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Seminar 26 – Load Calculation Consideration for Radiant Systems

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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.

Acknowledgements

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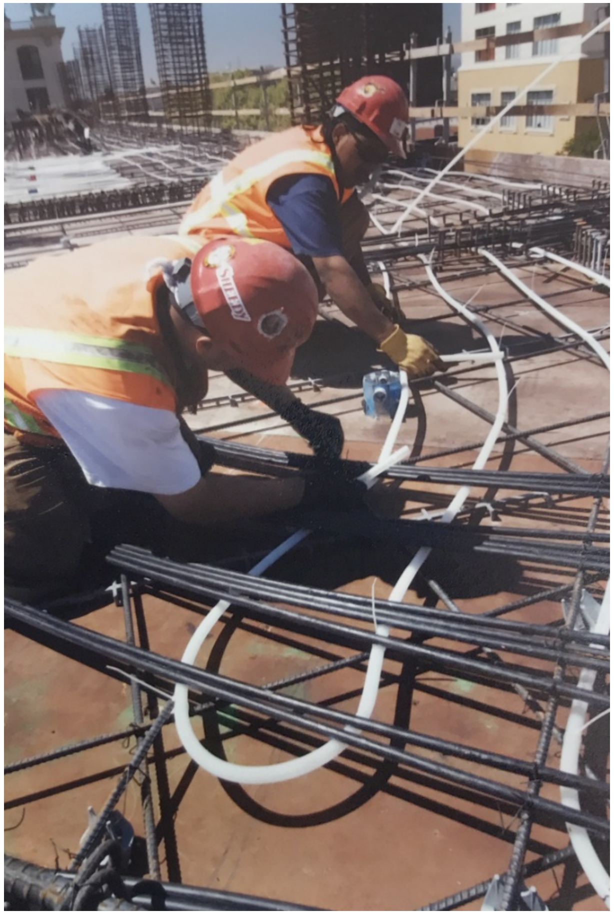
Price Industries

Outline/Agenda

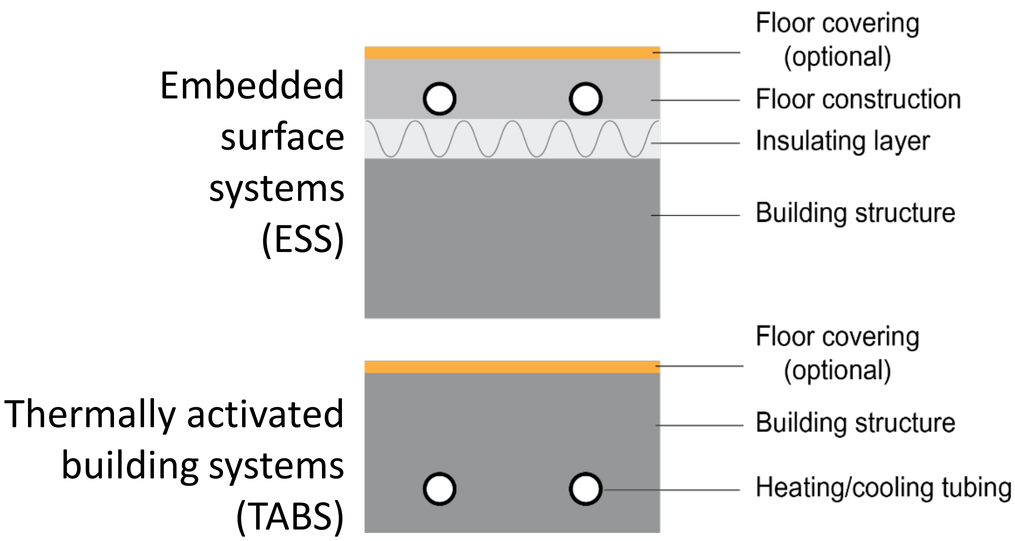
- Review types of high-thermal mass radiant system used in the web-tool
- Layout of web-tool
  - Steady-state
  - Transient
- Go through a couple examples
  - Steady-state
  - Transient



Construction workers installing high thermal mass radiant system.

Considerations for high-thermal mass radiant systems

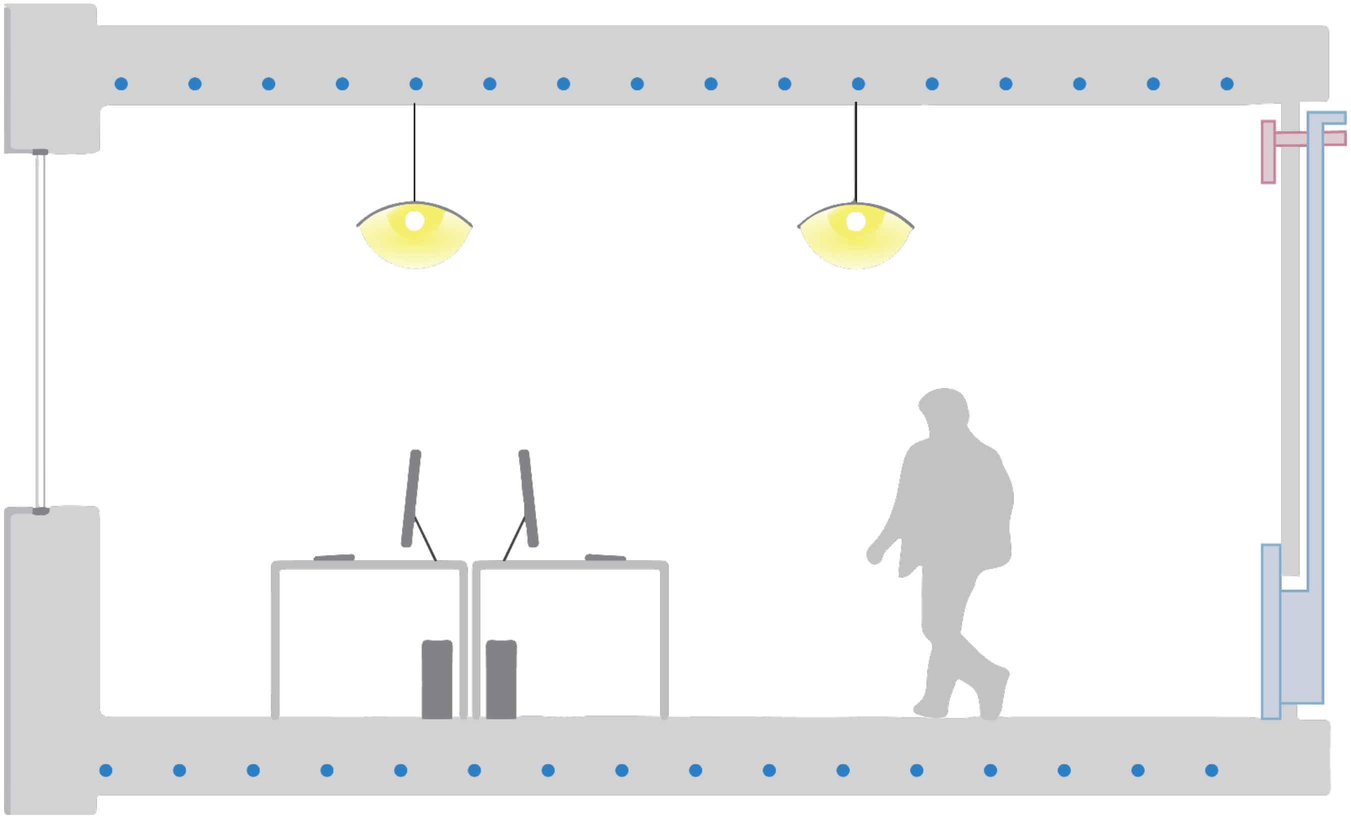
- Transient effects dominate
- Ability to activate/control a substantial amount of thermal mass in the room
  - Energy storage
  - Load shifting



