

# Stratum Ventilation

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# Presentation Outline

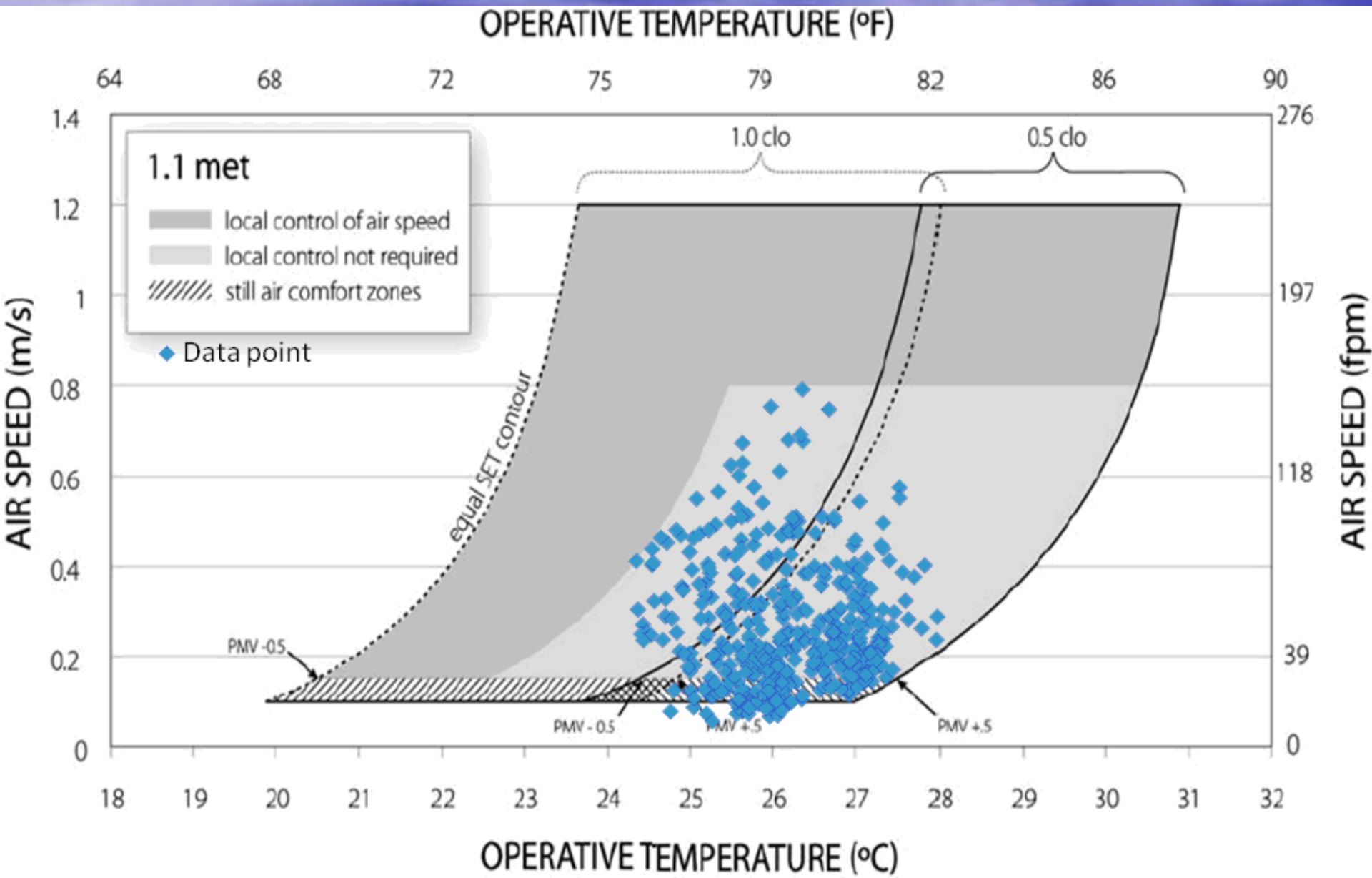
1. Trend in thermal comfort –  
Ventilative Cooling,
2. Concepts of Stratum Ventilation,
3. Performances of Stratum Ventilation.

