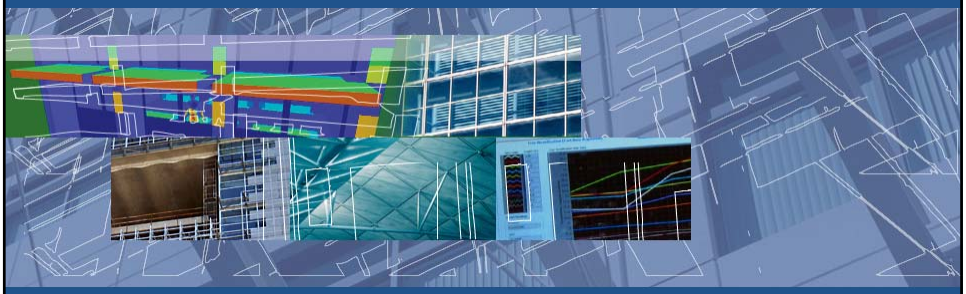
Evaluation of Low-Flow Operation for Energy Savings and Comfort

Edward Arens, Hui Zhang, Tyler Hoyt, Yongchao Zhai, Soazig Kaam, Fred Bauman
CBE

Gwelen Paliaga, Jeff Stein, Steve Taylor
Taylor Engineering

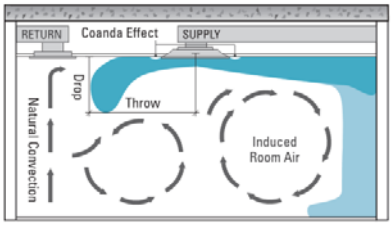
Brad Tully, Julian Rimmer
Price Industries



Center for the Built Environment April 2013

Background

- VAV systems are being currently designed with minimum turndowns of 30-50% of their maximum.
- Reasons:
  - Concern over diffusers dumping unmixed cold air on occupants
  - Concern over VAV controller stability (this recently proven a non-issue)



Courtesy of Price HVAC Handbook

- The fan, cooling, and reheat energy consequences are very large.
- Minimum flows of 10% meet code requirements for outside air.
- Some buildings appeared to be comfortable operating at 10% minimum flow in spite of the fear of dumping cold air.
- This project was to sort out what are the consequences of reducing the minimum flow rate in overhead systems.

But we actually found a lot more…

Center for the Built Environment April 2013 2

Project Overview

Objectives

- Measure energy savings (CEC-PIER funding)
- Determine comfort issues that may occur at low flow (ASHRAE funding)

Method

- Field study in 7 buildings
  - Background survey
  - "Right now" survey matched to zone trends
  - Energy monitoring
- Laboratory Study
  - Air distribution for various diffuser types

