Changing the Rules:
Innovative Low-Energy
Occupant-Responsive
HVAC Controls and
Systems

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Taylor Engineering
Project summary

To develop, evaluate, and demonstrate three ‘innovation components’ that will

• reduce energy use in buildings
• Improve occupant comfort

In combination, these components:

• Address the major control problems in a large majority of existing and new buildings
• Enlarge the roles of occupants, operators, and automation in control
The three innovations:

1. Low-energy personal comfort systems (PCS)

2. Control improvements to variable air volume (VAV) systems to eliminate widespread dysfunctional behavior

3. Advanced information technologies that enable occupants’ direct involvement with the VAV system
Low-energy personal comfort systems (PCS): CBE

- PCS testing at CBE has shown that individuals can be comfortable over a broad range of temperatures: 64-86°F

- CBE (with CIEE’s SPEED Program) is currently conducting the first field intervention studies of PCS in UC Berkeley campus buildings
Personal comfort systems: heated/cooled chair

Chair main features:

• Battery powered
• 2 – 4 days operation capacity; rechargeable
• User-adjustable heating and cooling levels
• Fully adjustable quality office chair

Max heating power 14 W
Max cooling power 3.6 W
Personal comfort systems: fan + footwarmer

**Fan unit**
- air temperature sensor
- occupancy sensor

**Footwarmer unit**
- USB to workstation computer
- occupancy sensing pressure plate

Control and monitoring software, database design
- air temperature
- speed and warmth choices
- occupancy

105 PEC units assembled, funded by PIER/CEC and CBE
Fan + footwarmer’s control/monitoring interface

Control and monitoring software, database design (*kudos to Ryan Luecke*)

- air temperature
- speed and warmth choices
- occupancy
Personal comfort systems: legwarmer
How PCS can reduce buildings’ energy use

- Wider setpoint dead band reduces total HVAC energy 5-8% per degree F

- Provides equal comfort in less controlled or slowly responding systems, such as:
  - Mixed-mode and natural ventilation
  - Radiant cooling

- PCS sensors can inform the central HVAC of workstation temperatures, occupancy, and their PCS control choices
Energy savings studies using PCS

- Deploy PCS prototypes within offices
- Meter heating/cooling energy at zone level
- Survey occupant comfort before and during
  - UCB Bancroft Library
  - Brower Center
Footwarmer tests: set point adjustments
Power usage at each heating set-point

Outside air temperature from 55 to 60 °F

- Foot Warmer
- Computer & Monitor
- Reheat
- Heating

Power [kW]

Heating Setpoint °F

70 No PCS  70  68  67  66
Control improvements to VAV reheat systems:
Taylor Engineering, CBE

- Several long-standing “rules-of-thumb” for HVAC system controls lead to energy-intensive operation.
  - Narrow temperature deadbands or setpoint ranges (70-74°F) ✓
  - Minimum ventilation airflow setpoints are often too high (20-50% of design flow), leading to overcooling.
    - Recently completed ASHRAE Research Project RP-1515 showed that lowering airflow rates reduced energy use and improved comfort.
  - Other innovative control improvements developed by Taylor Engineering will be field-tested and investigated:
    - Supply air temperature reset
    - Rogue zone identification and exclusion
    - Fighting zones
Energy savings with reduced minimum flows

Figure 3. Annual energy use for the prototype in San Francisco with VAV minimum fractions at 10%, 20%, and 30%.
VAV control improvements
Overcooling, overventilation…

