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Seminar 26 – Load Calculation Consideration for Radiant Systems

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cduarte@berkeley.edu p.raftery.berkeley.edu Development and Demonstration of an Interactive Web-based Design Tool for High-Thermal Mass Radiant Cooling Systems

Learning Objectives

- Understand how the difference between cooling loads for radiant cooling and all-air cooling is impacted by the heat gain characteristics, by indoor surface characteristics, and by the availability of passive cooling overnight.
- Understand the limitations of current radiant design tools and learn how this new webtool can help HVAC designers consider innovative radiant cooling systems with high-thermal mass.
- Understand experiments conducted to analyze differences in the cooling load of I) radiant and II) all-air systems, and rank the parameters that have impact on the difference in loads between these two systems.
- Explain the ideal load for radiant systems and understand the impact of an undersized radiant system on indoor air and surface temperatures.

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Funding

California Energy Commission EPIC Program

Center for the Built Environment

Price Industries

Outline/Agenda

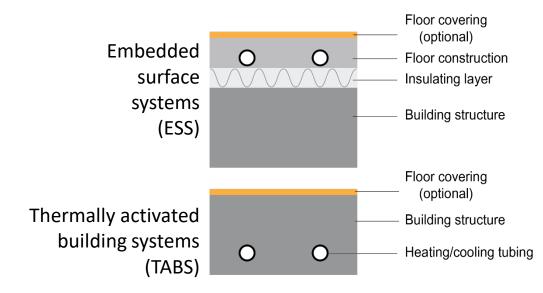
- Review types of high-thermal mass radiant system used in the web-tool
- Layout of web-tool
 - Steady-state
 - Transient
- Go through a couple examples
 - Steady-state
 - Transient



Construction workers installing high thermal mass radiant system.

Considerations for high-thermal mass radiant systems

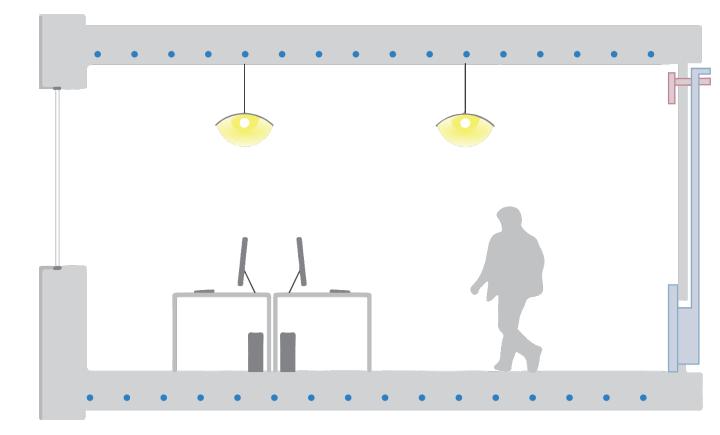
- Transient effects dominate
- Ability to activate/control a substantial amount of thermal mass in the room
 - Energy storage
 - Load shifting



Types of high thermal mass systems incorporated in the web-tool.

Considerations for high-thermal mass radiant systems

 Exposed surfaces are important!



The space's thermal mass is also important in determining a highthermal mass radiant system. Graphic source Caroline Karmann.

Current state of radiant system design approach

	100%	
 No consistent tool 	14%	Unknown
 Same methods as for all-air systems are used for radiant systems Limitations 	27%	Heat balance and advanced methods
 Steady-state Independent of control Independent of HVAC system 		
 Detailed simulation tools are perceived as complicated, time consuming, and high cost 	59%	Steady-state and radiant time series
	0%	

Methods used for cooling load calculations (N=22)

