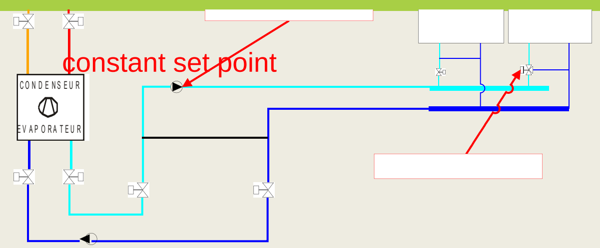
HVAC CONCEPTS FOR RADIANT COOLING SYSTEMS

Schematic principles

1) «Conventional» design for radiant cooling



cooling pumps

Constant flow rate

2 way valve (no bypass, variable flow)

hydronic connection with bypass

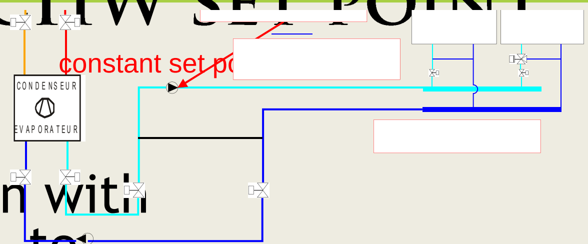
- Hydronic design with fixed 6/12°C Chilled water and mixing to 14-16 °C for the slab/panels
- Loss of the benefit of the higher COP with higher evaporation temperature
- Bypass on the demand side → low differential, more power for pumps

chilled water return

by-pass

Bypass (3 way valve)?

2) Improvement by controls: «conventional for radiant cooling» design optimised with gliding CHW set point



- Hydronic design with gliding 6/12°C to 12/17°C Chilled water and mixing to 14-16 °C for the slab/panels with gliding according to dehumidification (dew point)
- Only part time benefit of the higher COP with higher evaporation temperature

cooling pumps

Constant flow rate

2 way valve (no bypass, variable flow)

Radiant panel no bypass mixing after 2 way

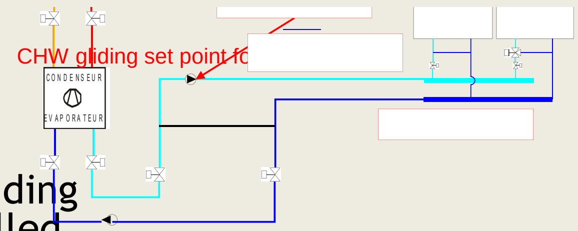
CHW gliding set point 7 --> 12 °C when no dehumidification needed

chilled water return

Higher return CHW temperature

by-pass

3) Further improvement by controls for radiant cooling: «conventional» design optimised with gliding CHW and CWT set point



- Hydronic design with gliding 6/12°C to 12/17°C Chilled water and mixing to 14-16 °C for the slab/panels with gliding according to dehumidification (dew point)
- Benefit of the higher COP with higher evaporation temperature
- Benefit of the lower condensing temperature

cooling pumps

Constant flow rate

2 way valve (no bypass, variable flow)

Radiant panel no bypass mixing after 2 way

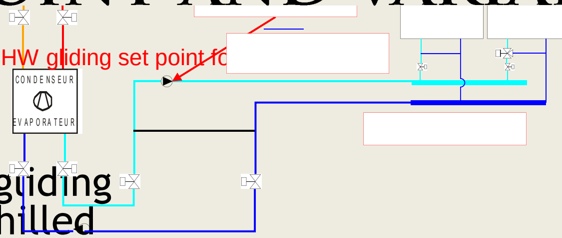
CHW gliding set point 7 --> 12 °C when no dehumidification needed

chilled water return

Higher return CHW temperature

by-pass

4) Further improvement by controls: «conventional» design optimised with gliding CHW and CWT set point and variable flow



- Hydronic design with guiding 6/12°C to 12/17°C Chilled water and mixing to 14-16 °C for the slab/panels with gliding according to dehumidification (dew point)
- Benefit of the higher COP with higher evaporation temperature
- Benefit of the lower condensing temperature
- Less power for CHW and condensing water loop

cooling pumps

Variable flow rate

2 way valve (no bypass, variable flow)

