



Effect of air movement

Air movement on good or bad?
thermal comfort and sensation



Air movement effects on humans

Moderate to low temperatures:

- unwanted local cooling of the skin (draught) ☹️

Moderate to high temperatures:

- increased convective heat loss 😊

Air movement preference - ASHRAE field studies

| Thermal sensation | Air velocity range (m/s) | Percent of occupants preferring | | | N _{obs} |
|-------------------|--------------------------|---------------------------------|-----------|------|------------------|
| | | Less | No change | More | |
| Slightly cool | 0 - 0.15 | 13.6 | 46.3 | 40.1 | 147 |
| | 0.15 - 0.25 | 16.7 | 41.7 | 41.6 | 48 |
| Neutral | 0 - 0.15 | 2 | 46 | 52 | 150 |
| | 0.15 - 0.25 | 2 | 68.6 | 29.4 | 51 |
| Slightly warm | 0 - 0.15 | 2.7 | 21.9 | 75.4 | 73 |
| | 0.15 - 0.25 | 8.4 | 33.3 | 58.3 | 24 |

Fangers PMV-equation

$$\begin{aligned}
 \mathbf{PMV} = & (0.303 e^{-0.36M} + 0.028) \{ (M-W) - 0.35 * 10^{-3} * \\
 & [5733 - 6.99 (M-W) - p_a] - 0.42 * [(M-W) - 58.15] \\
 & - 1.7 * 10^{-5} M (5867 - p_a) - 0.0014M (34-t_a) - 3.96 * \\
 & 10^{-8} f_{cl} * [(t_{cl} + 273)^4 - (t_r + 273)^4] - f_{cl}h_c (t_{cl} - t_a) \}
 \end{aligned}$$

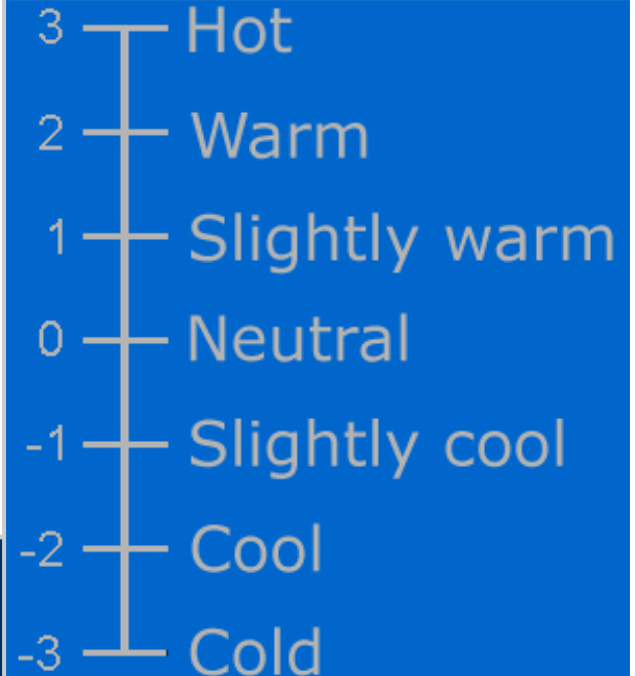
hvor:

$$t_{cl} = 35.7 - 0.028(M-W) - I_{cl} \{ 3.96 * 10^{-8} f_{cl} * [(t_{cl} + 273)^4 - (t_r + 273)^4] + f_{cl}h_c (t_{cl} - t_a) \}$$

$$h_c = 2.38 (t_{cl} - t_a)^{0,25} \quad \text{for } 2.38 (t_{cl} - t_a)^{0,25} > 12,1\sqrt{v_{ar}}$$

$$h_c = 12,1 \sqrt{v_{ar}} \quad \text{for } 2.38 (t_{cl} - t_a)^{0,25} < 12,1\sqrt{v_{ar}}$$

PMV Scale



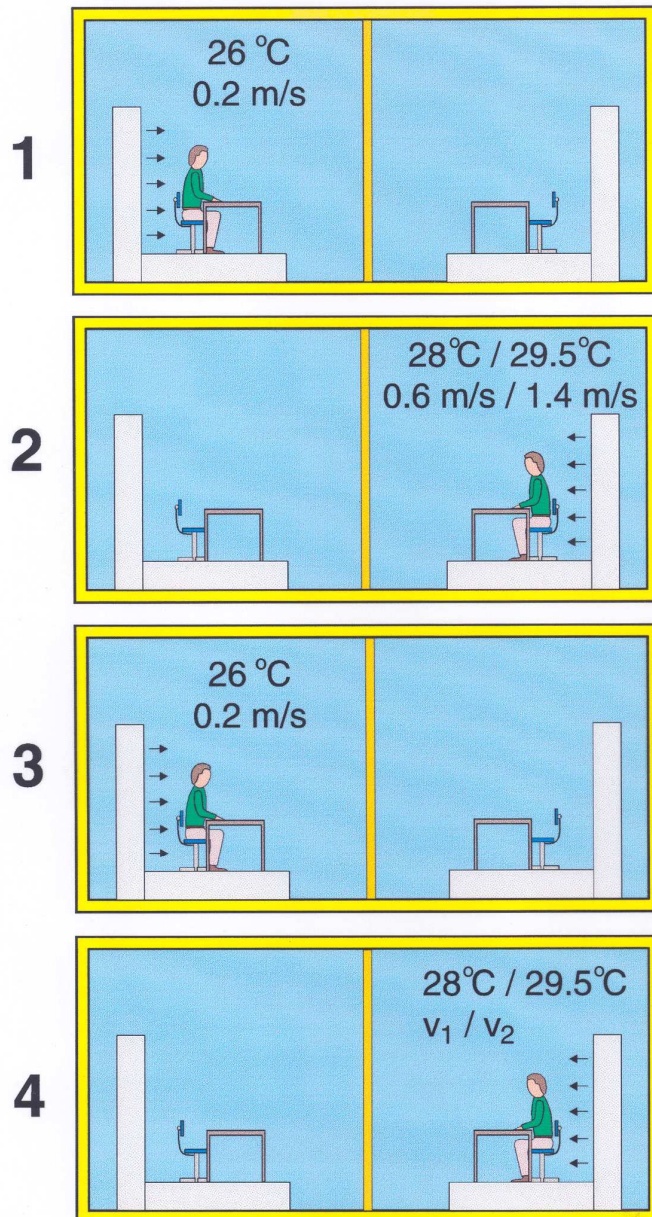
Comfort equation – relative influence of temperature and air velocity

| $\frac{\partial t}{\partial v}$ °C/(m·s ⁻¹) | at v = m · s ⁻¹ |
|--|-------------------------------|
| 13 | 0.1 |
| 6 | 0.2 |
| 2.5 | 0.5 |
| 1 | 1.0 |