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

Considerations for high-thermal mass radiant systems

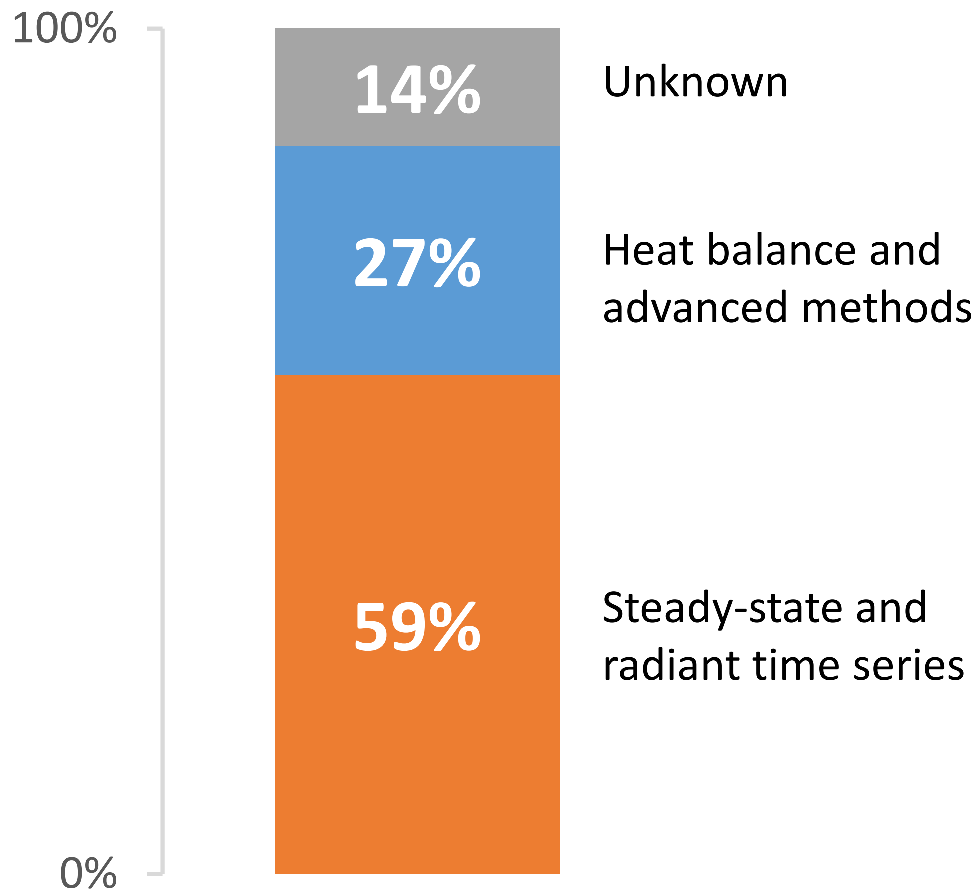
- Exposed surfaces are important!



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

Current state of radiant system design approach

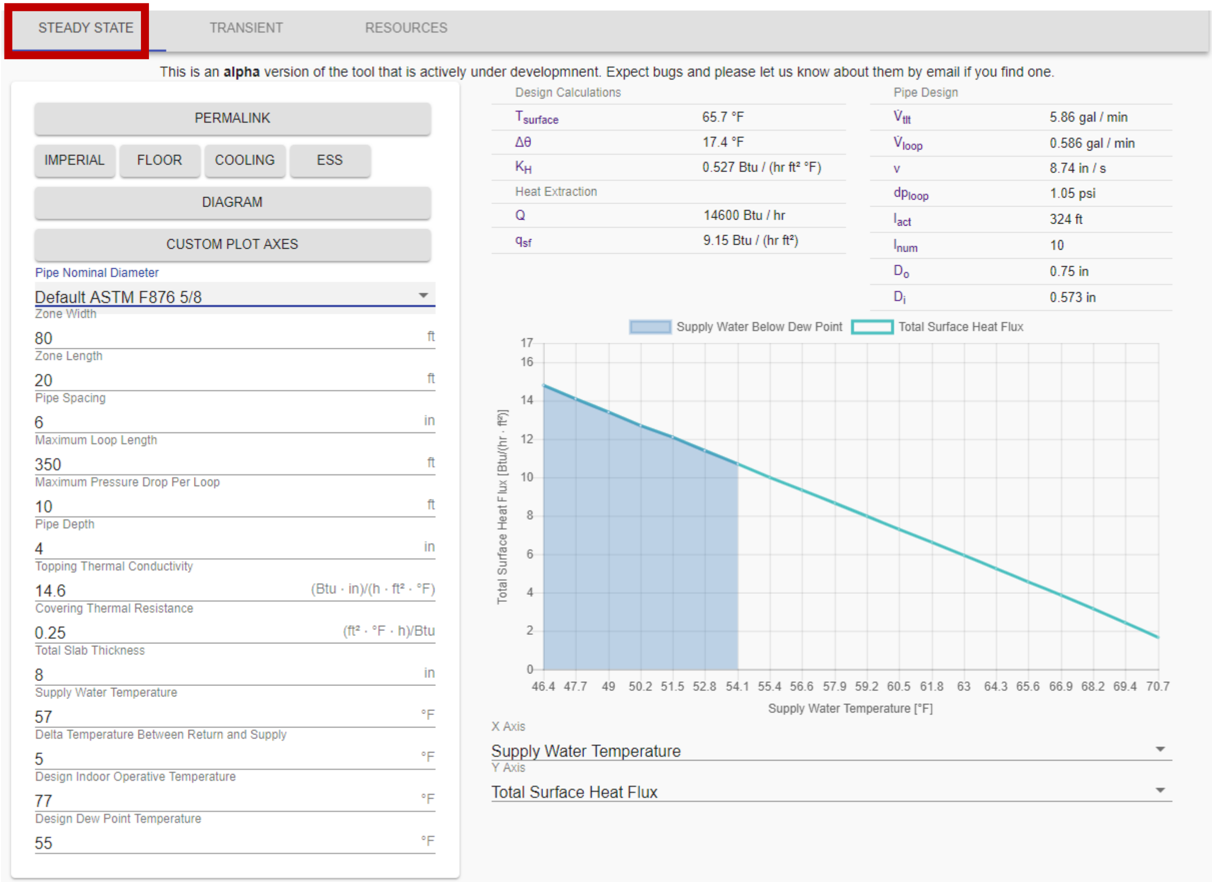
- No consistent tool
- Same methods as for all-air systems are used for radiant systems
  - Limitations
    - Steady-state
    - Independent of control
    - Independent of HVAC system
- Detailed simulation tools are perceived as complicated, time consuming, and high cost



