COOLING AND HEATING OF BUILDINGS BY ACTIVATING THE THERMAL MASS WITH EMBEDDED HYDRONIC PIPE SYSTEMS

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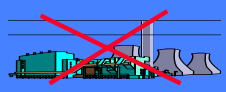
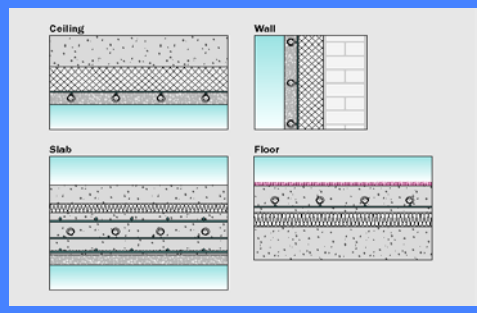
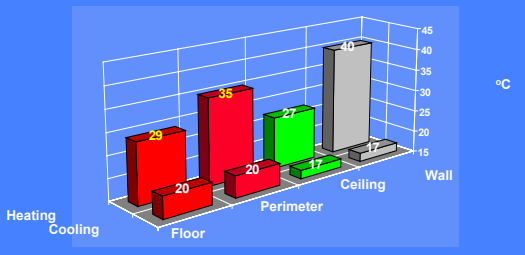


EMBEDDED PIPE SYSTEMS

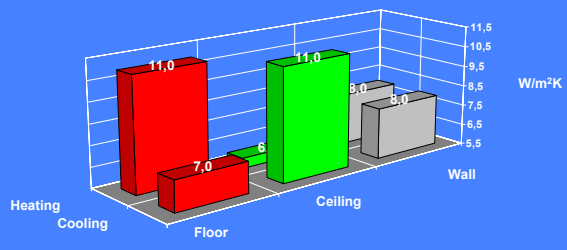


Max. - Min. surface temperatures



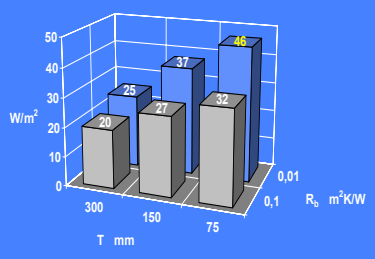
SURFACE HEATING AND COOLING

Heat transfer coefficient

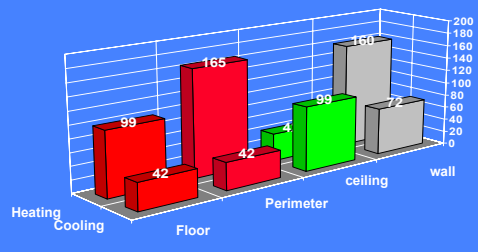


COOLING CAPACITY

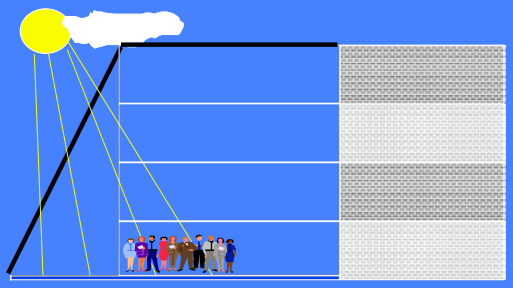
- Cooling capacity in W/m²for the following example
  - 17 mm PEX-pipe
  - 45 mm concrete above pipes
  - Concrete ~ 1,2 W/mK
  - Space temperature 26 °C
  - Supply water temperature 14 °C
  - Return water temperature 19 °C



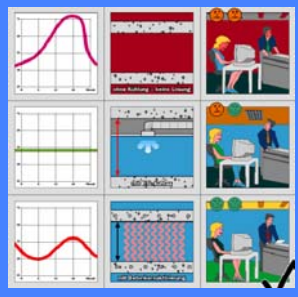
Max. heating-cooling-capacity



RADIANT FLOOR COOLING



COMFORT-PERFORMANCE



No cooling - decreased performance
Low energy costs
Low operation costs

Constant temperature
Draught
Noise
SBS
High energy costs
High operation costs

Temperature ramps
Reasonable energy costs
Low operation costs

COMFORT-PERFORMANCE

People 100

Energy 1

THERMAL COMFORT

- OPERATIVE TEMPERATURE
- -0,5 < PMV < +0,5 ; PPD < 10 %
- SPACES WITH MAINLY SEDENTARY OCCUPANTS :
  - SUMMER CLOTHING 0,5 clo
  - ACTIVITY LEVEL 1,2 met
- 23 °C < t_o < 26 °C.

