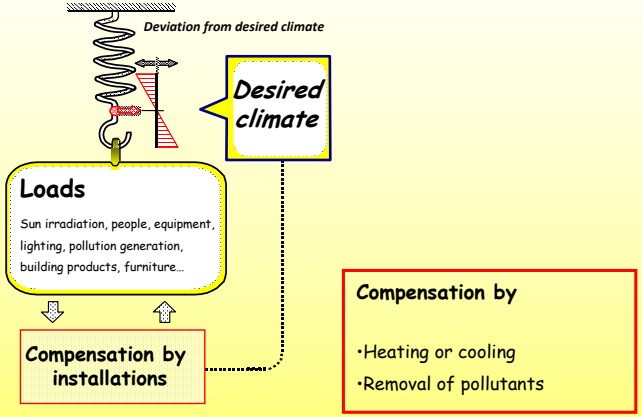

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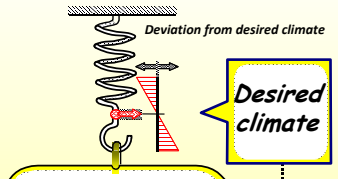

Desired climate

Loads

Sun irradiation, people, equipment, lighting, pollution generation, building products, furniture…

Compensation by installations

The complexity and size of the installations depend on

- The strength of the loads
- The indoor climate requirement