Related Research: Ventilation Effectiveness in UFAD and Displacement Ventilation

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CBE Translation

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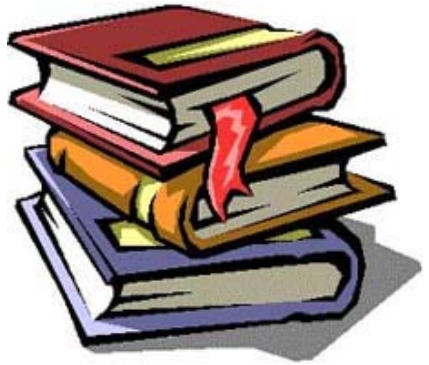
Overview

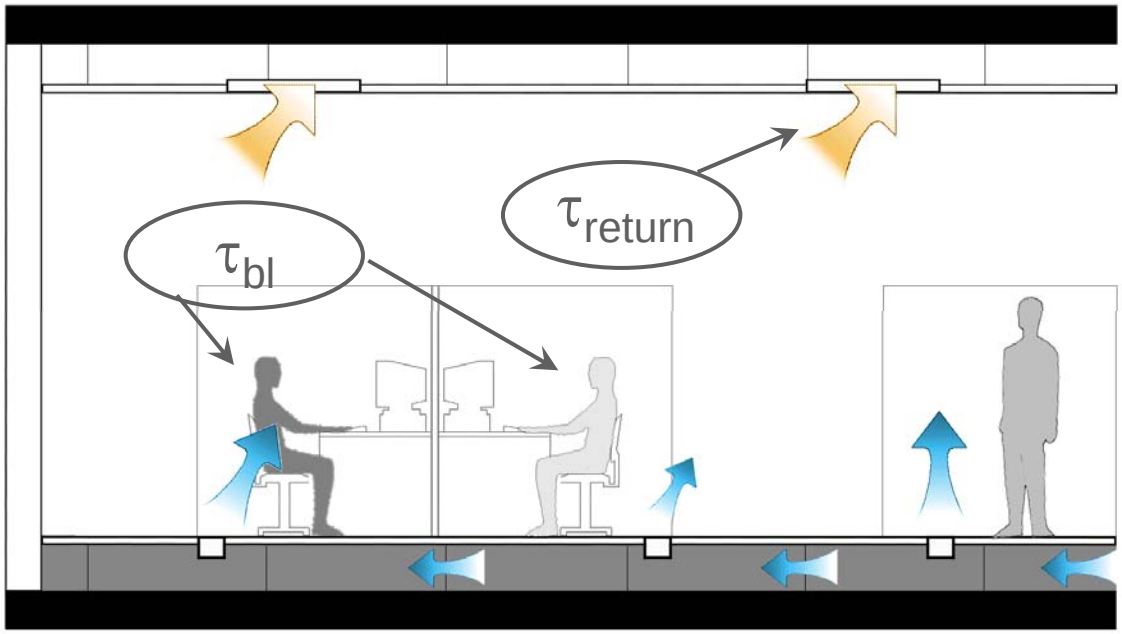
- **“Analysis and Testing of Methods to Determine Indoor Air Quality and Air-Exchange Effectiveness”**
- **Authors: Andreas Jung and Prof. Manfred Zeller**
- **Rheinisch-Westfälische Technical University of Aachen, Germany**
- **Published 1994**
- **Sponsored by FLT – Research Federation for Air and Drying Technology**
- **Laboratory study**



Definition of air change effectiveness (ACE)

$$\text{Local ACE} = \frac{\text{Age of air at return } (\tau_{return})}{\text{Age of air at any given point } (\tau_i)}$$