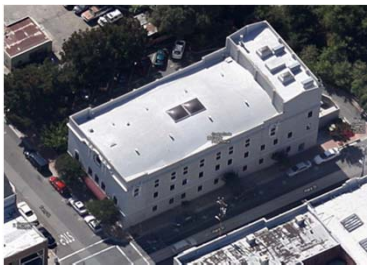
Status

- Final report and papers to ASHRAE next month

Center for the Built Environment April 2013 3

Yahoo! Sunnyvale Campus and 800 Ferry Building

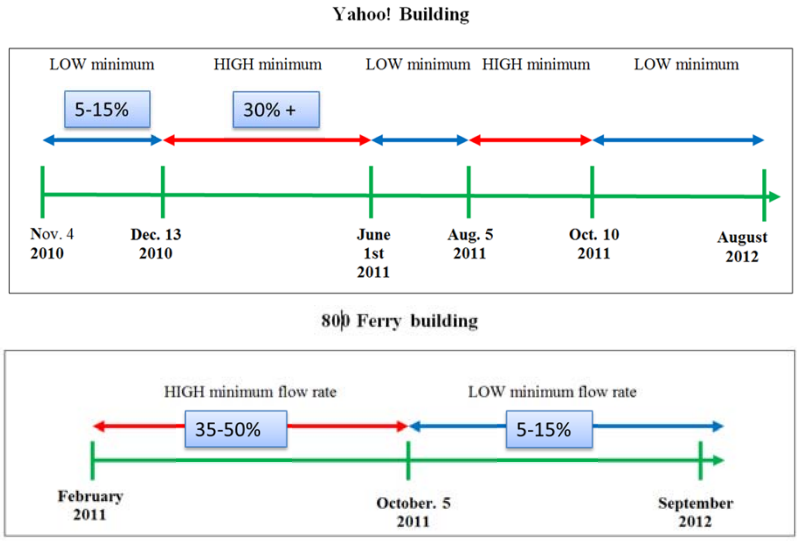
Yahoo! Building D



800 Ferry Building

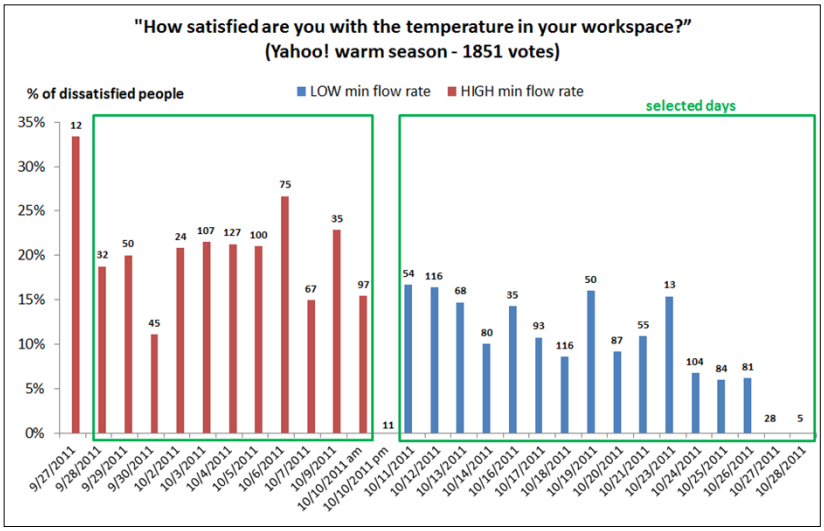
Center for the Built Environment April 2013 4

Intervention schedule, over 1.5 years

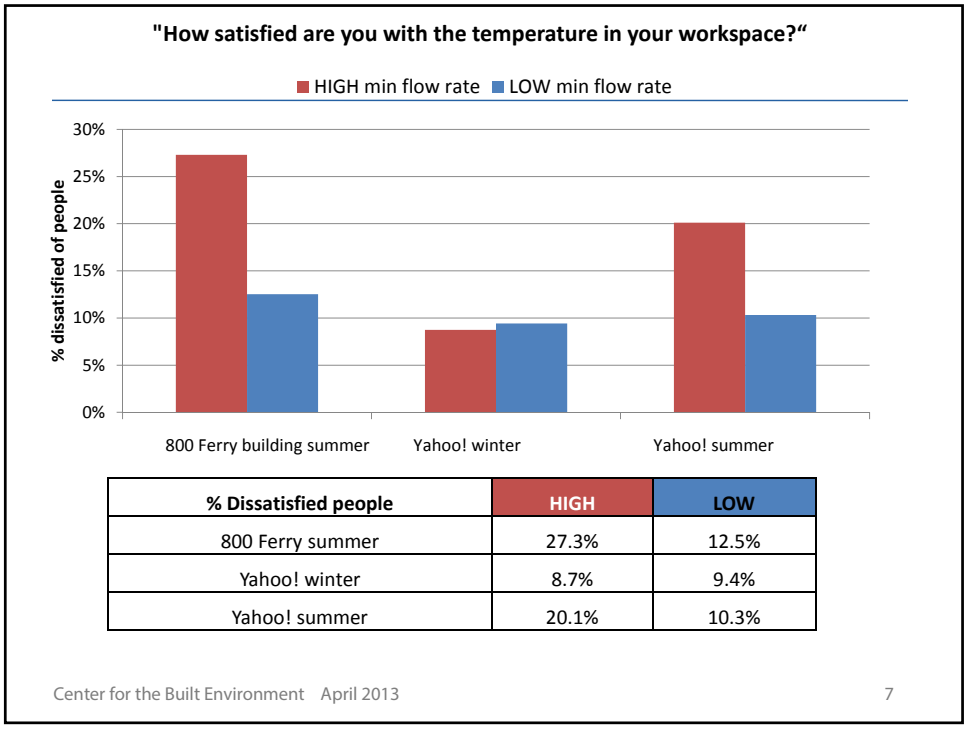


Center for the Built Environment April 2013 5

Temperature satisfaction survey results (an example: Yahoo! summer season)