Radiant panel no bypass mixing after 2 way

CHW gliding set point 7 --> 12 °C when no dehumidification needed

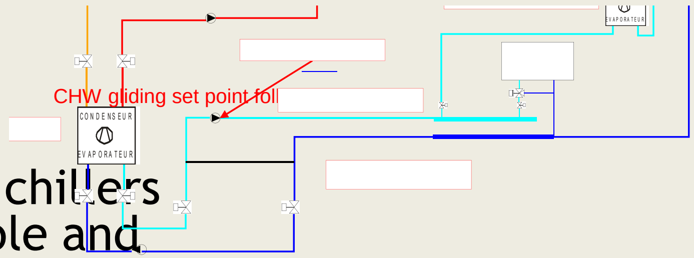
chilled water return

Higher return CHW temperature

by-pass

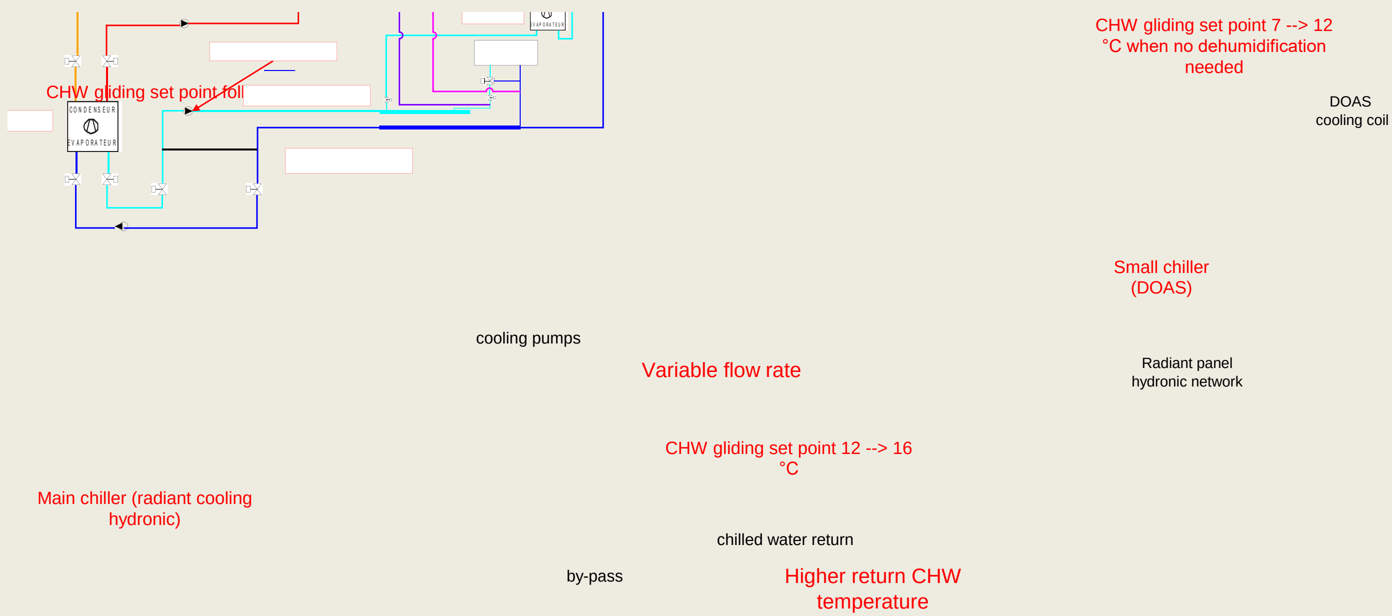
5) Improvement by design

- Separate chillers for sensible and latent cooling loads
  - Main chiller for sensible cooling
    - Higher CHW temperature (7°C → 12-14°C)
    - Higher COP
  - Smaller chiller for latent load
    - dehumidification