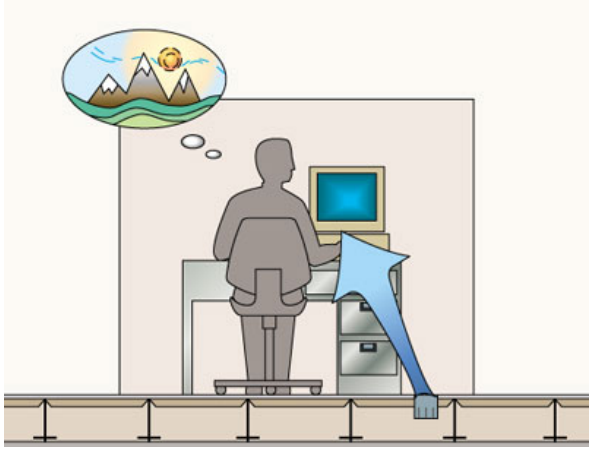
- ACE < 1 → short circuiting
- ACE = 1 → mixed
- ACE > 1 → better ventilation performance



ASHRAE Standard 62.1 – 2004, Addendum N

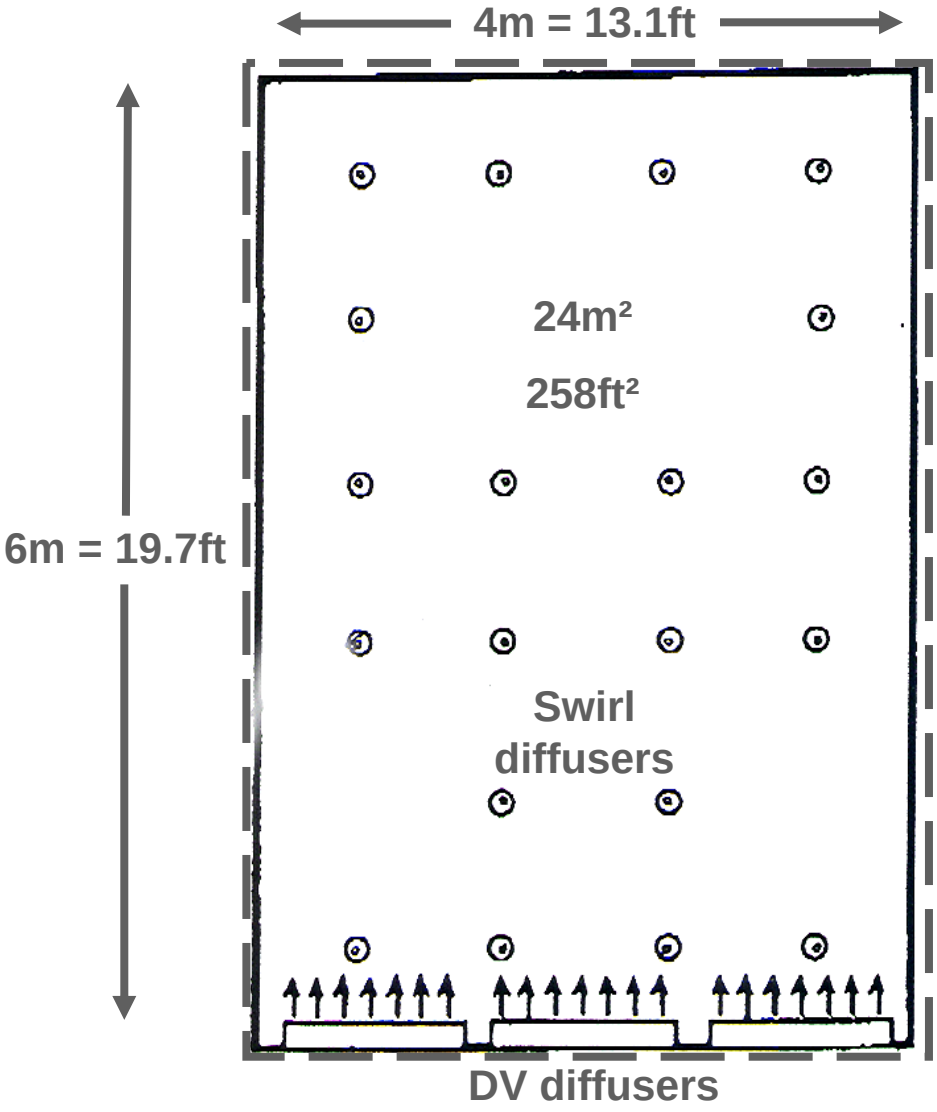
- **Global Air Exchange Effectiveness (ACE)**

