A THERMAL MODEL OF AN ACTIVE CHILLED BEAM

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BuildSim-Nordic 2016, Trondheim

26 September 2016

BACKGROUND	**Principles and benefits of active chilled beams**
OBJECTIVES	**Aim and purpose of the model**
METHODOLOGY	**Theory and measurements**
RESULTS	**Accuracy and practicability**
CONCLUSIONS	**Main findings and future work**

BACKGROUND OBJECTIVES METHODOLOGY RESULTS CONCLUSIONS

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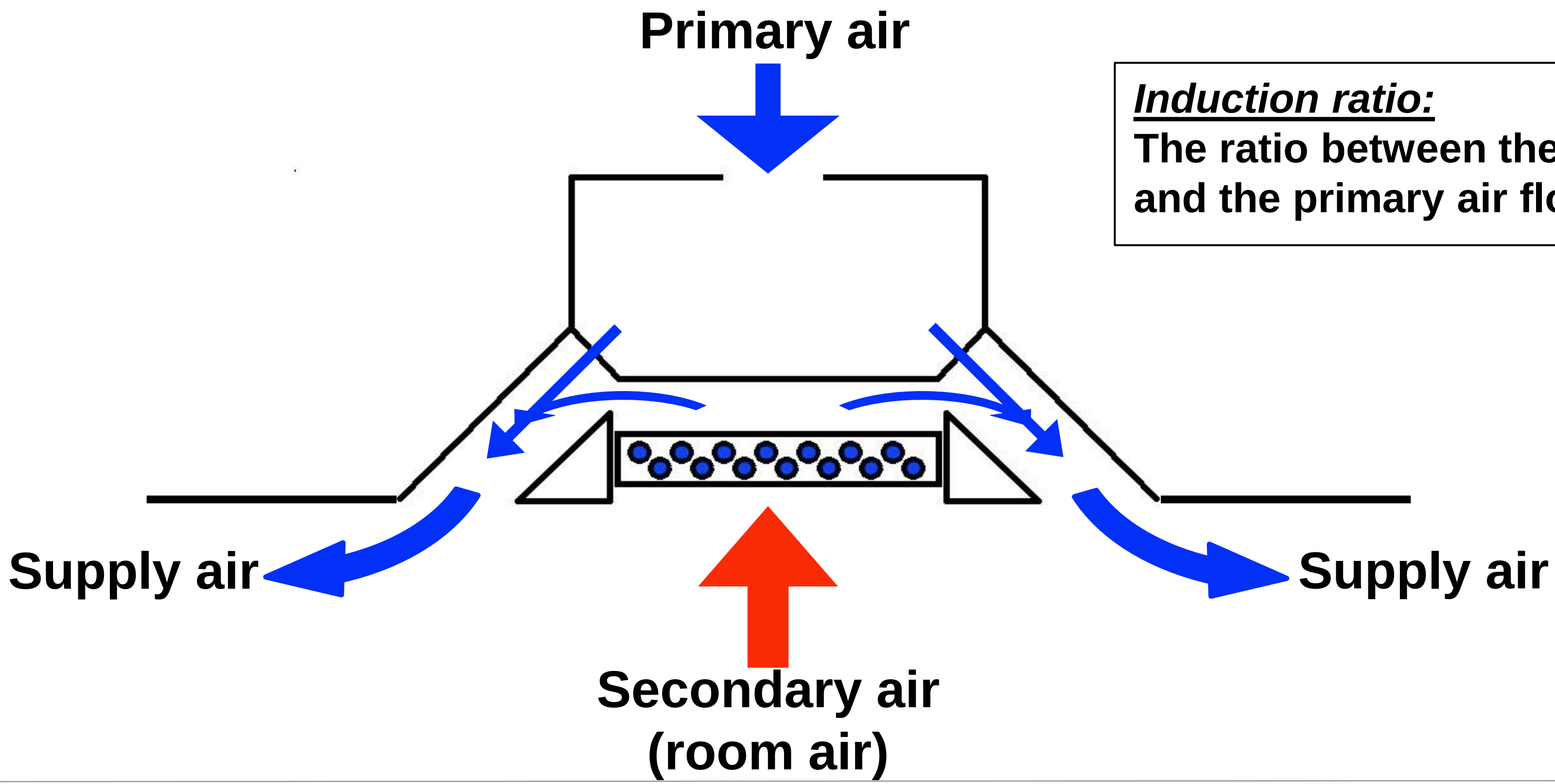


Induction ratio:
The ratio between the secondary and the primary air flow rates.

