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Flow interaction between diffuse ceiling ventilation and thermal plumes

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CONTENTS OF THE STUDY

- Test chamber
- Literature review
- Measurements
- CFD-simulations
- Results
- Conclusions

2016

2017

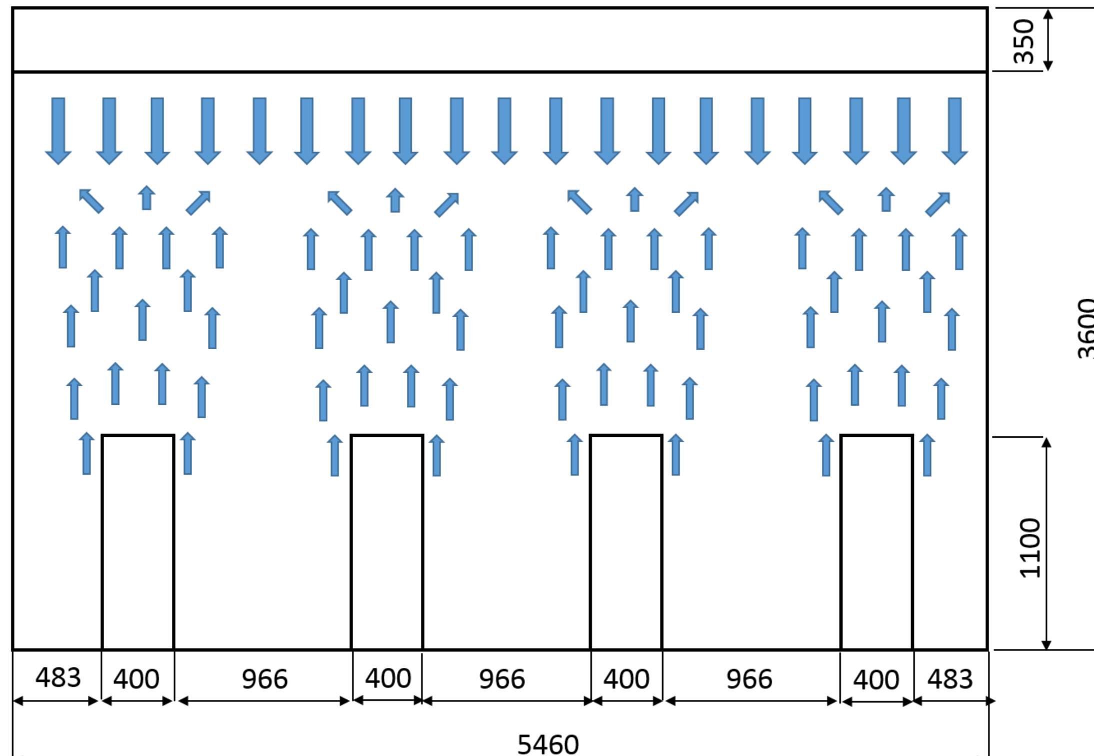
2018

Müller, D., Kandzia, C., Kosonen, R., Melikov, A. K., & Nielsen, P. V. (2013). Mixing Ventilation. Guide on mixing air distribution design. Federation of European Heating and Air-Conditioning Associations, REHVA, ISBN 978-2-930521-11-4.

Zhang, C. (2016). Diffuse Ceiling Ventilation – Air Distribution and Thermal Comfort. Dissertation, Aalborg University, Denmark.

FLOW INTERACTION – EFFECT ON THE FLOW FIELD

- Velocity and temperature
- Turbulent motion
- Frequency of fluctuations
- Airflow direction
- => Flow behavior
- => Draught rate
- => Thermal comfort



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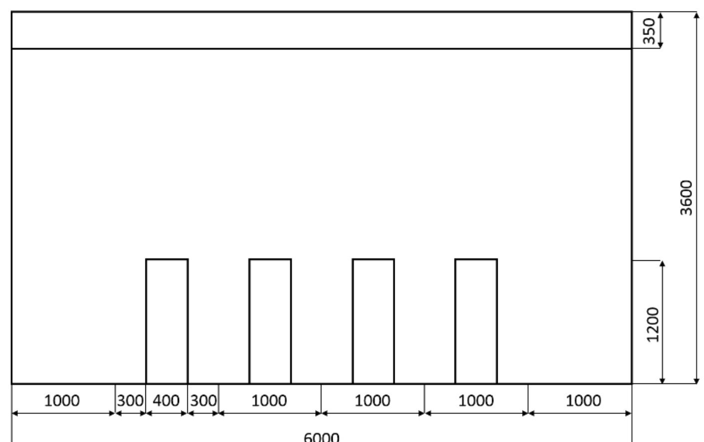
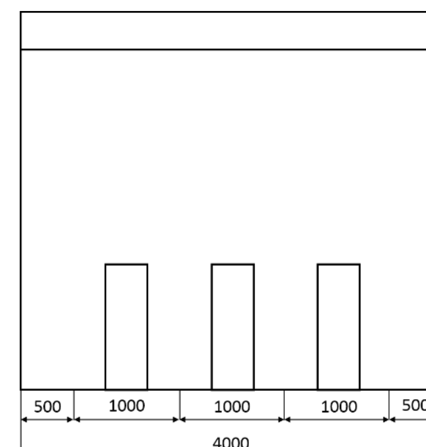
TEST CHAMBER

