# TABSCAL A HIGHLY ACCURATE AND SIMPLE TOOL TO USE FOR PRE-DESIGN ANALYSIS

Software developed by EMPA Materials Science & Technology

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# A high accuracy simulation software simple to use:allows to perform pre-design studies without learning to use the simulation program TRNSYS

- It is based on research and development platform by EMPA, in the late 90s and early 2000
- EMPA and its team specialises in building energy research has developed for the private industry the program TABSCAL in order to develop the market range of cooling by providing the engineers and accurate tool to pre-dimension radiant slab cooling and

# Presentation of TABSCAL

- The program TABSCAL will be used by the participants to the training program in the form of an exercise
- The participants will be able to take the software with them when they leave
- Participants have signed an agreement about the use of this program after the training program

# EMPA

- A lot of the significant work in the development of radiant cooling design has been performed by building energy group of EMPA in the early 2000


- Robert Weber
  - (software develop ment for TRNSYS → TABSCAL
- Andreas Pfeiffer

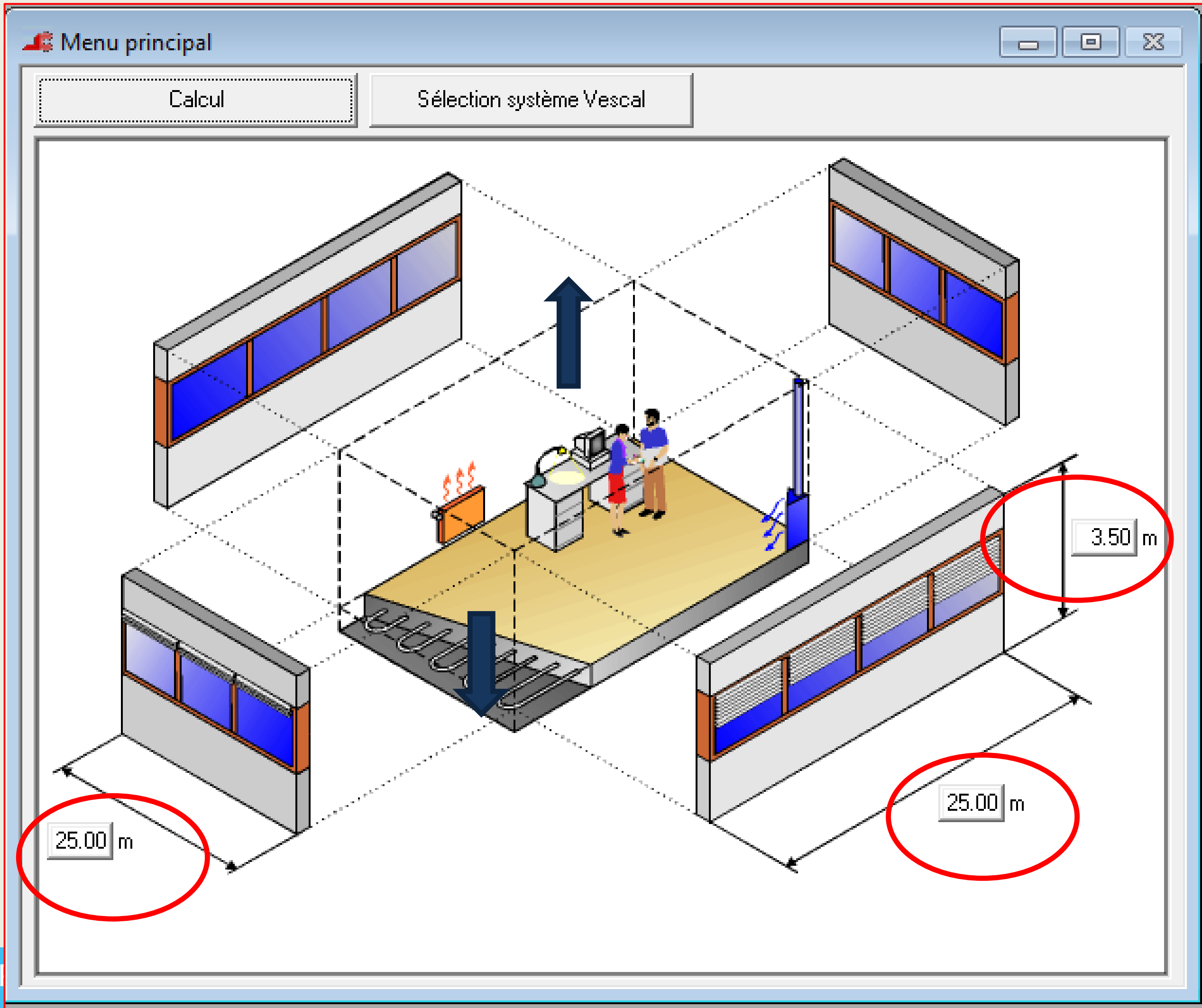

Koschenz, M. and Lehmann, B. (2000). Thermoaktive Bauteilsysteme tabs. EMPA Dübendorf, Eidgenössische Materialprüfungs- und Forschungsanstalt, Zentrum für Energie und
Nachhaltigkeit ZEN.

# Brief history of the development of TABSCAL

- In the late 90s, the building and a group of EMPA has assisted TRANSSOLAR in developing an accurate model of slab cooling to be adapted to the simulation program TRNSYS

# TABSCAL CAPABILITIES

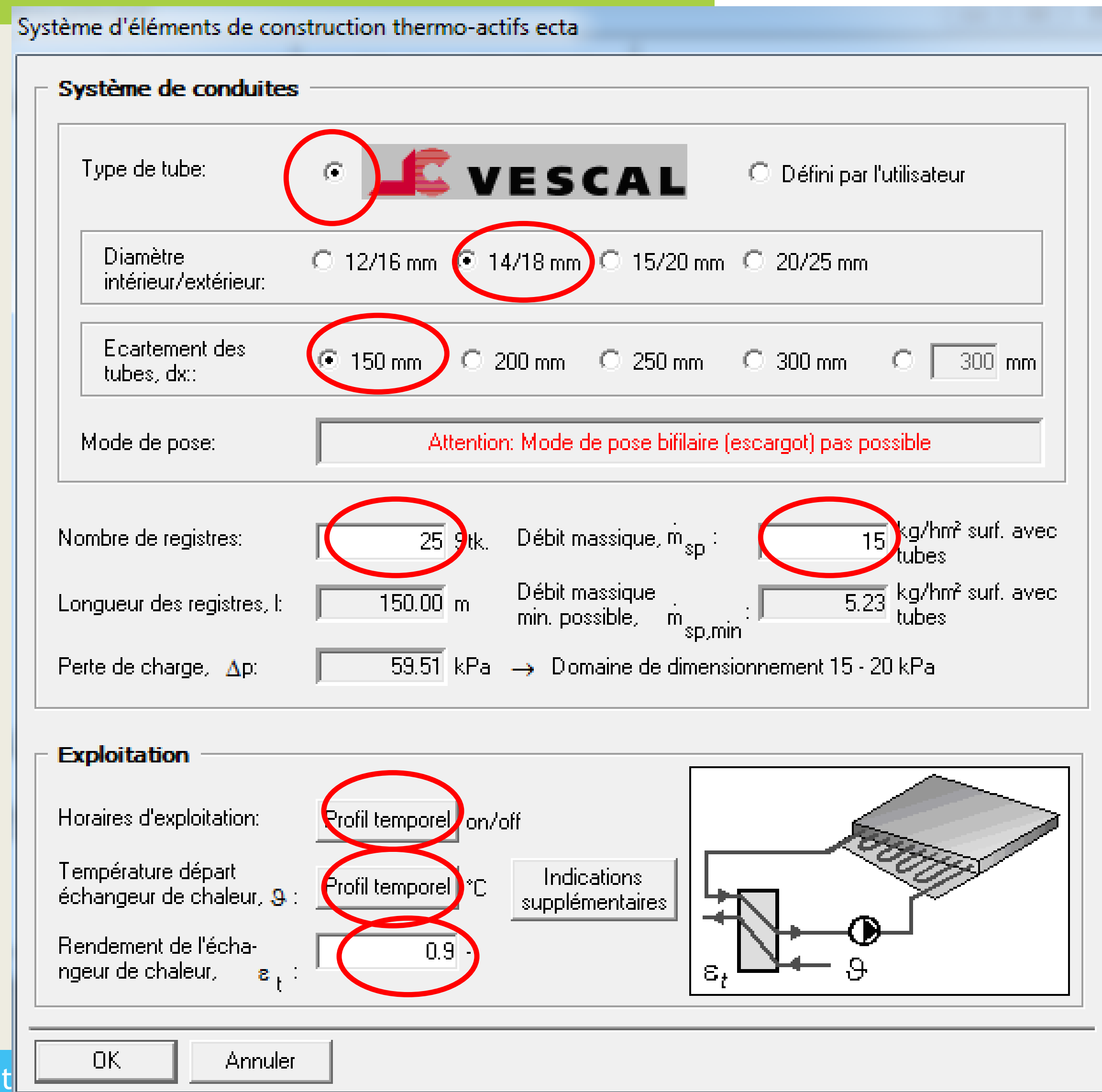
- Simulation of an intermediate floor of an office which is equipped with a slab cooling in the ceiling and in the floor for ceiling cooling of the floor below
- The area is defined by the size introduced on the first screen
  - Length
  - Width
  - Height