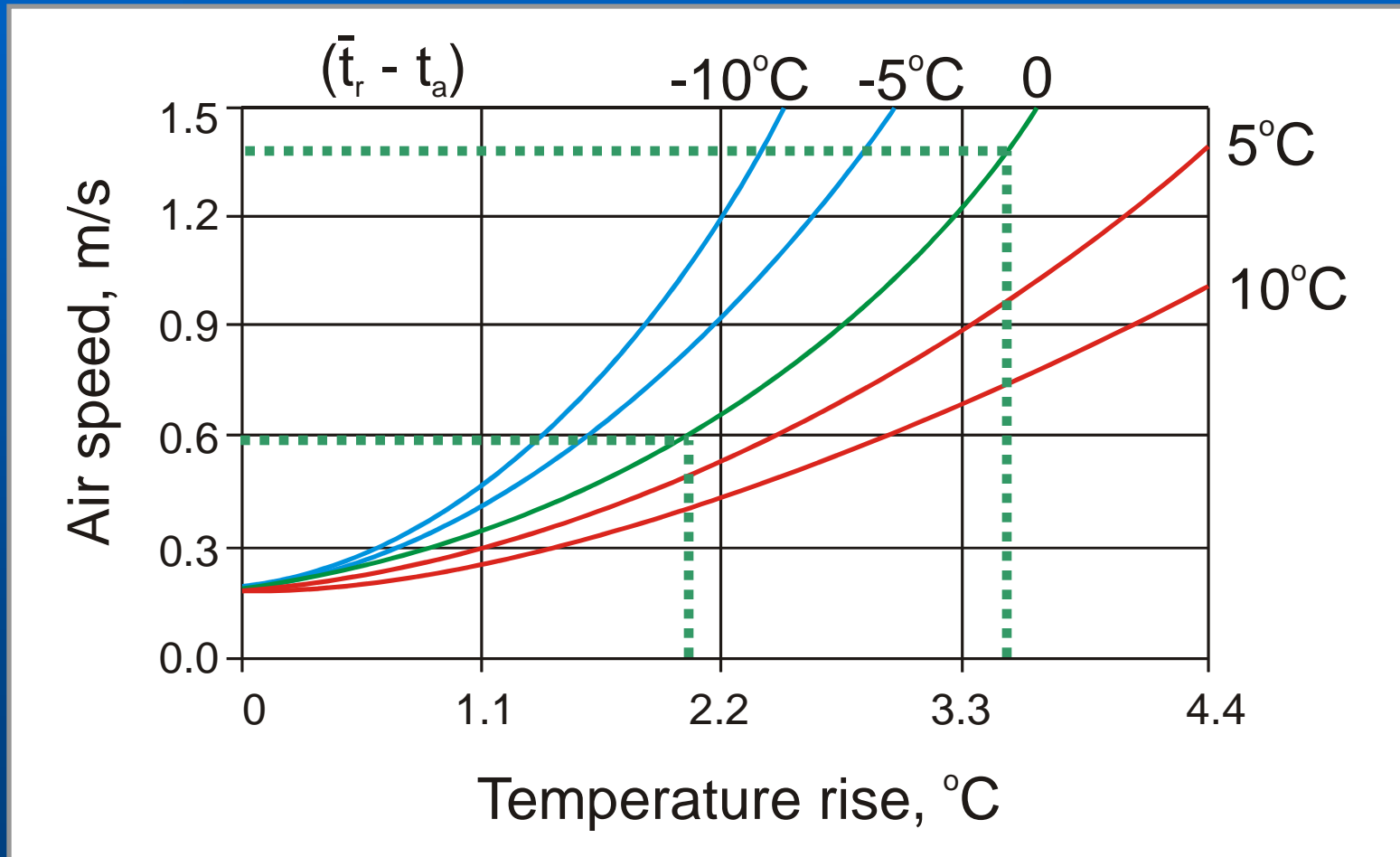
ASHRAE RP 843

- investigate the constant heat loss curves in ASHRAE 55

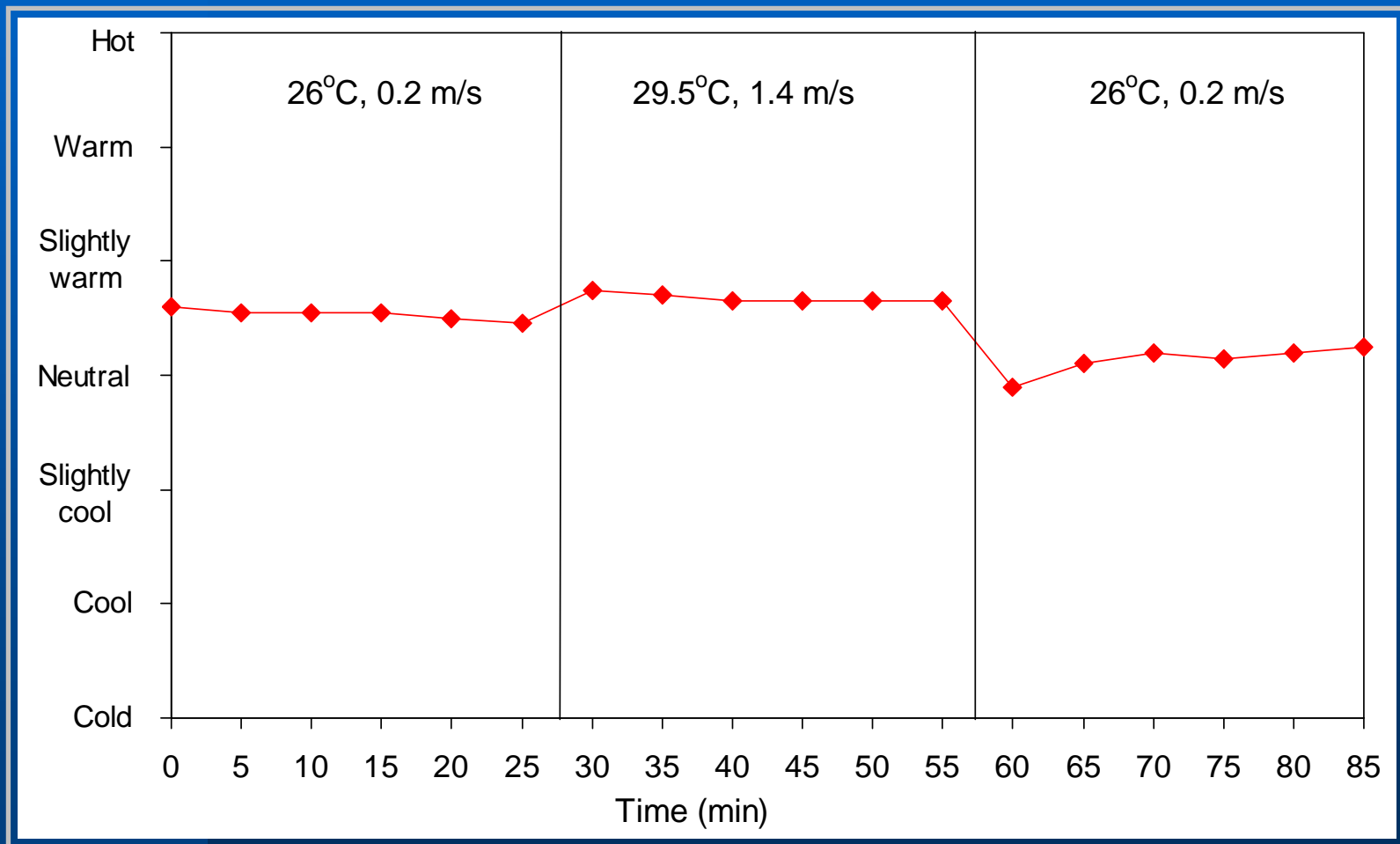
- investigate whether thermal comfort attained at high temperature and air velocity was preferable to a low air velocity and moderate temperature



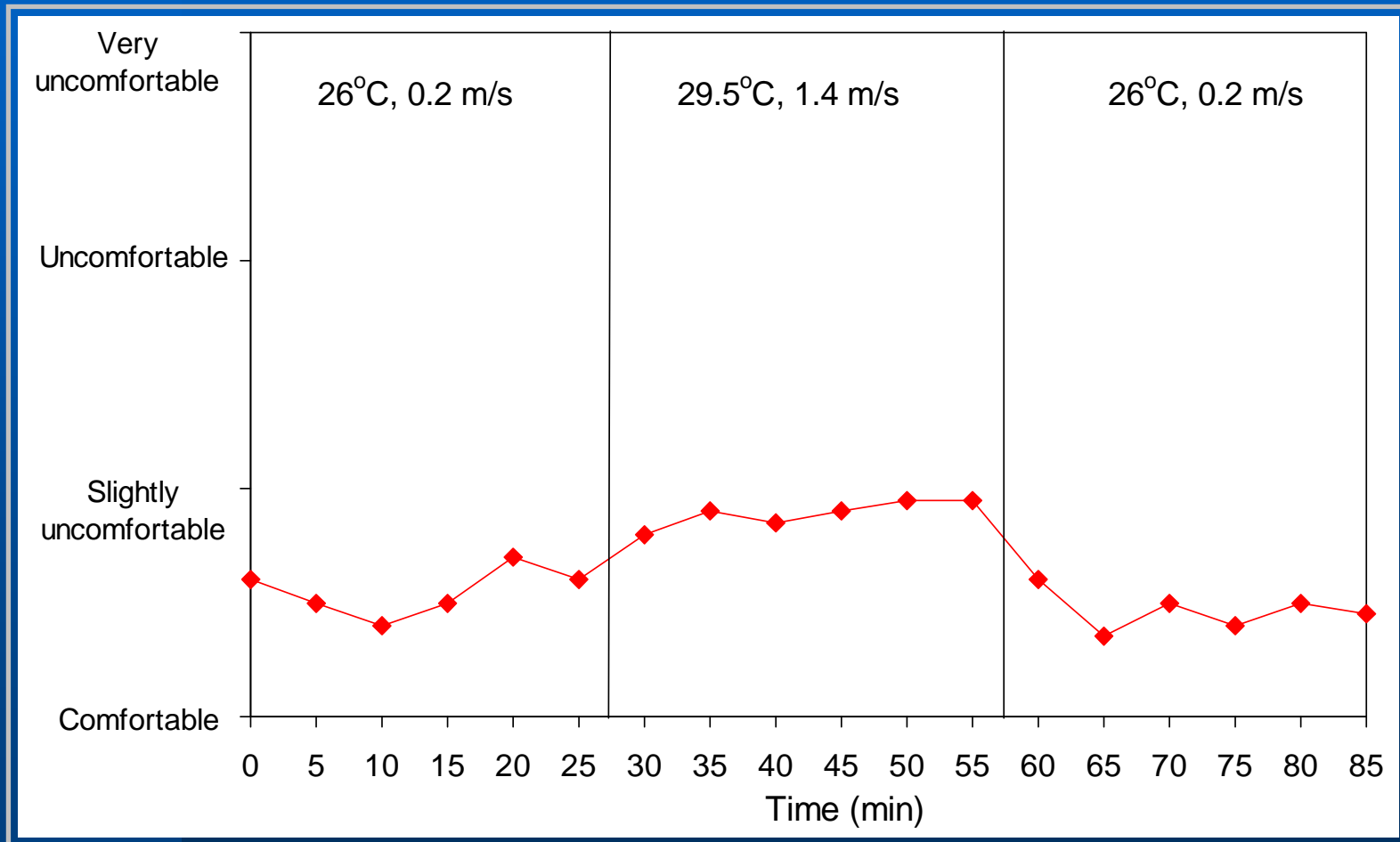
Good air movement (ASHRAE 55)