6) Improvement by design

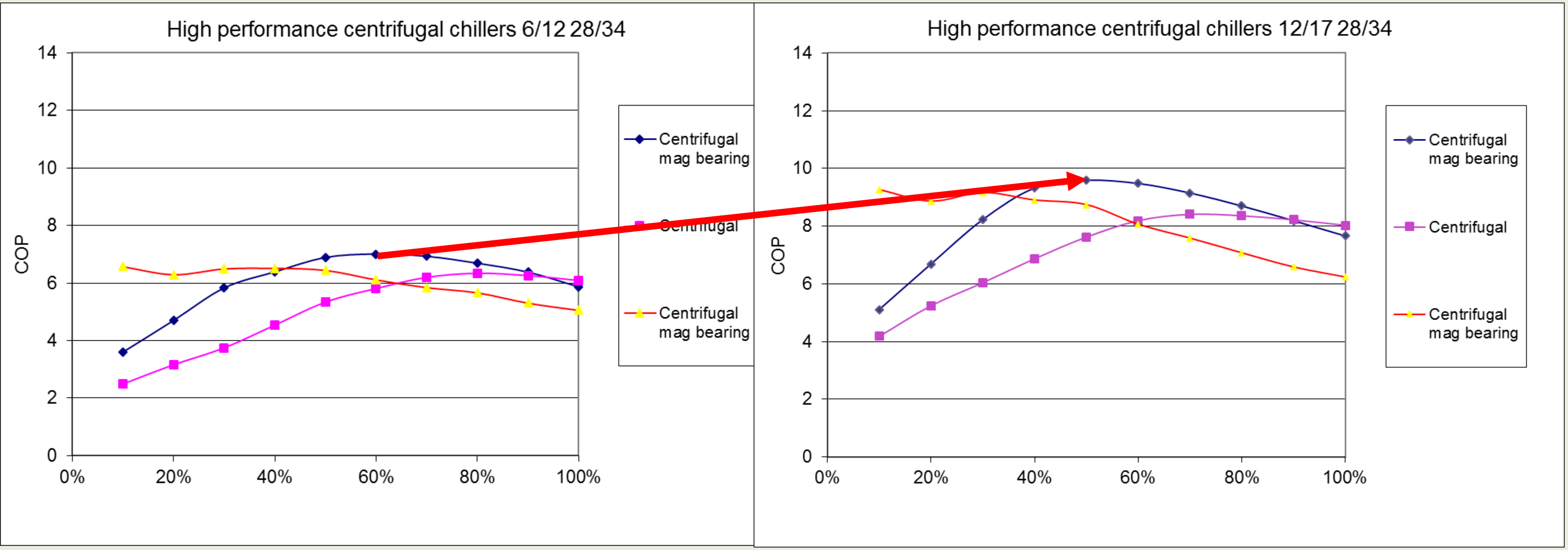
- Separate chillers for sensible and latent cooling loads
  - Main chiller for sensible cooling
    - Higher CHW temperature (7°C → 12-14°C)
    - Higher COP
  - Smaller chiller for latent load
    - Dehumidification
  - Free-cooling for the radiant network (Northern India, …)



Recap of the concepts

1. Conventional
2. Improved conventional by control
   - Gliding CHW temperature
3. Further improvement by controls: «conventional» design optimised with gliding CHW and CWT set point
4. Further improvement by controls: «conventional» design optimised with gliding CHW and CWT set point and variable flow
5. Improvement by design
6. Improvement by design

Chillers performances (AHRI 550/90) Influence of CHW temperature on COP



Importance of air velocity for comfort and heat exchange coefficients

- Convective h_c~2.7 W/m2-K at 0 m/sec air velocity
- Convective heat transfer with air velocity increases very rapidly
- Importance of ceiling fans in thermal comfort

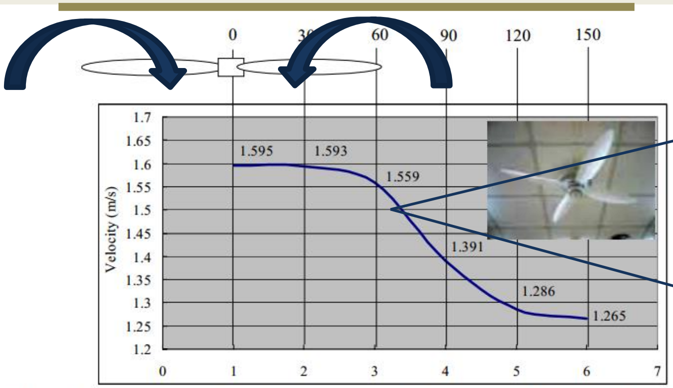


Figure 2. Profile of mean air velocity generated by the studied ceiling fan at height 150cm (fan was set at medium rotation speed)