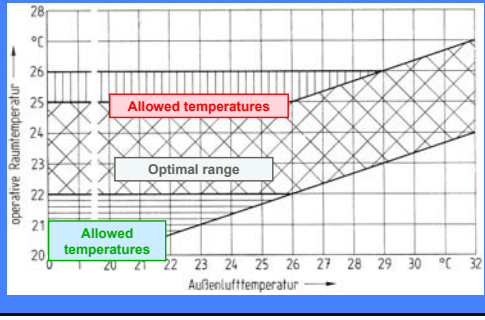
COMFORT CRITERIA

EN-ISO 7730

CR 1752

Class	Comfort requirements		Temperature range	
	PPD	PMV	Winter 1.0 clo 1.2 met	Summer 0.5 clo 1.2 met
	[%]	[/]	[°C]	[°C]
A	< 6	-0.2 < PMV < + 0.2	21-23	23.5-25.5
B	< 10	-0.5 < PMV < + 0.5	20-24	23.0-26.0
C	< 15	-0.7 <PMV < + 0.7	19-25	22.0-27.0

Definition of comfort conditions according to DIN 1946



Airport Bangkok

Airport Bangkok

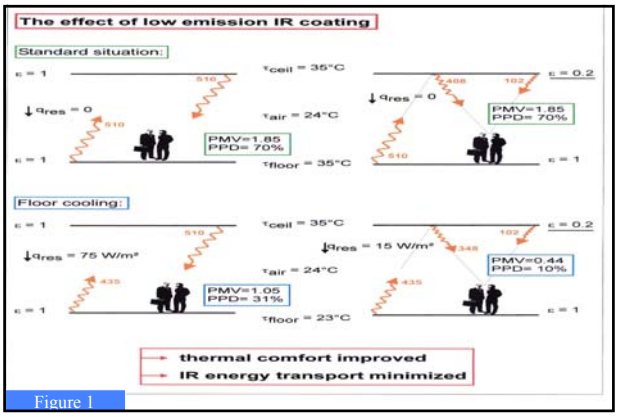


Figure 1

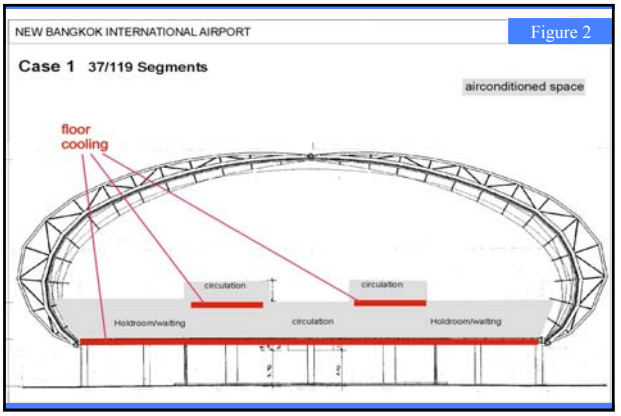


Figure 2