# TABSCAL INPUT DATA (1)

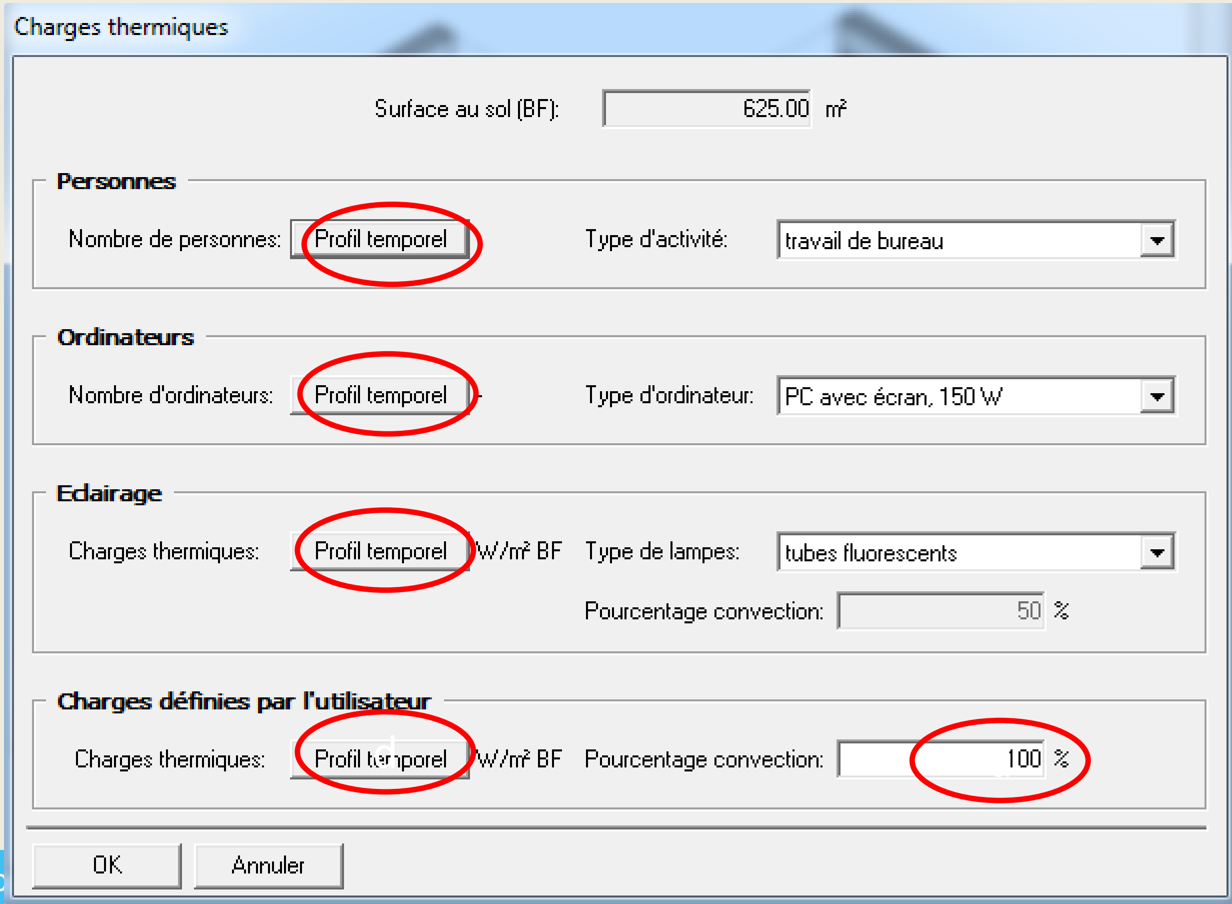
- The type of tube has to be choosen (Vescal) then
- the pipe diameter mm
- the tube spacing mm
- the number of loops
- he specific mass flow rate per area
- The operation of the slab hydronic circuit schedule
- The temperature schedule of the water supplied to the slab circuit
- The effectiveness of the plate heat exchanger
- **All these parameters can be changed, allowing the user to quantify the impact of any variation of these parameters**

TABSCAL help



# TABSCAL INPUT DATA (2)

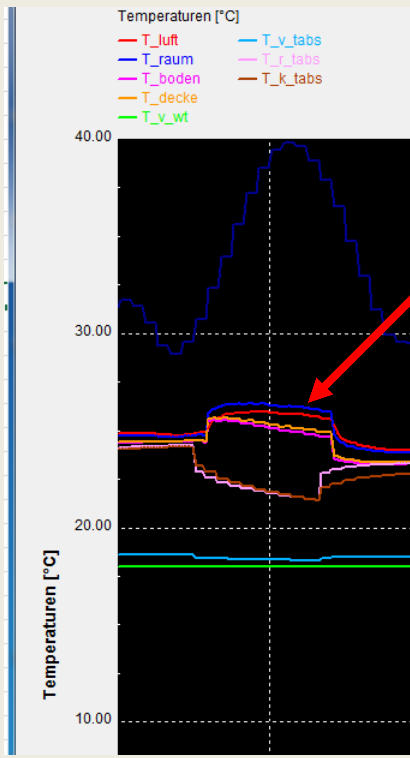
- Persons occupation schedule
- Computer, equipment schedule
- Lighting schedule
- User defined loads
  - And convection part of the gains



# CONVECTION/RADIATION DISTRIBUTION

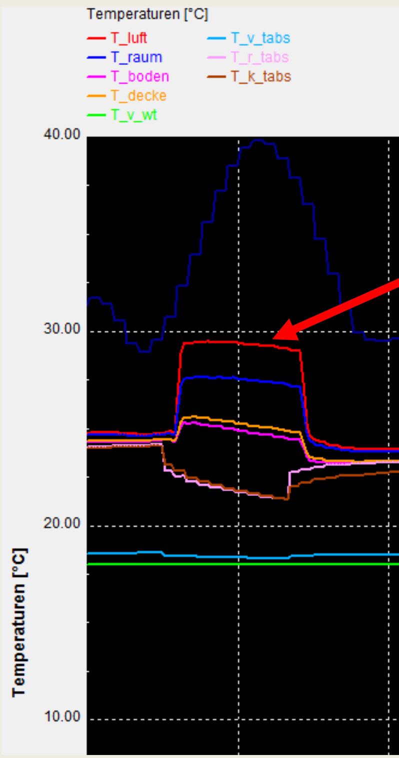
- The distribution between radiative and convective load can be assesses, by specifying only user defined loads and varying the percentage of convective part all other conditions remaining the same
- 100% radiant load

  (imagine a lamp in a cooled glass sphere)




Maximum air temperature in the office = 25.5°C (temperature profile over 24 hr)

100% convective load (fan heater)