Methods used for cooling load calculations (N=22)

Layout of the webtool: Steady-state

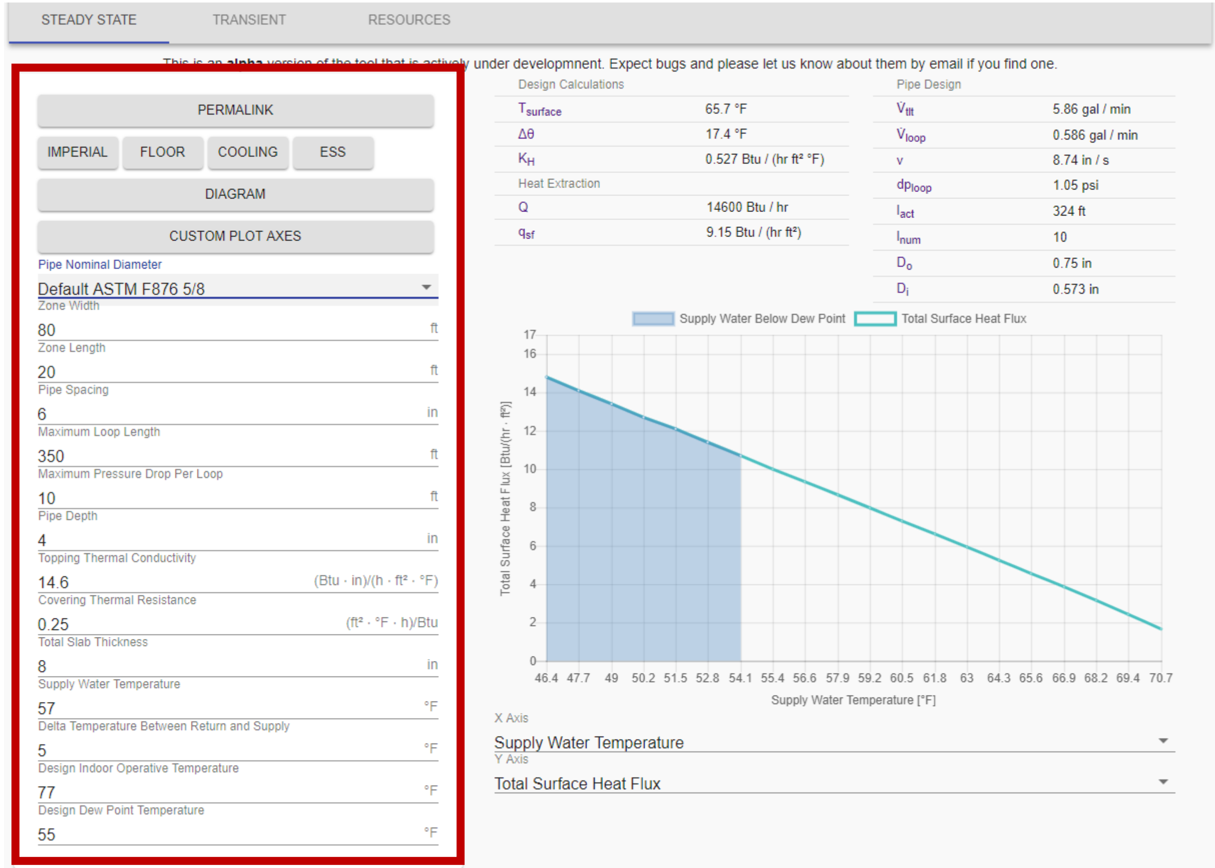
- Calculation type
  - Steady-state
  - ISO 11855 standard



Screenshot of web-tool for the early design of high-thermal mass radiant systems.

Layout of the webtool: Steady-state

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



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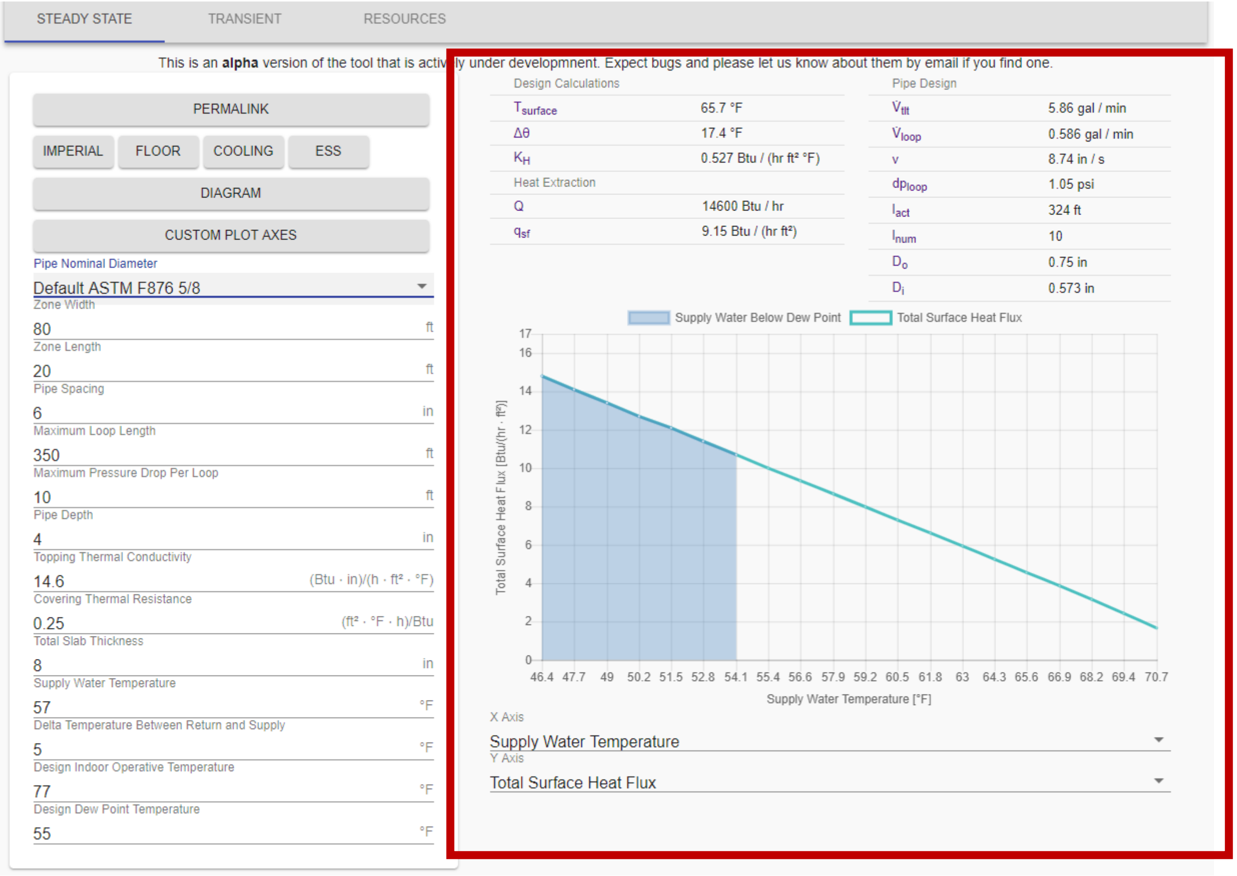
Layout of the webtool: Steady-state