- 6 m (L) x 4 m (W) x 3.6 m (H)
- Air handling unit - 0…25 l/s per floor square – cooling and heating – heat recovery
- 3 water circles - air handling unit, room devices and window simulation
- Human manikin, cylindrical and seated test dummies, thermal loads and furniture





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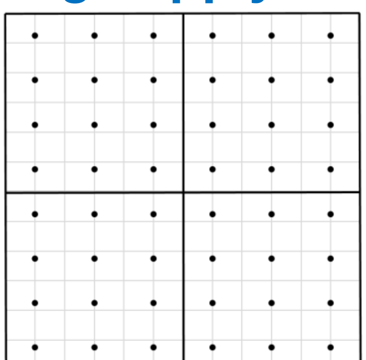
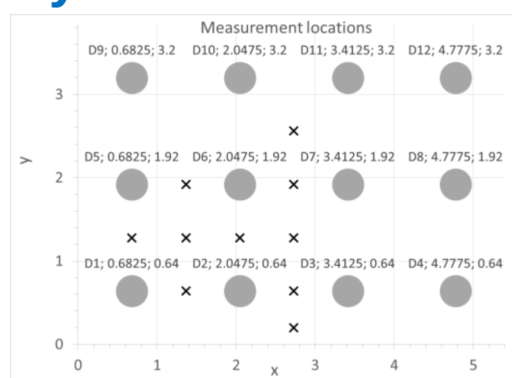
EXPERIMENTAL SET-UP

- 12 test dummies produce thermal plumes 40…80 W/m^2 (floor)
- Air distribution – through suspended ceiling plate at 3.2m (H)
- anemometers – height 0.1m, 0.6m, 1.1m, 1.4m, 1.7m…2.9m

Ceiling supply ~0.5%



Cylindrical dummies



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MEASUREMENTS

- Hot-sphere anemometer (7 pcs)
- Ultrasonic anemometer (1 pcs)
- Tinytag humidity and temperature sensors
- Swema 3000 – pressure differences
- Infrared thermography – surface temperature level
- Smoke visualization with led-lighting mast
- Low-weight ribbons – investigate large flow motion

Nielsen, P. V. (ed.), Allard, F., Awbi, H. B., Davidson, L., & Schälin, A. (2007). Computational Fluid Dynamics in Ventilation Design. REHVA Guidebook no 10, ISBN 2-9600468-9-7.

