The Art of Thermal Mass Modeling for Energy Conservation in Buildings, Part 2

ACI Spring 2012 Convention
March 18 – 21, Dallas, TX

American Concrete Institute®
Advancing concrete knowledge

ACI WEB SESSIONS

David Springer is president and co-founder of Davis Energy Group, a 30 year old mechanical engineering firm specializing in building energy efficiency. He manages a diversity of projects involving design, energy analysis, measurement and evaluation, standards development, and technology commercialization. He currently manages the U.S. DOE Building America team, Alliance for Residential Building Innovation (ARBI). He has authored eighteen papers and articles on energy subjects and holds six patents. Mr. Springer is an active member of ASHRAE, serving on the SPC 152R standards committee and the Radiant Heating and Cooling technical committee (TC 6.5), and is a member of the UC Davis Mechanical and Aerospace Engineering Board of Advisors. He earned his B.S. from U.C. Davis in 1973 in Biological Science.

ACI WEB SESSIONS

Radiant Cooling in a Hot Dry Climate

American Concrete Institute Convention
March 19, 2012
Dallas, Texas

Presenter: David Springer

Alliance for Residential Building Innovation

Davis Energy Group

Building America U.S. Department of Energy

What Does This Have to Do with Concrete?

- Will demonstrate how a concrete slab foundation can be an integral component in:
  - Reducing heating and cooling energy use
  - Improving comfort
  - Helping to achieve a zero net energy goal in residential buildings
  - Optimizing electricity time of use
- Using:
  - Measured performance data
  - Computer simulations

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Characteristics of an Ideal Comfort System

- Superior comfort
- Low energy use
- Zonal temperature control
- Minimal use of space for equipment & ducts
- Quiet operation
- Easy and inexpensive to maintain
- Utility friendly
  - Favorable load shape
  - Demand response capability

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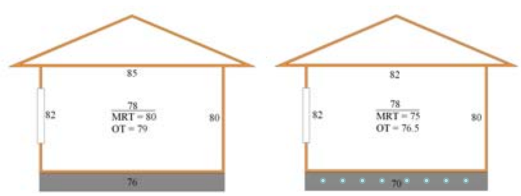
How to Improve Comfort …

…without increasing energy bills



Forced-Air Cooling   Radiant Cooling

Radiant cooling lowers the temperature of the floor surface and provides better comfort (lower operative temperature) at the same indoor air temperature and thermostat setting.

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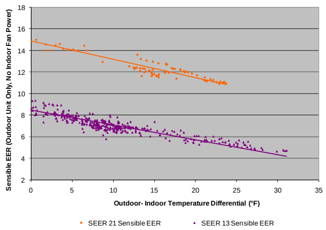
How to Improve Equipment Efficiency

- Correct sizing
  - Equipment
  - Distribution system
- Install high efficiency equipment
- Install it correctly
- Reduce "thermal lift"



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Radiant Distribution Advantages

- Improved comfort in all seasons
- Eliminates space required for ducting
- Easy to zone
- Quiet
- Higher evaporator temperature (cooling)
- Can shift the load by storing energy in the slab

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The Concept of "Active Mass"

- Passive Mass:
  - Slab exchanges heat with indoor air convectively
  - Slab temperature affected more by ground heat exchanges than by air temperature
  - Mass tends to moderate indoor temperature but doesn't control it
- Active Mass:
  - Slab can be charged or discharged at will to maintain desired operative temperature
  - Charging can occur at times when the outdoor temperature favors higher system performance

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How to Make Chilled (or Hot) Water

- Chilled Water
  - Air-to-water heat pump
  - Condensing unit with refrigerant-to-water heat exchanger
- Hot Water
  - Air-to-water heat pump
  - "Combined" system (water heater with fan coil)

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Some Research Questions

- What is the distribution efficiency of radiant floor systems and how does it compare to forced air systems?
- How much can performance be improved by reducing thermal lift, and is it possible to maintain comfort while operating equipment at optimal times of the day?
- Is condensation on cooled floor surfaces a problem and how can it be mitigated?

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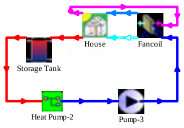
Research Approach

- Monitor installed systems
- Calibrate a simulation model using monitoring data to evaluate under different conditions

Borrego Springs, CA



TRNSYS Model

Tucson, AZ

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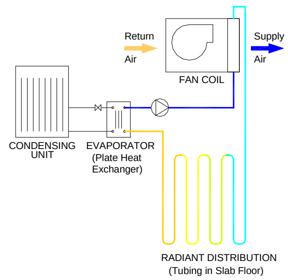
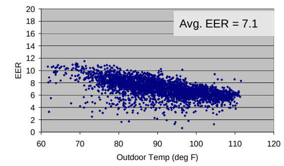
Addressing the Dewpoint Problem

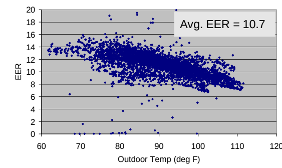
- Chilled water fan coil in series with radiant floor
- Fan coil provides latent cooling (moisture removal) as well as sensible cooling and raises the temperature of the water entering the radiant system
- Fan coil requires little or no ducting