- Global warming (IPCC).
- International concensus to reduce CO<sub>2</sub> emission.
- Recent guidelines issued by governments in East Asia:
- Hong Kong EMSD guidelines on energy saving: the room temperature of an air-conditioned space in summer months is set to 25.5°C;
- National Development and Reform Commission of Chinese State Council issued a guideline to set the indoor temperature to 26°C in the cooling season;
- Room temperature in the “Presidential Office” in Taipei has been set to 27°C after Mr. Ma Ying-jeou’s inauguration;
- Ministry of Knowledge and Economy of Korea recommend room temperature ranging from 26 to 28 °C in summer;
- Ministry of Environment of Japanese Cabinet encourages to set the temperature of offices to 28°C in summer months.

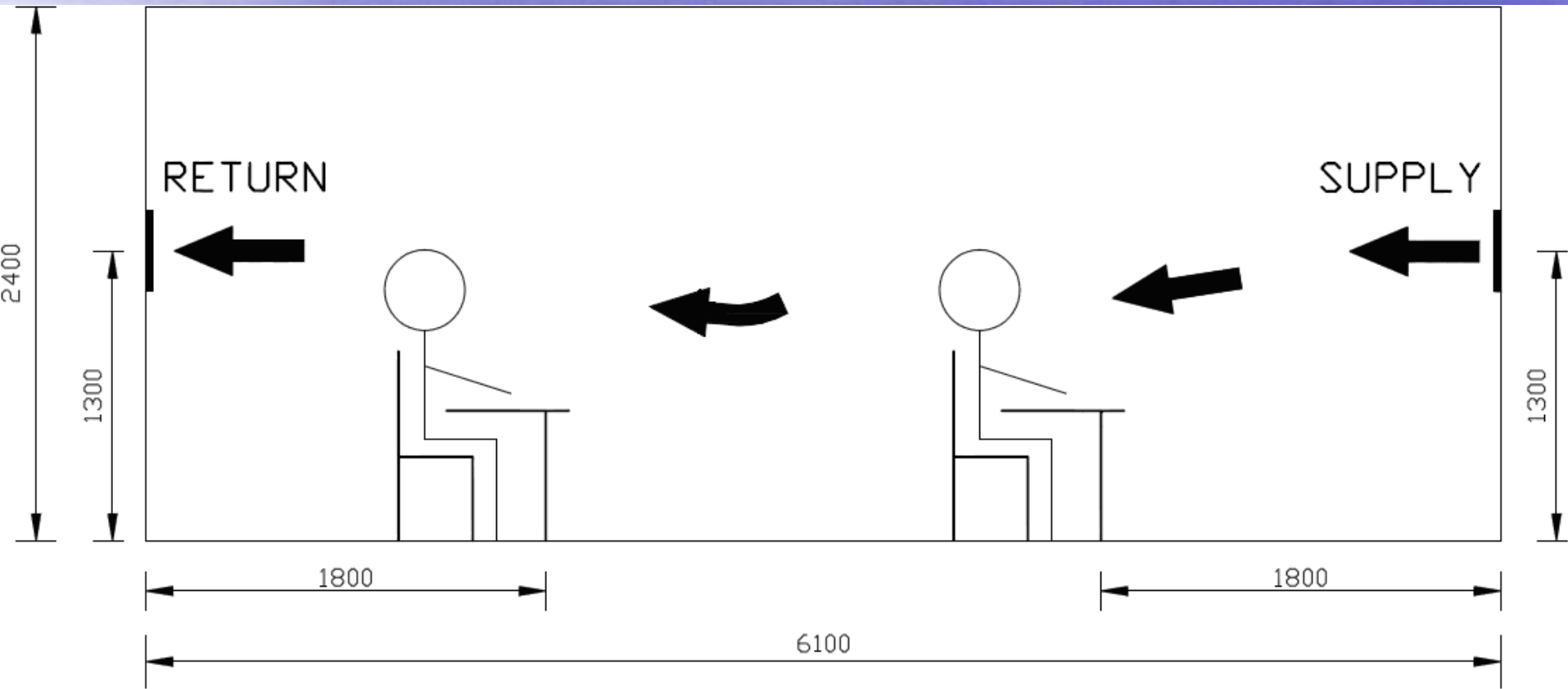
- Conventional theory presumes: Occupants exposed to uniform ambience (One of the implications: Air speed unperceivable).
- Thermal neutrality (heat balance) without sweating might not longer be possible!
- Solution?
- **Ventilative cooling**

# ASHRAE Standard 55-2004?

ASHRAE Standard 55-2010 allows elevated air movement to broadly offset the need to cool the air in warm conditions