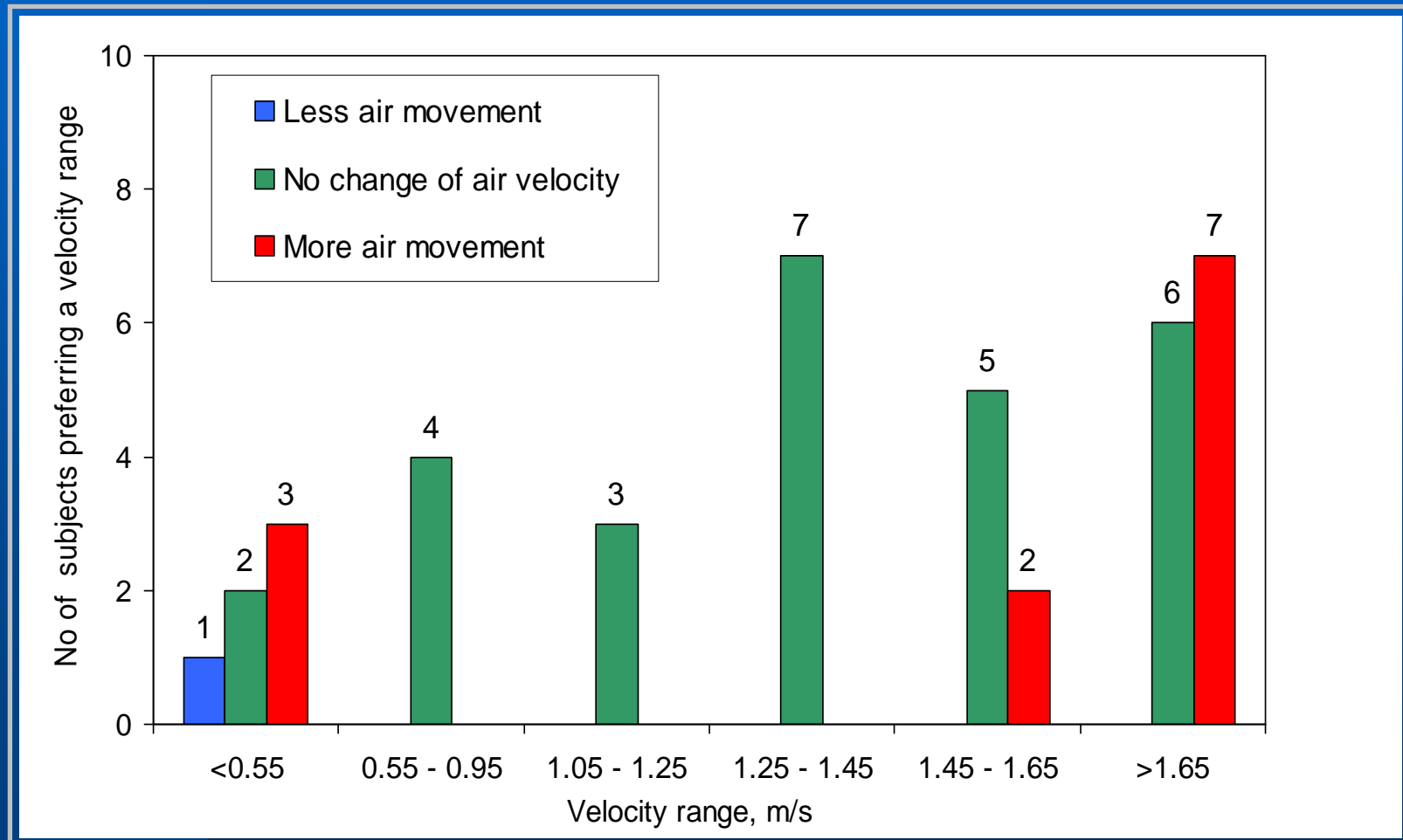
Mean thermal sensation



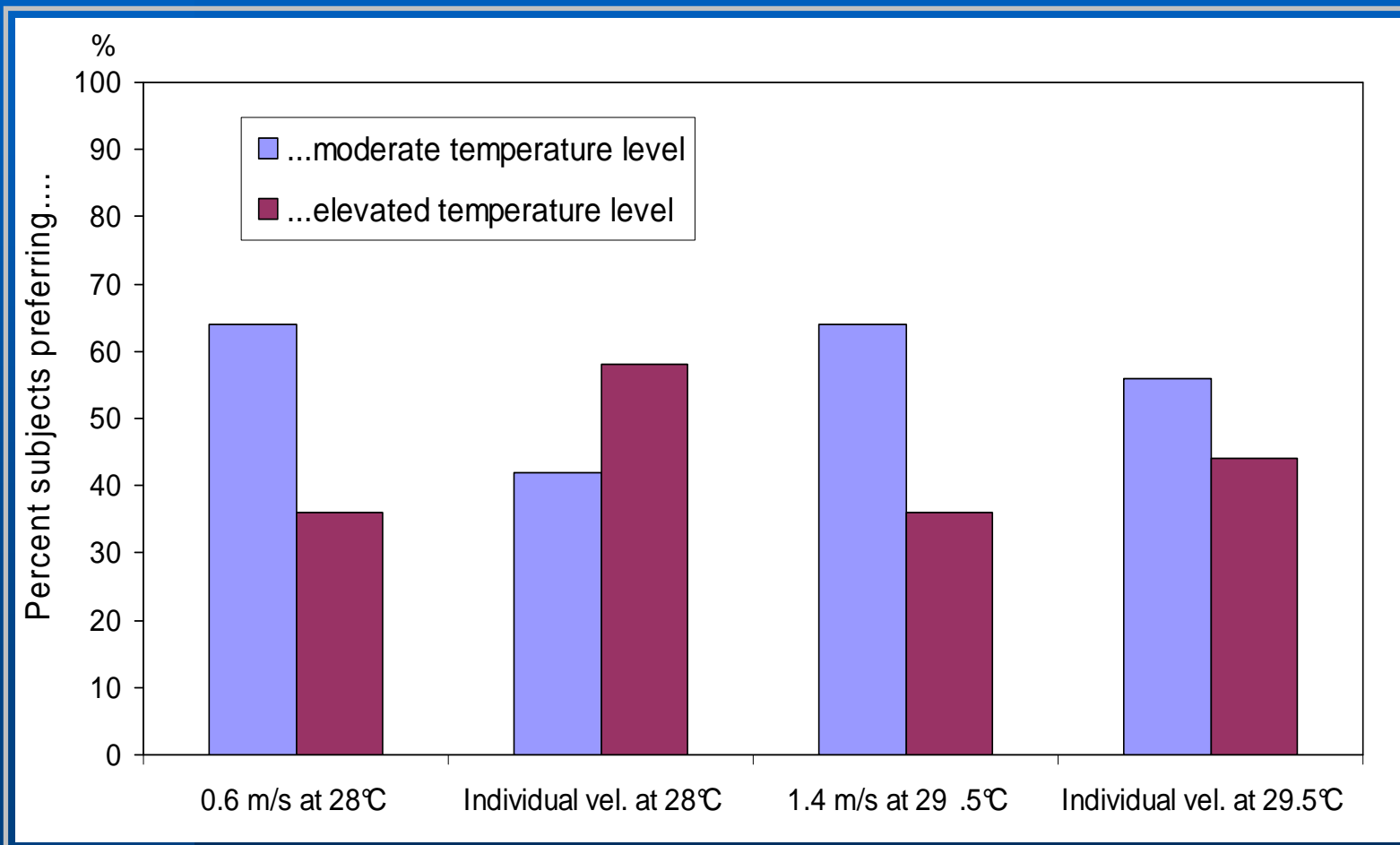
Mean comfort vote



Preferred velocity range



Preferred environment

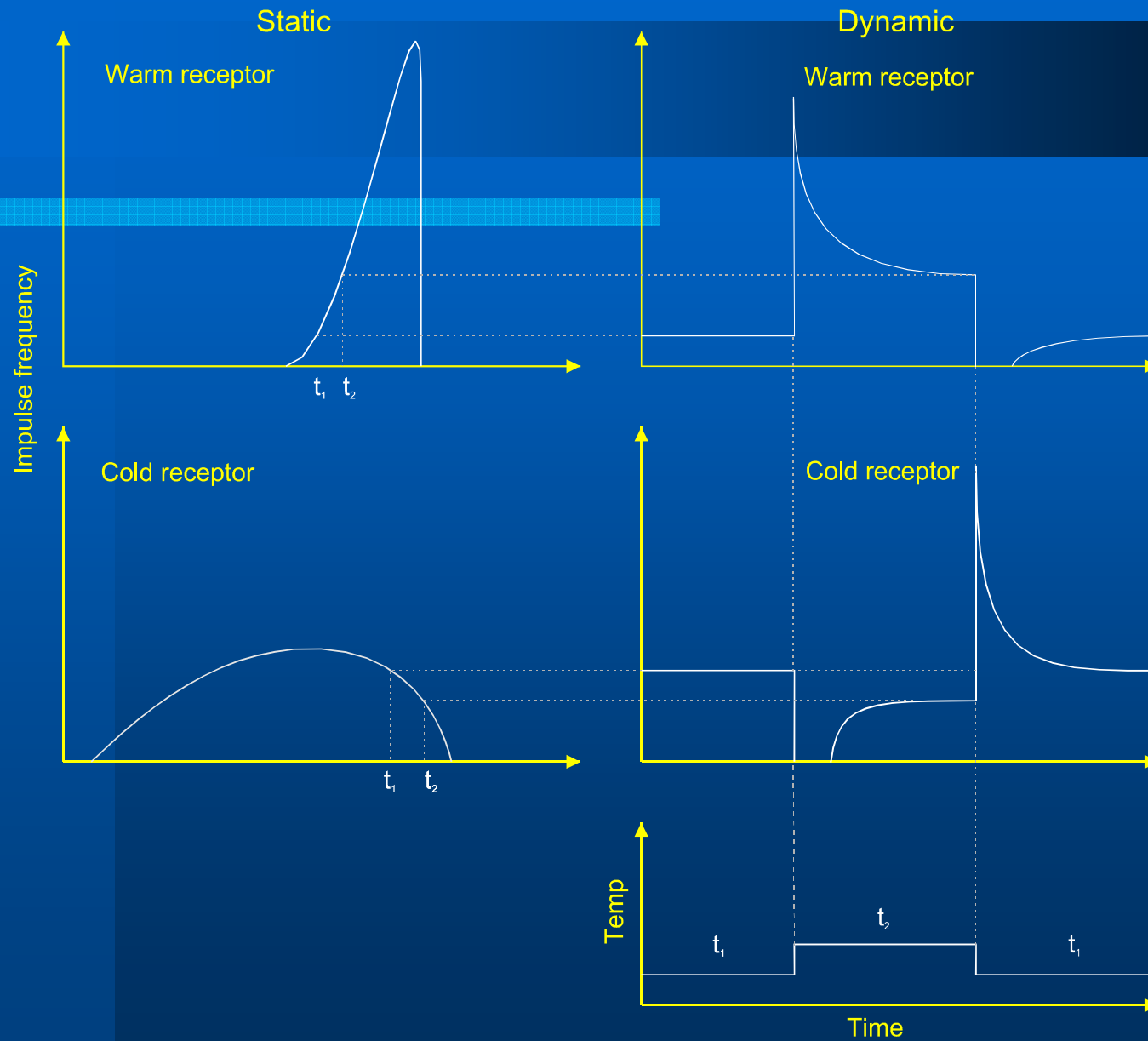


Draught

unwanted, local cooling of the skin
caused by air movement

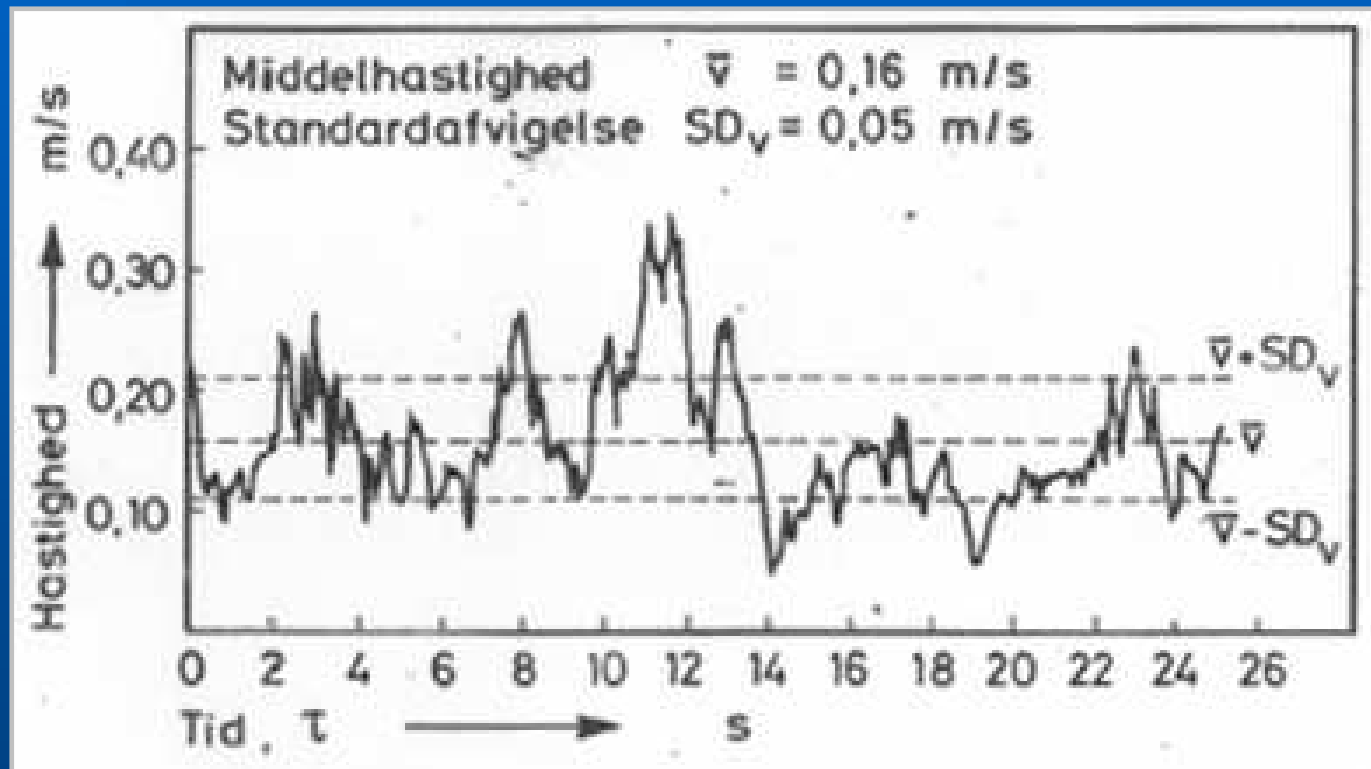


