UFAD EnergyPlus Model: Plenum and RAS Testing and Modeling

CBE
Fred Bauman, Tom Webster, and many others

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Energy performance of UFAD systems

- **Goal/Significance**
  - Develop a version of the whole-building energy simulation program, EnergyPlus, capable of modeling UFAD systems
  - This will be the first validated UFAD energy simulation tool
- **Project details**
  - Project start: November 1, 2002
  - Final report and software: February 28, 2006
  - Ready for next release of EnergyPlus: April 15, 2006
  - Primary funding ($610K) from California Energy Commission (CEC) Public Interest Energy Research (PIER) program
  - Additional support from CBE, U.S. Department of Energy, and York International

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Research team

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Lawrence Berkeley National Laboratory

- Fred Buhl

York International

- Jack Geortner and others

Project Advisory Committee (PAC)

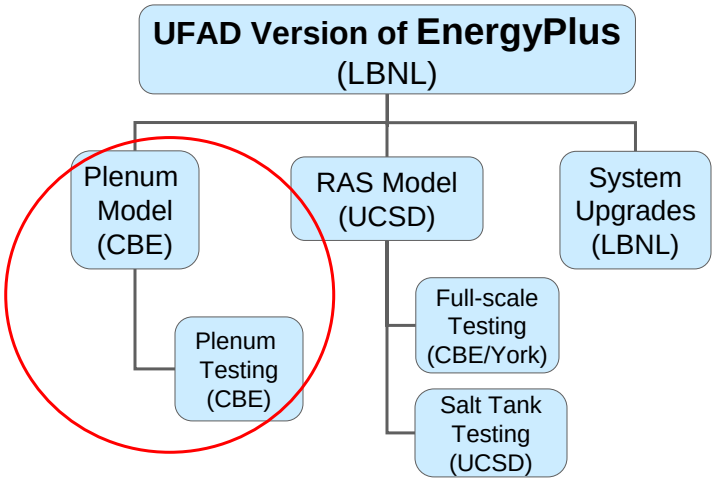
Commission Project Manager

- Norm Bourassa (current), CEC
- Martha Brook (former), CEC

PAC

- Dru Crawley, US DOE
- Dan Fisher, Oklahoma State University
- Phil Haves, LBNL
- Blair McCarry/Kevin Hydes, Stantec
- Mike Scofield, Conservation Mechanical
- Dennis Stanke, Trane
- Steve Taylor, Taylor Engineering

Energy performance of UFAD systems



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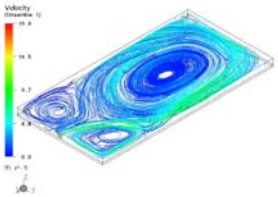
Thermal performance of underfloor plenums

- **CFD model**
- **Full-scale experiments**
- **Validate model vs. test facility**
- **Study thermal performance for range of design and operating conditions using CFD model**
- **Develop simplified plenum model for implementation in EnergyPlus**



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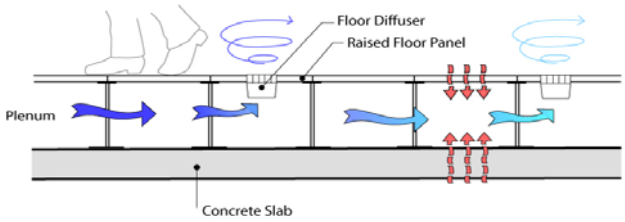
Thermal performance of underfloor plenums

Recent publications

- **"Testing and Modeling Underfloor Air Supply Plenums"**
  Paper on CFD plenum model validation submitted to ASHRAE Transactions in October 2005 (see handouts)
- **"Heat Transfer Pathways in UFAD Systems"**
  Paper on simplified heat transfer analysis submitted to ASHRAE Transactions in June 2005



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Key findings – Underfloor plenums

- Airflow delivery and pressure distribution are very uniform within same plenum zone.
- Air leakage from pressurized plenum can be significant and must be controlled and accounted for.
- Heat gain into supply plenum (thermal decay) can be quite high (30-40% of room load) in multi-story buildings.
- Plenum inlet conditions can have an important impact on the velocity and temperature distribution in plenum.
- Overall energy balance of plenum varies by no more than 10% for most practical plenum configurations