# Stratum ventilation was proposed for small to medium rooms





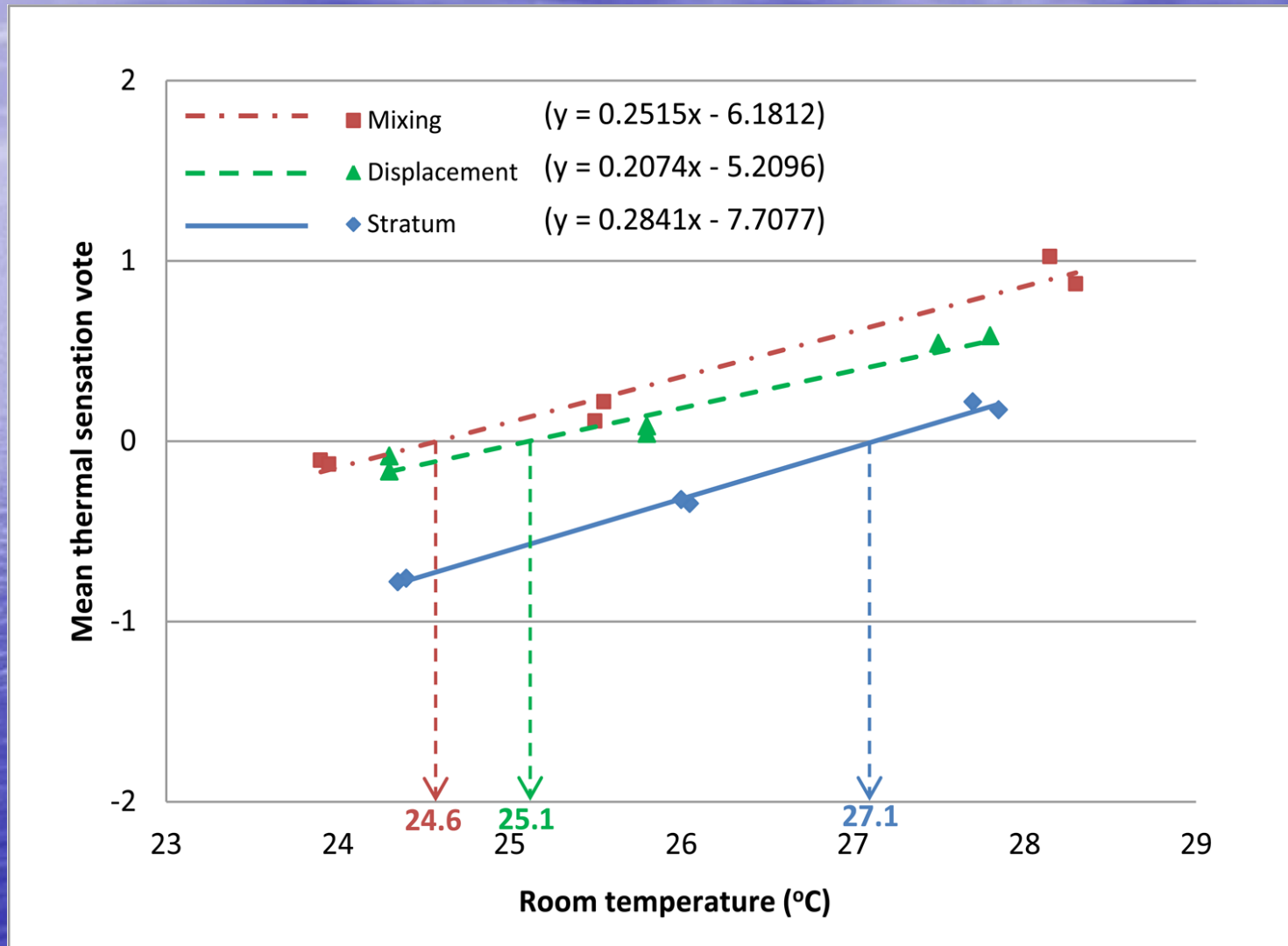
Air supply stratum formed under cooling condition