Static and dynamic properties of cold and warm receptors



(Hensel 1974)

Air velocity fluctuations



$$Tu = \frac{SD_{\bar{v}}}{\bar{v}} = \frac{0.05}{0.16} = 31\%$$

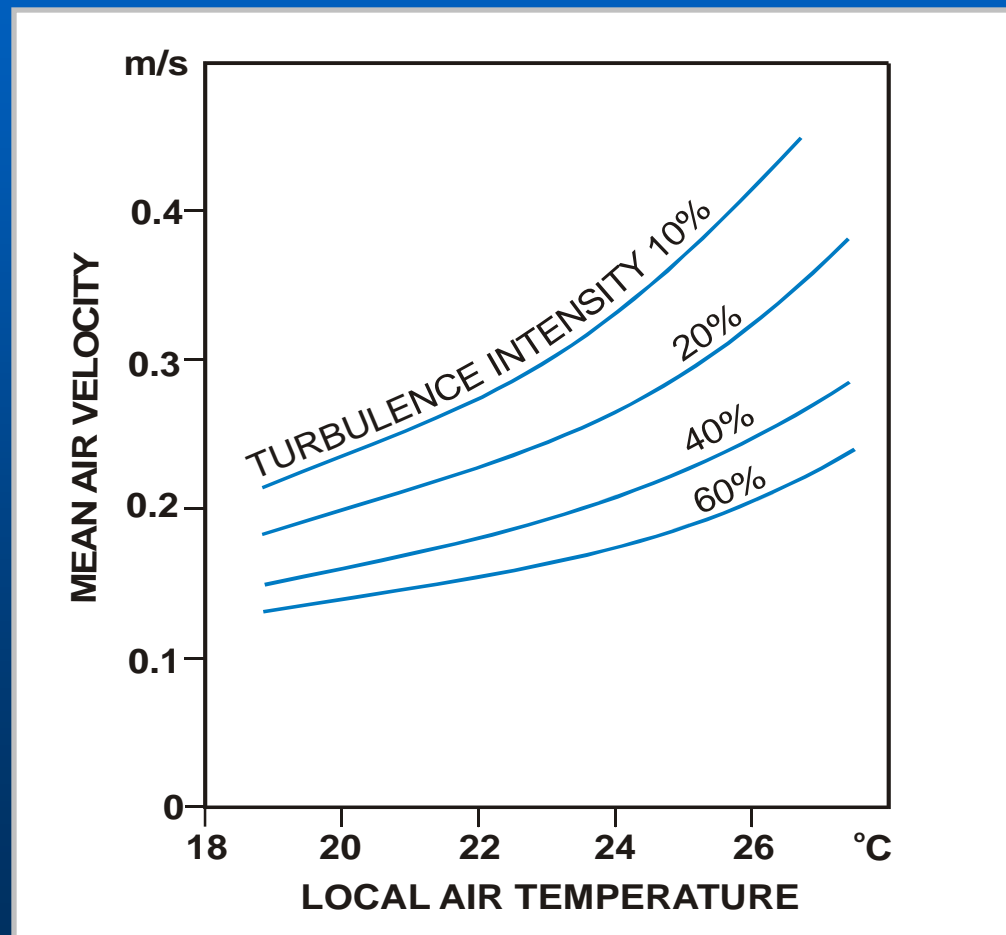
Parameters

- Air velocity
- Air velocity fluctuations
- Air temperature

Combined in the draught model (Fanger et al. 1988)