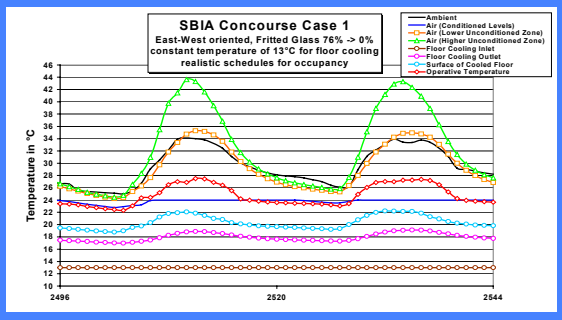


Figure 3

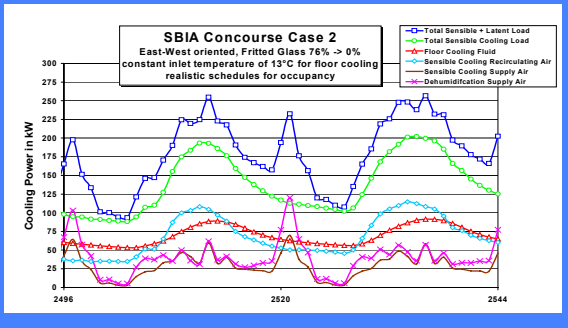


Figure 4

Figure 5

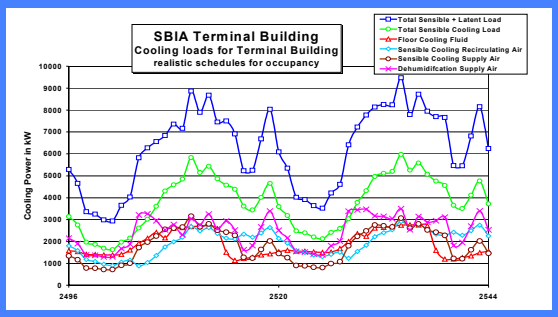
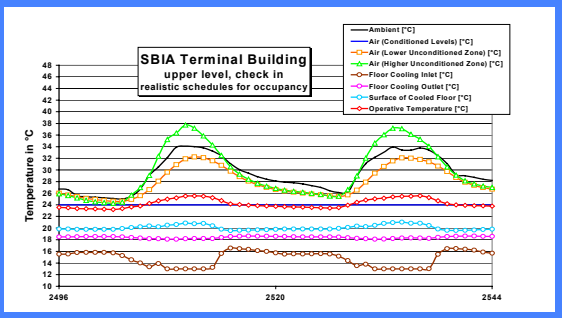


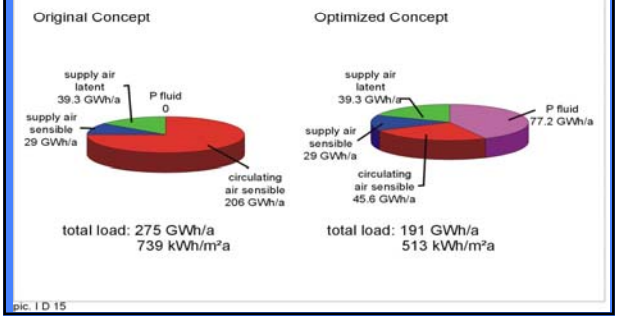
Figure 6



NEW BANGKOK INTERNATIONAL AIRPORT

Figure 7

Comparison of Cooling loads entire Airport



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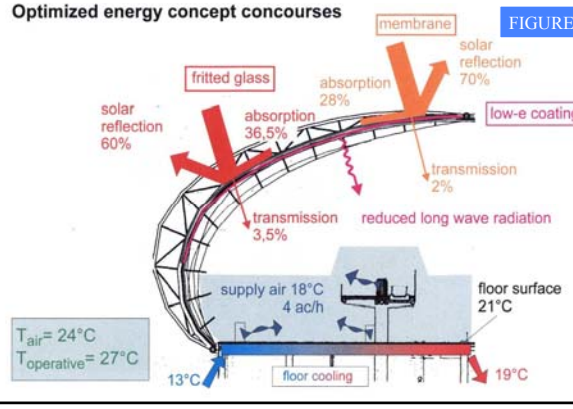
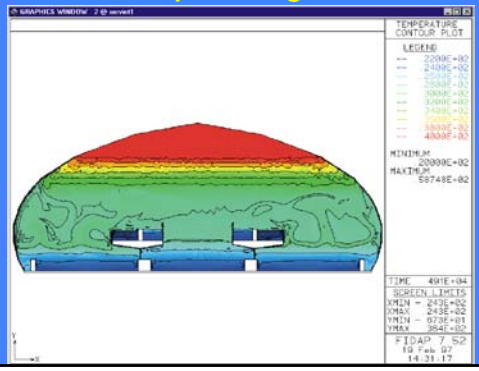
Optimized energy concept concourses