- Calculation type
  - Steady-state
  - ISO 11855 standard
- Inputs
  - Radiant system type
  - Design parameters
  - Metric/Imperial units
- Outputs
  - Design values
    - Surface heat flux
    - Hydronic heat capacity
    - Waterflow rate
    - Pipe design
    - Surface temperature
  - Visualization of the design space



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- Calculation type
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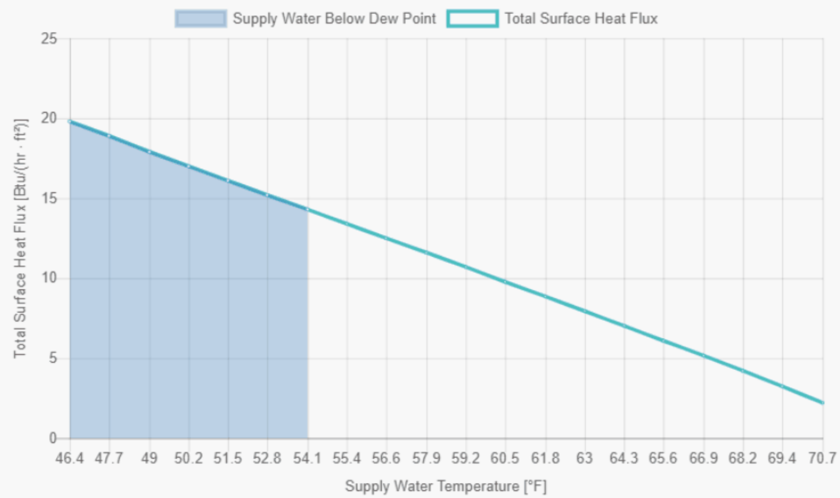
Design Calculations	
$T_{surface}$	63.9 °F
$\Delta\theta$	17.4 °F
K_H	0.704 Btu / (hr ft² °F)
Heat Extraction	
Q	24500 Btu / hr
q_{sf}	12.2 Btu / (hr ft²)

Pipe Design	
$\dot{V}_{tlt}$	9.8 gal / min
$\dot{V}_{loop}$	0.816 gal / min
v	12.2 in / s
dp_{loop}	1.9 psi
l_{act}	337 ft
l_{num}	12
D_o	0.75 in
D_i	0.573 in



X Axis

Supply Water Temperature

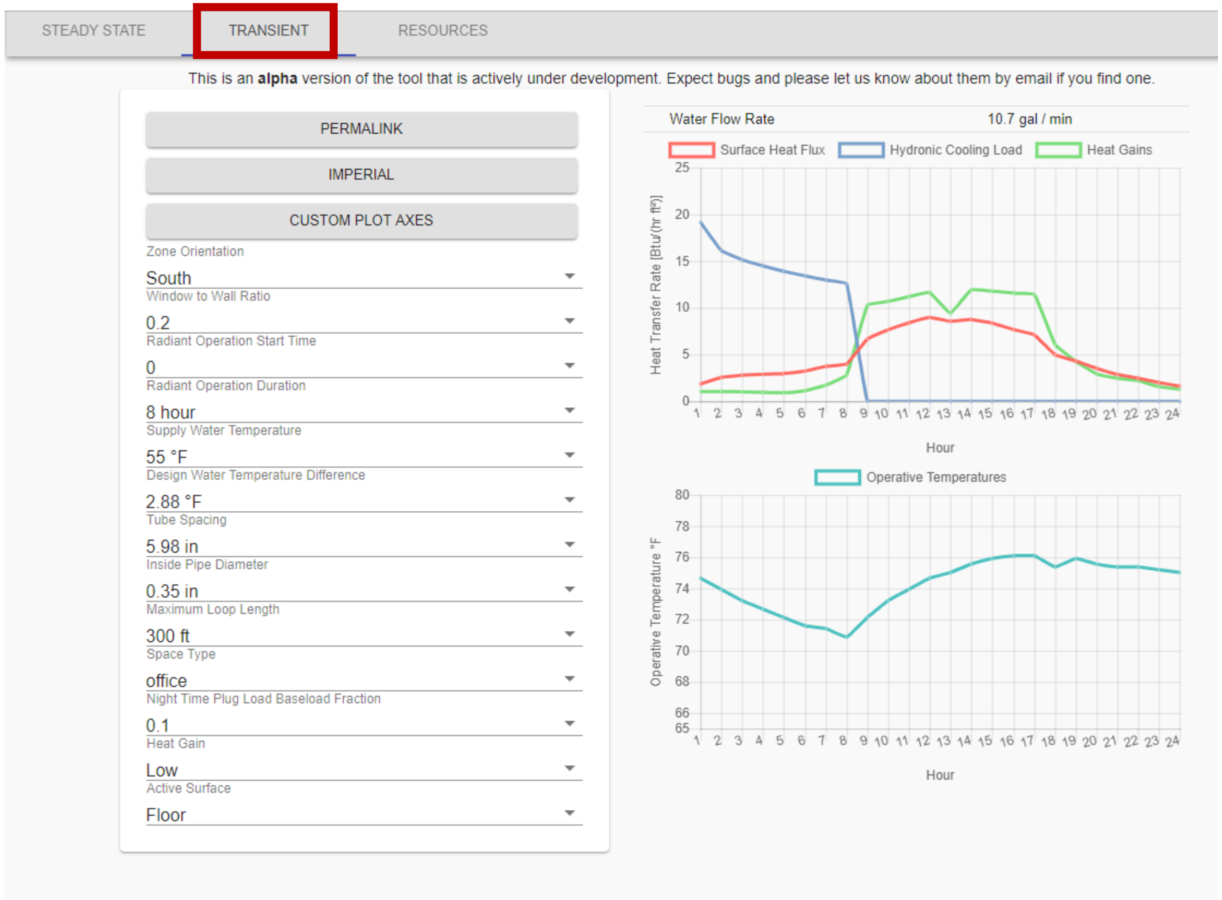
Y Axis

Total Surface Heat Flux

Screenshot of web-tool for the early design of high-thermal mass radiant systems.