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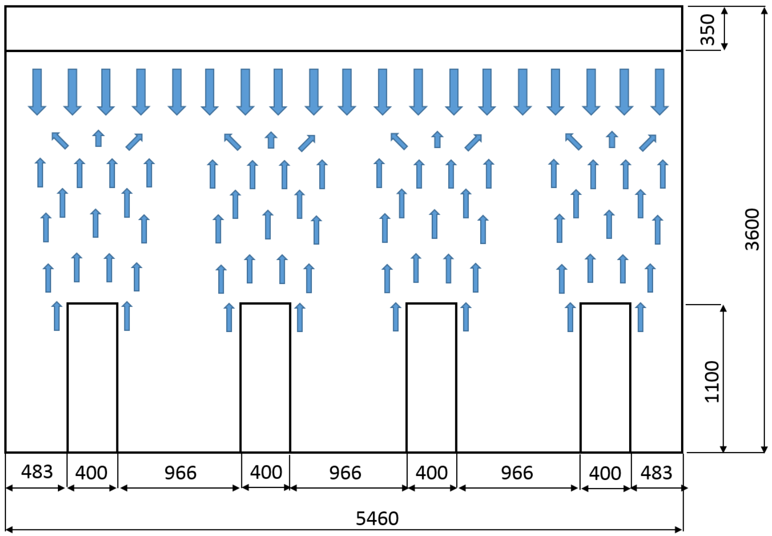
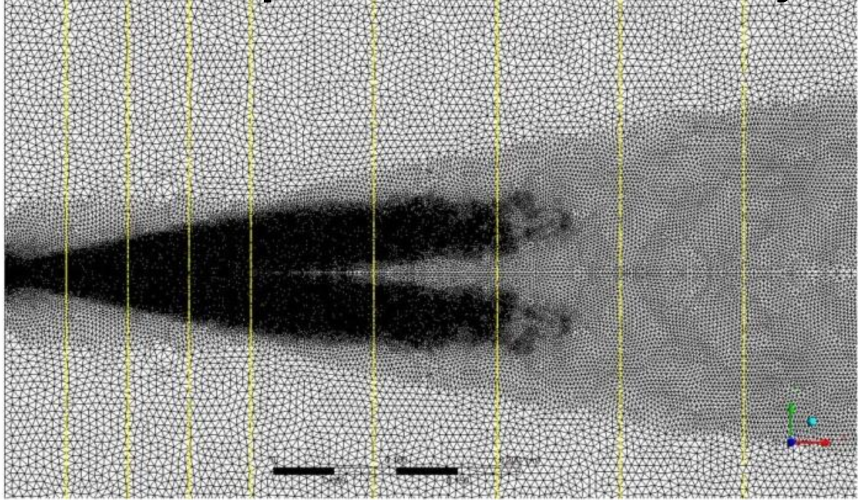
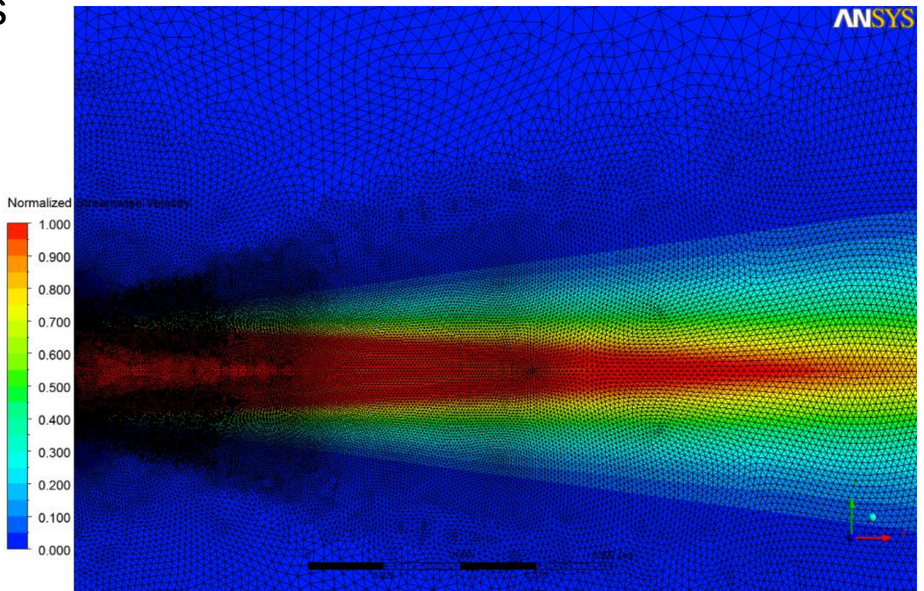
Grid adaptation – ventilation jet

CFD-SIMULATIONS

- RANS, URANS, LES
- ANSYS ICEM CFD and ANSYS CFX 17.0
- Tetrahedron grid and prismatic elements