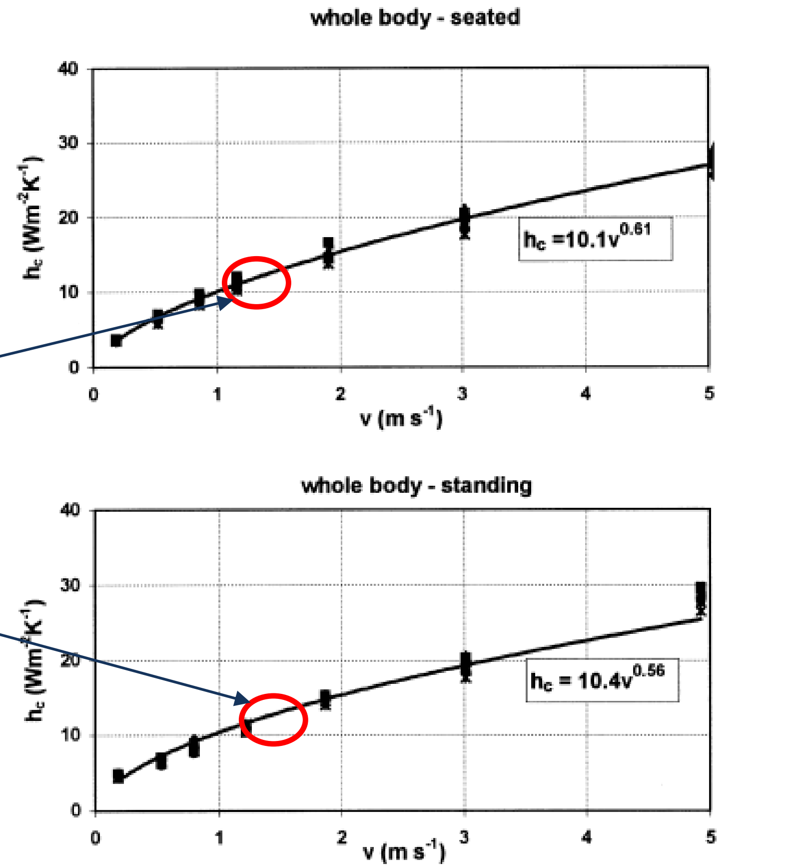