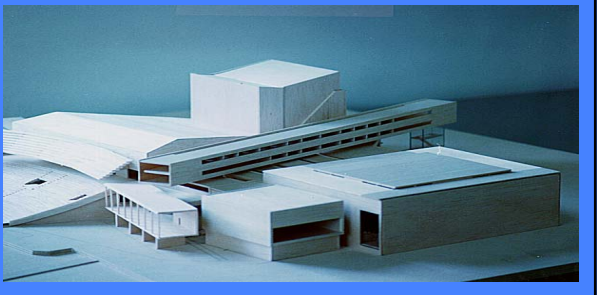
FIGURE 8



Airport Bangkok

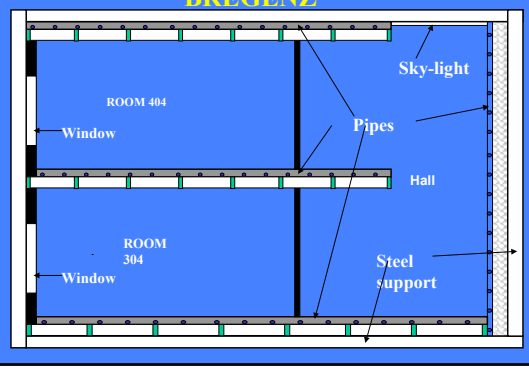


OPEN AIR THEATER BREGENZ



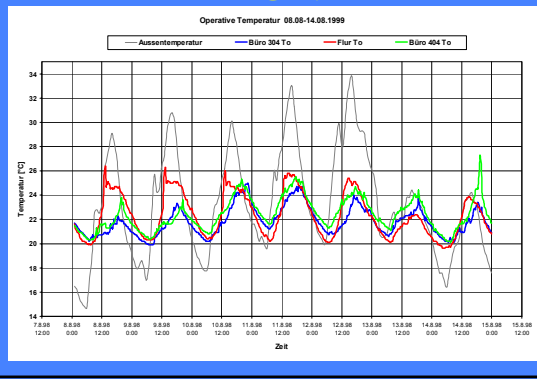
OPEN AIR THEATER BREGENZ

BREGENZ

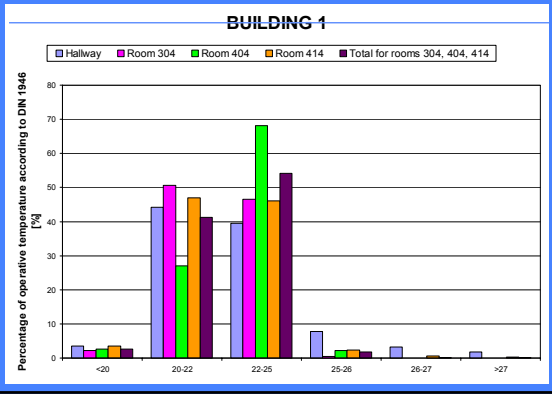


OPEN AIR THEATER BREGENZ

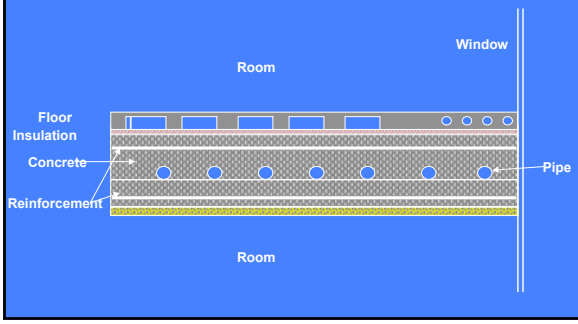
BREGENZ



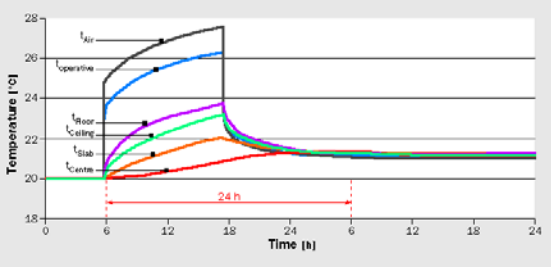
BUILDING 1



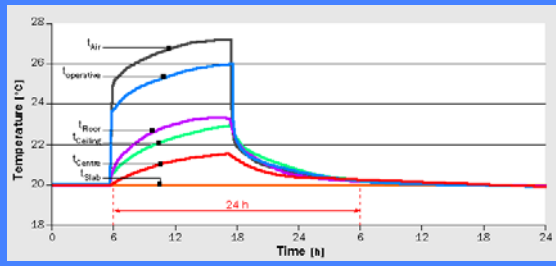
CONCRETE SLAB COOLING/HEATING



CALCULATED TEMPERATURES



CALCULATED TEMPERATURES



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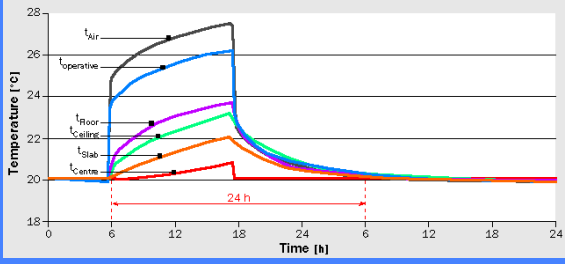
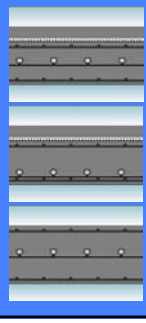


Calculated cooling-heating capacity



	Cooling	Heating
Supply water temperature:	16 °C	25 °C
Return water temperature:	20 °C	
Space temperature:	26 °C	20 °C
Floor :	9 W/m²	*5 W/m²*
Ceiling :	39 W/m²	*14 W/m²*
Totat:	**48 W/m²**	***19 W/m²***
Floor :	9 W/m²	*5 W/m²*
Ceiling :	47 W/m²	*16 W/m²*
Total	**56 W/m²**	***21 W/m²***