Air supply stratum formed under heating condition



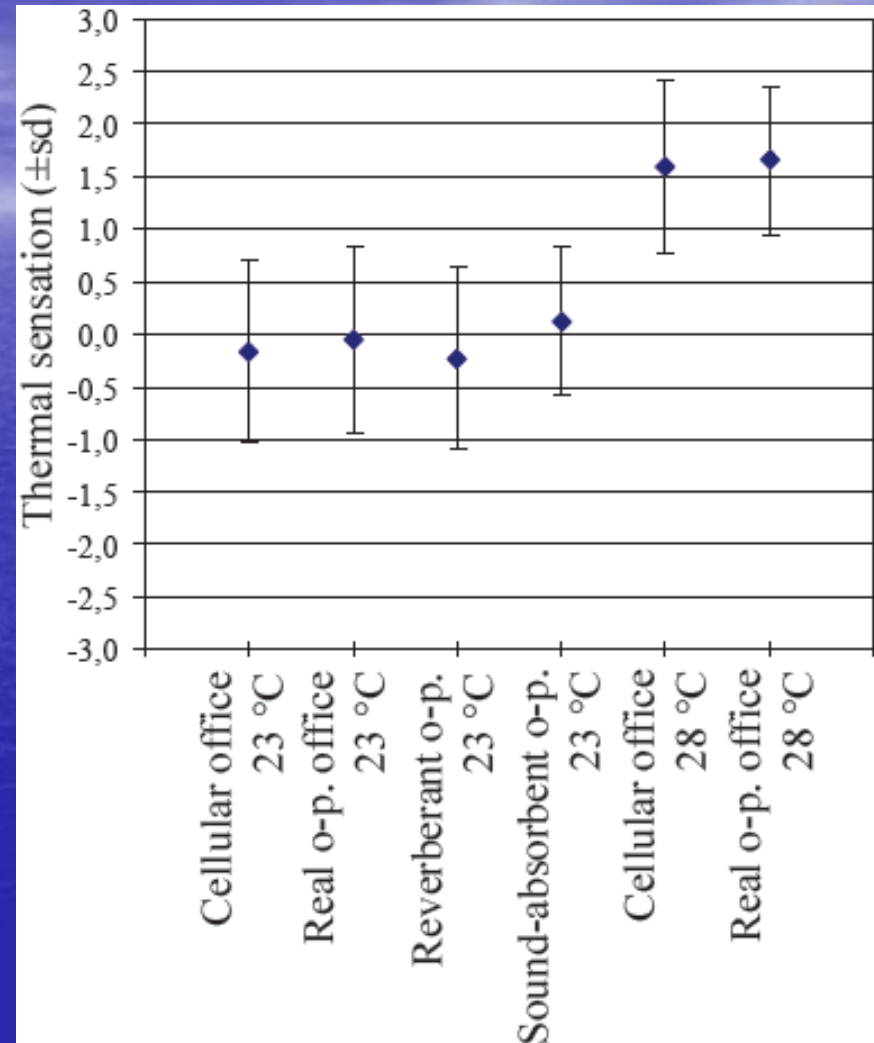
# Thermal Sensation Votes of 24 Male + 24 Female subjects



# Thermal Sensation Votes of 24 Male + 24 Female subjects

Nominal room temp. (°C)	Row	Seat No.	Accumulated number of thermal sensation vote							Mean thermal sensation (-3 to +3)	P-value (2-tailed)
			-3	-2	-1	0	+1	+2	+3		
<b>28</b>	1st	1 to 8	0	1	2	17	3	1	0	0.04	<b>0.071</b>
	2nd	9 to 16	0	0	1	17	5	1	0	0.25	
<b>26</b>	1st	1 to 8	0	2	8	14	0	0	0	-0.50	<b>0.004</b>
	2nd	9 to 16	0	0	2	20	2	0	0	0.00	
<b>24</b>	1st	1 to 8	2	7	8	7	0	0	0	-1.17	<b>0.297</b>
	<b>2nd</b>	<b>9 to 16</b>	<b>1</b>	<b>3</b>	<b>8</b>	<b>11</b>	<b>1</b>	<b>0</b>	<b>0</b>	<b>-0.67</b>	