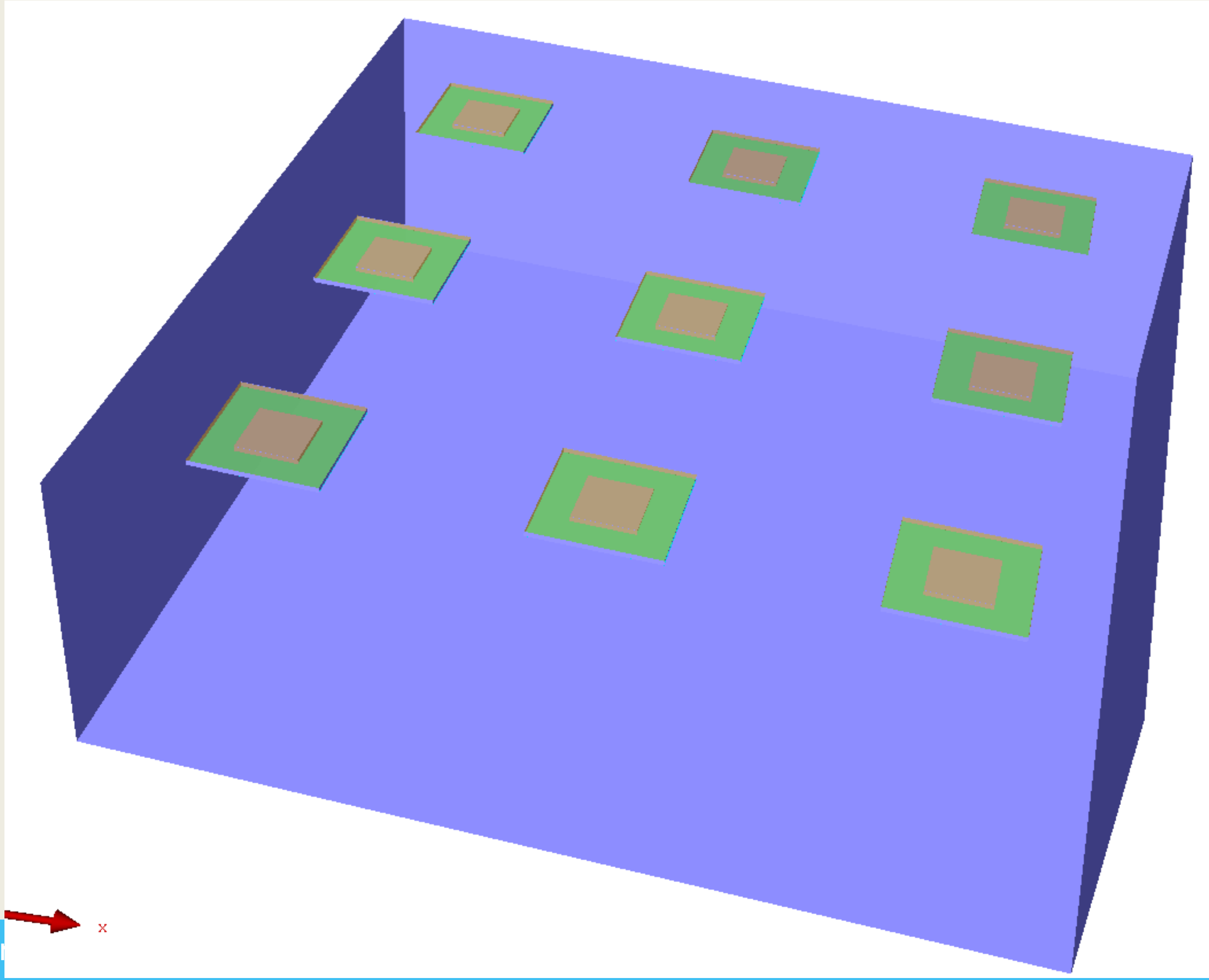