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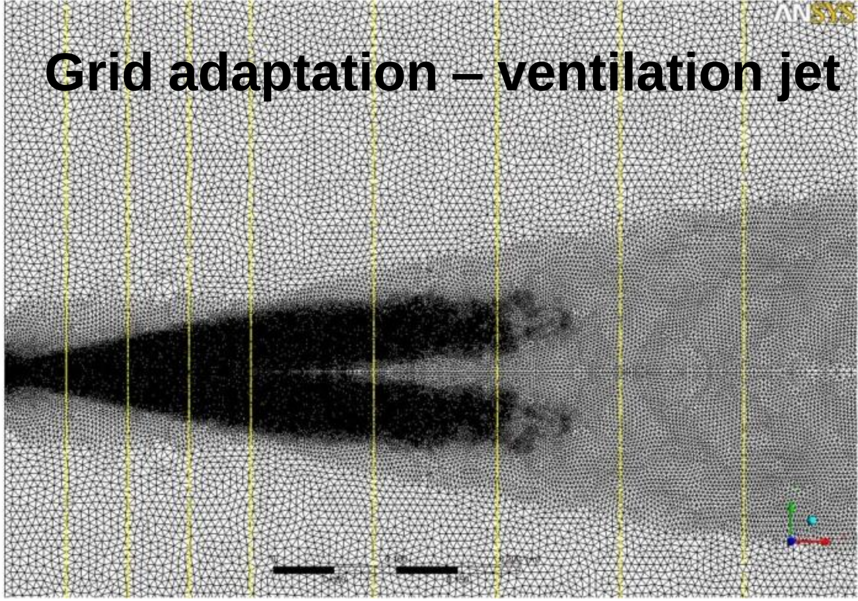
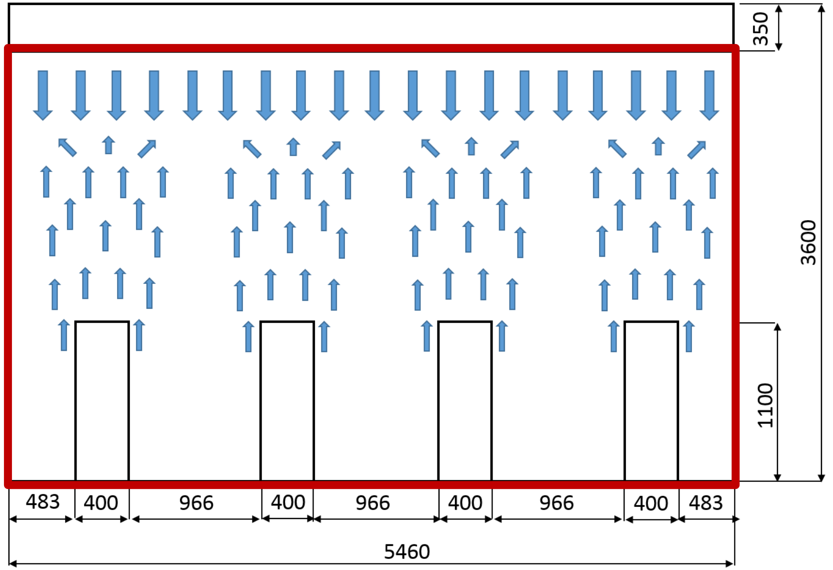
CFD-DOMAIN - EXPERIMENTS

- Temperature for the walls, floor and ceiling
- Nozzles at the suspended ceiling d~14mm
- Supply air jets – velocity, temp, turbulence
- Heat sources – heat flux from dummies
- Exhaust outlet – mass flow (not opening)
- Small opening for balancing the mass conservation in the domain (near zero)

=> This may avoid over-specification of BC





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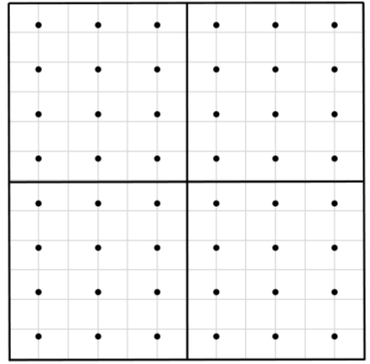
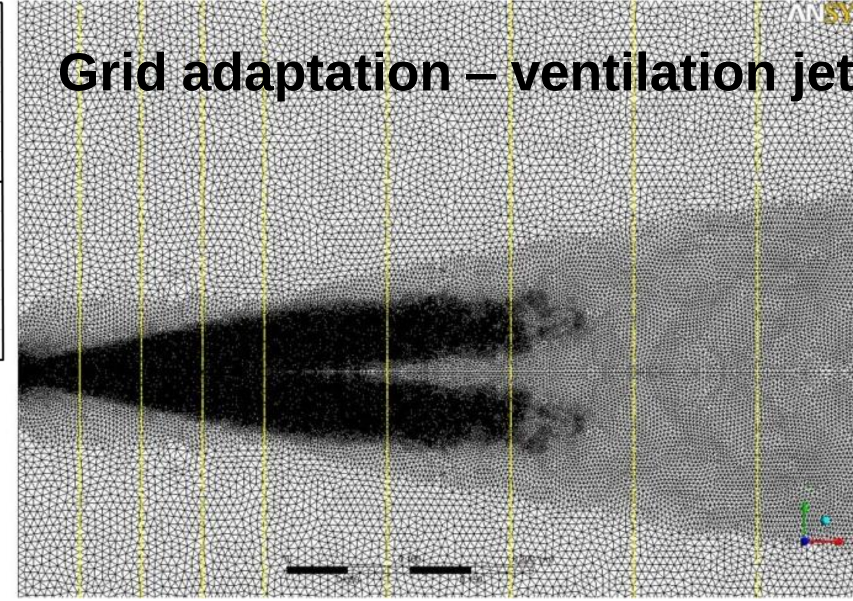
CFD-SIMULATIONS