Efficient heat transfer makes active chilled beams suitable for high temperature cooling.

Advantages of high temperature cooling:

- Better performance of chillers
- More free cooling
- Reduced losses in distribution
- Reduced latent load / Reduced risk of condensation
- Reduced risk of draught
- Reduced need for individual room control

Main objective:

An accurate and practicable active chilled beam model.

Main features:

In contrast to existing models (black box models: $P = k \cdot \Delta T^n$):

- It includes information about flow rate and temperature of supply air.
- The unknown parameters are independent of operating conditions.
- It takes into account that not only the temperature difference, but also the temperature levels, influences the cooling capacity.

Theory

The model is based on NTU correlations and well-established heat transfer theory.

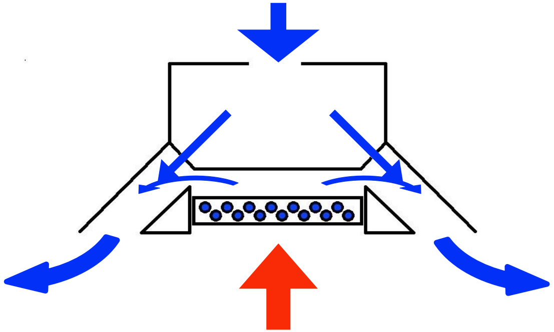
Modelling an active chilled beam involves two main challenges.

- Determination of the induction ratio.
- Determination of the airside convective heat transfer coefficient.

Determination of Induction Ratio

The induction ratio can be determined by applying an energy balance.

The induction ratio is influenced by the operating conditions. Primarily by the primary air flow and the chilled water temperature.



Determination of airside heat transfer

All geometrical properties are lumped into two unknown parameters (C_1 & C_2).

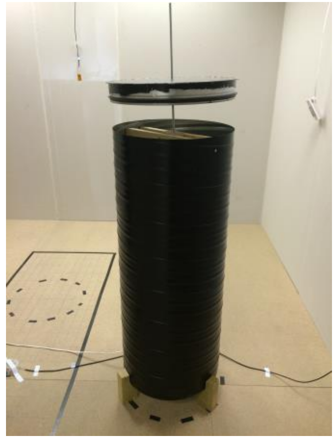
$$(hA)_a = C_1 \cdot k_a \cdot \left(\frac{\dot{m}_a}{\mu_a}\right)^{C_2} \cdot Pr_a^{0.36} \cdot \left(\frac{Pr_a}{Pr_{as}}\right)^{0.25}$$

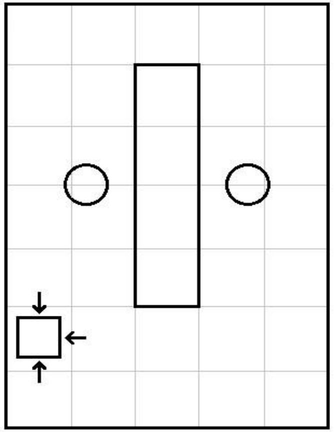
Consequently, it is required to do measurements at at least two different air flow rates in order to calibrate the model.

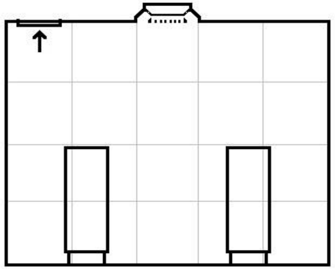
Measurements

All measurements carried out in a full scale mock-up of an office room (12.6 m²).

3 primary air flow rates.
4 chilled water temperatures.
2 chilled water flow rates.
2 levels of internal heat gain.
= 48 combinations.