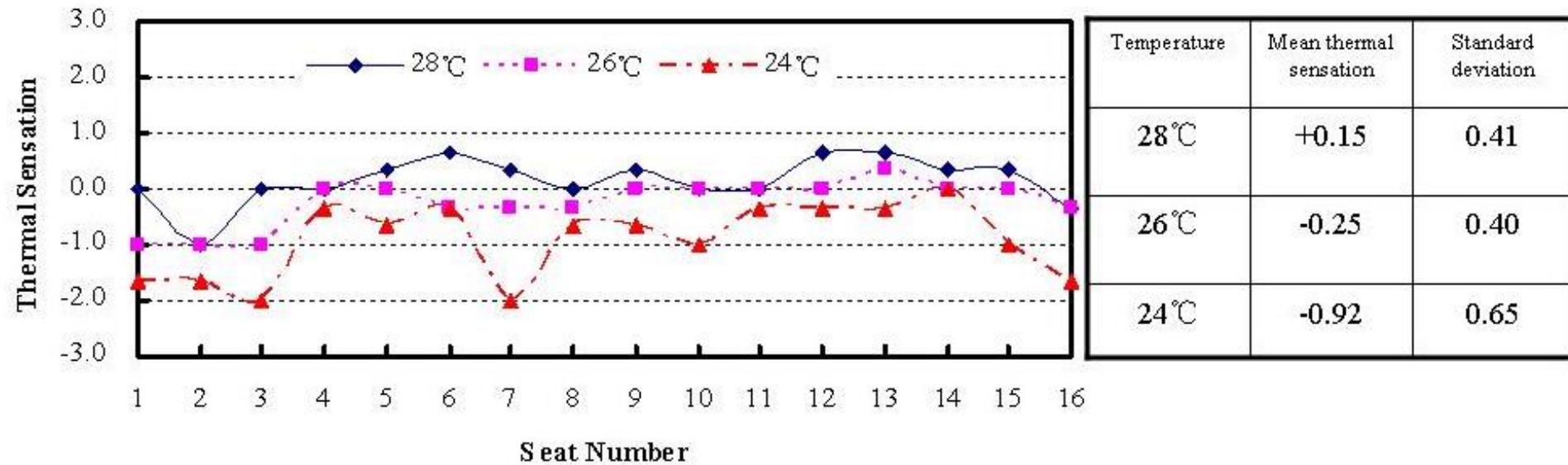
Balazova I, Clausen G, Jens H, Rindel JH, Poulsen T and Wyon DP. Open-plan office environments: A laboratory experiment to examine the effect of office noise and temperature on human perception, comfort and office work performance. Indoor Air 2008, 17-22 August 2008, Copenhagen, Denmark.



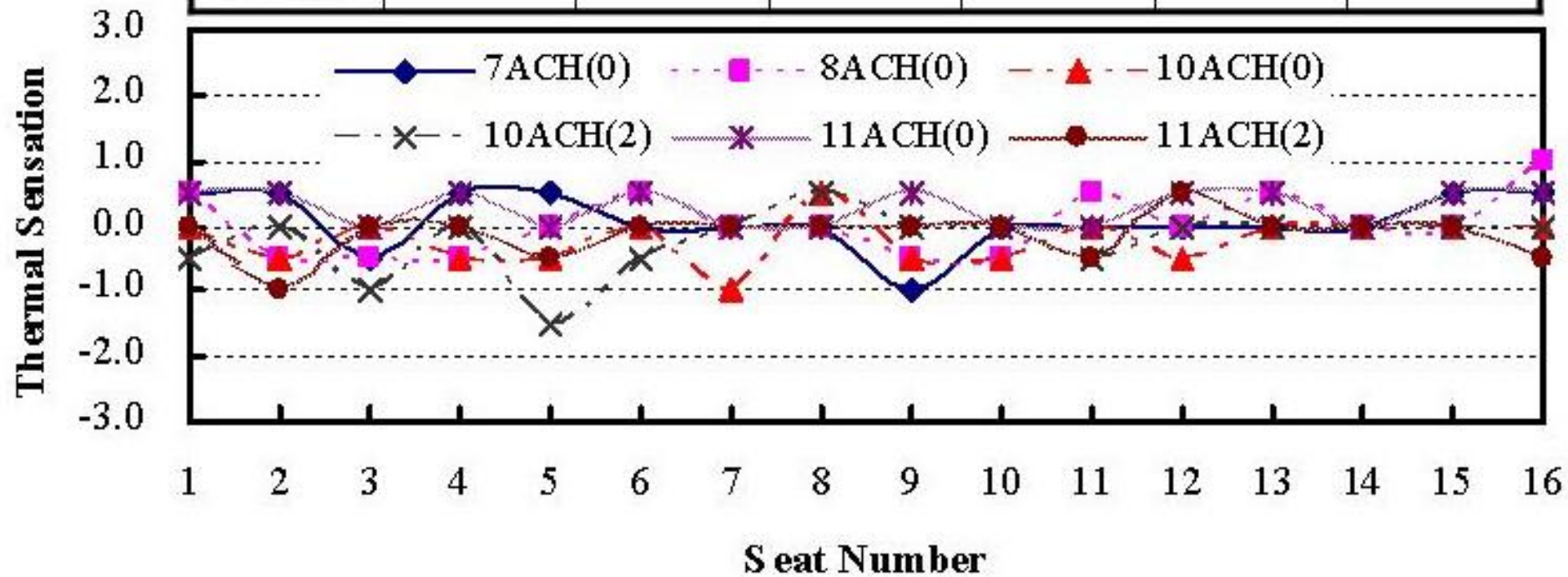
Yu WJ, Cheong KWD, Kosonen R, Xie YH, Leow HC.  
 A thermal comfort study on displacement ventilation in  
 the tropics. Proceedings of Healthy Buildings 2003, 7-11  
 December 2003, Singapore.