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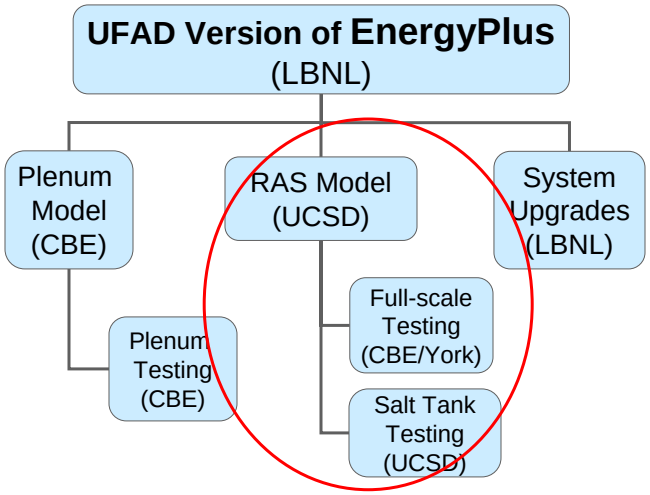
Energy performance of UFAD systems



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Room air stratification (RAS)

Approach

- Full-scale laboratory tests of commercially available floor diffusers in realistic office setting
- Study impact of various design and operating parameters on room air stratification (RAS)

Parameters investigated

- Type and number of diffusers
- Diffuser throw
- Supply volume
- Supply temperature
- Room load
- Plenum leakage
- Perimeter/interior zones
- Window blinds

York test lab

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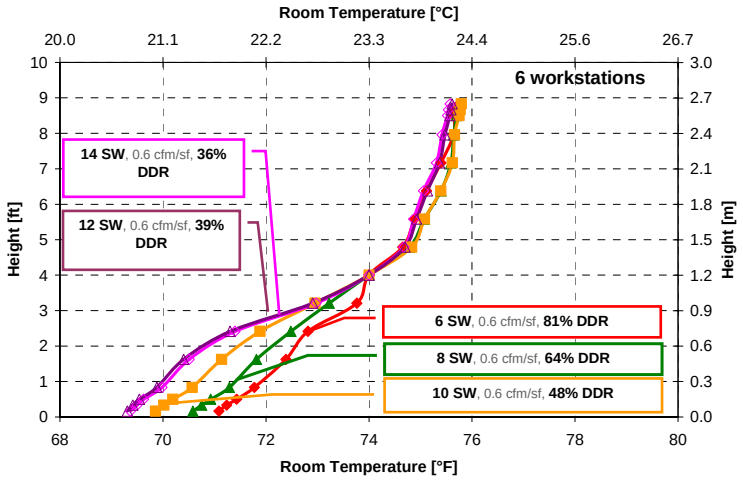
Sample room air stratification test results



SW = swirl diffusers DDR = diffuser design ratio

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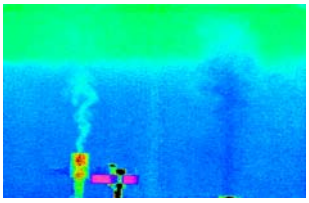
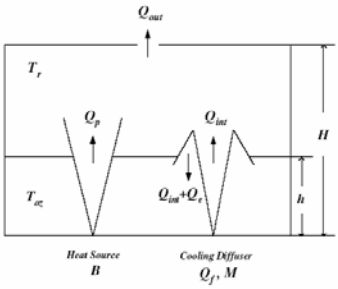
Testing and modeling RAS in UFAD systems



Heat Source Cooling Diffuser



Salt Tank Testing **Theoretical Modeling**

Conducted by UC San Diego

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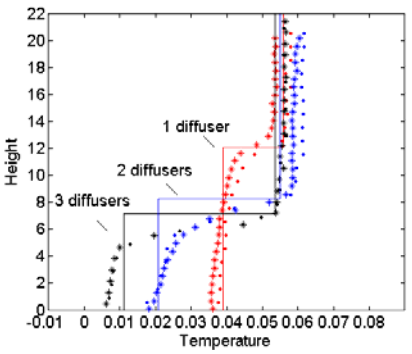
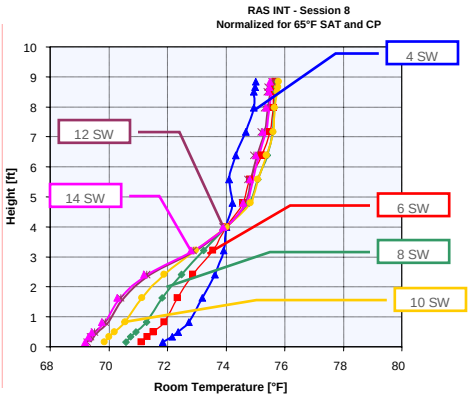
Comparison of RAS testing and modeling





Salt tank testing and modeling
UCSD

Full-scale testing
CBE

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Key findings – RAS testing

- Besides reducing airflow, lowering diffuser throw for a given load and setpoint increases stratification
- Diffuser throw characteristics depend on diffuser type and operating conditions
- Closing blinds in perimeter zones increases stratification and lowers airflow for given load and thermostat setting
- Plenum airflow leakage into the occupied zone will tend to increase stratification (cooler temperatures near floor), but is not detrimental if properly controlled
- Application of the CBE advanced thermal comfort model to a range of measured stratification levels (up to 7°F in occupied zone) for a constant load found only small differences in comfort