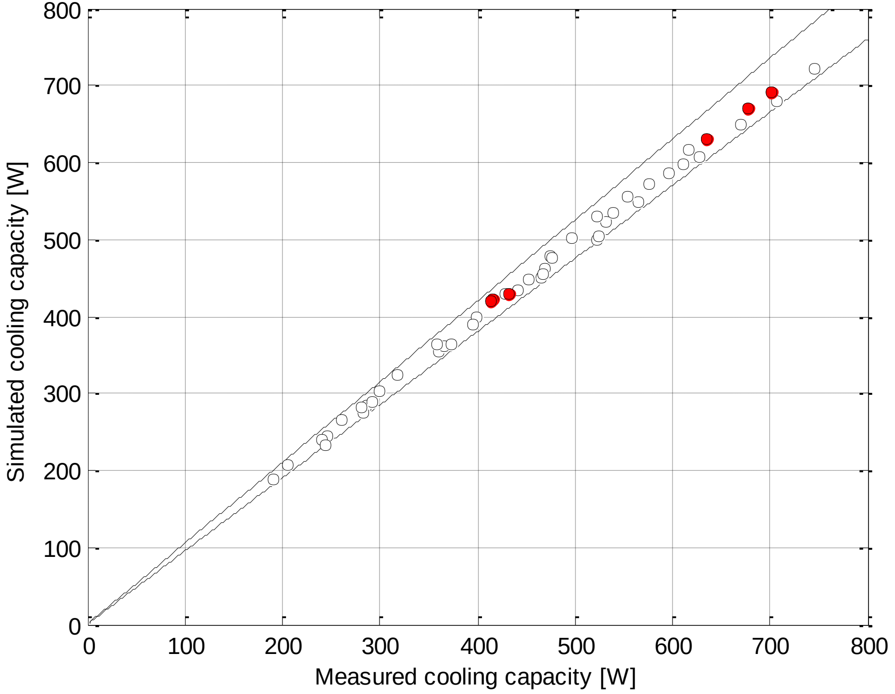




RESULTS

48 combinations of operating conditions.

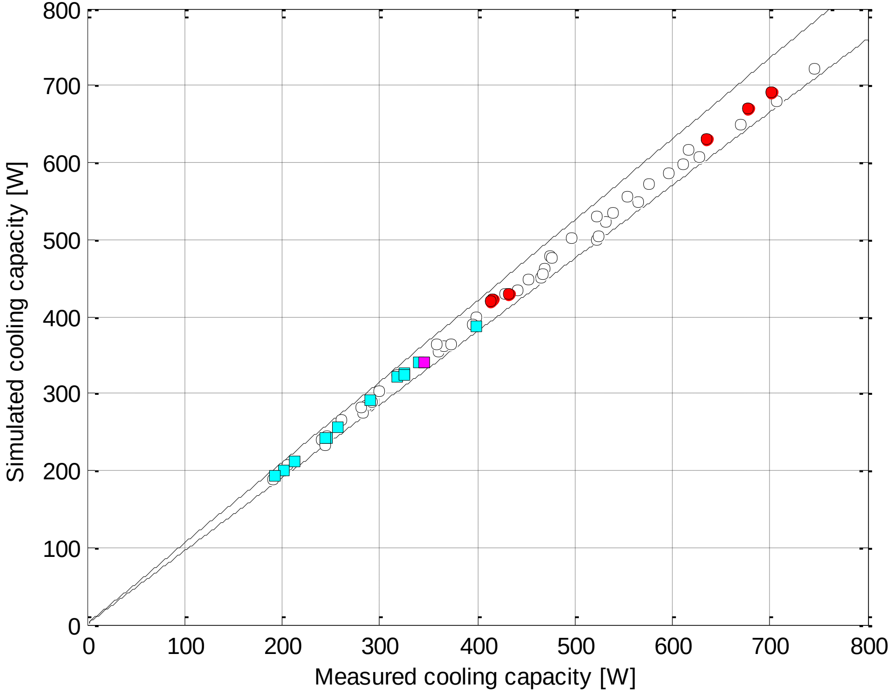
Number of cases used for calibration	Induction ratio	Error [%]	
		Avg.	Max
48	$f(q_p, T_{w,in})$	1.6	4.5
48	Constant	2.0	4.5
6	$f(q_p, T_{w,in})$	1.7	4.7
6	Constant	2.2	5.3
2	Constant	2.7	6.7



PERFORMANCE AT SUBTURBULENT FLOW

13 cases of different chilled water flow rate
$750 < Re_D < 3\,000$

Number of cases used for calibration	Induction ratio	Error [%]	
		Avg.	Max
1 (+6)	$f(q_p, T_{w,in})$	1.0	3.6