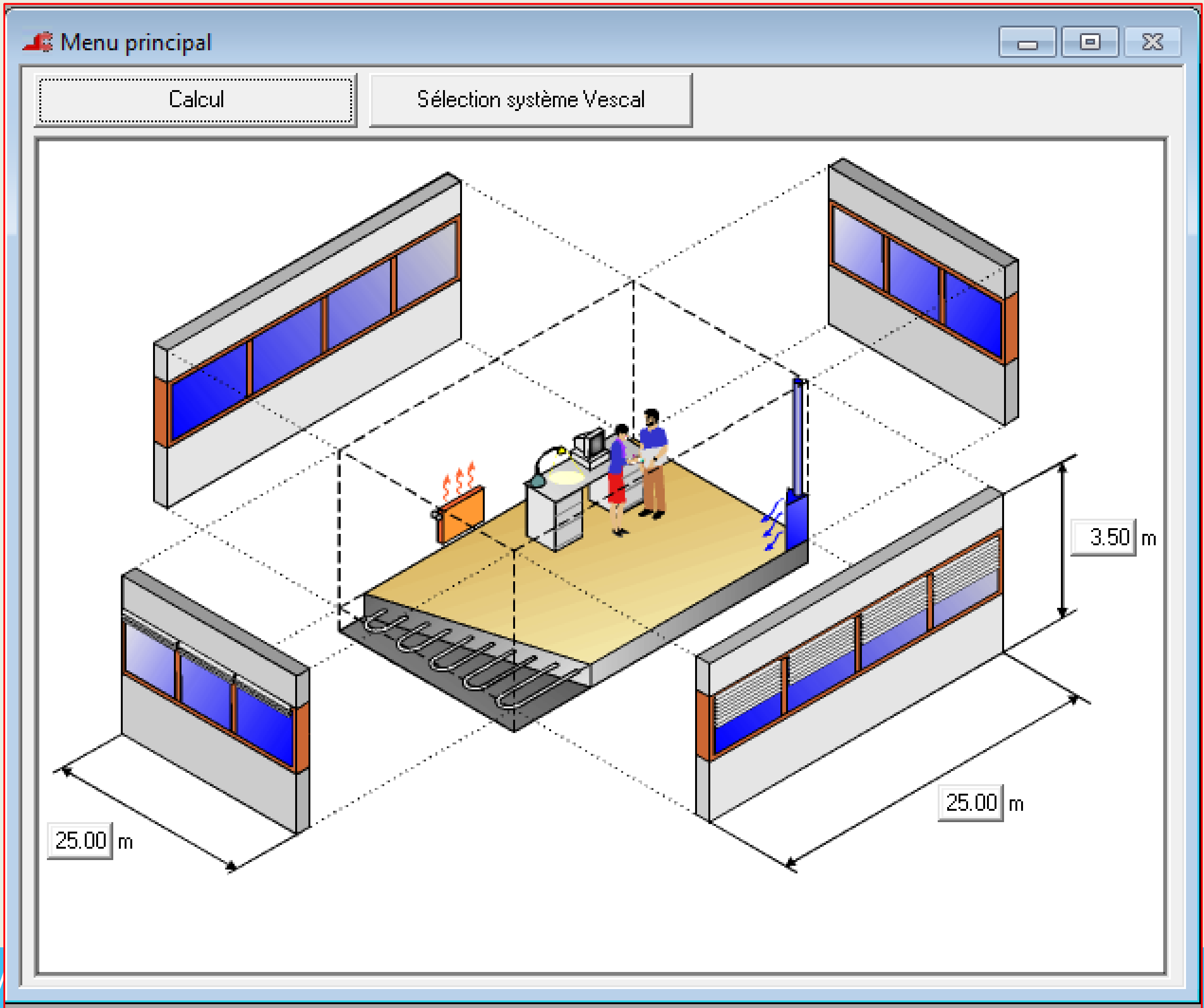



Maximum air temperature in the office = 29°C (temperature profile over 24 hr)

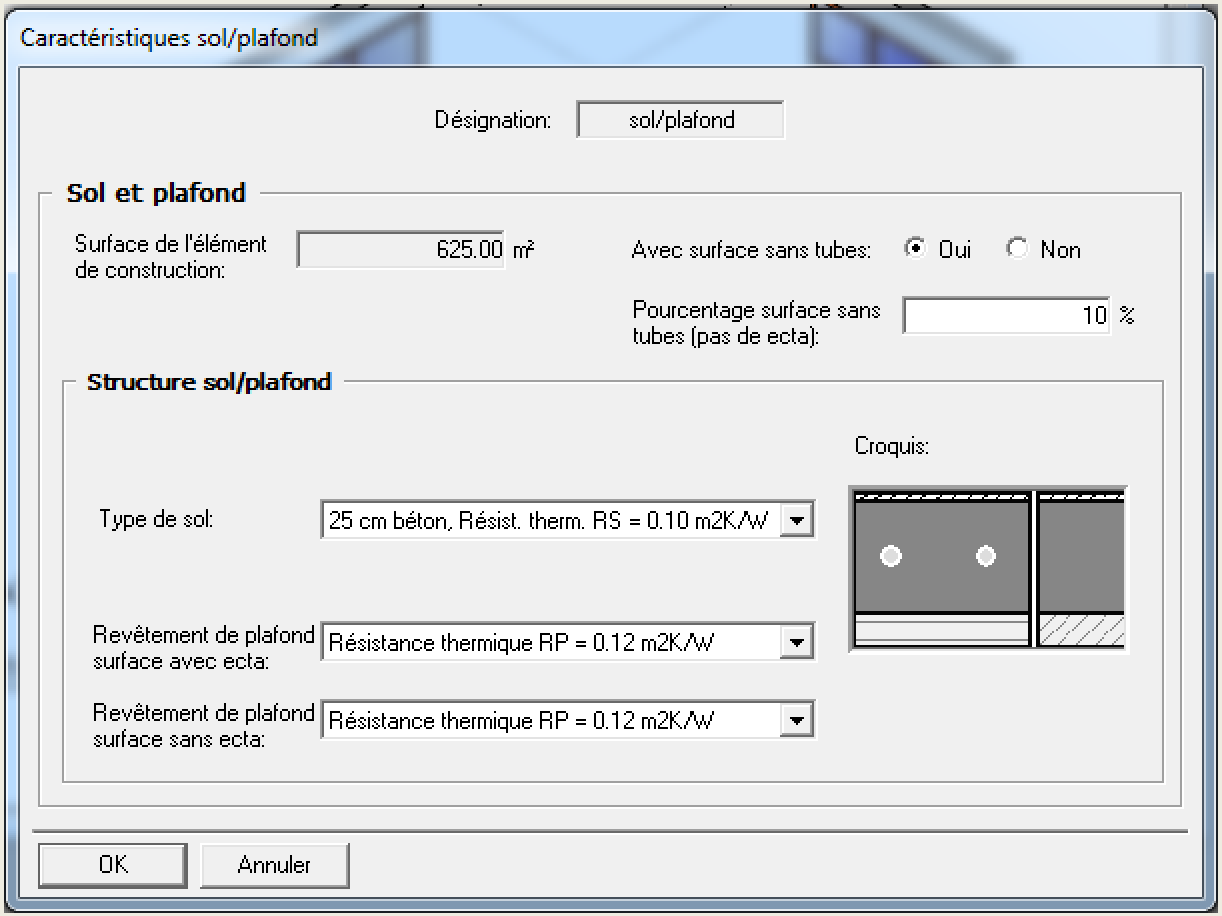
# ENTERING INPUT DATA IN TABSCAL

[Tabscal help PJ1e.pdf]

[Tabscal ]Exercise



# TABSCAL CAPABILITIES (2)



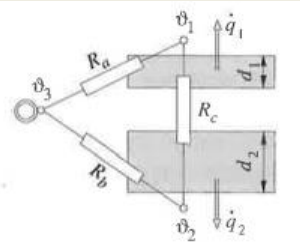



*Fig. 4-2: Widerstandsnetzwerk, Dreiecksschaltung*

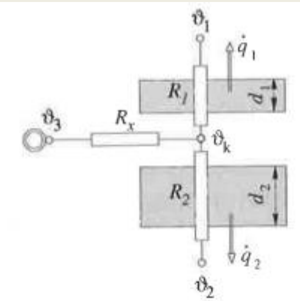



*Fig. 4-3: Widerstandsnetzwerk, Sternform*

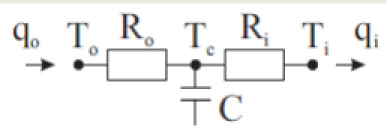



**Figure 4-1:** RC-model representation (Sourbron, 2012)

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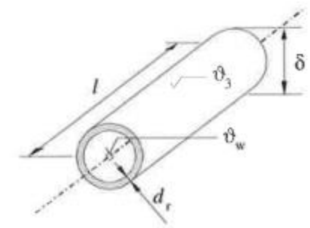


Fig. 4-4: Rohrmantel mit Temperaturbezeichnungen

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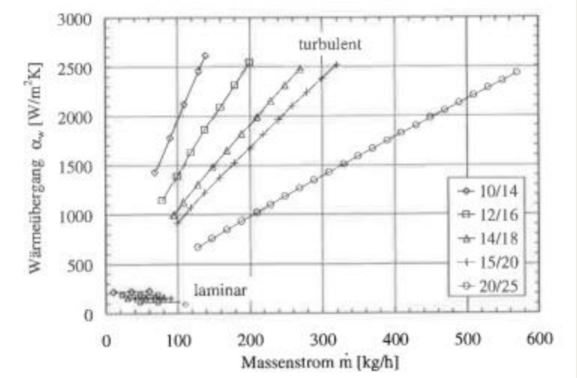


*Fig. 4-5: Konvektiver Wärmeübergang für verschiedene Rohrdimensionen bei laminarer und turbulenter Strömung ($\vartheta_w = 20$ °C; max. Strömungsgeschwindigkeit $w = 0.5$ m/s)*

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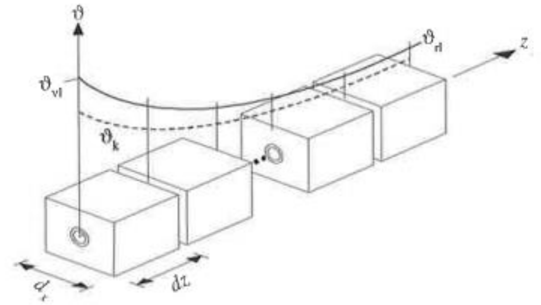

Fig. 4-7: Änderung der Wassertemperatur in z-Richtung

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# EnergyPlus modelling

## 4-3 Modelling in EnergyPlus - Simulation models & Radiant system models

This section has been retrieved by the documentation of EnergyPlus. In this section, the methods which EnergyPlus uses to simulate heat conduction and concrete core activation are analyzed and the controls of CCA are explained.