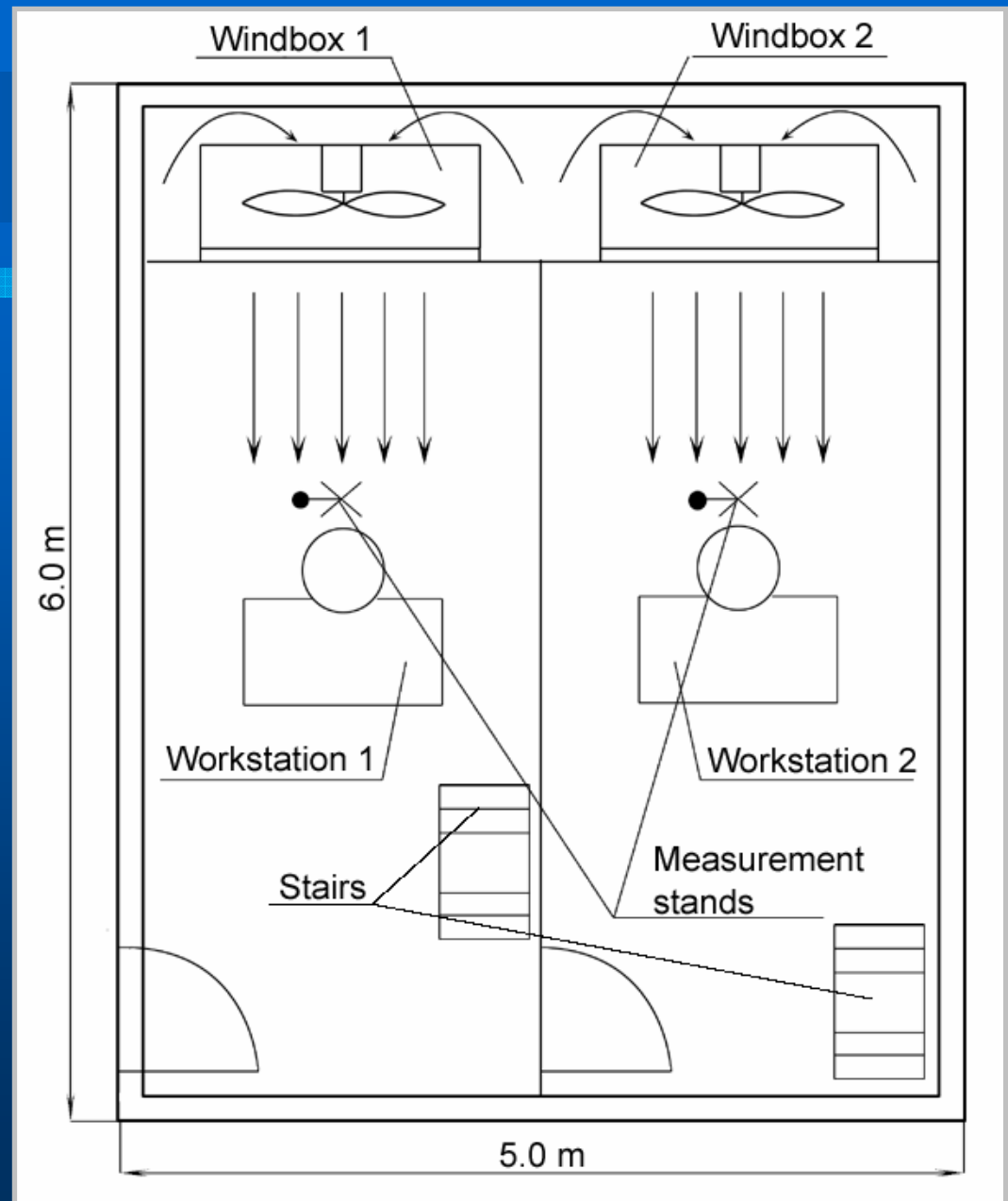
$$DR = (34 - t_a) \cdot (\bar{v} - 0.05)^{0.62} \cdot (0.37 \cdot \bar{v} \cdot Tu + 3.14)$$

ISO 7730, ASHRAE 55, DS 474,.....