Fig. 7 Convective heat transfer regression models for the whole body, in seated and standing positions

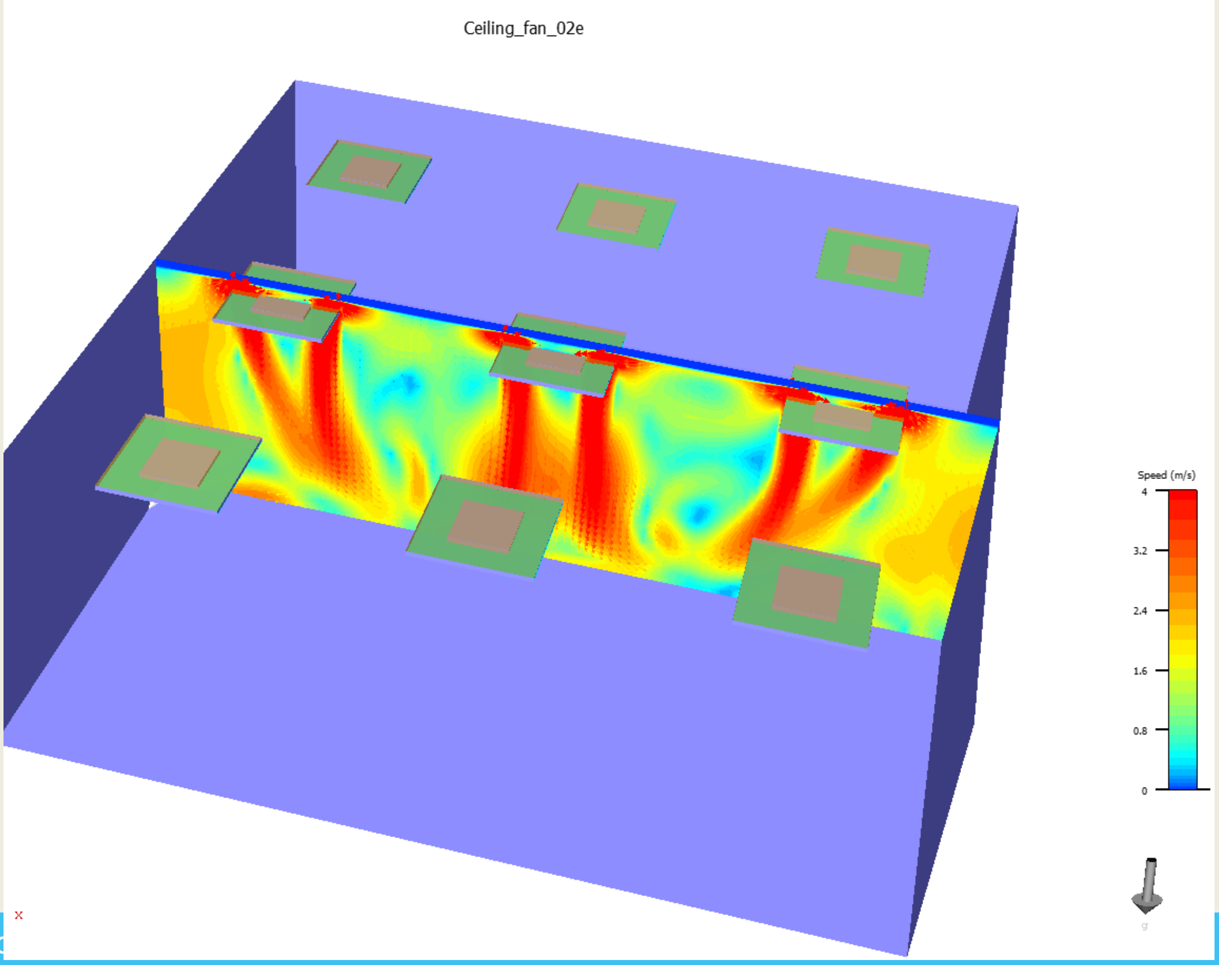
- Richard J. de Dear · Edward Arens · Zhang Hui · Masayuki Oguro, Convective and radiative heat transfer coefficients for individual human body segments, Int J Biometeorol (1997) 40:141–156
- Hsu-Cheng Chiang, Chung-shu Pan, Hsi-Sheng Wu, Bing-Chwen Yang, Measurement of Flow Characteristics of a Ceiling Fan with Varying Rotational Speed, Proceedings of Clima 2007 WellBeing Indoors

CFD (Computational Fluid Dynamics) analysis of the air flow pattern on the ceiling