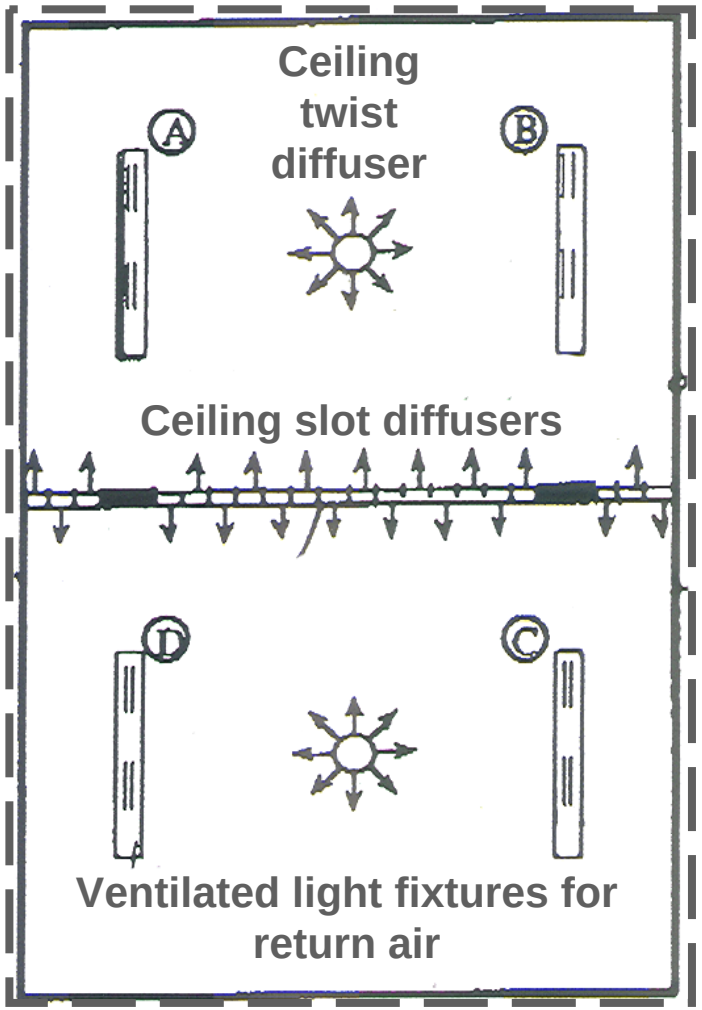
	Heating	Cooling
Overhead (OH) system	0.8	1.0
Displacement Ventilation (DV) System	0.7	1.2
Underfloor Air Distribution (UFAD) System*	0.7	1.0