Layout of the webtool: Transient

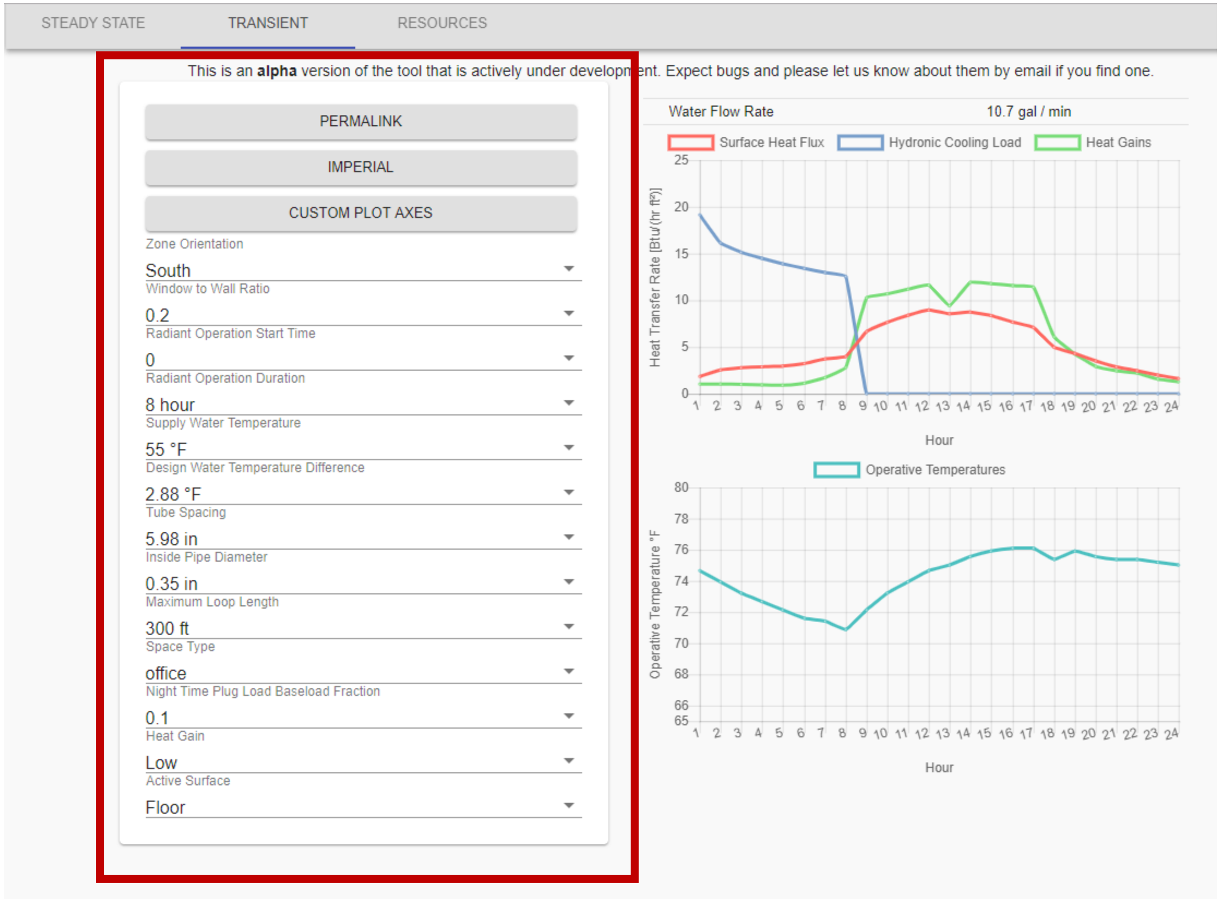
- Calculation type
  - Transient
  - Over 2.5 million EnergyPlus simulations



Screenshot of web-tool for the early design of high-thermal mass radiant systems.

Layout of the webtool: Transient

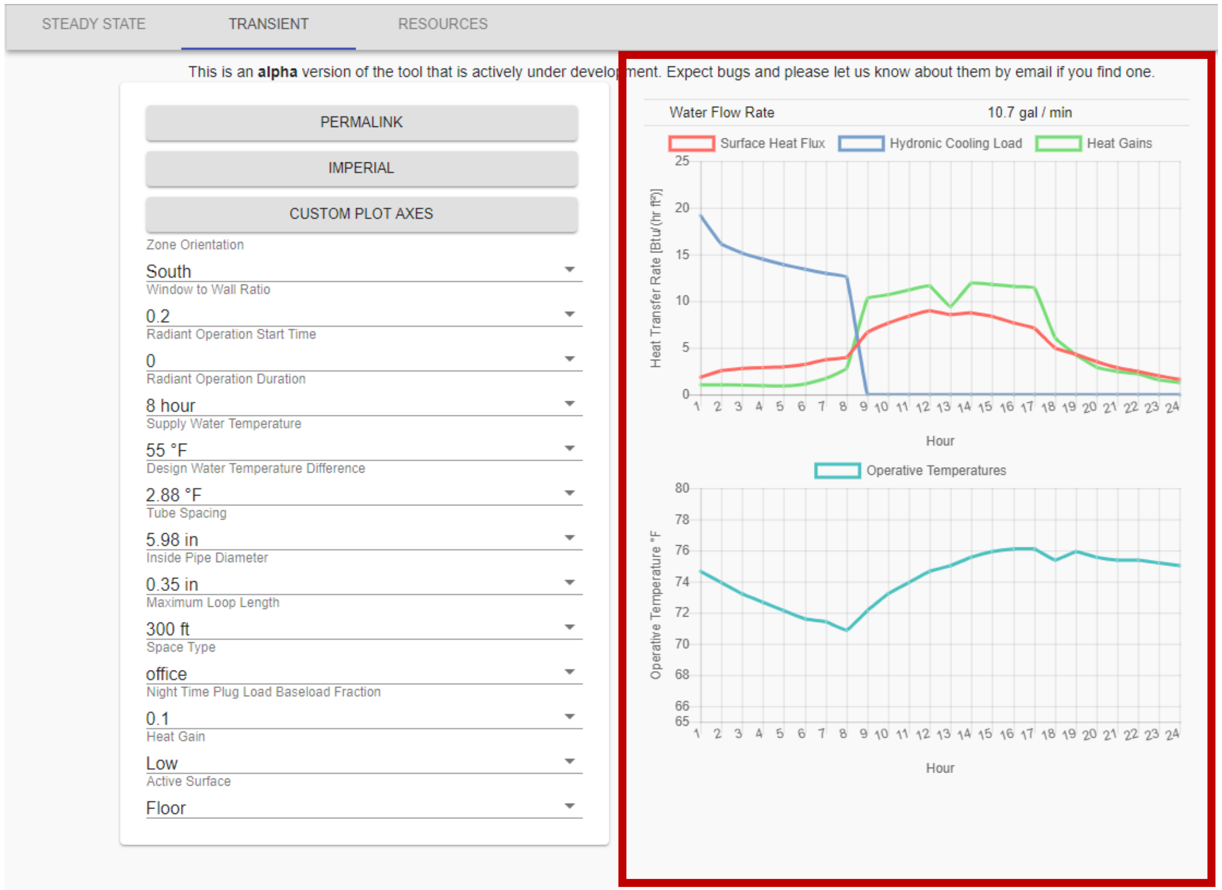
- Calculation type
  - Transient
  - Over 2.5 million EnergyPlus simulations
- Inputs
  - Design parameters
  - Time



Screenshot of web-tool for the early design of high-thermal mass radiant systems.