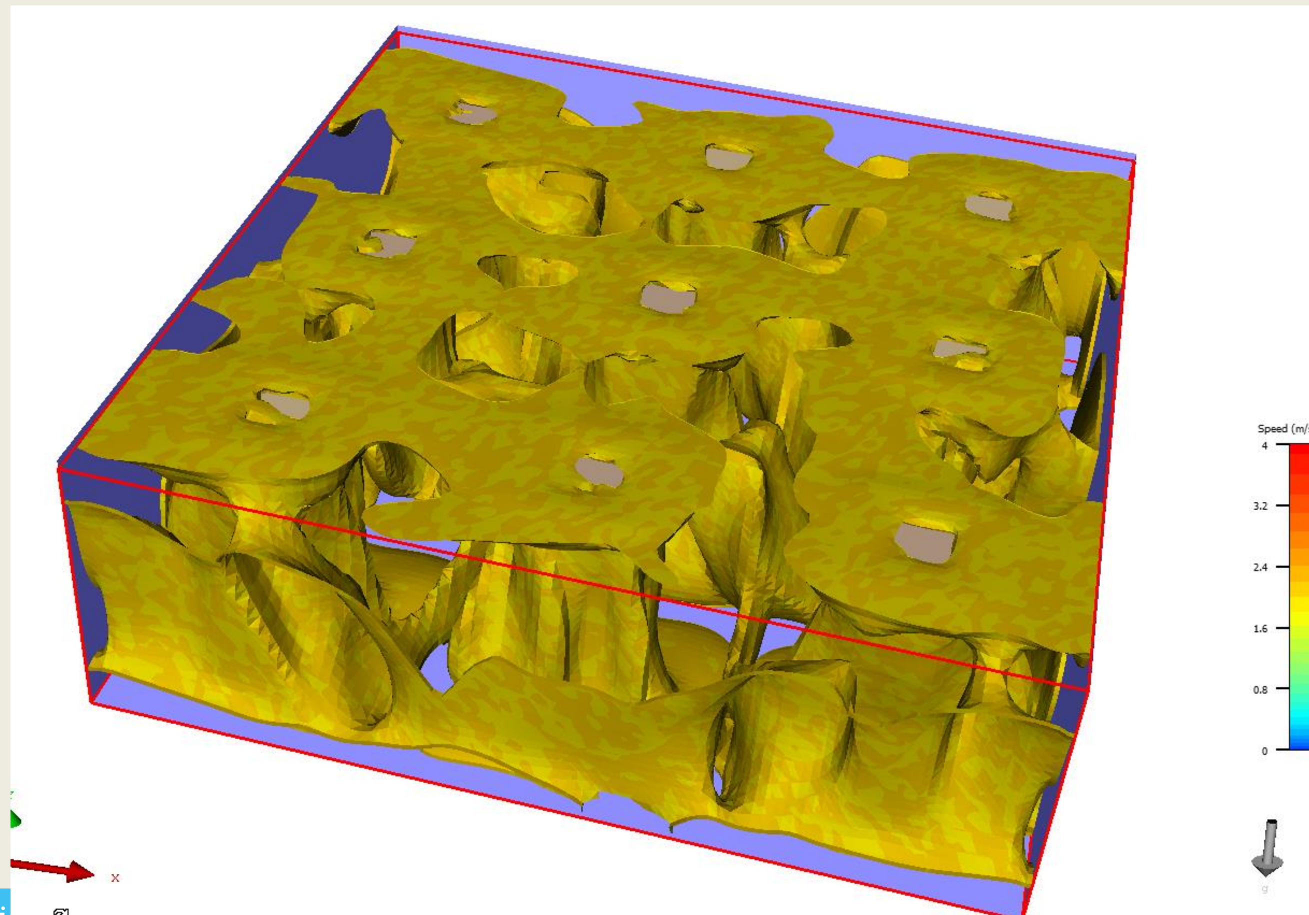
- 9x9m2 office
- 9 ceiling fans
- 7500 cfm each (max speed)



- Velocity on the ceiling



- Volume where the air speed is > 2 m/sec



Increase of the heat transfer at the ceiling by the use of ceiling fans

- Increased heat transfer coefficient by air movement
  - Ceiling
  - ~2.0 m/sec at ceiling level → h_c increased from 2.8 to ~8.8 W/m_2-K
  - H_r+h_{conv} ~ 13 W/m_2-K
  - COP of gained heat transfer ~> 8 with high efficiency fan

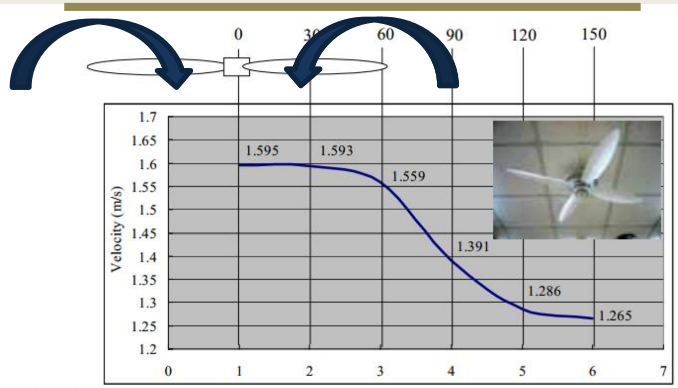


Figure 2. Profile of mean air velocity generated by the studied ceiling fan at height 150cm (fan was set at medium rotation speed)

Watmuff et al. (1977) report that this equation should be

$$h = 2.8 + 3.0V$$

SOLAR ENGINEERING OF THERMAL PROCESSES

Second Edition

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- Further studies needed on the topics and integration in building simulation software
- Possible in TRNSYS (by using correlations)
- Other softwares ?

THANK YOU