- Calculation type
 - Steady-state
 - ISO 11855 standard

STEADY STATE TRANSIENT RESOURCES				
This is an alpha version of the tool that is actively un	nder developmnent. Ex Design Calculations	pect bugs and please let us know abou	it them by email if you Pipe Design	I find one.
PERMALINK	T _{surface}	65.7 °F	V _{tit}	5.86 gal / min
	Δθ	17.4 °F	Ϋ́ _{loop}	0.586 gal / min
IMPERIAL FLOOR COOLING ESS	K _H	0.527 Btu / (hr ft² °F)	v	8.74 in / s
DIAGRAM	Heat Extraction		dploop	1.05 psi
DIAGRAM	Q	14600 Btu / hr	lact	324 ft
CUSTOM PLOT AXES	q _{sf}	9.15 Btu / (hr ft²)	I _{num}	10
Pipe Nominal Diameter			Do	0.75 in
Default ASTM F876 5/8			Di	0.573 in
Zone Width		Supply Water Below Dew Point	Total Surface Hea	t Flux
80 ft Zone Length	17			
20 ft	16			
Pipe Spacing	14			
<u>6</u> in	12 10 10 8			
Maximum Loop Length	12 12			
350 ft Maximum Pressure Drop Per Loop	변 × 10			
10 ft	E E			
Pipe Depth	8 He a			
4 in	6 Surface			
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14.6 (Btu · in)/(h · ft² · °F) Covering Thermal Resistance	4 Lotal			
0.25 (ft² · °F · h)/Btu	2			
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Delta Temperature Between Return and Supply	X Axis			
5 °F	Supply Water Temp	perature		▼
Design Indoor Operative Temperature	Total Surface Heat	Elux		
77 °F Design Dew Point Temperature	Total Sunace Heat	T IUA		·
55 °F				
<u> </u>				

- Calculation type
 - Steady-state
 - ISO 11855 standard
- Inputs
 - Radiant system type
 - Design parameters
 - Metric/Imperial units

STEADY STA	TE	TRANSIENT	RESOUR	CES																		
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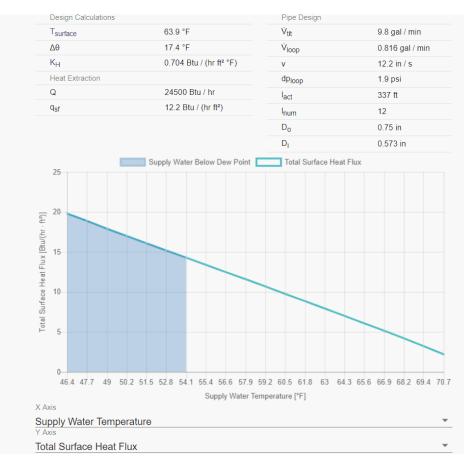
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 - Hydronic heat capacity
 - Waterflow rate
 - Pipe design
 - Surface temperature
 - Visualization of the design space

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sian Indoor (Operative Temp	erature			Y Axis		-				
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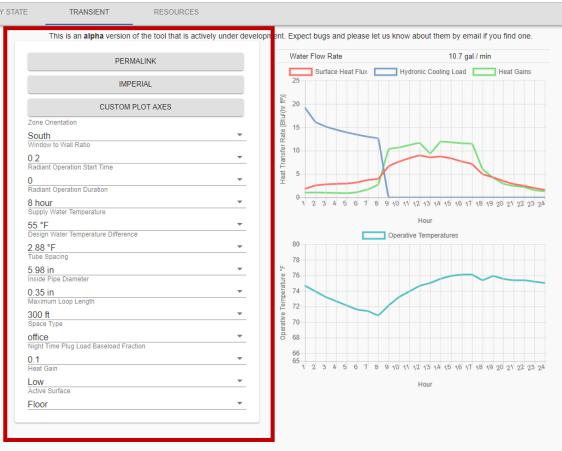
Layout of the webtool: Transient

- Calculation type
 - Transient
 - Over 2.5 million EnergyPlus simulations



Layout of the webtool: Transient

- Calculation type
 - Transient
 - Over 2.5 million EnergyPlus simulations
- Inputs
 - Design parameters
 - Time