One of the most important forms of heat transfer in energy analysis is heat conduction through building elements such as walls, floors and roofs (ENERGYPLUS, 2013). While some thermally lightweight structures can be approximated by steady state heat conduction, a method that applies to all structures must account for the presence of thermal mass within the building elements. As mentioned in chapter 2, TABS refer to temperature-controlled surfaces that heat or cool indoor spaces by adding or removing sensible heat and where more than half of heat transfer occurs through thermal radiation (American Society of Heating and Engineers, 2008). Moreover, since HVAC systems are integrated in the building's structural components, such as slabs, there is the effect of thermal storage inside them. This fact requires dynamic calculation methods based on transient heat conduction which means that conduction occurs when the temperature within an object changes as a function of time. Therefore, steady state calculations are insufficient. In the following sections the calculation methods of radiant system models is presented.

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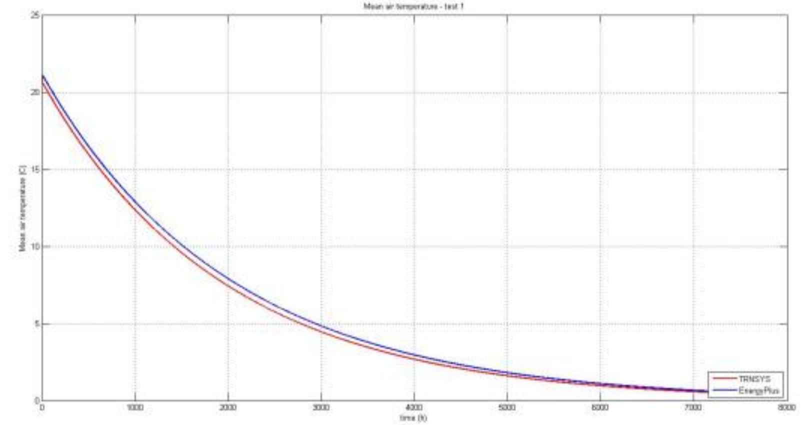


**Figure 5-1:** Differences in mean air temperature between TRNSYS and EnergyPlus - Test 1

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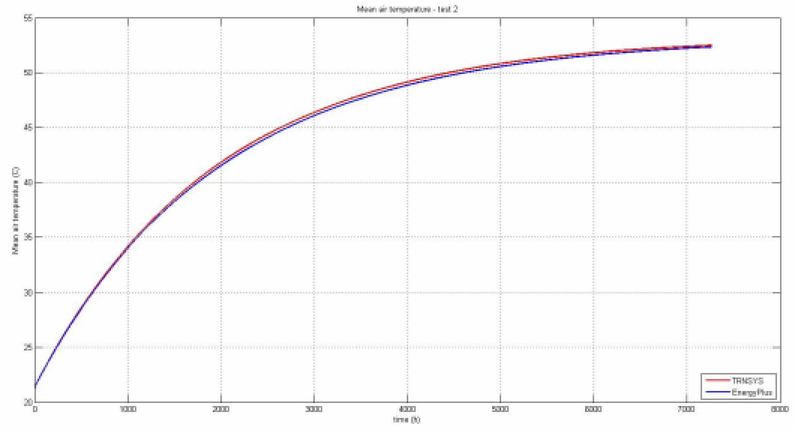


**Figure 5-2:** Differences in mean air temperature between TRNSYS and EnergyPlus - Test 2

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# Radiant panel model TRNSYS

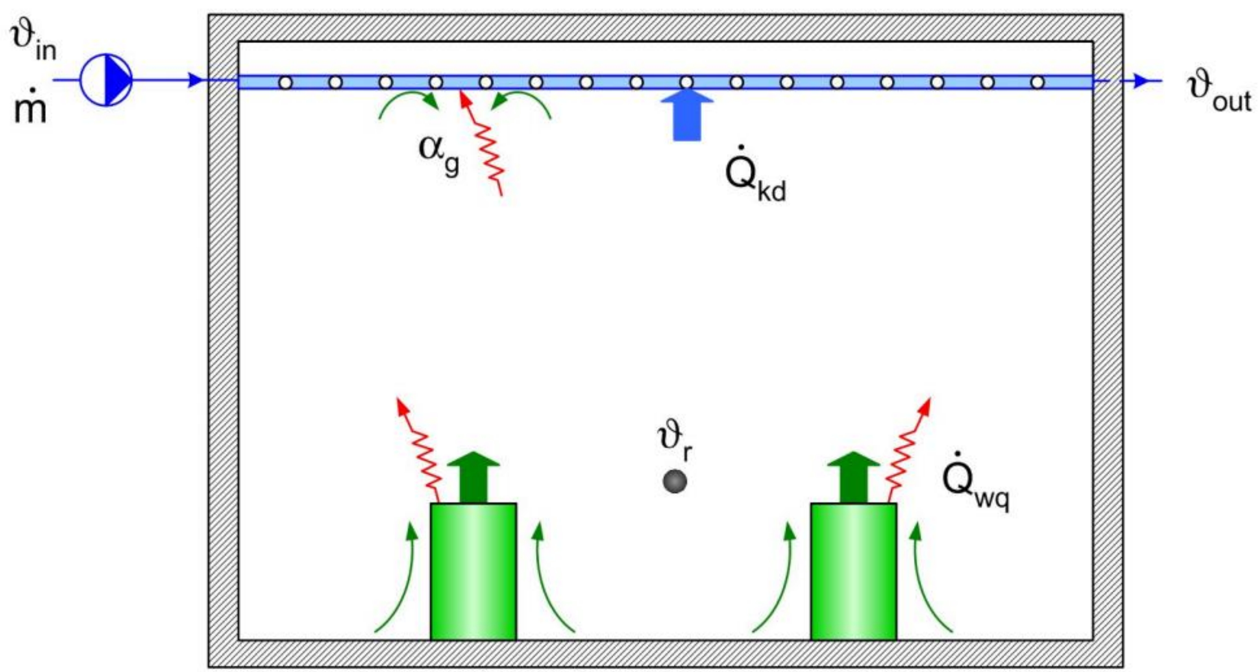


*Fig. 1: Adiabater Raum zur Prüfung von Raumkühlflächen nach DIN 4715-1, Teil 1*

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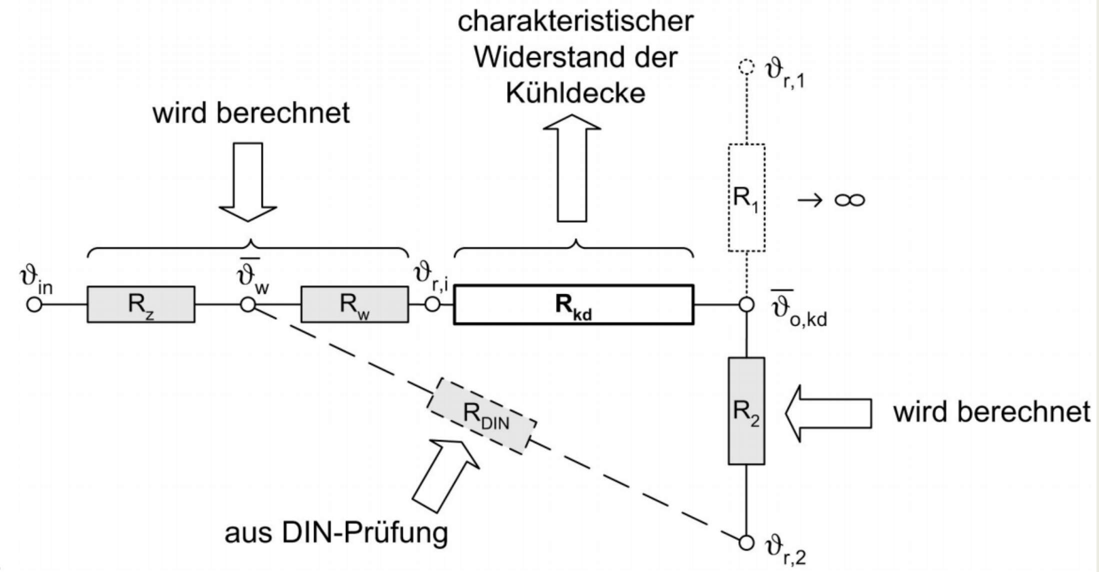


*Fig. 2: Widerstandsnetzwerk einer Kühldecke: Ermittlung des konstant bleibenden charakteristischen Widerstandes $R_{kd}$*