Parameters \ Case	1	2	3	4	5	6	7	8	9	10	11
Ventilation Mode	DV	DV	DV	DV	DV	DV	DV	MV	MV	MV	MV
Overall AMV	-0.38	-0.06	-0.32	0.19	-0.43	-0.19	0.79	0	-0.17	0.09	0.57
Standard Deviation	±0.6	±0.88	±0.61	±1.01	±0.70	±0.98	±0.88	±0.87	±1.02	±0.87	±1.03

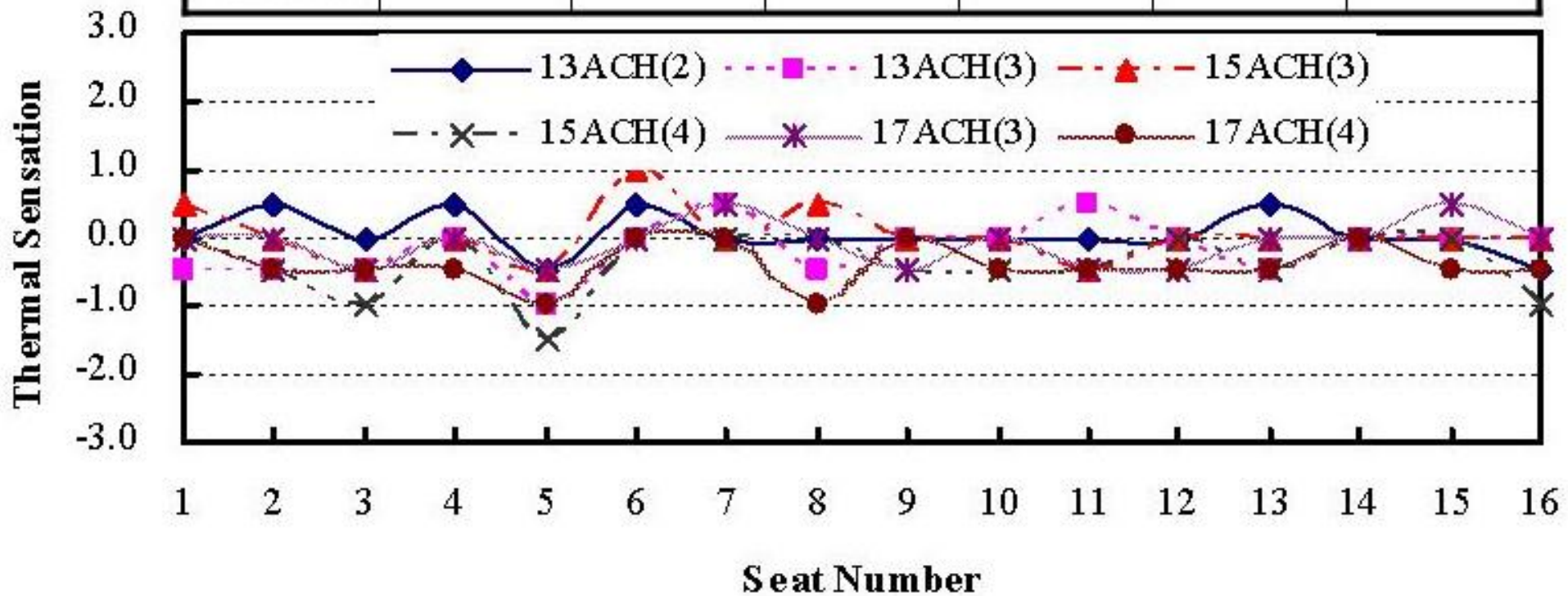
# Thermal Sensation Votes of 24 Male + 24 Female subjects



Condition	7ACH(0)	8ACH(0)	10ACH(0)	10ACH(2)	11ACH(0)	11ACH(2)
Mean thermal sensation	+0.09	+0.03	-0.22	-0.22	+0.28	-0.13
Standard deviation	0.40	0.45	0.35	0.47	0.25	0.33