Layout of the webtool: Transient

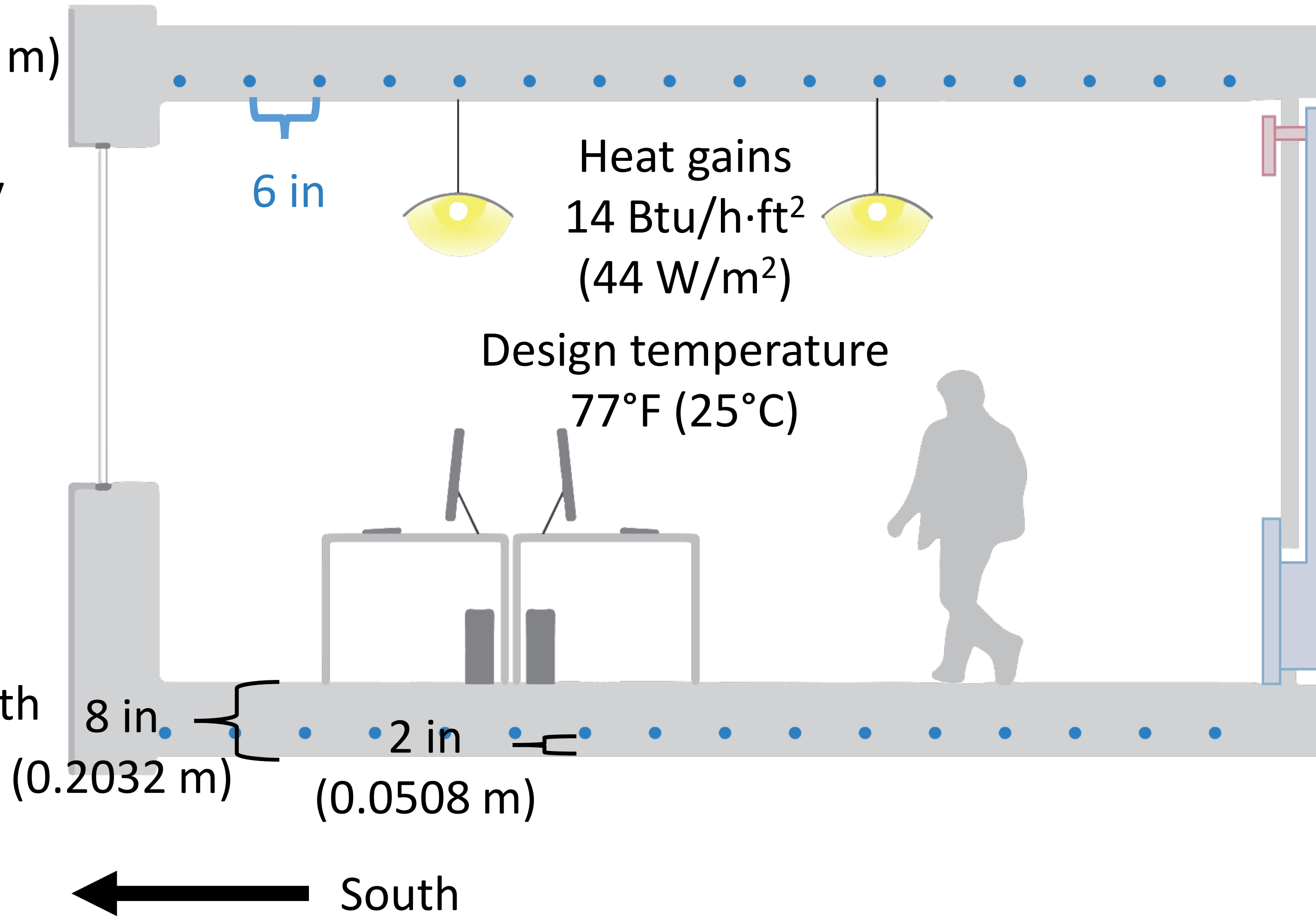
- Calculation type
  - Transient
  - Over 2.5 million EnergyPlus simulations
- Inputs
  - Design parameters
  - Time
- Outputs
  - 24-hour cooling day design values
    - Surface heat flux
    - Hydronic heat capacity
    - Operative temperature



Screenshot of web-tool for the early design of high-thermal mass radiant systems.