306H: one person

306E: two person
BMS screenshot of HVAC for 3rd floor

<table>
<thead>
<tr>
<th>RM #</th>
<th>RM. ART</th>
<th>RM. SP</th>
<th>REHEAT</th>
<th>S CFM SP</th>
<th>S CFM</th>
<th>DAMPER</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>72.6 F</td>
<td>71.0 F</td>
<td>-0.0 %</td>
<td>401 CFM</td>
<td>397 CFM</td>
<td>72.2 %</td>
</tr>
<tr>
<td>300A-1</td>
<td>75.8 F</td>
<td>70.0 F</td>
<td>-0.0 %</td>
<td>902 CFM</td>
<td>-549 CFM</td>
<td>27.1 %</td>
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<tr>
<td>300A-2</td>
<td>76.3 F</td>
<td>73.0 F</td>
<td>-0.0 %</td>
<td>1598 CFM</td>
<td>1582 CFM</td>
<td>29.0 %</td>
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<tr>
<td>304</td>
<td>71.4 F</td>
<td>71.0 F</td>
<td>-0.0 %</td>
<td>200 CFM</td>
<td>191 CFM</td>
<td>54.1 %</td>
</tr>
<tr>
<td>304B</td>
<td>74.1 F</td>
<td>74.0 F</td>
<td>40.7 %</td>
<td>301 CFM</td>
<td>302 CFM</td>
<td>40.8 %</td>
</tr>
<tr>
<td>306B</td>
<td>73.4 F</td>
<td>74.0 F</td>
<td>1.5 %</td>
<td>208 CFM</td>
<td>203 CFM</td>
<td>45.5 %</td>
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<tr>
<td>306C</td>
<td>73.8 F</td>
<td>74.0 F</td>
<td>14.2 %</td>
<td>307 CFM</td>
<td>305 CFM</td>
<td>59.2 %</td>
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<tr>
<td>306E</td>
<td>75.6 F</td>
<td>75.0 F</td>
<td>25.5 %</td>
<td>939 CFM</td>
<td>904 CFM</td>
<td>47.5 %</td>
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<tr>
<td>306H</td>
<td>74.6 F</td>
<td>75.0 F</td>
<td>80.9 %</td>
<td>300 CFM</td>
<td>287 CFM</td>
<td>38.8 %</td>
</tr>
<tr>
<td>306J</td>
<td>73.2 F</td>
<td>73.5 F</td>
<td>19.6 %</td>
<td>513 CFM</td>
<td>487 CFM</td>
<td>54.1 %</td>
</tr>
</tbody>
</table>
"How satisfied are you with the temperature in your workspace?“

<table>
<thead>
<tr>
<th>% Dissatisfied people</th>
<th>HIGH</th>
<th>LOW</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 Ferry Building</td>
<td>27.3%</td>
<td>12.5%</td>
</tr>
<tr>
<td>Yahoo! cool season</td>
<td>8.7%</td>
<td>9.4%</td>
</tr>
<tr>
<td>Yahoo! warm season</td>
<td>20.1%</td>
<td>10.3%</td>
</tr>
</tbody>
</table>
Electricity Savings (Fan & Cooling)

<table>
<thead>
<tr>
<th>Building</th>
<th>Traditional Logic</th>
<th>Dual Maximum Logic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building A</td>
<td>8%</td>
<td>20%</td>
</tr>
<tr>
<td>Building B</td>
<td>17%</td>
<td>9%</td>
</tr>
<tr>
<td>Building E</td>
<td>19%</td>
<td>22%</td>
</tr>
</tbody>
</table>

Gas Savings (Reheat)

<table>
<thead>
<tr>
<th>Building</th>
<th>Traditional Logic</th>
<th>Dual Maximum Logic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building A</td>
<td>16%</td>
<td>19%</td>
</tr>
<tr>
<td>Building B</td>
<td>9%</td>
<td>4%</td>
</tr>
<tr>
<td>Building E</td>
<td>6%</td>
<td>6%</td>
</tr>
</tbody>
</table>

/high ~30% (low ~10-15%/low ~10-15%)

<---Savings
Advanced information technologies: EECS

- EECS previously developed the open-source software platform sMAP (Simple Measurement and Actuation Profile)
  - Implementing control logic: actuation across a wide range of control systems
  - Used by EECS and CBE for sensing and reporting data from field studies: *it’s great!!*
  - Enables smart phone “apps” that allow more occupant and operator interaction with HVAC controls
  - E.g., occupant polling to determine setpoint temperature, or providing feedback to operators in response to control changes
sMAP as visualization and reporting tool (here, weekends = weekdays)
sMAP as development platform

- This project will use sMAP platform to:
  - integrate PCS with app-based occupant feedback to central systems.
  - improve control of VAV systems to achieve energy savings and improved comfort.
Management of field demonstrations: CIEE

- CIEE is currently managing the CEC-funded State Partnership for Energy Efficient Demonstrations (SPEED) program, which includes the PCS field demonstration (by CBE) on the UC Berkeley campus.
- CIEE is involved with planning and implementation of the UC Berkeley Operational Excellence Energy Management Program.
- CIEE is also seeking collaboration with the University of California/California State University/Investor-Owned Utility Energy Efficiency Partnership.
- Demonstrations for this project will be conducted in conjunction with all of the above programs.
Standards and codes: addenda and revisions to implement occupant-responsive control in buildings

- Title-24 Code
- Title-20 Code
- ASHRAE Standard 55
- ASHRAE Standard 90.1 and 189.1
- LEED
- ASHRAE Performance Measurement Protocols
Feedback loop for commercial building sector

Source: Karl Brown, CIEE