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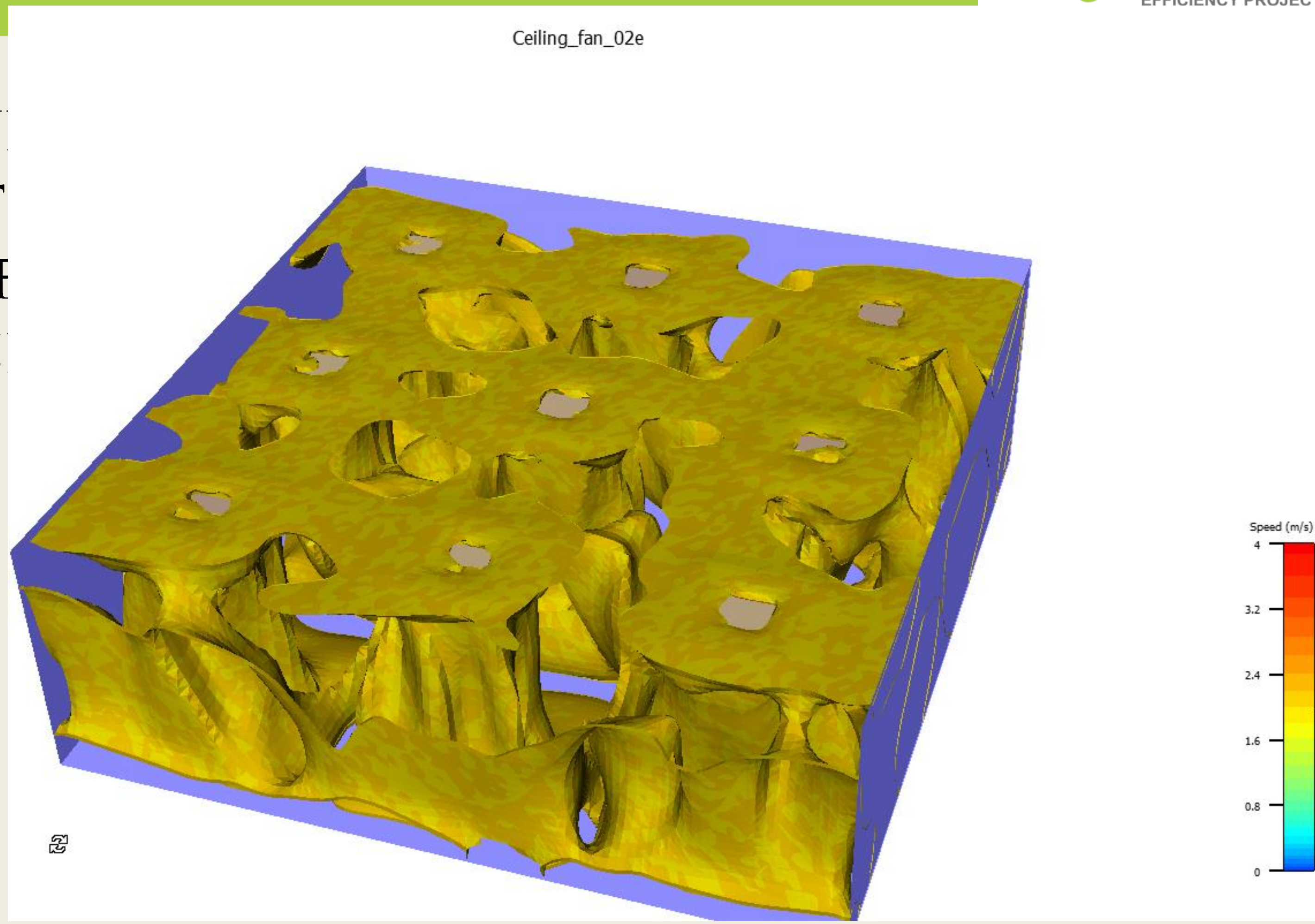
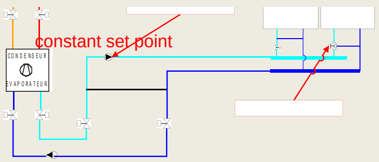
# CFD MODEL FOR STU OF HEAT TRRANSF COEFFIC NTT $H_C$



# 1) «Conventional» design

- 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

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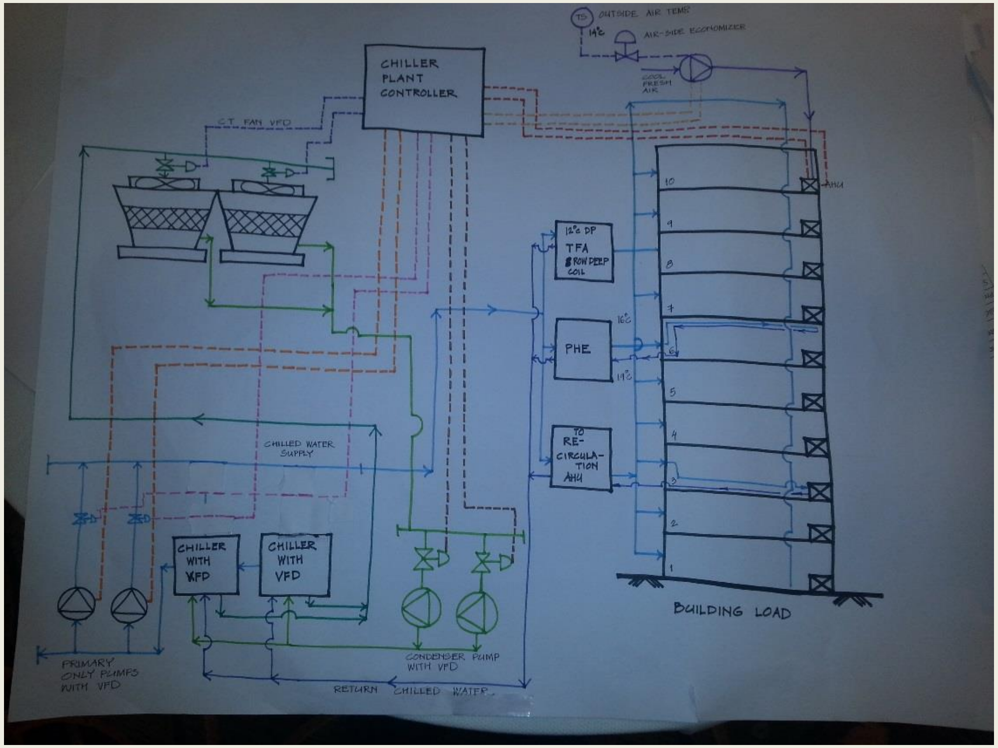
CHILLER PLANT CONTROLLER
C.T. FAN VFD
TS
OUTSIDE AIR TEMP
14°C
AIR-SIDE ECONOMIZER
COOL FRESH AIR
AHU
10
9
8
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6
5
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3
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1
12°c DP TFA 8 ROW DEEP COIL
16°C
PHE
19°C
TO RE-CIRCULATION AHU
CHILLED WATER SUPPLY
CHILLER WITH VFD
CHILLER WITH VFD
PRIMARY ONLY PUMPS WITH VFD
CONDENSER PUMP WITH VFD
RETURN CHILLED WATER
BUILDING LOAD

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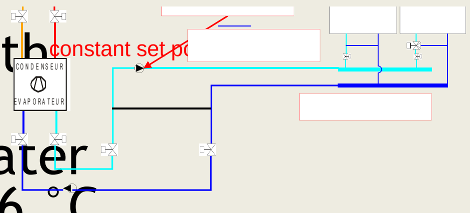
# 2) Improvement by controls: «conventional» design optimised with gliding CHW set point

- 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

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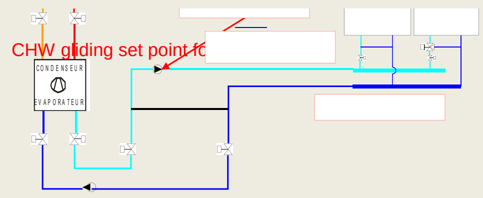
# 3) Further improvement by controls: «conventional» design optimised with gliding CHW and CWT set point

- 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

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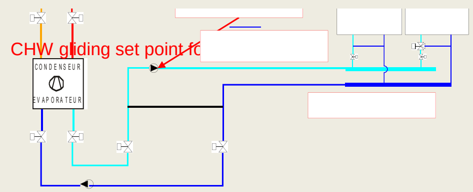
# 4) Further improvement by controls: «conventional» design optimised with gliding CHW and CWT set point and variable flow

- 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
- Less power for CHW and condensing water loop

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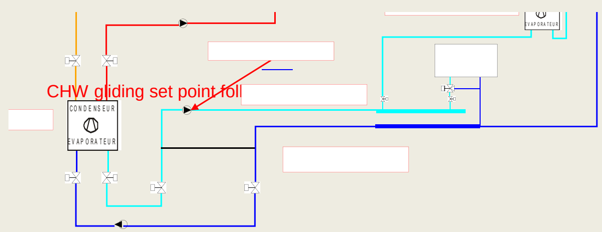
# 5) Improvement by design