Example: Verify that system parameters meet the required load

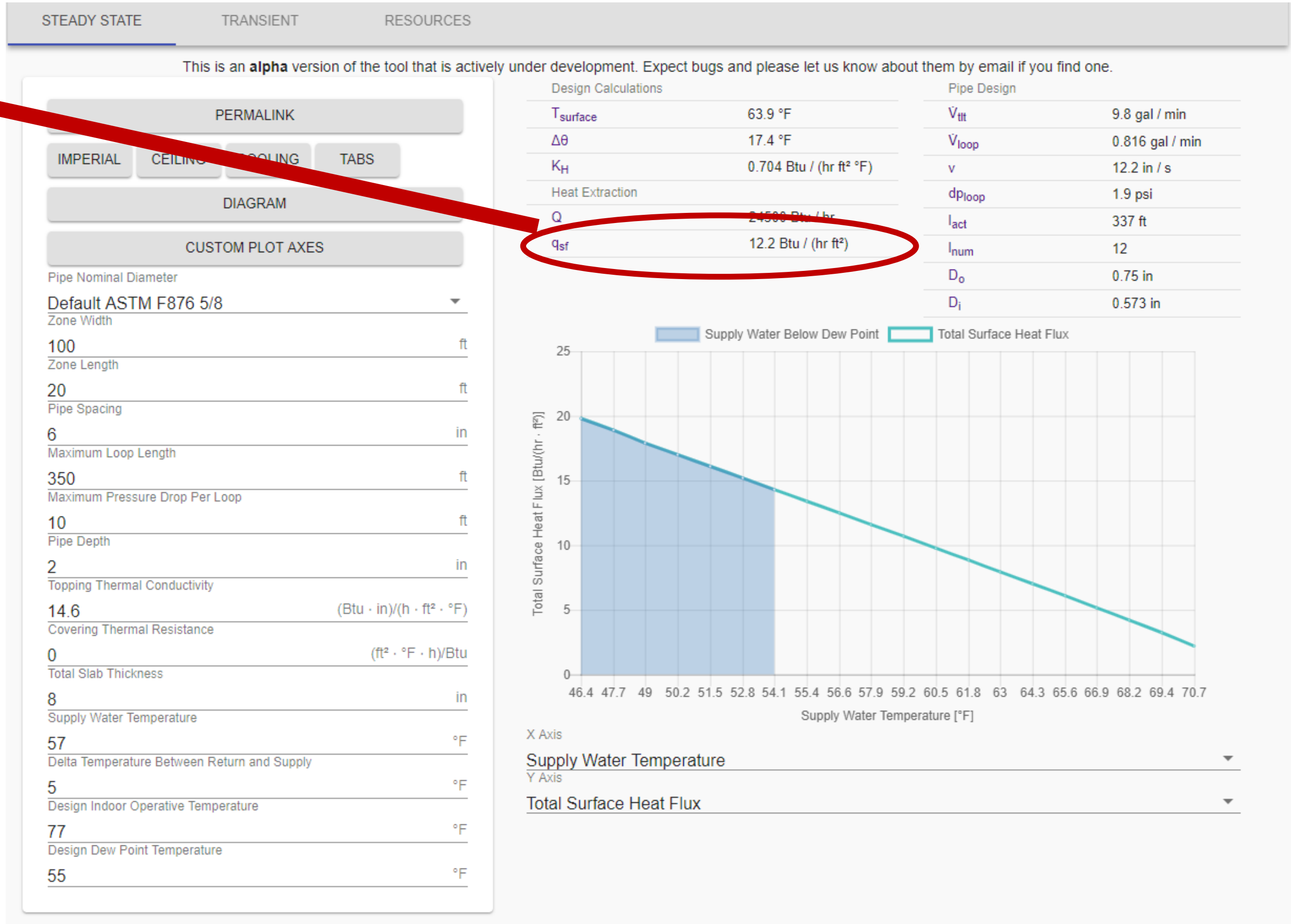
- 100 x 20 ft (30.5 x 6 m) office zone
- 57°F (13.9°C) supply water temperature
- 5°F (2.8°C) supply/return difference
- 55°F (12.8°C) dew point temperature
- 350 ft (107 m) maximum loop length



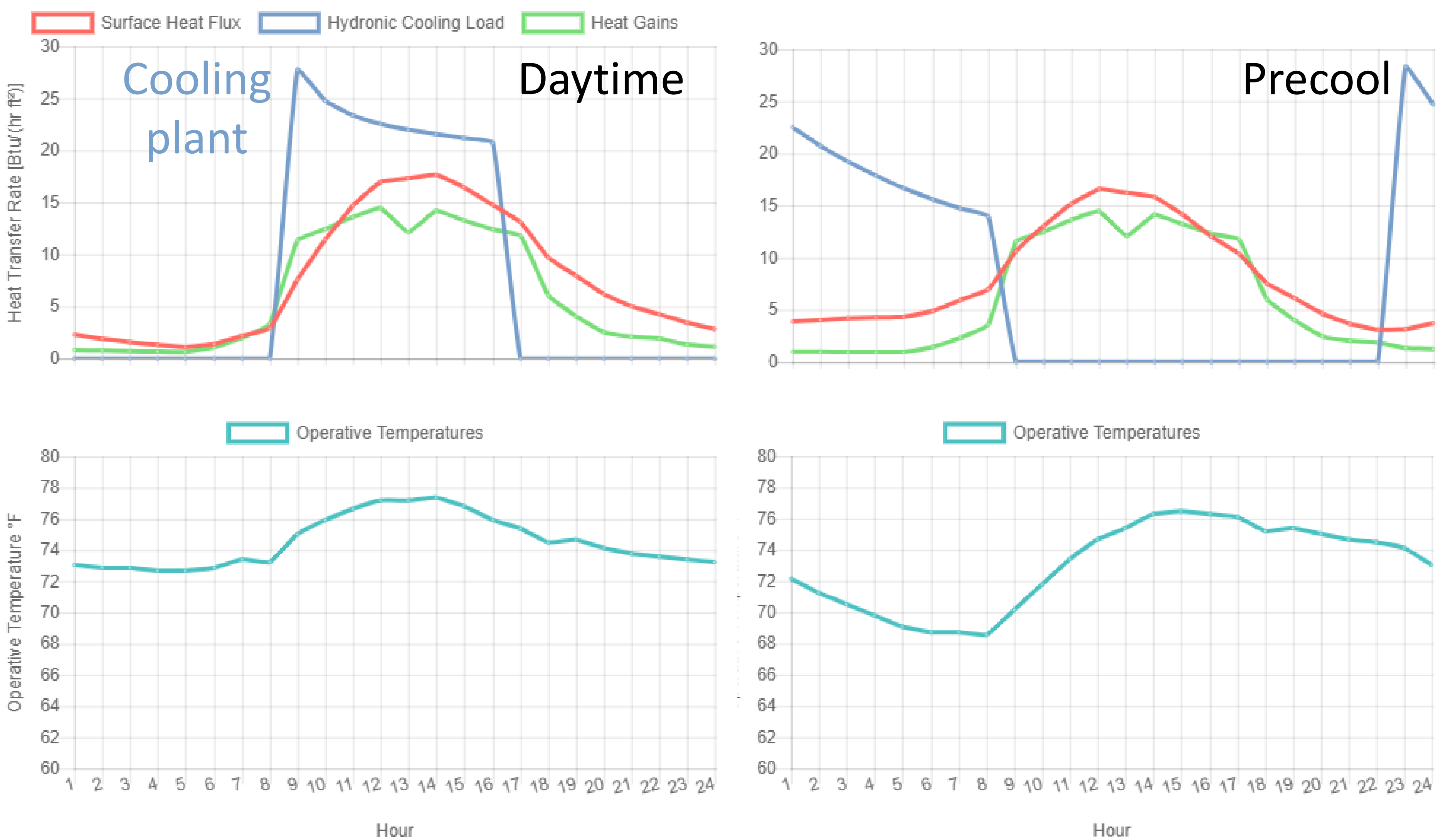
Demo: Steady-state example

Surface heat flux = 12.2 Btu/h·ft^2 (38.5 W/m^2)