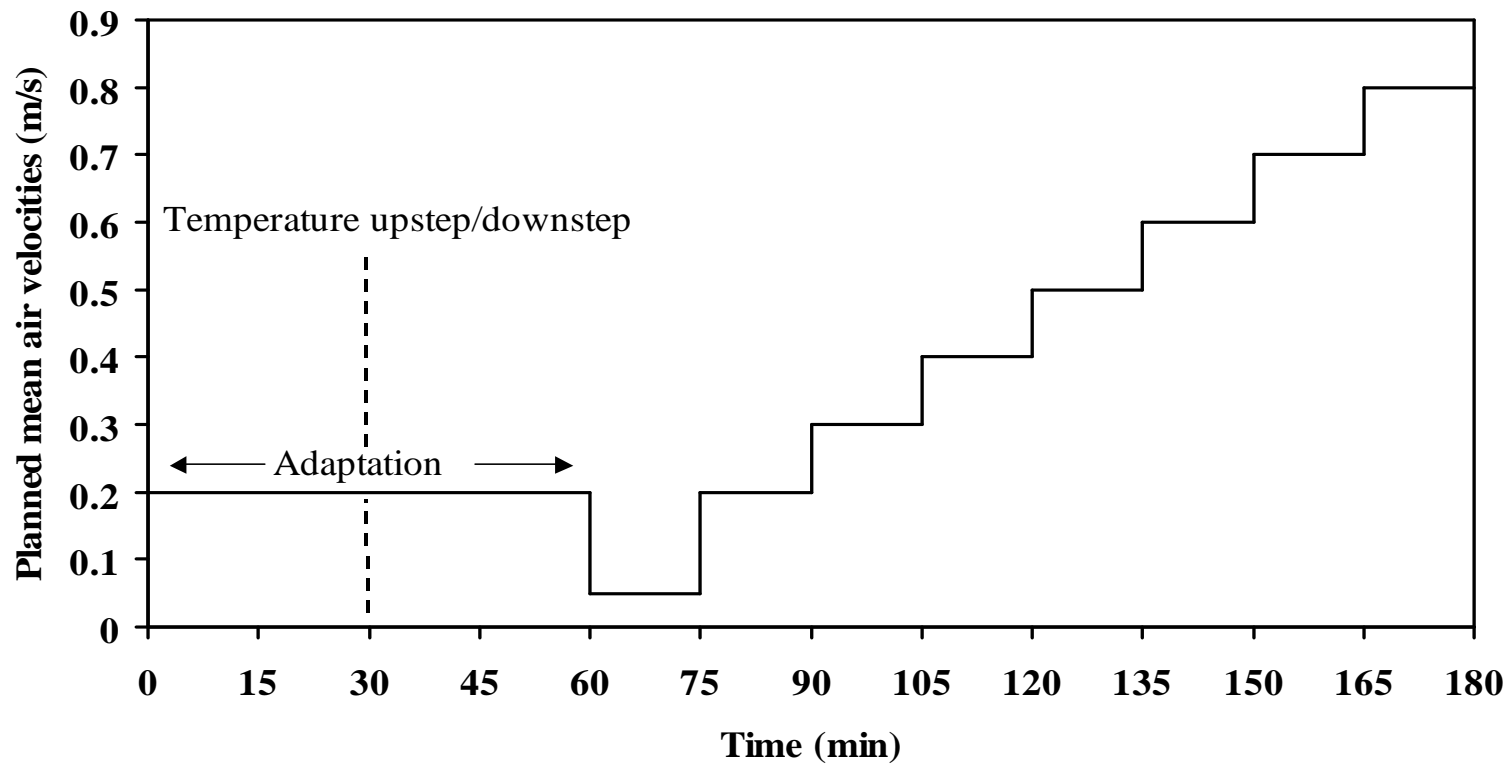


ASHRAE RP 843

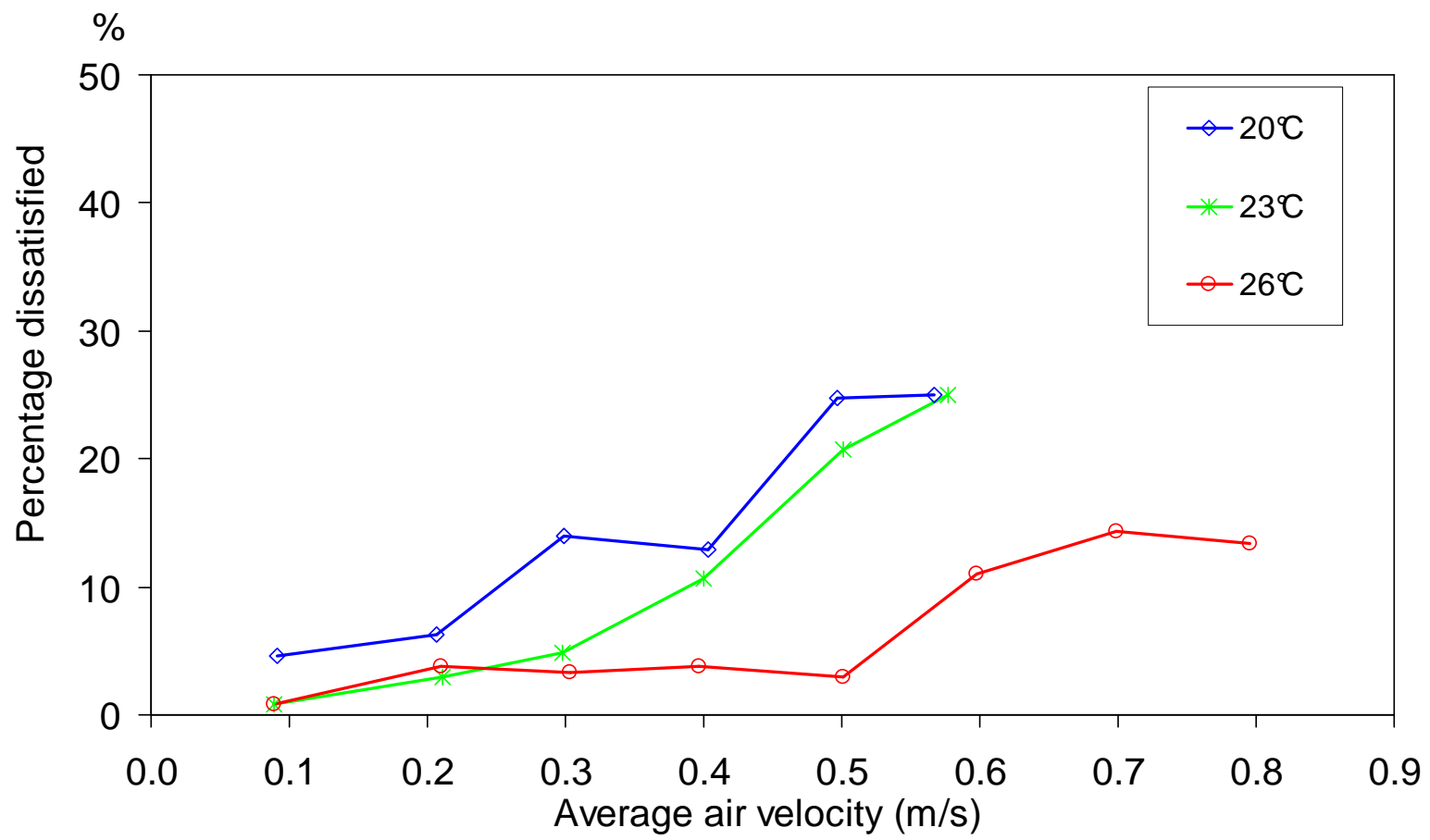
- study the draught criteria at high temperatures and at thermal sensations above and below neutral



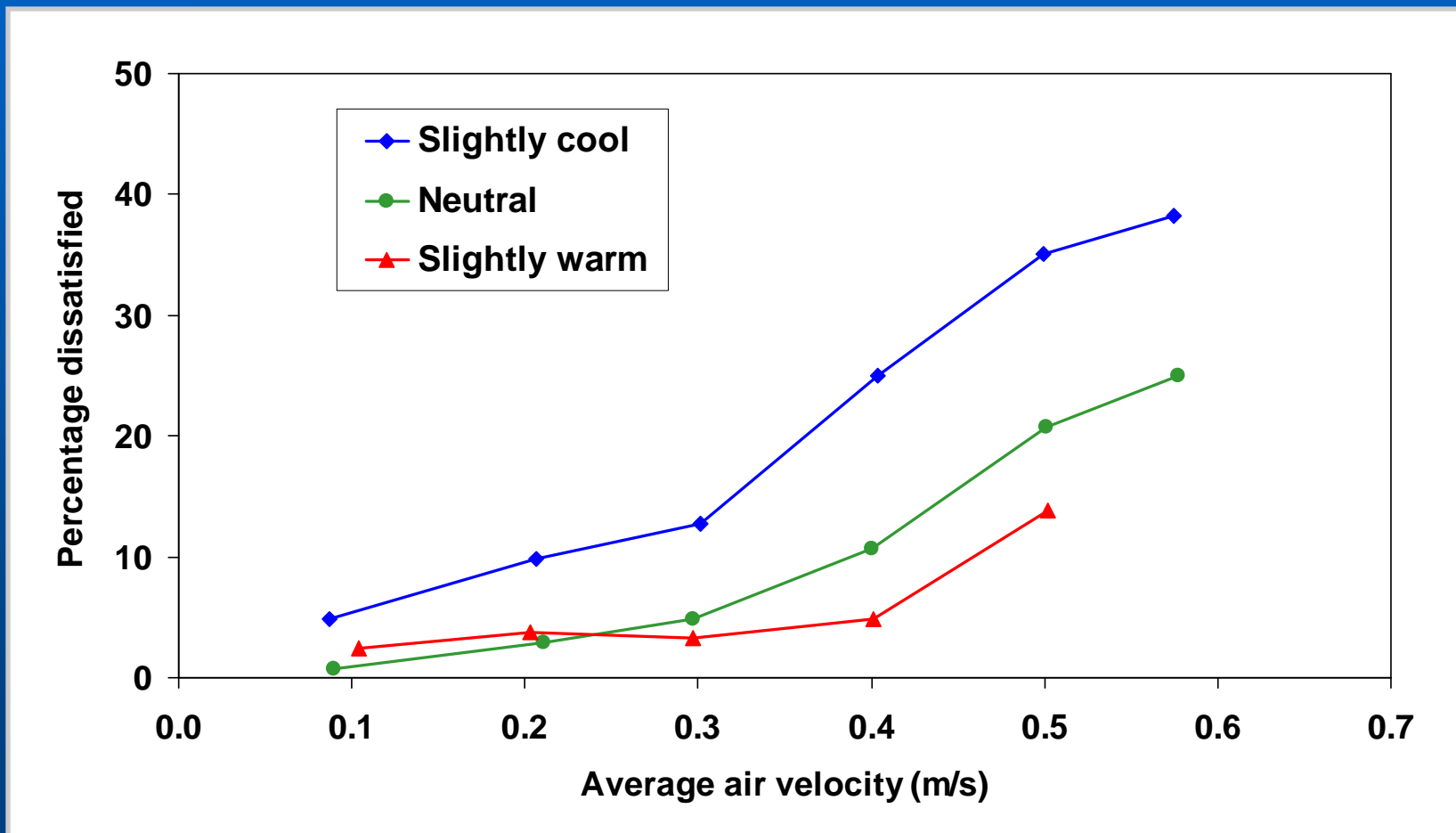
Experimental exposure



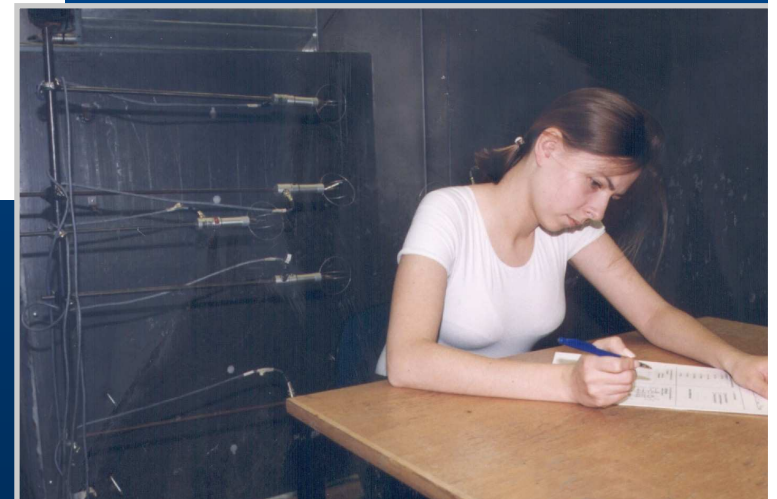
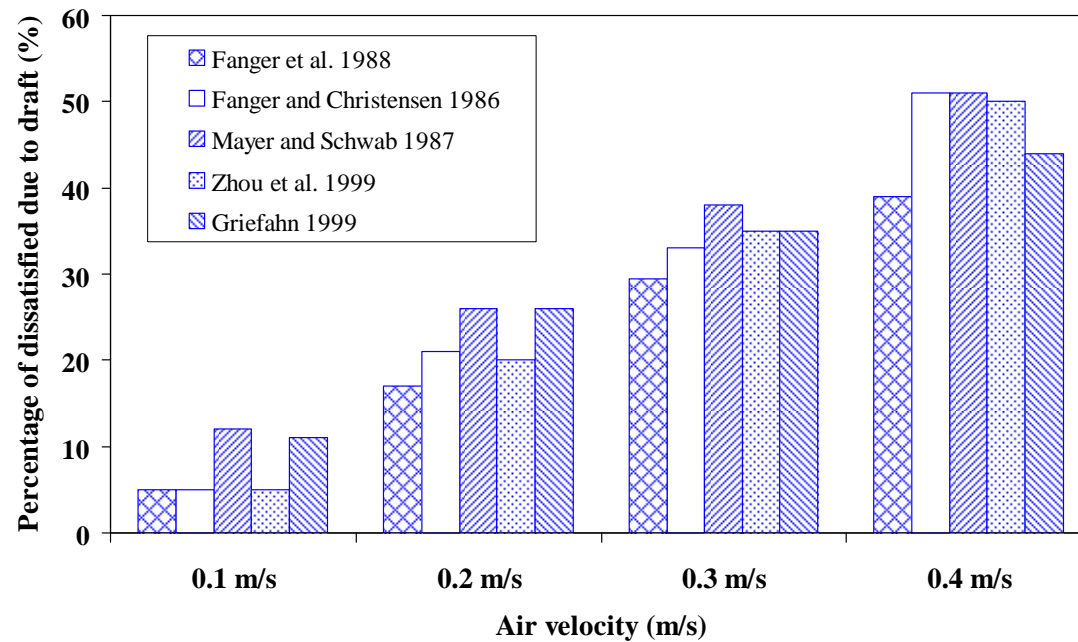
Draught and air temperature