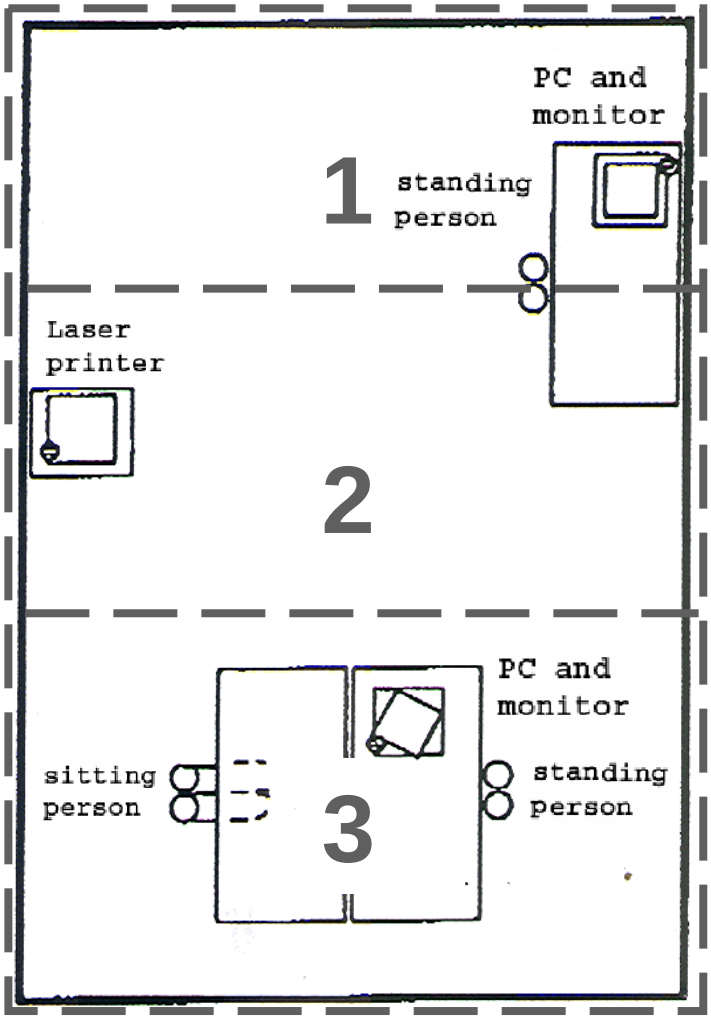
*No data available,
assuming worst case scenario

Floor and ceiling plans





Location of heat sources



Nearly adiabatic conditions

Test conditions

- 100% outside air for all tests

- CASE 1

  Investigate impact of air exchange rates (2.5, 5 and 8 per hour = 0.35, 0.7 and 1 cfm/sf) at constant internal load (20 W/m^2 = 1.8 W/ft^2)

- CASE 2

  Investigate impact of arrangement and type of heat sources (3 load levels: 20, 40 and 65 W/m^2 = 1.8, 3.7 and 6 W/ft^2)

  air exchange rates were adjusted to maintain same room temperature difference (return – supply) of about 8.5K = 15.3°F

Heat source distribution

Internal Gain	20 W/m²		40 W/m²		65 W/m²	
a) Distribution	Amount	Internal Gain [W]	Amount	Internal Gain [W]	Amount	Internal Gain [W]
Manikins	2	200	2	200	3	300
PC + Monitor	1	140	1	140	2	360
Laser Printer	1	60	1	60	1	60
Lighting		80		80		80
Floor Heating				480		740
Total load:		480		960		1540
Point load:		85%		40%		45%
Area load:		15%		60%		55%

b) Air exchange	Temperature difference between return and supply air		
2.5 h-1	8.5 K		Design
5 h-1	4.2 K	8.5 K	case
8 h-1	2.7 K		8.5 K