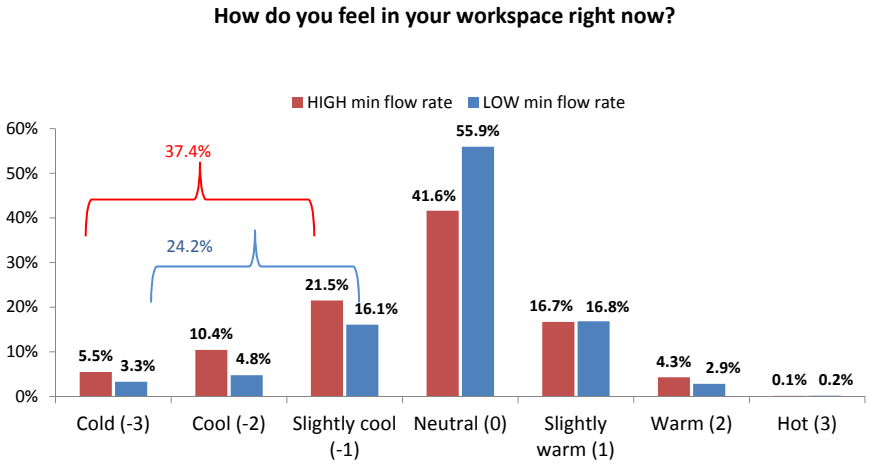
Center for the Built Environment April 2013 6



% Dissatisfied people	HIGH	LOW
800 Ferry summer	27.3%	12.5%
Yahoo! winter	8.7%	9.4%
Yahoo! summer	20.1%	10.3%

Center for the Built Environment April 2013 7

Thermal sensation distribution (Yahoo! summer)

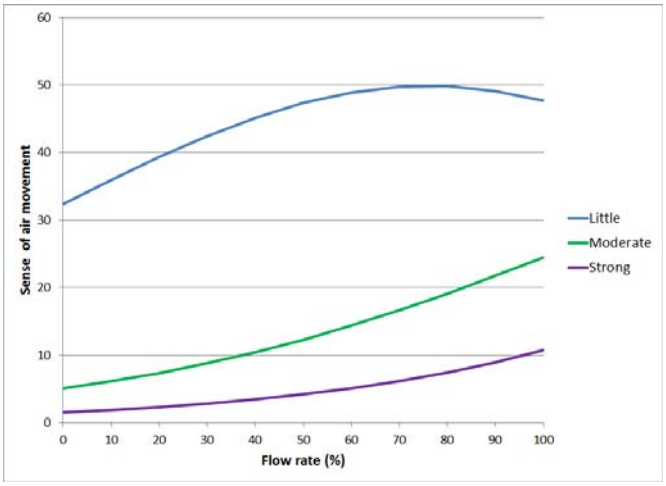


Center for the Built Environment April 2013 8

Sense of air movement (800 Ferry building)

Have you noticed any air movement in your workspace?

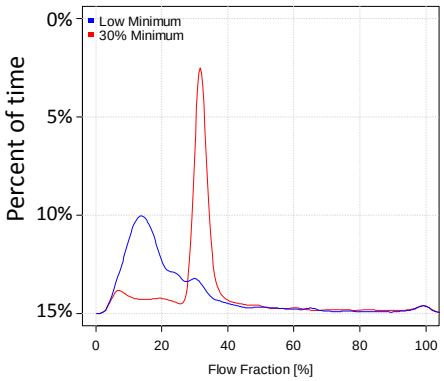
- ☐ *No air movement*
- ☐ *A little*
- ☐ *A moderate amount*
- ☐ *Strong air movement*