Floor :	26 W/m²	*15 W/m²*
Ceiling :	37 W/m²	*14 W/m²*
Total :	**63 W/m²**	***29 W/m²***

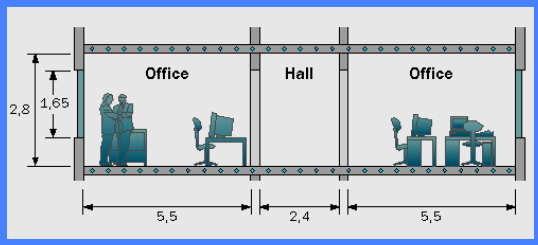
CONCRETE SLAB COOLING/HEATING

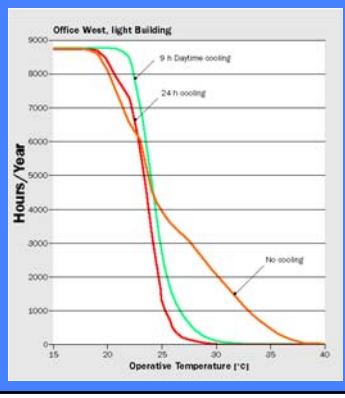
- **Building requirements**
  - **Well insulated**
  - **Window U-values < 1,2 W/m²K**
  - **Solar shielding**
  - **Cooling load ~30-50 W/m²**
  - **Heat load < 20 W/m² *only system***
  - **20 W/m² < Heat load < 30 W/m² *optimal control***
  - **30 W/m² < Heat load , *additional system***

CONCRETE SLAB COOLING/HEATING

- **Heating and cooling of multi-storey buildings**
- **Offices, schools, commercial buildings**
- **Heat storage/transfer between day and night**
- **Heat transfer between south and north facing rooms ?**
- **Use of dynamic computer simulations ?**

COMPUTER-SIMULATION





COMPUTER-SIMULATION

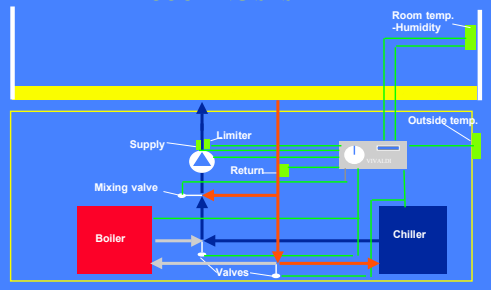
COMPUTER-SIMULATION

$$Gt_{Übertemperatur} = \Sigma\,(\theta_{operativ} - 26°C) \cdot 1h$$

für

$\theta_{operativ} > 26°C$)