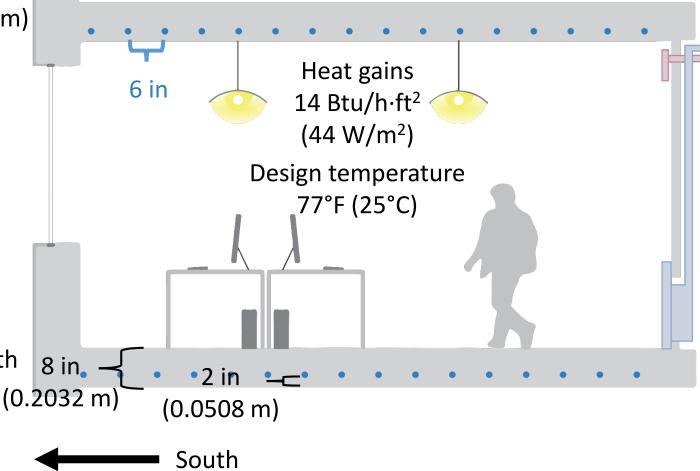
Layout of the webtool: Transient

- Calculation type
 - Transient
 - Over 2.5 million EnergyPlus simulations
- Inputs
 - Design parameters
 - Time
- Outputs
 - 24-hour cooling day design values
 - Surface heat flux
 - Hydronic heat capacity
 - Operative temperature



Example: Verify that system parameters meet the required load

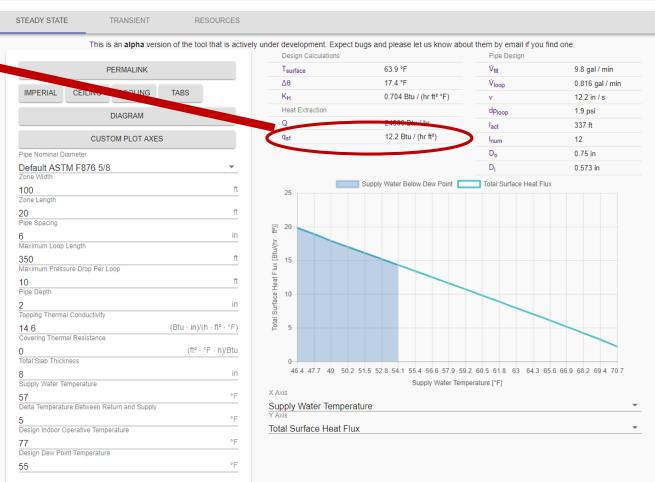
- 100 x 20 ft (30.5 x 6 m) office zone
- 57°F (13.9°C) supply water temperature
- 5°F (2.8°C) supply/return difference
- 55°F (12.8°C) dew point temperature
- 350 ft (107 m) maximum loop length



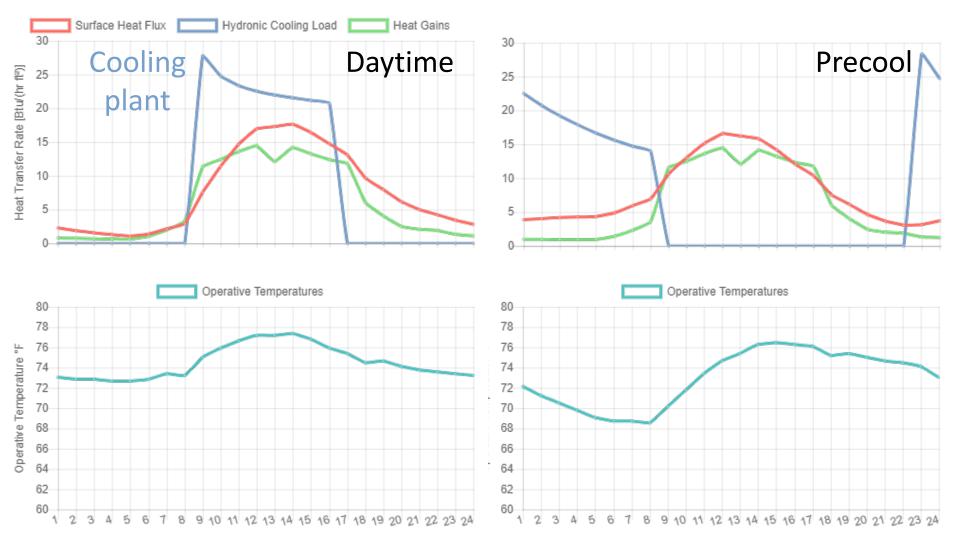
Demo: Steady-state example

Surface heat flux = 12.2 Btu/h·ft² (38.5 W/m²)

Initial design does not meet the required heat gain load of 14 Btu/h·ft² (44 W/m²)!