- 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

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# 6) Improvement by design

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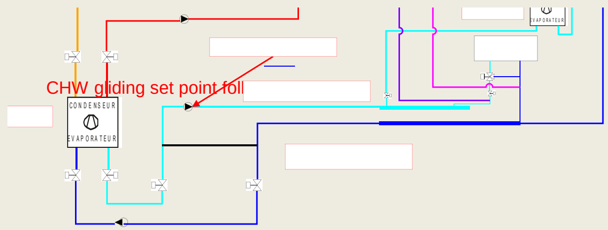
BUILDING ENERGY EFFICIENCY PROJECT

- 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, …)

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# 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

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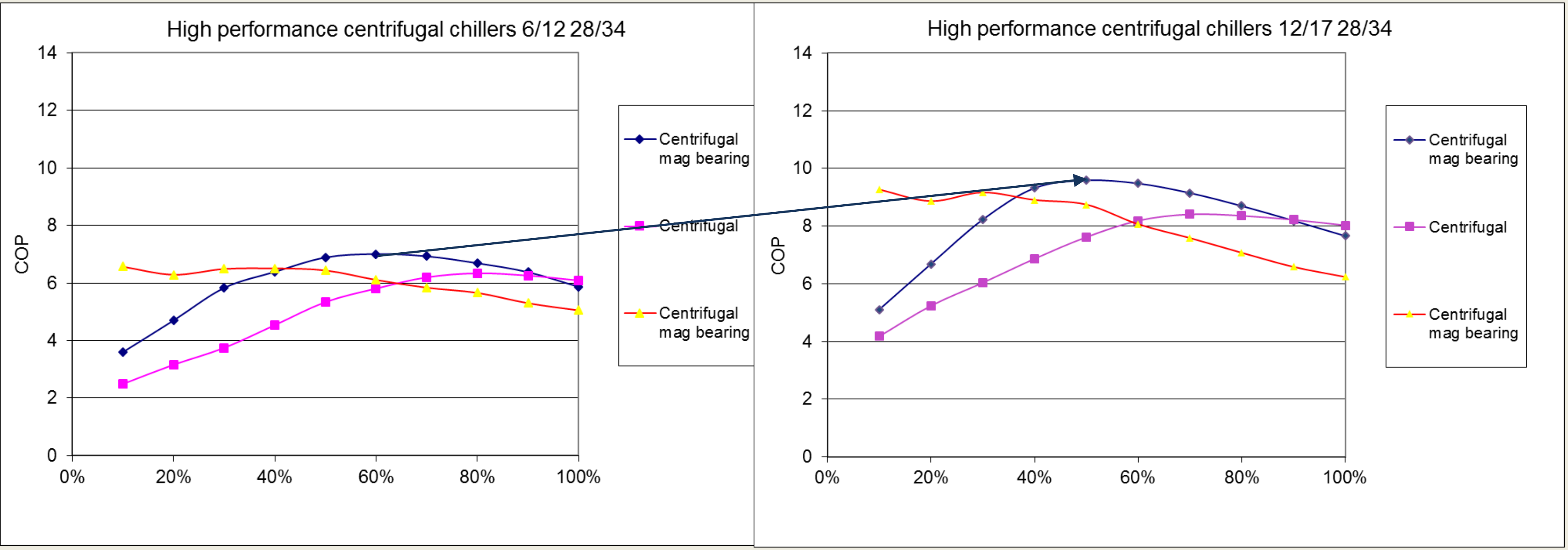
# Chillers performances (AHRI 550/90) Influence of CHW temperature on COP

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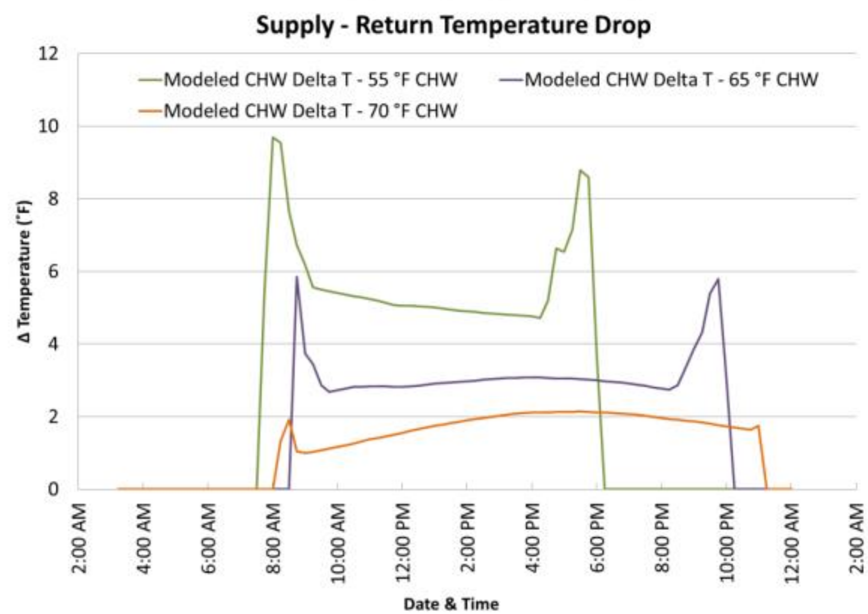
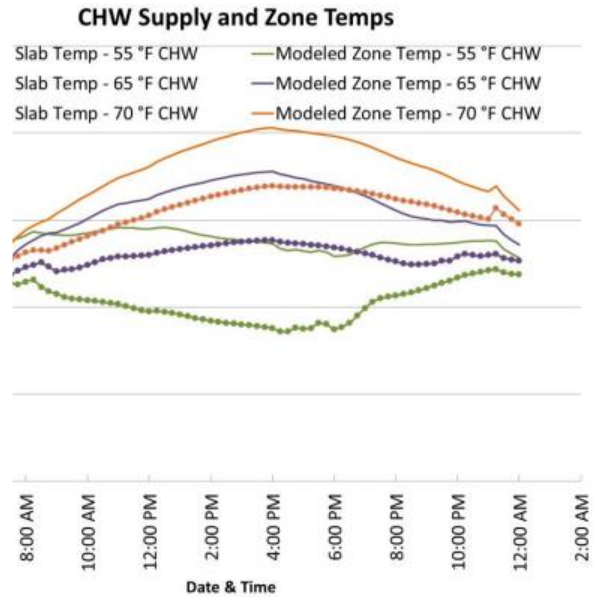



**Figure 11: Sensitivity of Heat Extraction from Slab to CHW Supply Temp**

*2013 California Building Energy Efficiency Standards* *April 2011*

*ydronic Radiant Cooling* *Page*




**ity of Zone Temperature to CHW Supply Temp**

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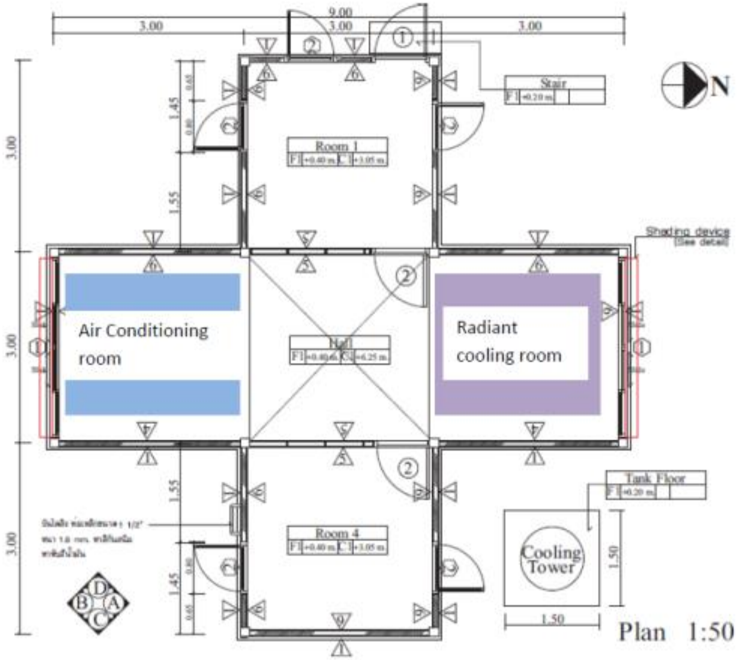


(a) Configuration of the experimental room



IV RESULTS AND DISCUSSIONS

This experiment was chosen to present in hot and humid period of 3-4 April 2013. The experiment conducted for a room with nighttime function (bedroom) and start at 17.00-06.00 in the morning. The activity of human in the room was assumed sleeping. The primary aims were to compare energy consumption of air conditioning room and radiant cooling room and show thermal comfort could be achieved in the both room. The calculation in the above section was performed to produce results for comparison.