CONTROL OF A COMBINED FLOOR HEATING-COOLING SYSTEM



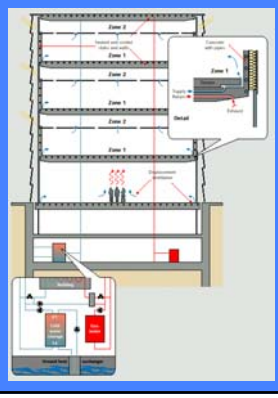
Operation time

		Mai to September Mean water temperature according to outside temperature		
Operation		24 hours 0905	18 – 6 0901	22-6 0902
	°C	%	%	%
Temperature interval	**<20**	**0,0**	**0,0**	**0,0**
	20-22	**11,3**	**3,9**	**1,8**
	22-25	**88,0**	**87,6**	**91,6**
	25-26	**0,7**	**6,3**	**5,1**
	26-27	**0,0**	**1,7**	**1,3**
	>27	**0,0**	**0,5**	**0,1**
Pump running	**hours**	**1217**	**515**	**412**
	%	**33**	**14**	**11**

ART MUSEUM BREGENZ

ART MUSEUM IN BREGENZ

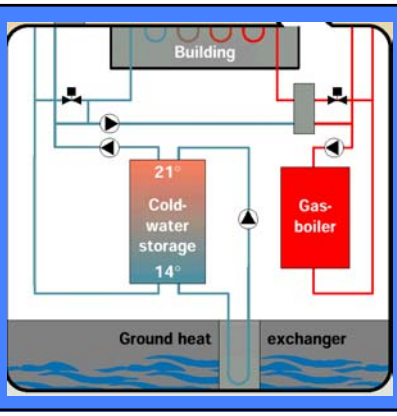
- Design requirements
  - Air temperature variations during a day within 4 K
  - Relative humidity variations less than 6 % during a day.
  - Seasonal variations between 48 and 58 %
  - Room temperature in winter 18 °C to 22 °C
  - Room temperature in summer 22 °C to 26 °C, occasional up to 28 °C
- Design load 250 persons pr. day, 2 hours
- Displacement ventilation < 0,2 h^{-1}
- Floor area 2.800 m² , 4 floors
- 28.000 m plastic pipes embedded in walls and floor slabs



ART MUSEUM BREGENZ

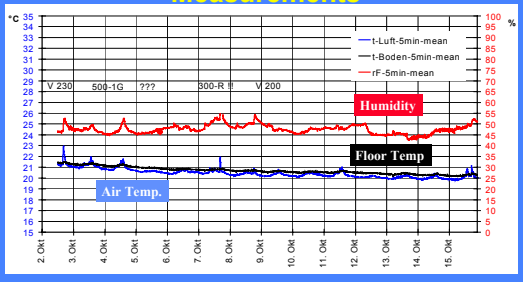
- 3.750 m² floor area
- 4.725 m² embedded pipes
- Condensing boiler
- Ventilation 750 m³/h per floor (first design was 25.000 m³/h

ART MUSEUM IN BREGENZ



ART MUSEUM BREGENZ

ART MUSEUM BREGENZ - Measurements

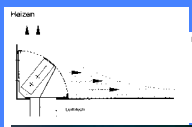


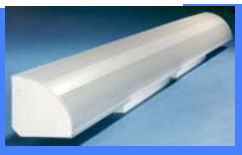
Office building Stuttgart

- 1998
- 11.000 m²
- 3-4 floors
- Operable windows
- Co-generation
- Solar collectors
- Absorption cooling
- Free cooling
- Compressor cooling
- Displacement ventilation

Displacement ventilation

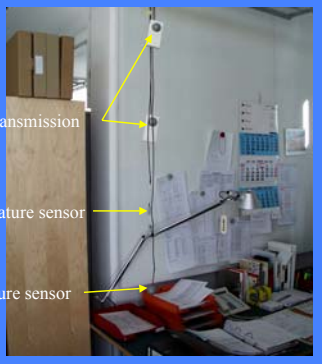
- **Air supply**
  Integrated convector for heating