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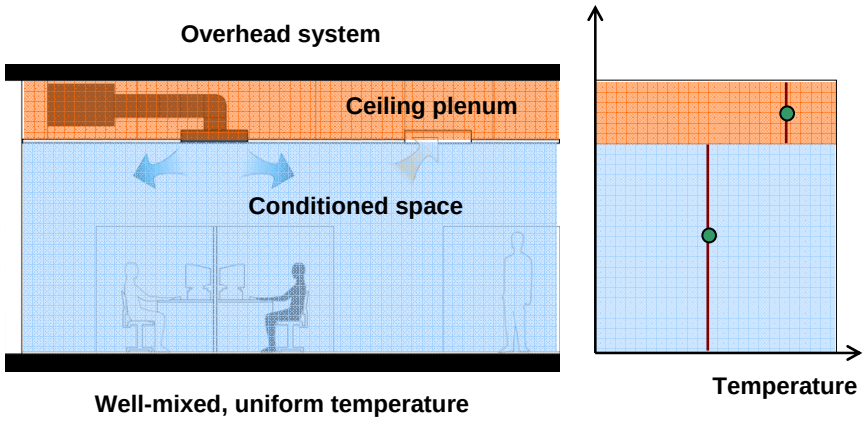
Current EnergyPlus model



Well-mixed, uniform temperature in conditioned space

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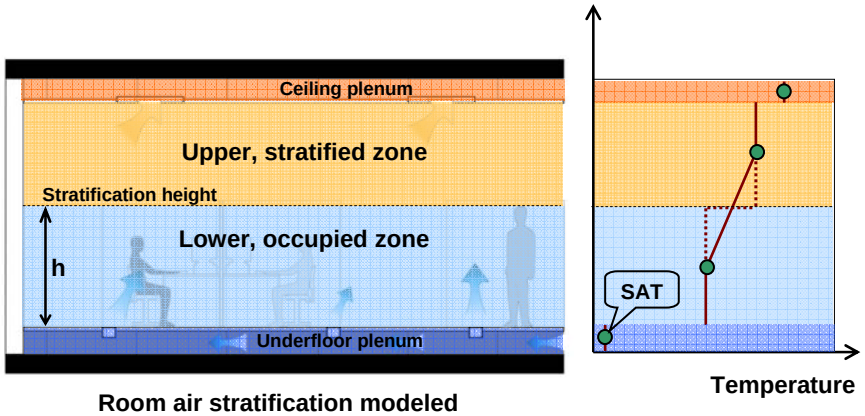
New EnergyPlus UFAD model



Room air stratification modeled as two zones separated at stratification height, h

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Inputs and outputs for UFAD interior model

Inputs

Supply conditions

- Supply temp. Ts
- Total airflow rate Q

Diffusers

- Type (swirl, VA)
- Number n
- Area of each diffuser A

Heat load and plumes

- Total heat load W
- Number of plumes m
- Heat source height hs

Outputs

- Return temp. TR
- Occupied zone temp. TL
- Strat. height h

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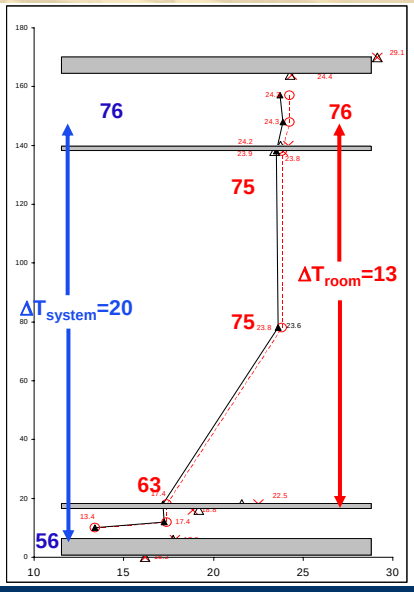
Validation of EnergyPlus

- **Comparison with full-scale RAS test data**
- **Interior zones – Allan Daly**
- **Perimeter zones – Ian Doebber**
- **Consideration of radiation is key to make sense out of heat flows in UFAD (stratified) systems**



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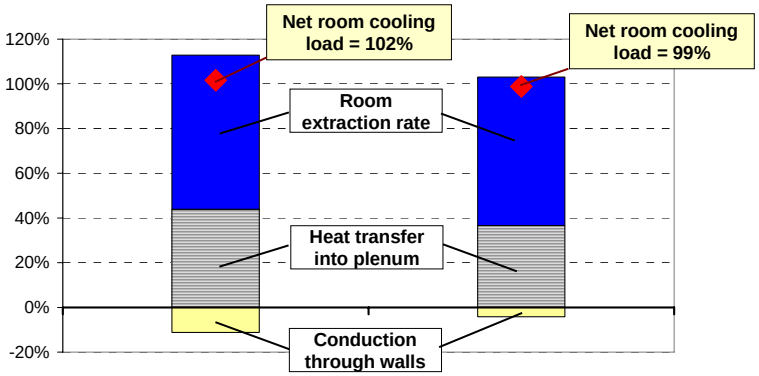
Energy balance – Testing and EPlus modeling

Full-scale laboratory measurements demonstrate good room energy balance. EPlus simulations match well.