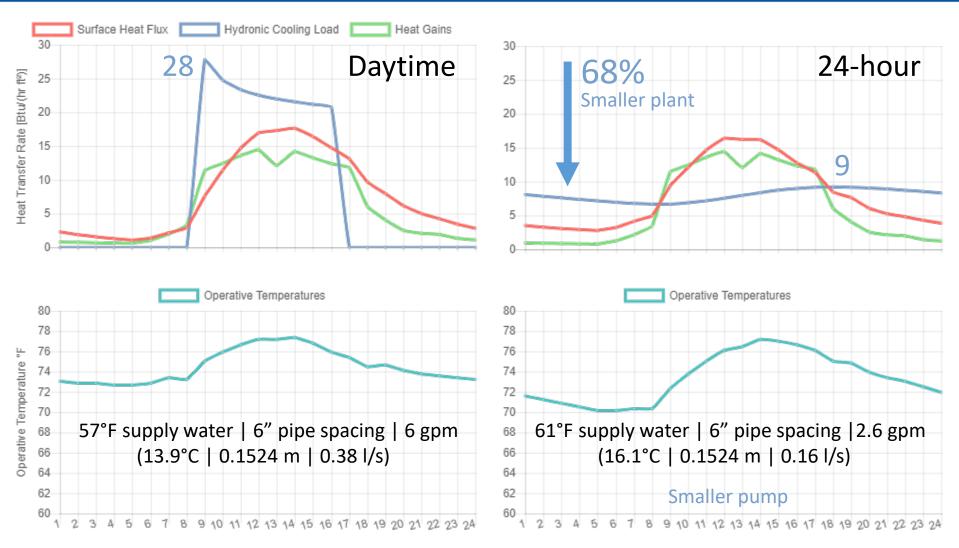
Demo: Transient example



Hour

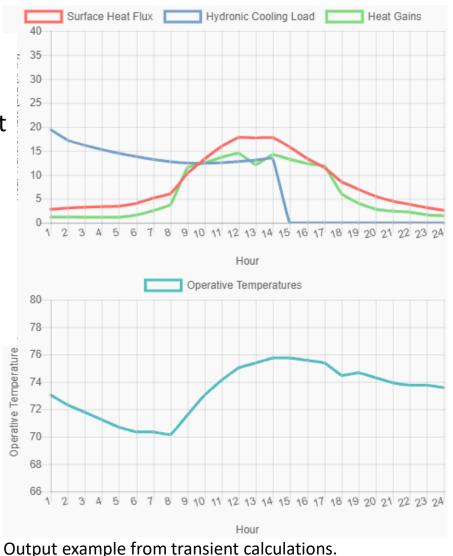
Hour

Demo: Transient example



Conclusion

- Tool facilitates existing steady-state calculations
- High thermal mass systems need transient tools
- Transient tool allows designers to explore ways to reduce:
 - Energy consumption
 - Cooling plant size
 - Electricity costs



Next steps

- Continue development
- Resources
 - User's guide documentation
 - Sequences of operation for radiant control
 - EnergyPlus example models that includes control sequences



Infrared picture of ceiling with high-thermal mass radiant system.

Bibliography

- Feng, J. (Dove), F. Bauman, S. Schiavon. 2014. Critical review of water based radiant cooling system design methods. Proceedings of Indoor Air 2014.
- Raftery, P., C. Duarte, S. Schiavon, F. Bauman. 2017. CBE Rad Tool. radiant.cbe.berkeley.edu

Questions?

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