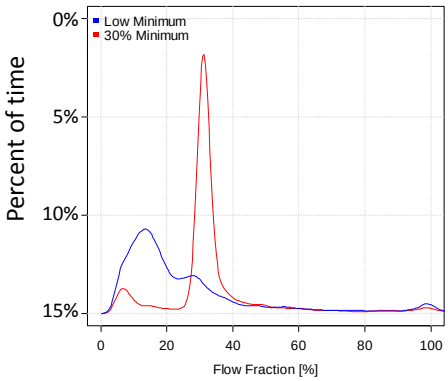
Center for the Built Environment April 2013 9

Measured flow fractions: Yahoo! campus

Summer – All Occupied Hours

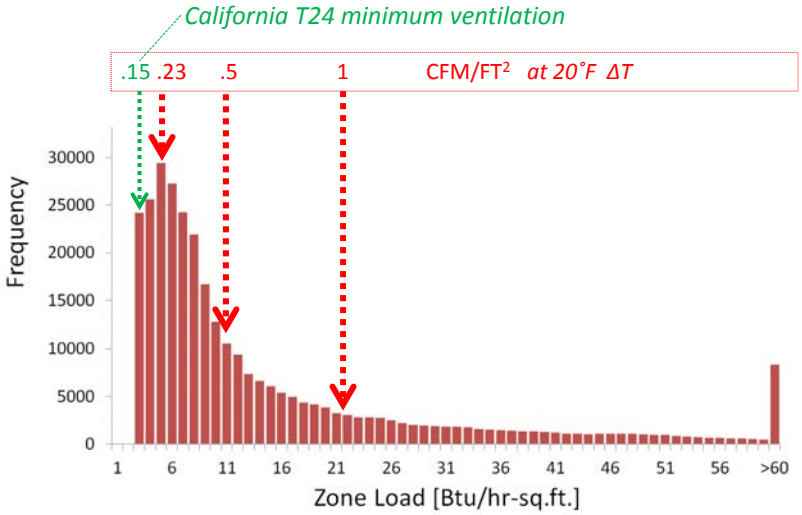


Winter – All Occupied Hours



Center for the Built Environment April 2013 10

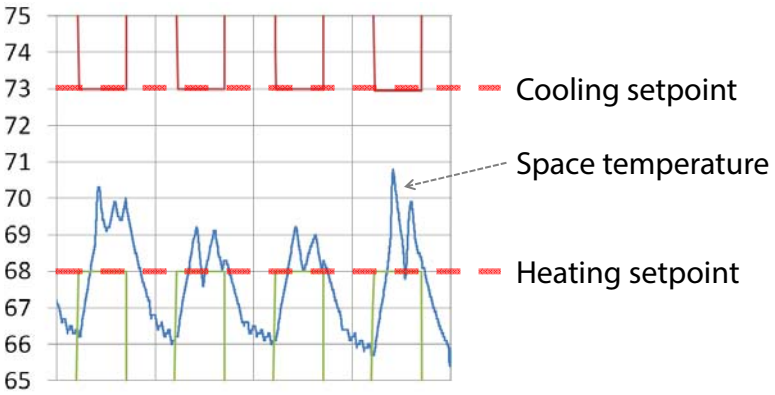
Loads are surprisingly low



140 Zones, 2 buildings, 1 warm month (Sept)

Center for the Built Environment April 2013 11

What happens when loads are lower than the VAV minimum?

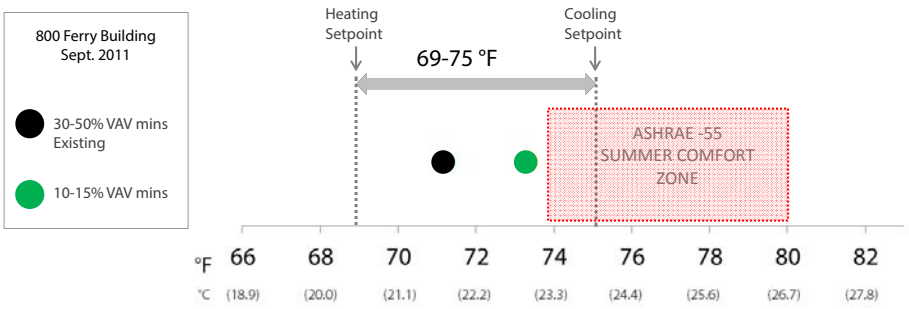


Zones spend a lot of time at heating setpoint in cooling season.