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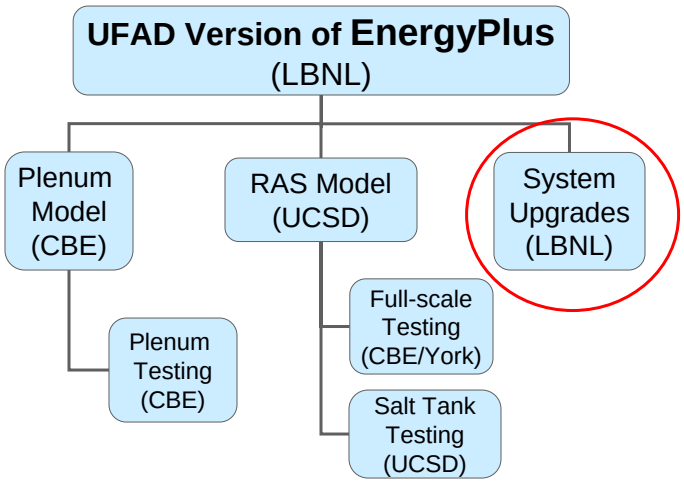
Energy performance of UFAD systems



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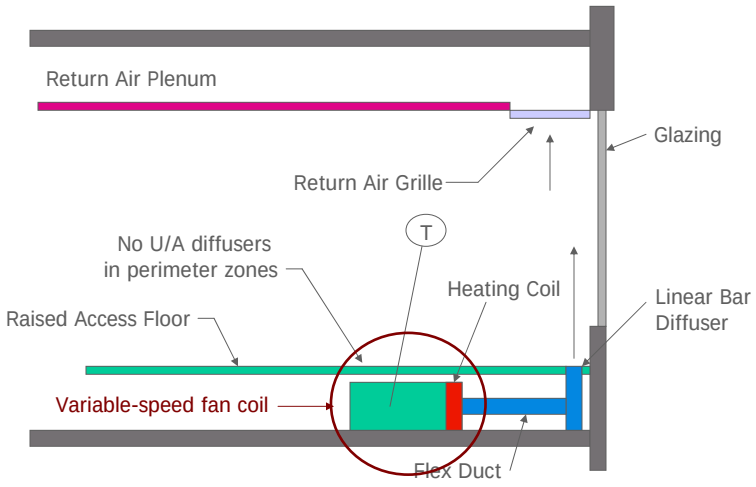
E+ system upgrades: Variable speed fan coil



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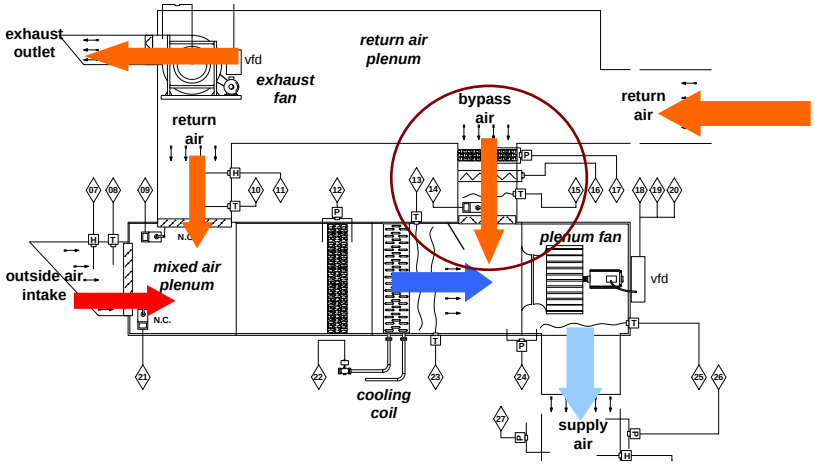
E+ system upgrades: Return air bypass



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Next steps

- Interior and perimeter zone RAS models into EPlus
- Validate RAS models in EPlus with full-scale data
- Complete validation of plenum model
- Draft final report due January 2006
- Final report and software due February 28, 2006
- Ready for next release of EnergyPlus (April 15, 2006)

Future directions with EnergyPlus/UFAD

- UFAD energy analysis study
- Comparison with field data
- Investigate demand response performance
- EnergyPlus in Title 24
- EnergyPlus/UFAD training seminars