Local values of ACE for design case

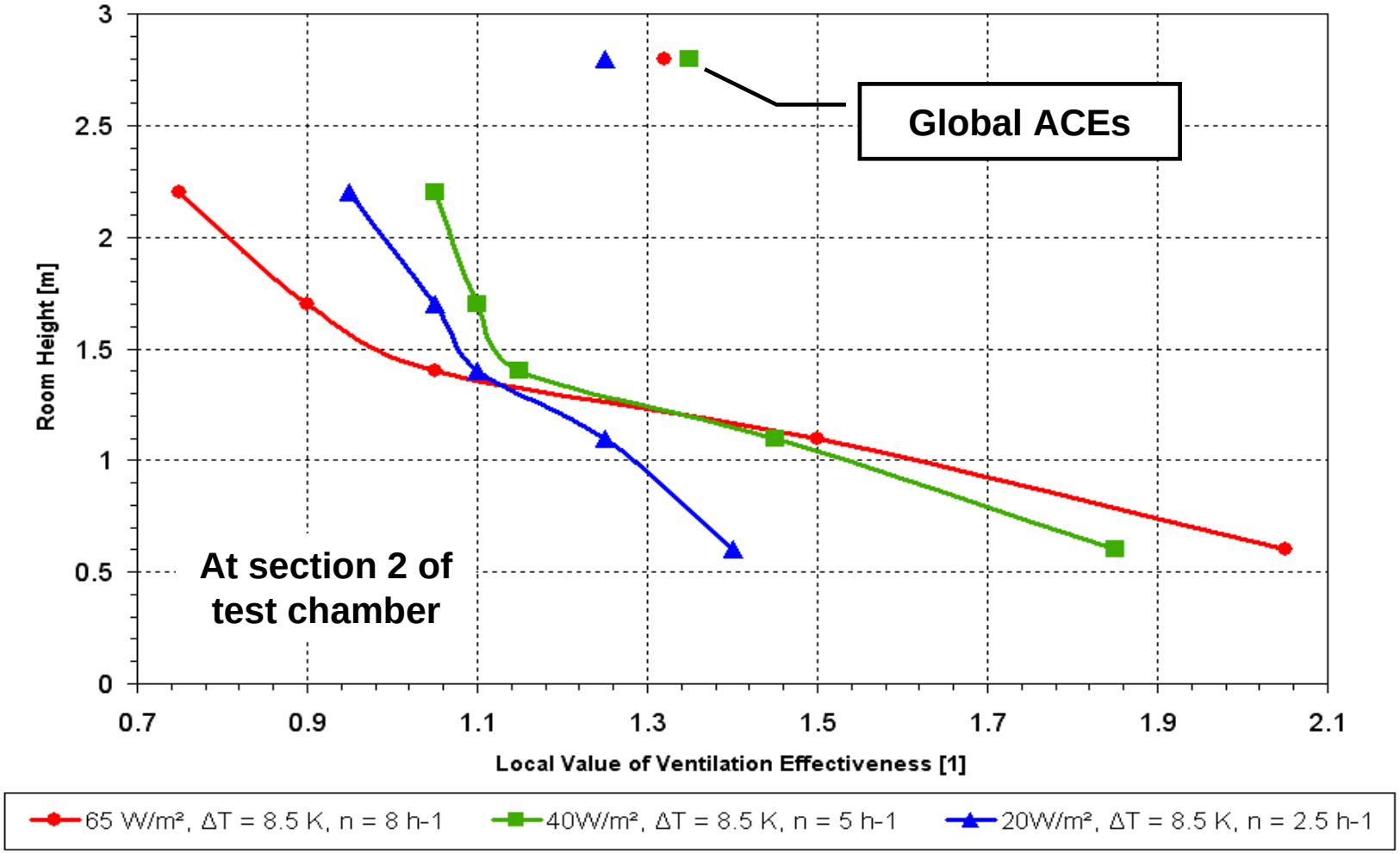
Measurement	Place of Measurement	Ceiling Twist	Ceiling Slot	Floor Twist	DV
Local value of ventilation effectiveness [1]	Light fixture A	0.95	0.98	1.03	0.96
	Light fixture B	1.03	0.98	1.22	1.22
	Light fixture C	1.05	1.03	1.00	0.94
	Light fixture D	1.01	1.00	0.88	0.89
	Section 3				
	Nose of standing manikin	0.95	0.94	1.47	1.22
	0.3m in front of standing manikin	0.95	0.93	1.13	1.00
	Nose of sitting manikin	0.97	0.95	2.01	1.68
	0.3m in front of sitting manikin	0.98	0.95	1.79	1.44
	Section 1				
	Nose of standing manikin	0.93	0.93	1.87	1.90
	0.3m in front of standing manikin	0.92	0.93	1.20	1.04

Floor twist diffusers

- **Test Conditions**
  - Number and arrangement of diffusers changed between tests to achieve constant airflow rates per diffuser (~35 m^3/h = 20 cfm)
  - Throw height of diffusers is ~1.1 m (3.6 ft)