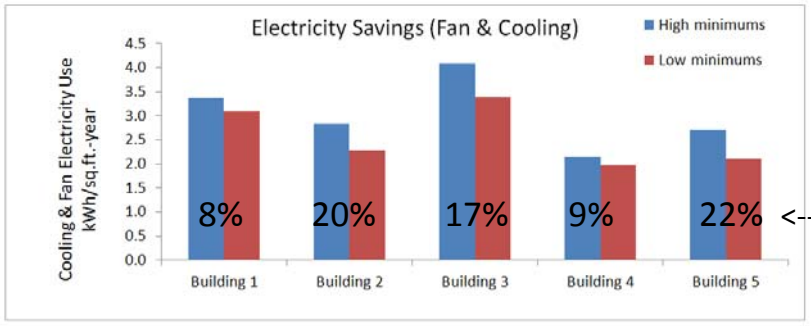
Explanation for summer cold complaints. *See ASHRAE 2012 Chicago Seminar 14, "Why Are We Over Cooling Buildings in the Summer"*

Center for the Built Environment April 2013 12

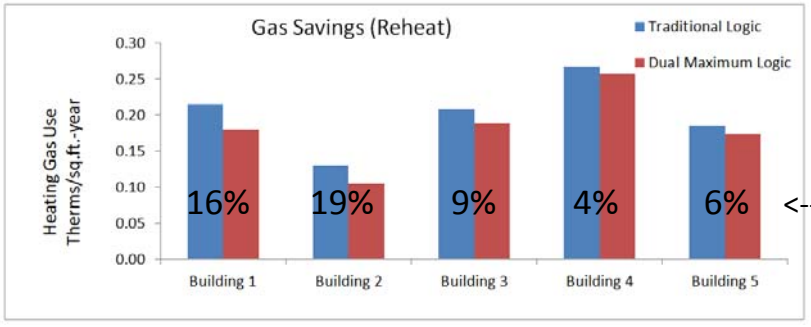
800 Ferry average temperature vs. Standard 55



Center for the Built Environment April 2013 13



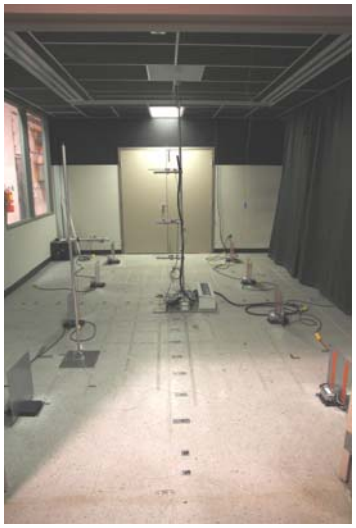
<---Savings



<---Savings

Center for the Built Environment April 2013 14

Diffuser air distribution lab testing at Price Industries

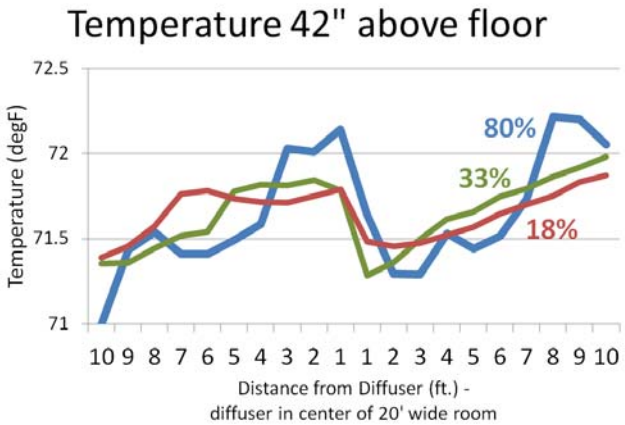


Price Industries testing chamber

- Diffuser types
  - square plaque
  - perforated w/ blades in neck
  - perforated w/ blades in face
  - high side wall
  - linear slot
  - round cone
- Flowrate: 18% - 80%
- Simulated load
- Measurement points: 4", 24", 42" and 66" height