Case Study 1: Borrego Springs

- House 1
  - SEER 13 condensing unit
  - Fan coil with standard evaporator coil
  - Conventional ducted system, ducts in conditioned space
- House 2
  - Same 13 SEER condensing unit
  - Refrigerant-to-water heat exchanger replaced indoor evaporator coil
  - Series flow through air handler & radiant floor





Case Study 2: Tucson SEED House

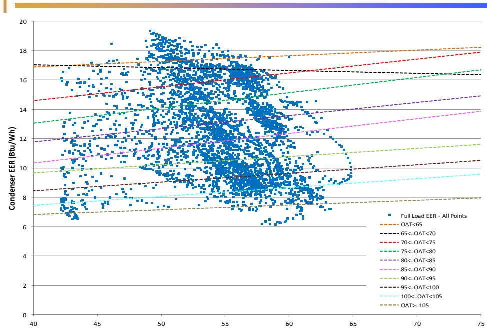
- Estimate distribution efficiency of fully insulated slab
- Look at relationship between EER and thermal lift
- Evaluate whether the fan coil is needed to prevent condensation on the floor
- Test “cool & coast” control strategy

Comparative Distribution Efficiency

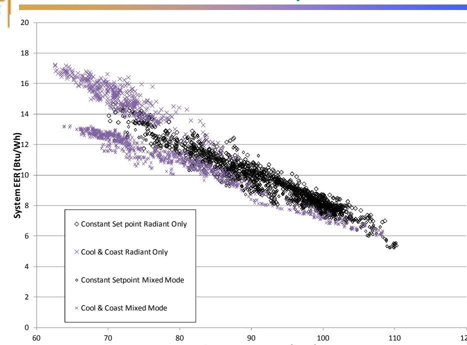
- Measured ground heat transfers using temperature sensors above and below under-slab insulation
- Compared results to calculated values for a typical ducted system (using ASHRAE Std. 152)

Case	Distribution Efficiency
Radiant Floor	98%
Benchmark FAU	65%
Benchmark w/ Tight Ducts	78%
Benchmark w/ Ducts in Conditioned Space	95%

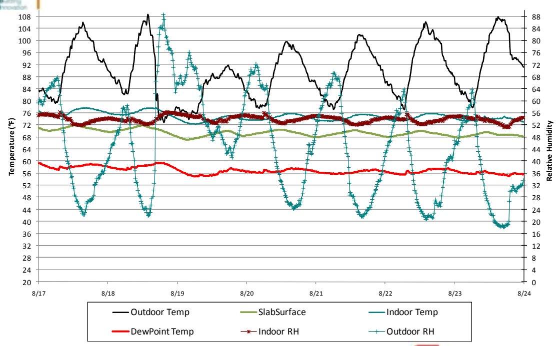
EER vs. Evaporator Water Temperature



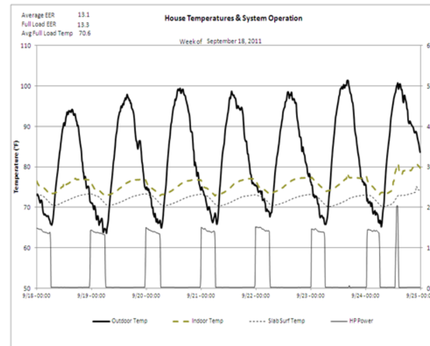
EER vs. Outdoor Temperature



Risk of Condensation on Floor Surface



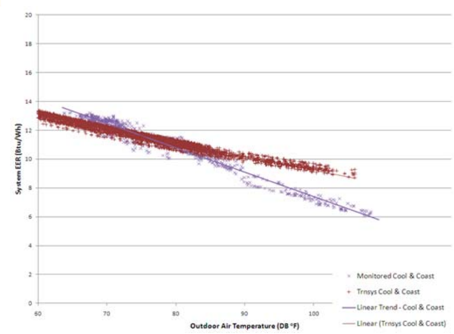
"Cool & Coast" Performance



TRNSYS Modeling

- Air-to-water heat pumps not included in equipment libraries of DOE-2 or EnergyPlus
- Limited capability for modeling radiant heating & cooling
- Working with TESS to develop TRNSYS models using performance maps from manufacturers & monitoring data
- Preliminary Results
  - TRNSYS shows similar trends as monitored results
  - TRNSYS shows performance crossover at about 70°

TRNSYS vs. Monitored EER



Preliminary TRNSYS Results

	Mixed Mode Delivery (kWh)	Radiant Floor Only (kWh)
Fixed Setpoint	2,493	1,703
Cool & Coast	2,330	1,408
% Savings	7%	17%

- Results support trends seen in monitored data
- More calibration is needed
  - Slopes of performance curves differ
  - Indoor temperature response to forced air cooling is too rapid
  - Model shows higher heat pump energy use in mixed mode despite higher entering water temperatures

Summary of Observations

- Radiant cooling offers a way to substantially improve system (heat pump & distribution) efficiencies, particularly in dry climates
- Insulating the slab is critical
- Well insulated buildings have small daily temperature swings and facilitate nighttime cooling operation (~17% energy savings)
- The relatively high evaporator temperature in radiant systems contributes to energy savings (~6% per 5°F increase in entering water temperature)
- In the house tested (with ERV), the fan coil was not needed to avoid the risk of condensation
- Radiant cooling limits the use of floor coverings and works best in single story homes
- More air source heat pump product offerings and controls are needed

Thank You!

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