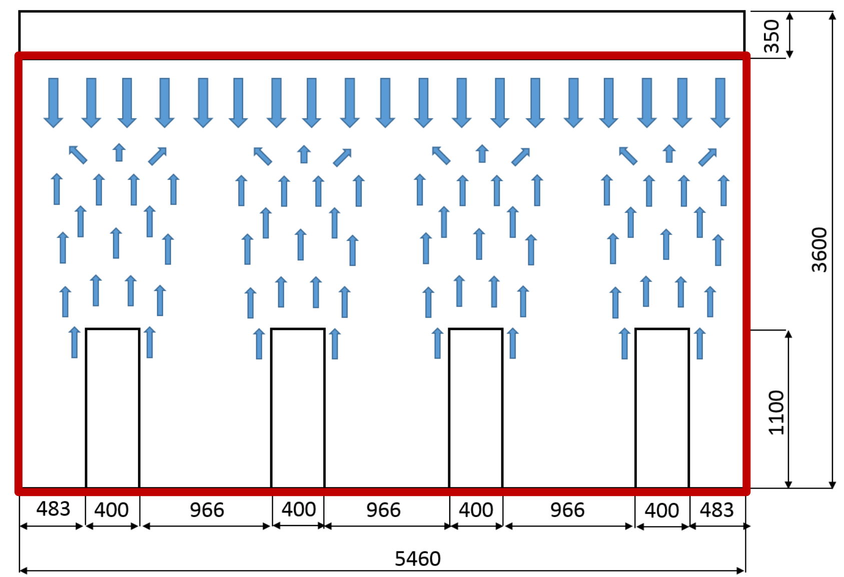




- LES initial condition from RANS

  Otherwise start from stagnant situation
- Supply air jets individually => box method

  Otherwise real geometry with nozzles
- Iteration, residuals, grid dependency
- Sensitivity analysis for the BC



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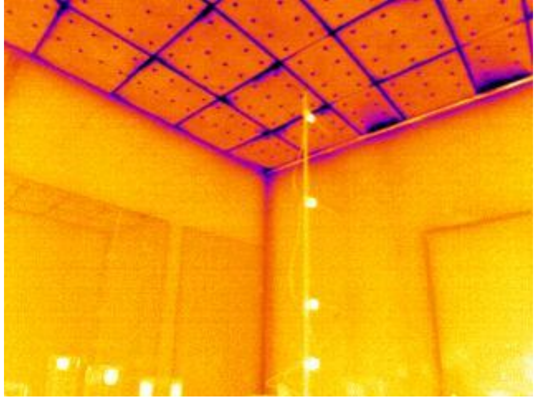
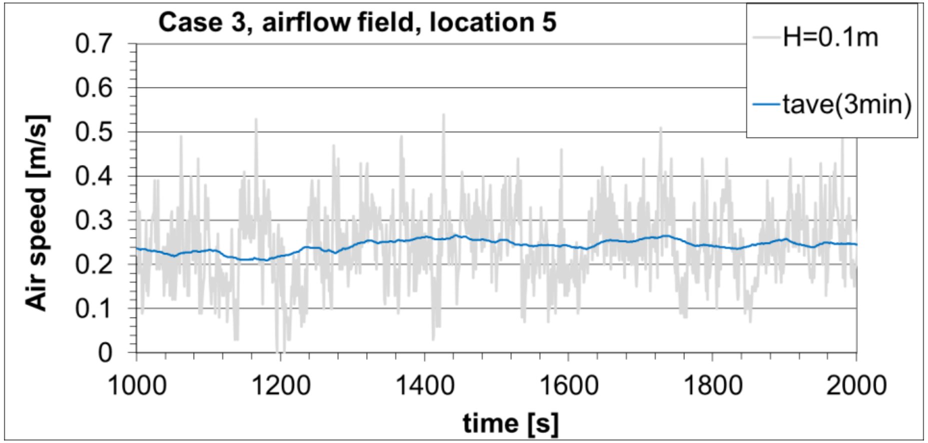
RESULTS



- Large scale motion seems to occur randomly
- Flow motion increased while heat load increased
- Flow behavior varies depending on location
- Fluctuation different near dummies and surrounding



Flow interaction – thermal plume

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CONCLUSIONS

- Objectives - Airflow interaction phenomena
- Experimental set-up in a test chamber
- CFD-simulations for a generic view
- Results - Effects on the flow field