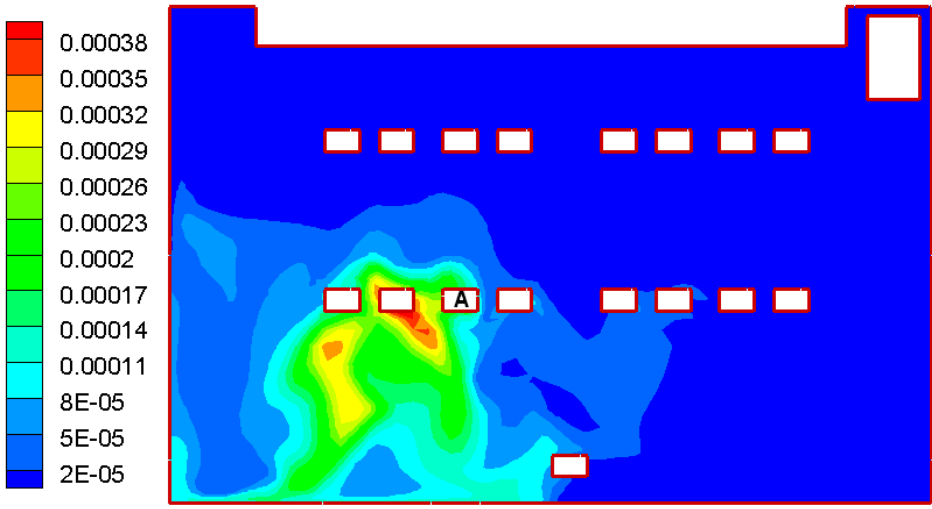
Condition	13ACH(2)	13ACH(3)	15ACH(3)	15ACH(4)	17ACH(3)	17ACH(4)
Mean thermal sensation	+0.06	-0.16	+0.03	-0.38	-0.09	-0.41
Standard deviation	0.30	0.38	0.37	0.45	0.32	0.32