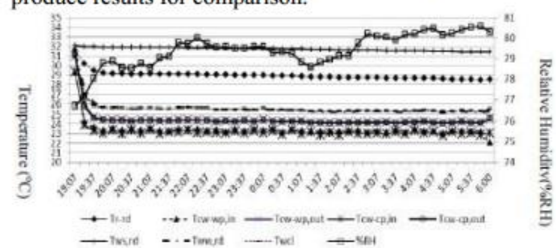


Figure 3. Measurements results of temperatures of radiant cooling room.

A iant
Cooling for Residential Building in a Tropical Climate

S. Wongkee, S. Chirarattananon, and P. Chaiwiwatworakul
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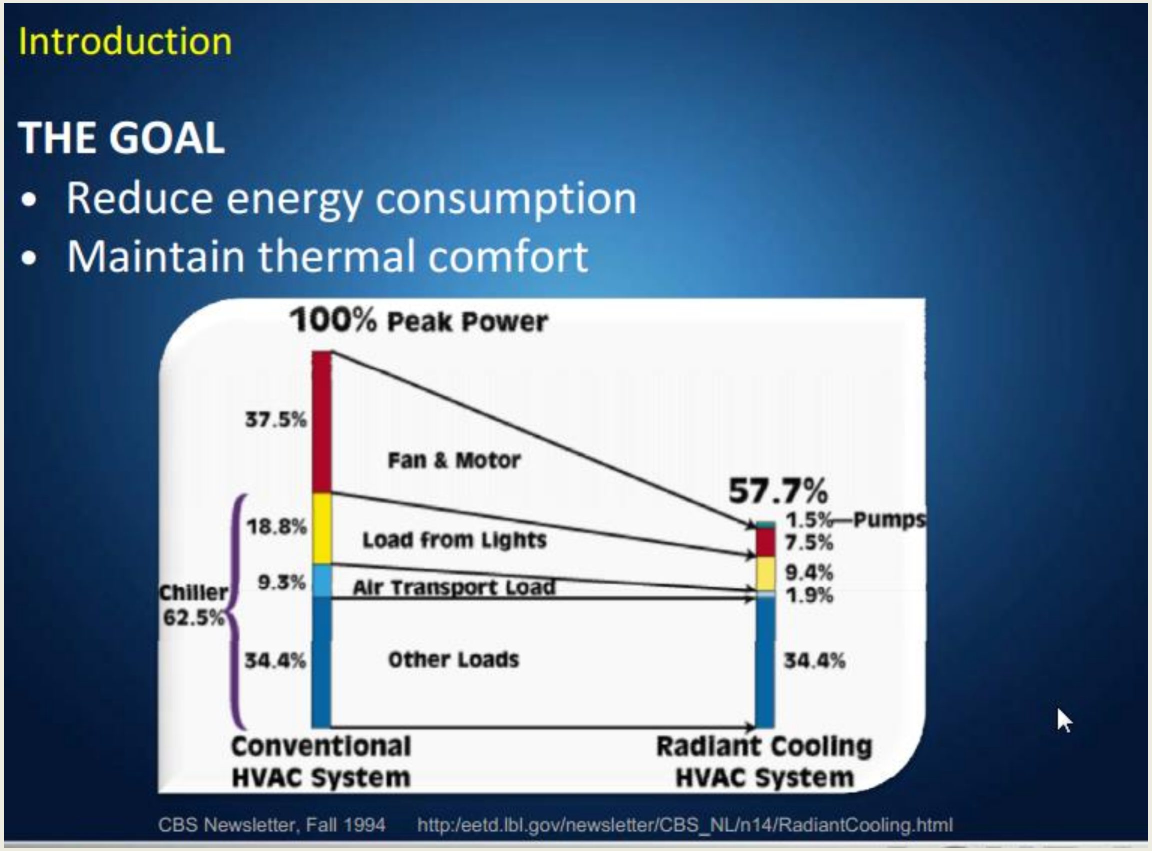
ASHRAE - WI - Application of Hydronic Radiant and Beam Systems 14MAY10.pdf

Panel research started in ~90 years ago



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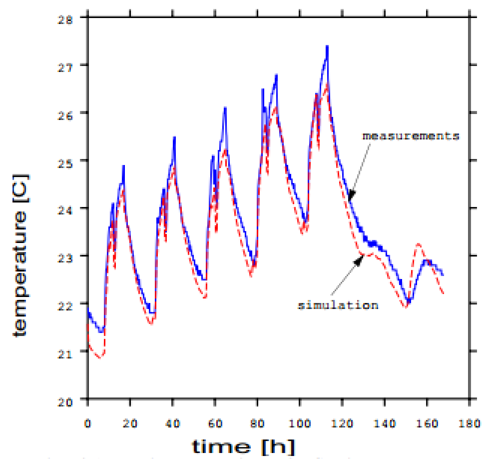


**Figure 9. Average air temperature in the DOW-Chemical test room**

The simulation results for the room air temperature show good agreement with the air temperature measured at 1.1 m above the floor. The last day presents the highest discrepancy, in that the simulated time of the peak temperature occurs about 4 hours earlier than the time of the measured peak. This might be due to a discrepancy between the simulated schedule of the blinds, and the real one.

Approach and Model Evaluation 14

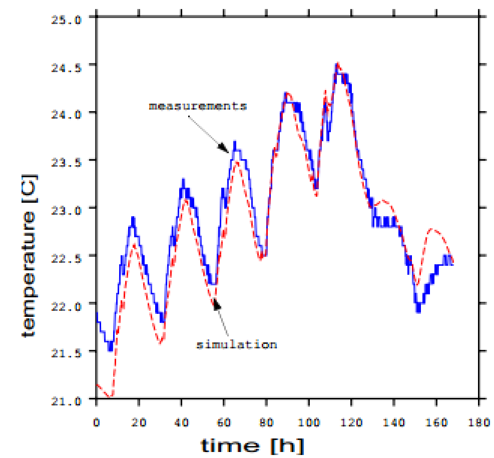


**Figure 10. Cooled ceiling surface temperature in the DOW-Chemical test room**

The simulation results for the cooled ceiling surface agree well with the measurements. The last 2 days present, again, the highest discrepancy, which might be due to a difference between the modeled and the real blinds operation.

Approach and Model Evaluation 15

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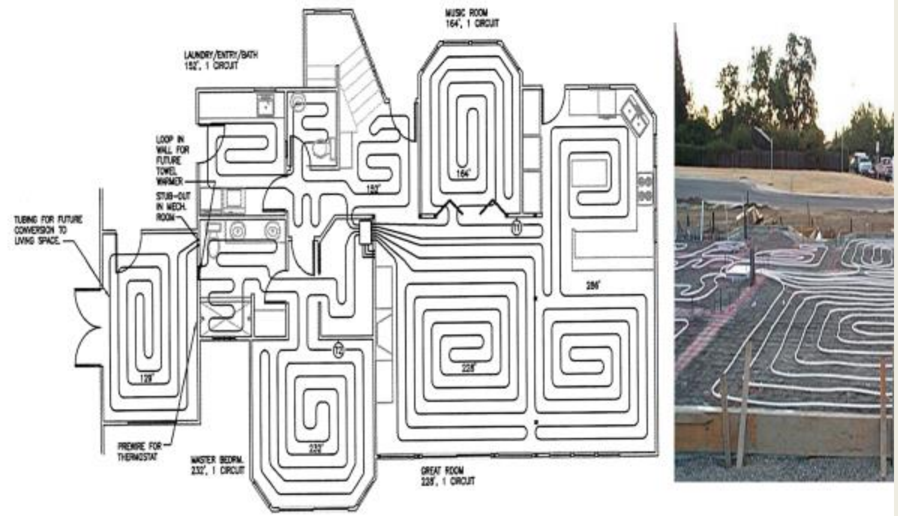


***Figure 3b*** *Home radiant tubing layout.*

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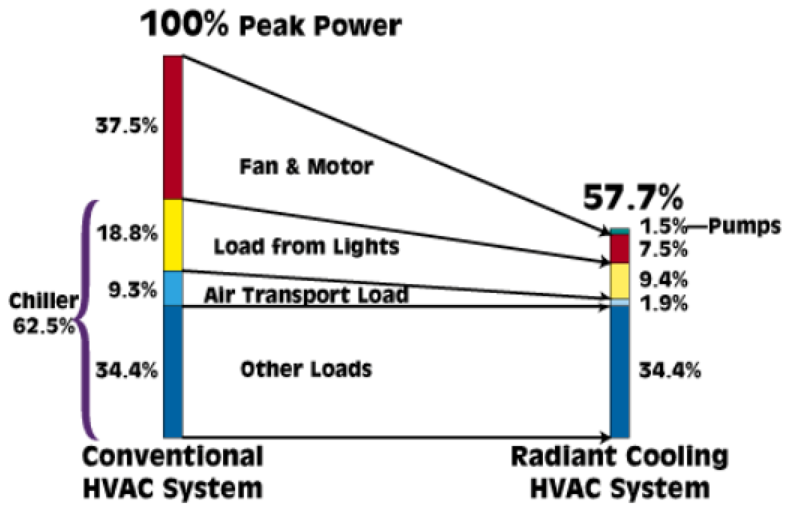

Comparison of electrical peak power load for conventional systems and radiant cooling systems (percentages are relative to overall peak power for the conventional system).