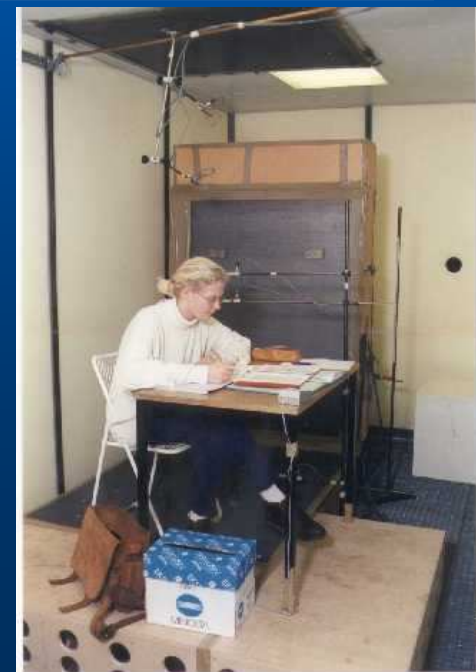
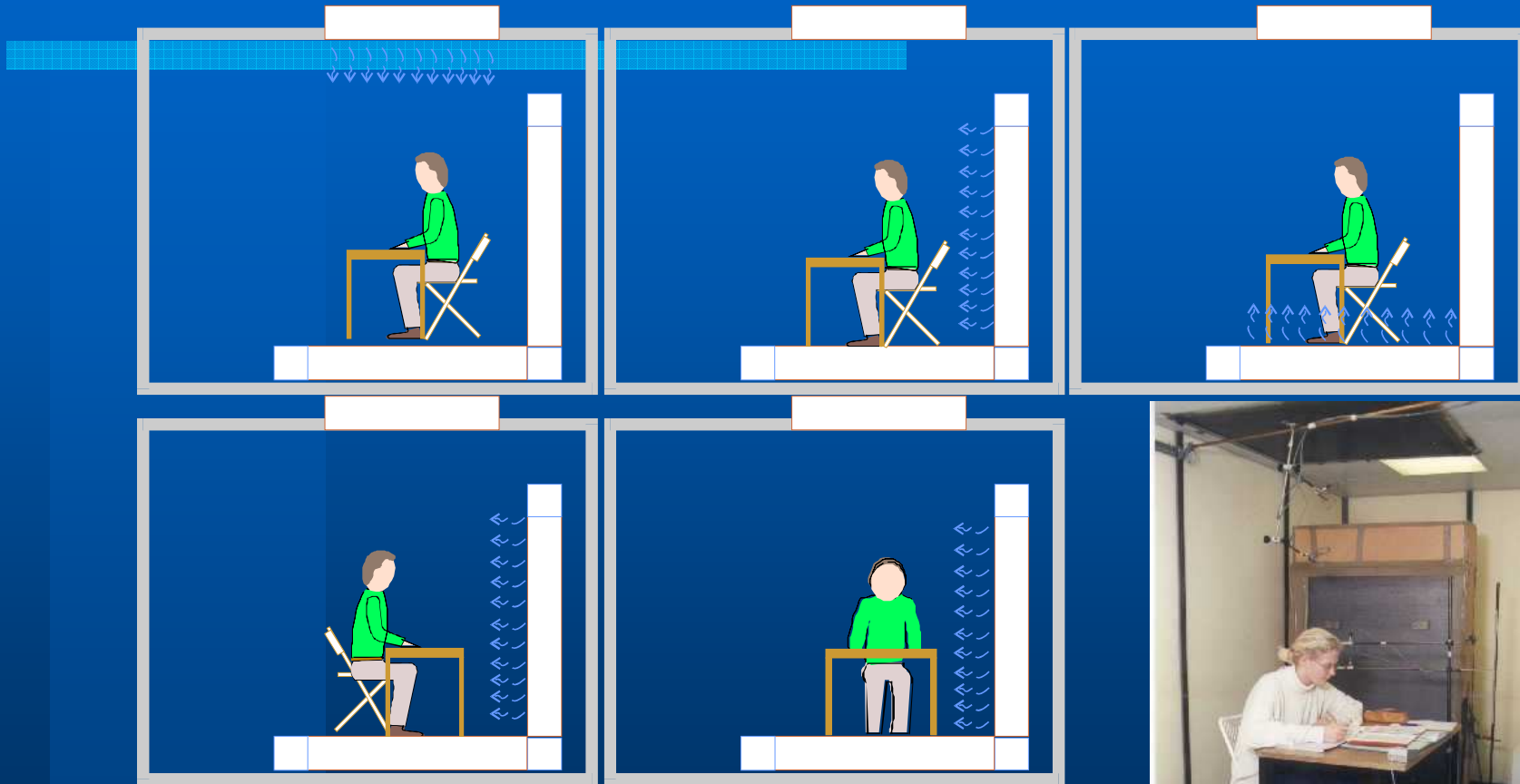
Draught and overall thermal sensation