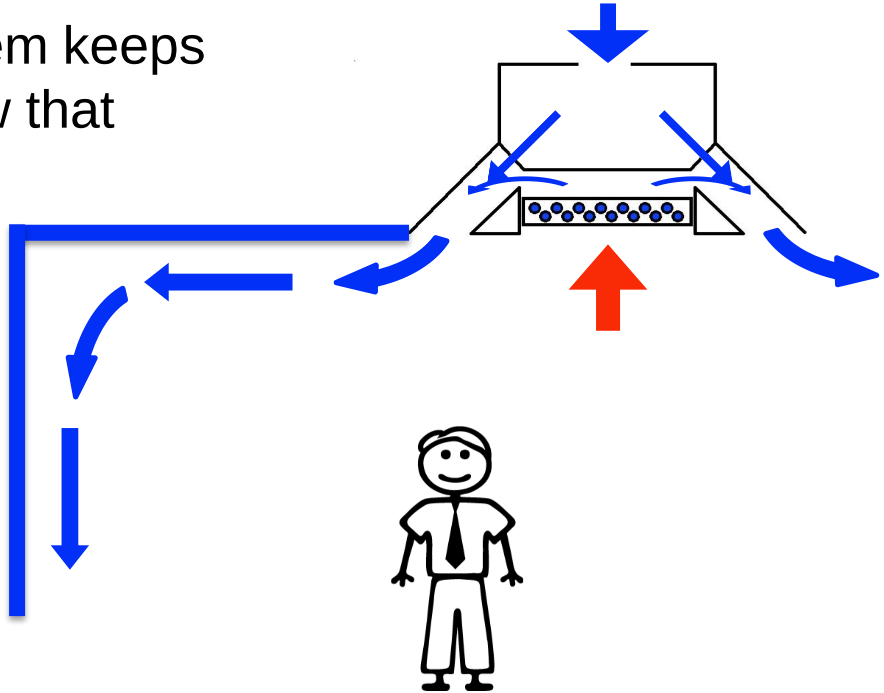
CONCLUSIONS

- **Accurate results in a wide range of operating conditions.**
- **Very few cases needed for calibration.**
- **Taking into account that the induction ratio is not constant adds extra accuracy.**

- **The model is ecpecially valuable if you:**
  - **need to know the temperature and flow of supply air.**
  - **simulating a VAV-system.**
  - **want to know the energy demand of the chilled water circulation pump.**

Further work

Take into account that the system keeps ceiling (and walls) cool and how that influences the thermal climate.



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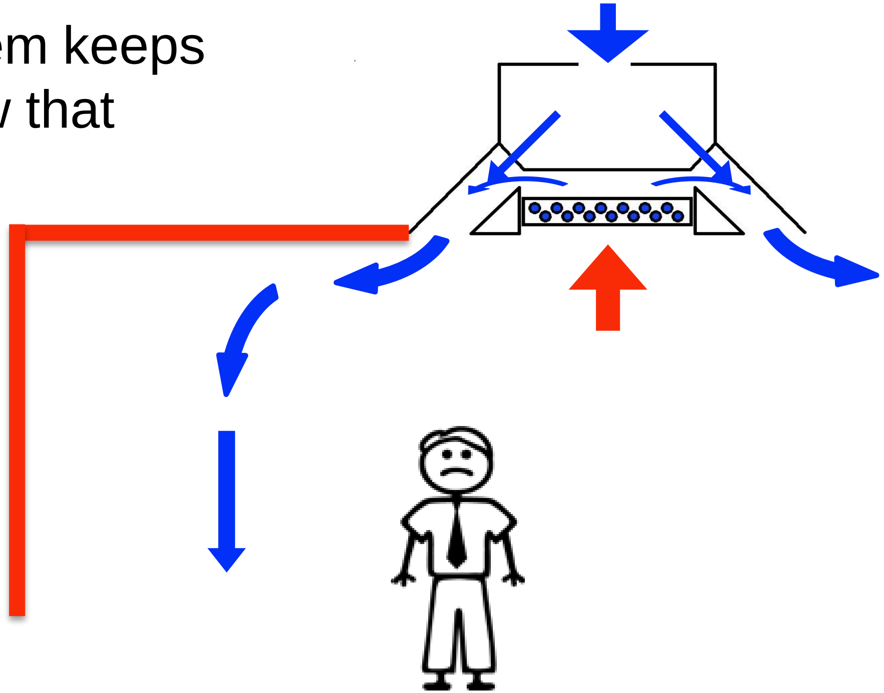

Thank you for your attention!

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