Center for the Built Environment April 2013 15

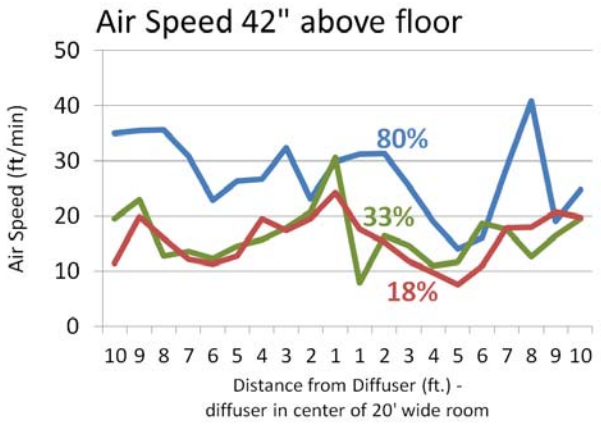
Perforated diffuser temperature results



Model PDN
Perforated w/ blades in neck

Center for the Built Environment April 2013 16

Perforated diffuser air speed results



Model PDN
Perforated w/ blades in neck

Center for the Built Environment April 2013 17

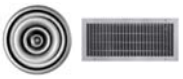
Diffuser testing observations

Diffusers mounted on ceiling – <u>with coanda effect</u>

- Excellent air distribution (ADPI) down to 10% flow
- Discharge air temperature has small effect
- Air speeds decrease at lower flow

Diffusers w/o ceiling – i.e., <u>no coanda effect</u>

- Worse air distribution at low flow & potential discomfort
- Architectural and HVAC implications that need further study



More detail will be provided by ASHRAE RP-1546

Price Industries sidewall test

Center for the Built Environment April 2013 18

Key findings

Comfort

- Comfort improves rather than gets worse at low flow
- Dumping & draft are not found to be an issue at low flow
- High minimums are likely a key cause of overcooling in US office buildings

Energy

- Energy savings is significant and similar to simulation predictions

Diffuser air distribution

- Good air distribution performance at low flow – supports field study findings (Exception is for diffusers without ceilings)
- Draft risk increases at high flow, not low flow

Center for the Built Environment April 2013 19

Implications

Change Standard Practice

- Market barriers removed: Controllability, comfort, air distribution
- Demonstrated benefits: Energy savings, reduced overcooling

Cost effective

- Less than 1 year payback opportunity in existing buildings
- Instantaneous payback in new construction due to minimal first cost add

Changing Codes and Standards

- Title 24-2008 requires no greater than 20% minimum
  (slow adoption will likely improve as a result of this project)
- Proposed ASHRAE 90.1-2013 – similar to Title 24-2008
- ASHRAE Standard 55 – potential requirement to prevent overcooling

Ongoing efforts

- CEC-PIER project will investigate potential code requirements for lower than 20%
- ASHRAE Standard 195P (proposed) – method of test for VAV controllers

Center for the Built Environment April 2013 20

Thank you

Ed Arens
earens@berkeley.edu

Gwelen Paliaga
gpaliaga@taylor-engineering.com

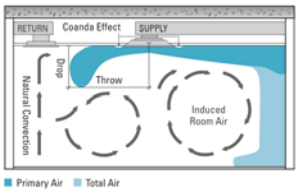
Additional detailed discussion of results

ASHRAE RP-1515 Final Report
In progress

ASHRAE Seminar 70, Dallas, January 2013
Save Energy and Improve Comfort with Advanced VAV Zone Controls
Steve Taylor, Gwelen Paliaga, Edward Arens

ASHRAE Journal, December 2012
Dual Maximum VAV Box Control Logic
Steve Taylor, Jeff Stein, Gwelen Paliaga, Hwakong Cheng

ASHRAE Seminar 14, Chicago, January 2012
Why Are We Over Cooling Buildings in the Summer?
Presenter #2: Why is it too cold? Explanations & Solutions
Gwelen Paliaga



Center for the Built Environment April 2013 21