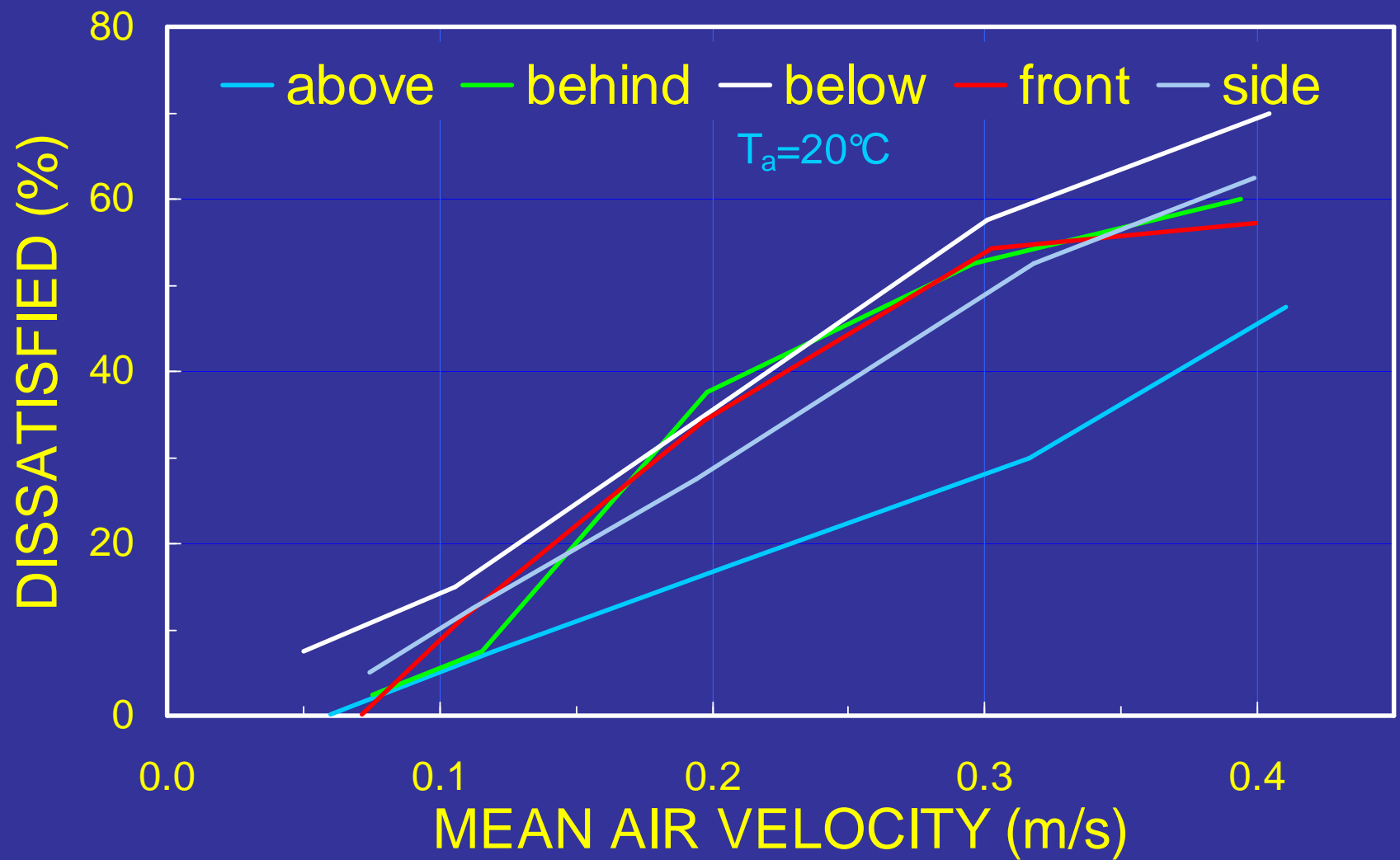


Comparison of draught dissatisfaction

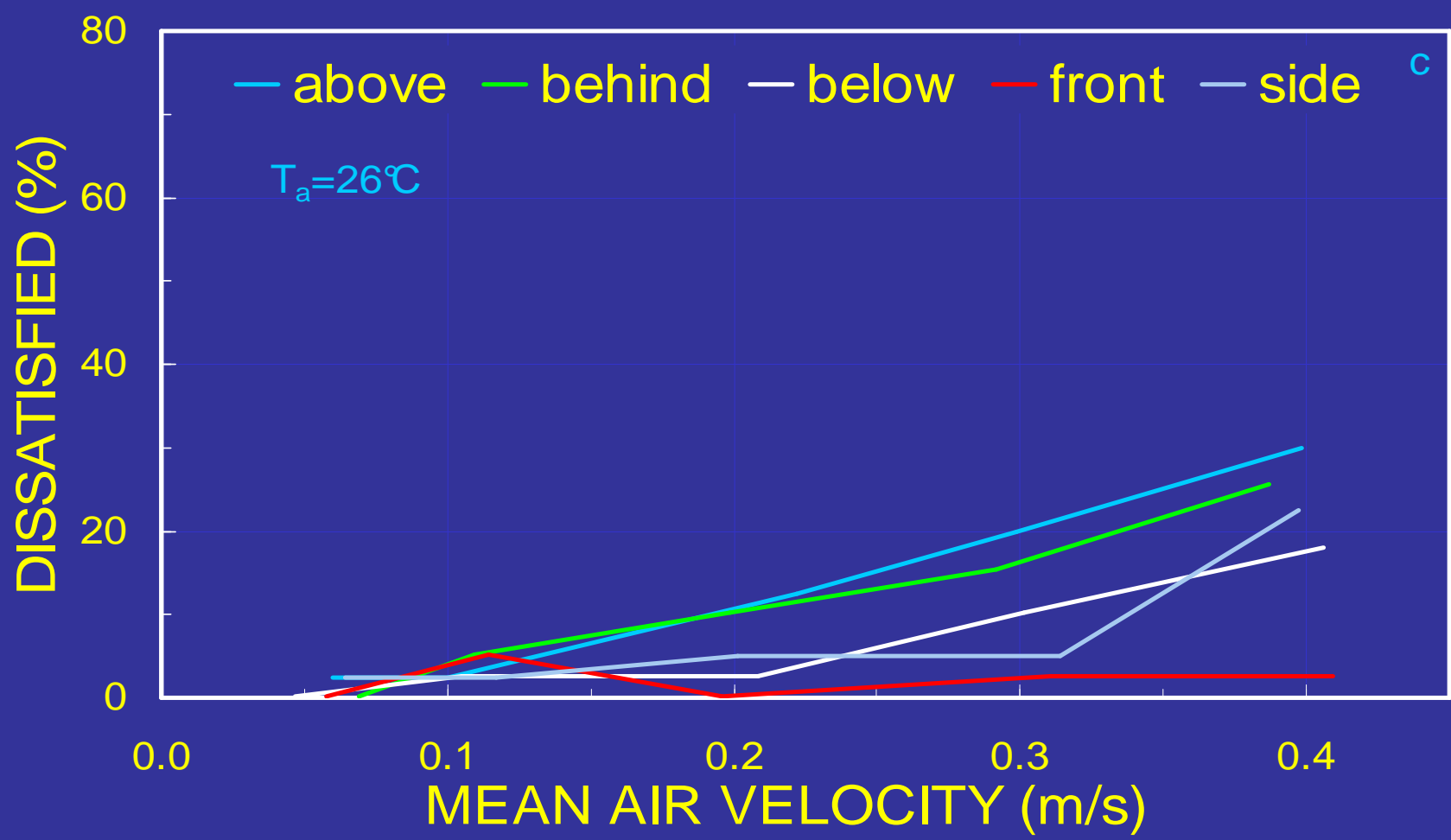


Airflow direction and draught

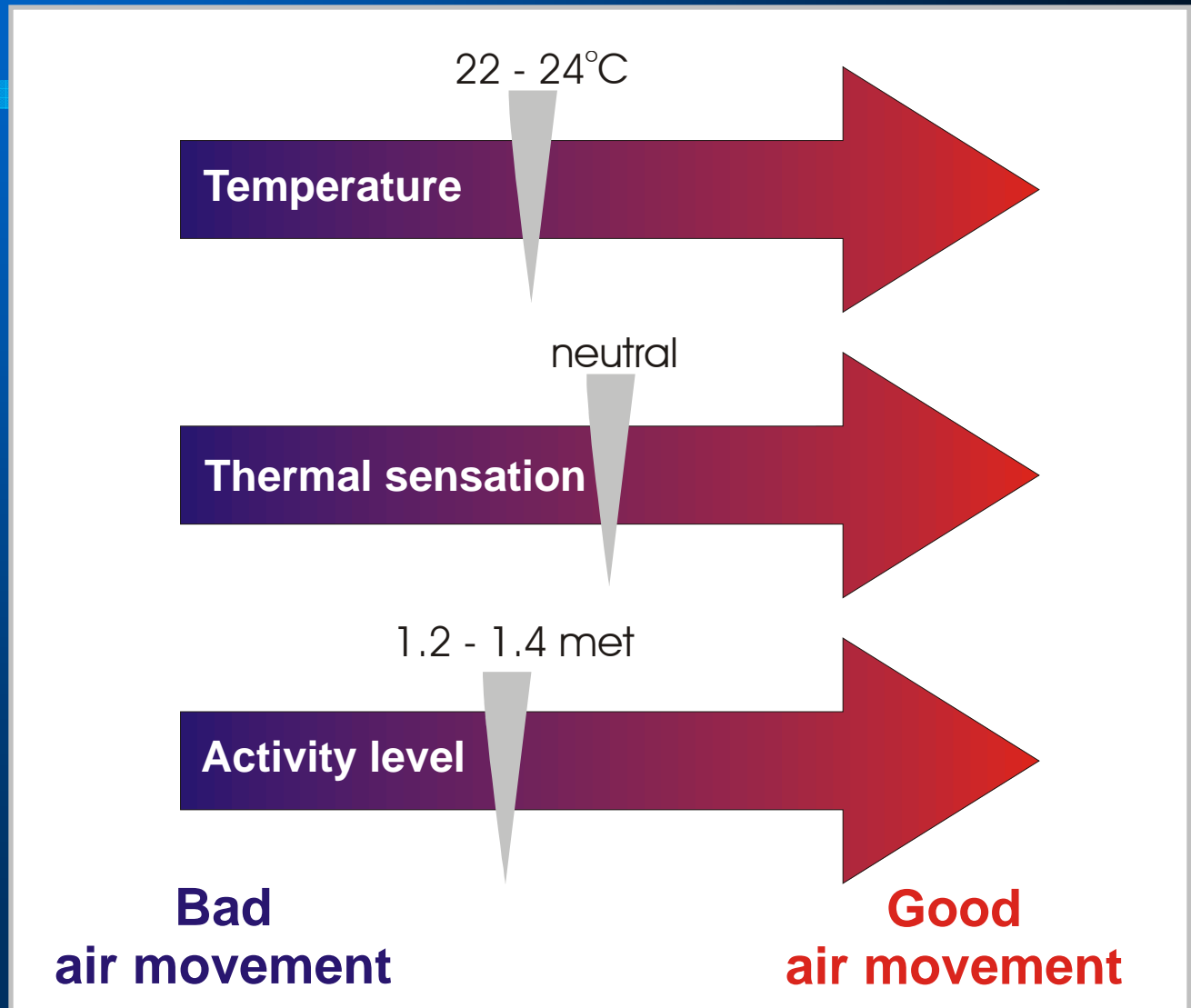




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In summary



Are you bothered by draught at your workplace?