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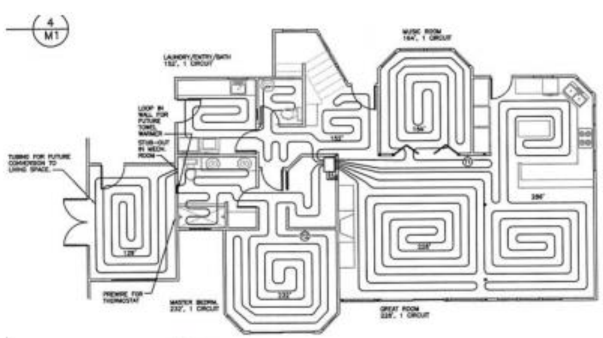
CALIFORNIA ENERGY COMMISSION

# Final Report Compilation for

# Residential Hydronic Radiant Cooling and Heating Assessment



TECHNICAL REPORT

October 2003

Chapter 2

# PRESENT STATE OF KNOWLEDGE ABOUT RADIANT COOLING SYSTEMS

## 2.1 All-Air Systems vs. Radiant Cooling Systems

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**OPERATION AND CONTROL OF ACTIVATED SLAB HEATING AND COOLING SYSTEMS**

*Bjarne W. Olesen, Ph.D.*
Wirsbo-VELTA, Norderstedt, Germany

*Francesco Currò Dossi*
Velta-Italia, Terlan, Italy

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9th REHVA World Congress for Building Technologies – CLIMA 2007, Helsinki, 10th - 14th June 2007

**CONTROL OF THERMALLY ACTIVATED BUILDING SYSTEMS**

Markus Gwerder[1], Jürg Tödtli[1], Beat Lehmann[2], Franz Renggli[1], Viktor Dorer[2]

[1]Siemens Switzerland Inc., Building Technologies Group, Zug, Switzerland
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*Corresponding email: markus.gwerder@siemens.com*

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# Table of contents



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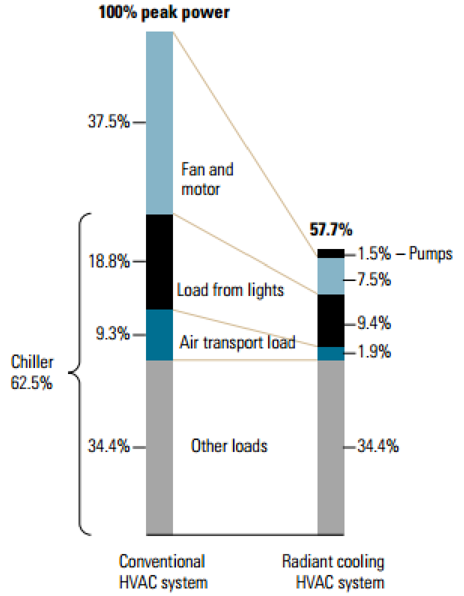
**Figure 1: Peak power demand for conventional and radiant cooling**

The hydronic radiant cooling system reduces peak power demand by pumping chilled water to provide radiant cooling, rather than by blowing chilled air. Note that the cooling load from lights decreases because the radiant system's 100 percent outside air ventilation directly vents half of the lights' heat to the outdoors. In conventional buildings, most of that heat stays in the building with recirculating supply air.




Source: LBNL

RADIANT COOLING

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energydesignresources **e-NEWS** Issue 85 ▸ March 2012

## In This Issue



# RADIANT HEATING AND COOLING

## *A Holistic Approach to Energy Efficiency*

### Introduction

Radiant heating and cooling systems are more energy efficient compared to traditional forced air systems for several reasons. But let's start at the building occupant since their comfort is one of the main reasons we have the built environment.

#### Thermal Comfort Benefit

There are six primary factors that affect thermal comfort (see Figure 1). The use of a radiant heating and cooling system has an effect on the radiant temperature, and air speed which can allow for a wider range for the temperature set point of the space. Instead of a seasonal temperature range of 72°F to 76°F with traditional forced air systems a radiant system could provide thermal comfort with a seasonal temperature range of 68°F to 80°F. This wider temperature range reduces the associated heating and cooling energy needed which equates to annual energy savings.

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Design and Control of Hydronic Radiant Cooling Systems

By

Jingjuan Feng

A dissertation submitted in partial satisfaction of the

requirements for the degree of

Doctor of Philosophy

in

Architecture

in the

Graduate Division

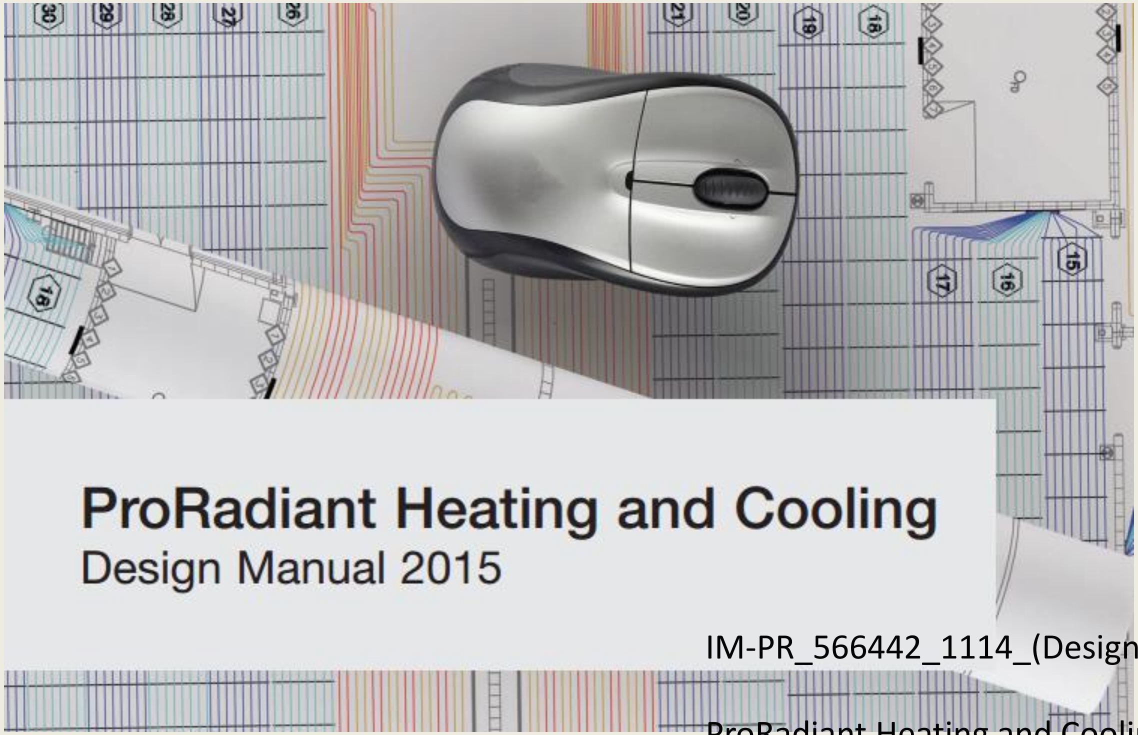
of the

University of California, Berkeley

Committee in charge:

Professor Stefano Schiavon, Chair
Professor Gail Brager
Professor Edward Arens
Professor Francesco Borrelli

Spring 2014




IM-PR_566442_1114_(Design_Manual).pdf

ProRadiant Heating and Cooling

Design Manual 2015

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INTERNAL REPORT APRIL 2006

# RADIANT COOLING RESEARCH SCOPING STUDY

**Timothy Moore, Fred Bauman, and Charlie Huizenga**
Center for the Built Environment (CBE)
University of California, Berkeley

April 20, 2006

IR_RadCoolScoping_2006.pdf

## 1. BACKGROUND

RADIANT COOLING RESEARCH SCOPING STUDY

### 1.1 OBJECTIVE

The objective of this project is to characterize the opportunities and limitations of radiant cooling strategies for North America and identify research needs that CBE might most effectively address. Based on literature, case studies, and interviews with experienced designers, CBE has set out to determine the focus of radiant cooling research that will best address shortcomings of industry resources and thus provide the most benefit to CBE partners.

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Radiant Cooling Presentation.pdf

Using Embedded Tube Radiant Cooling

Systems to Maximize LEED Points

Devin Abellon, P.E. – Business Development  Ma

# THANK YOU