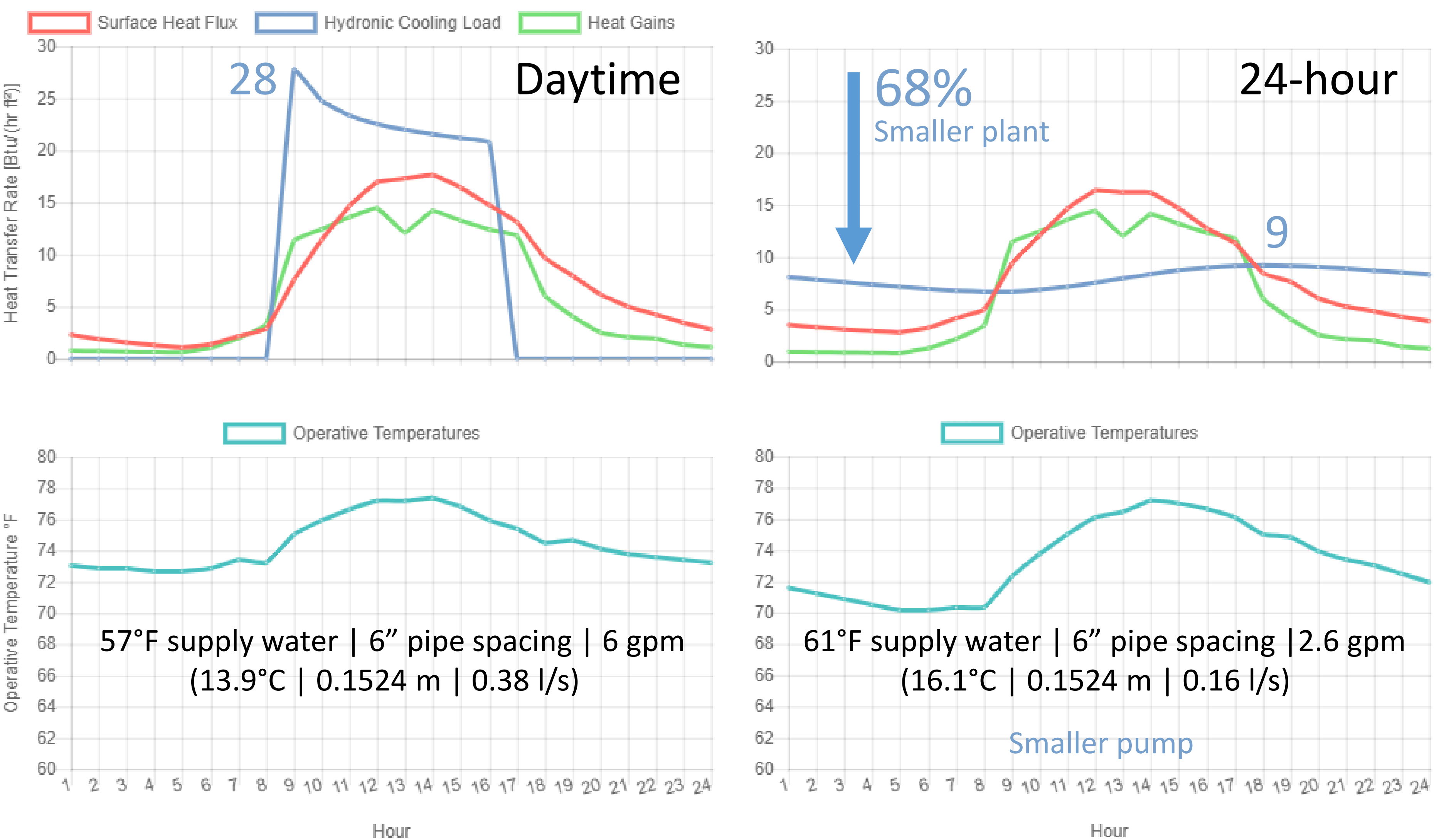
Initial design does not meet the required heat gain load of 14 Btu/h·ft^2 (44 W/m^2)!



Demo: Transient example

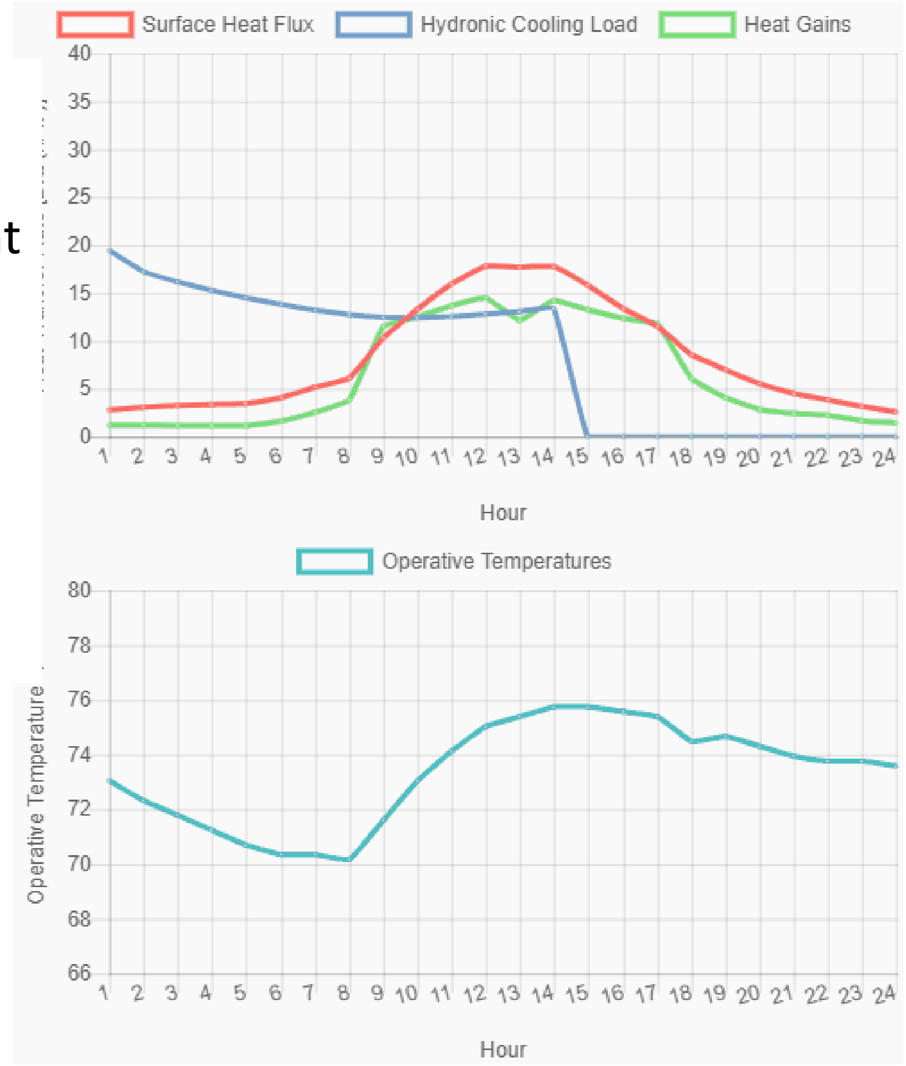


Demo: Transient example



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



Output example from transient calculations.

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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