- **Findings**
  - Higher global ACE and especially local ACE in lower occupied zone
  - Lowest local ACE in occupied zone still 15% higher than for best case in mixed systems

Findings for floor twist diffusers – Case 2
Local and global air exchange effectiveness



Findings for displacement ventilation (DV) systems

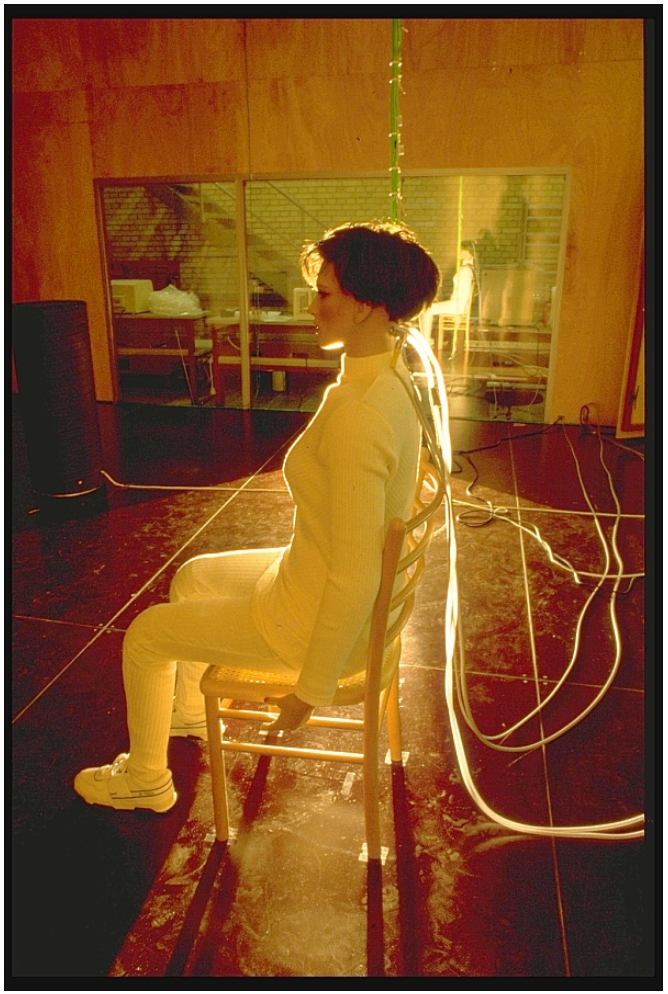
- **In contrast to floor diffusers:**
  - Greater variation of ACE with height
  - High sensitivity to heat source configuration
  - Local disturbances have very strong impact on ACE

Source: Department of Building Technology and Structural Engineering, Aalborg University, Denmark

DV systems – local disturbances

- **Effect of computer fan**
  - Test conditions
    - Fan airflow: 50 m^3/h = 30 cfm
    - Total room airflow: 168 m^3/h = 99 cfm
  - Findings
    - Without fan: ACE=3 next to the nose of manikin
    - Fan in operation: ACE<1 next to nose due to destruction of thermal boundary layer produced by manikins

- **Effect of breathing**
  - Test conditions
    - Simulated breathing
  - Findings
    - ACE drops from 3.0 to 2.0



Source: Department of Building Technology and Structural Engineering, Aalborg University, Denmark

Conclusion

- **Ceiling twist and ceiling slot diffusers**
  - Create nearly mixed conditions
  - Attention to short-circuiting
- **Floor twist diffusers and DV systems**
  - Significantly increase supply of fresh air within the breathing zone of occupants
  - UFAD
    - Global ACEs are in the range of 1.2 to 1.3
    - Local ACEs are in the range of 1.2 to 1.8
  - DV
    - Global ACEs are in the range of 1.2 to 1.3
    - Local ACEs are in the range of 0.8 to 3.7

- **Research needed to investigate typical U.S. UFAD configurations**

Questions?

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