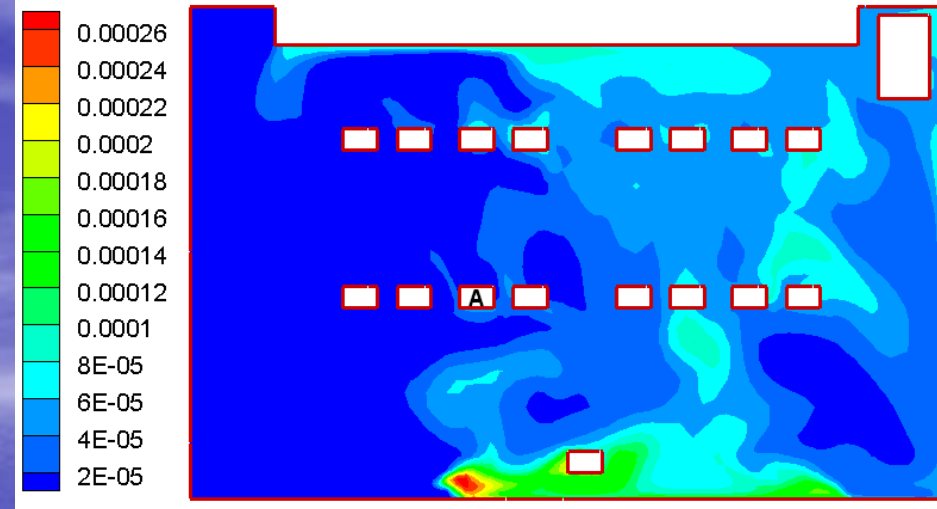


## Measured air temperature and velocity

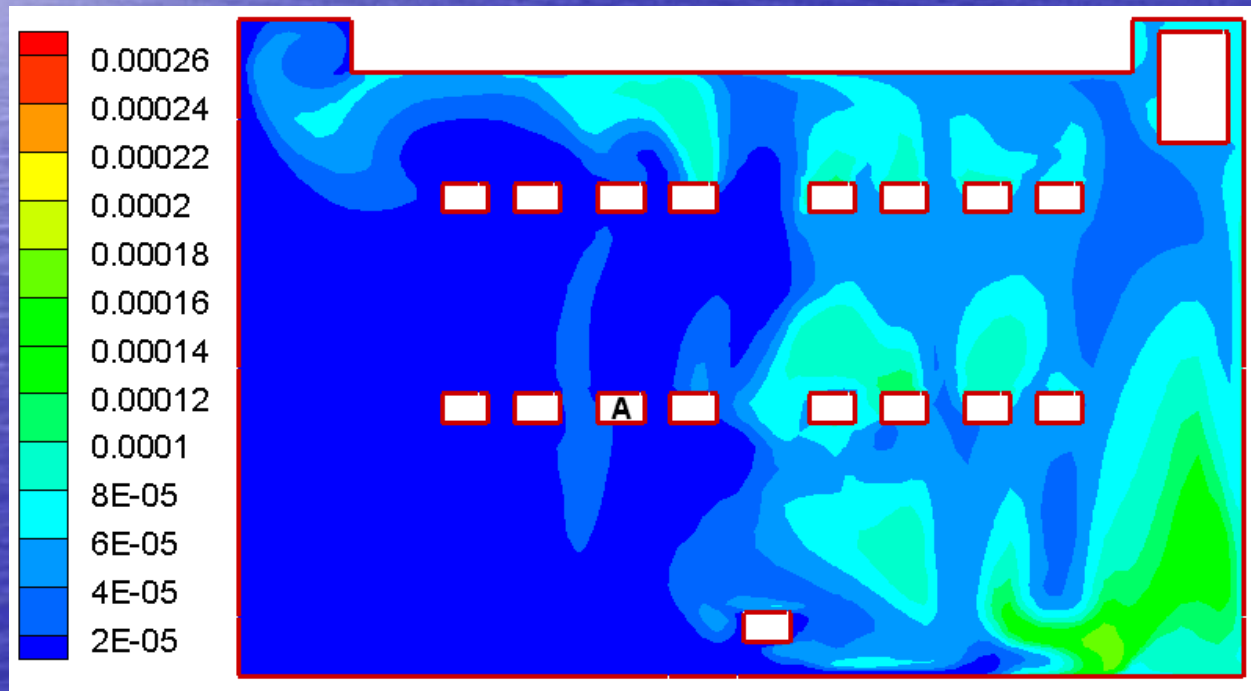
Point	Room temperature 28 (°C)			Room temperature 26 (°C)			Room temperature 24 (°C)		
	T (°C)	V (m/s)	EDT (K)	T (°C)	V (m/s)	EDT (K)	T (°C)	V (m/s)	EDT (K)
P1	28.0	0.10	0.7	25.8	0.07	1.1	24.2	0.11	0.7
P2	27.5	0.23	-0.8	25.2	0.17	-0.3	23.4	0.20	-0.8
P3	27.6	0.24	-0.8	25.7	0.22	-0.2	23.9	0.12	0.4
P4	28.0	0.16	0.3	26.0	0.13	0.8	24.5	0.15	0.7
P5	27.2	0.34	-2.0	24.1	0.36	-2.9	22.9	0.27	-1.8
<b>ADPI</b>			<b>80%</b>			<b>60%</b>			<b>80%</b>



Mixing ventilation



Displacement ventilation



Stratum ventilation

# Energy Performance

Qualitatively, 8 factors contribute to energy saving of stratum ventilation:

1. Neutral temperature of 27°C → Higher humidity ratio for identical RH → lower latent load;
2. Smaller temperature difference between the indoors and outdoors → smaller transmission load;
3. Smaller enthalpy difference → lower ventilation load;
4. Longer free cooling period;

# Energy Performance

5. Higher ventilation effectiveness —> lower ventilation load;
6. Reverse temperature gradient in the occupied zone —> no over-cooling of the lower zone;
7. Elevated supply air temperature —> higher evaporative temperature of the associate chiller(s); and
8. Lower cooling capacity —> smaller pumps and fans.

# Year-round primary energy consumption (kWh)

System	Solar-assisted?	
	No	Yes
Mixing ventilation	53,360	n/a
Hybrid displacement ventilation	39,806	24,062
Hybrid stratum ventilation	31,785	19,620
Saving from mixing ventilation to hybrid displacement ventilation	25.40%	54.90 %
Saving from hybrid displacement ventilation to hybrid stratum ventilation	20.15%	18.46 %
Saving from mixing ventilation to hybrid stratum ventilation	40.43%	63.23 %

## Smaller capacity of stratum ventilation leads to

- (a) smaller mechanical plant and ductwork;
- (b) air conditioning system occupies less indoor space;
- (c) scaffolding is not necessary if the air ducts are installed in a cavity wall;
- (d) substantially lower year-round energy consumption.

### Qualitatively,

1. Initial cost is expected to be lower for Factors (a) to (c);
2. Operation cost is expected to be lower for Factors (a) and (d); and
3. lifecycle carbon footprint will be smaller for Factors (a) to (d).

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