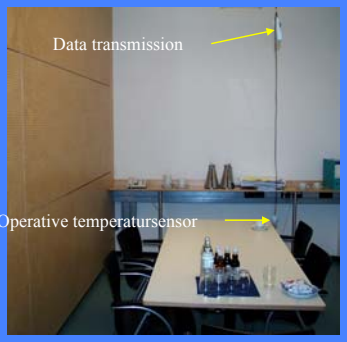




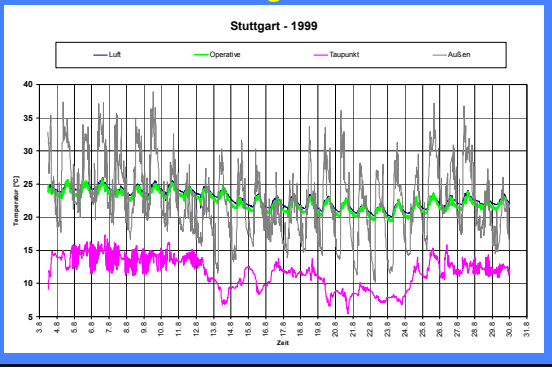
Technische Daten

Definition			H = 3 Rohre	N = 1 Rohr
Wasser-Vorlauftemperatur	t_W	in °C	75	75
Wasser-Volumenstrom	V_W	in l/h	100	100
Luftvolumenstrom	$\dot{V}$	in m³/h · m	150	150
A-bewerteter Schallleistungspegel	L_{WA}	in dB(A)	25	25
Gesamt-Druckverlust (Zuluft)	Δp_t	in Pa	< 20	< 20
Strömungsgeschwindigkeit	$\bar{v}_L$	in m/s	0,15	0,15
Abstand	A	in m	≤ 1,5	≤ 1,5
Leistung	Q	in W/m	500	350

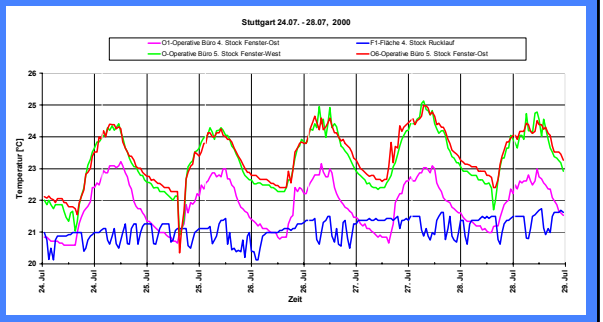




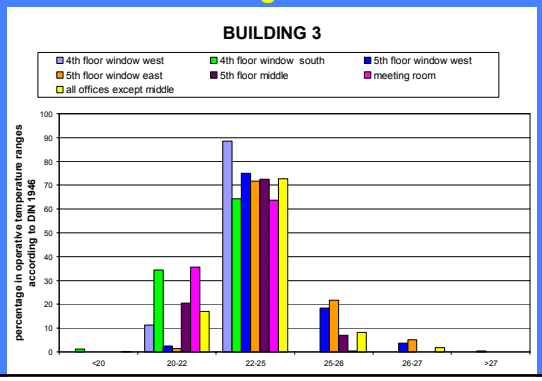
Stuttgart



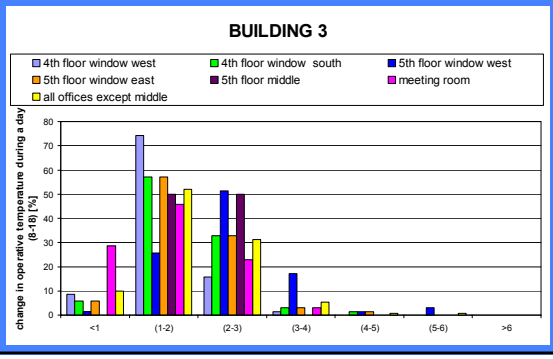
Stuttgart



Stuttgart



STUTTGART



Office building in Hamburg

- 2000
- 14.000 m²
- 7.500 m² slab cooling
- Baseboard heaters
- 2 ach, 18 °C
- Operable windows

Transportation of modules

INSTALLATION

PRE-FABRICATION

PRE-FABRICATION

CONCLUSIONS

- **Hydraulic heating/cooling system with pipes embedded in the building structure is an interesting alternative to full air conditioning**
  - **High temperature cooling-low temperature heating**
  - **No noise**
  - **No draught**
  - **Low installation and running costs**
  - **Lower peak load and reduced equipment size**
  - **Lower building height**
  - **Combined with mechanical ventilation**
  - **Reduced capacity?**
  - **Acoustic?**
  - **Latent load?**