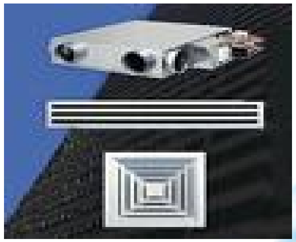
Modular Active Chilled Beams

Presented by:

Darren Alexander, P.Eng.

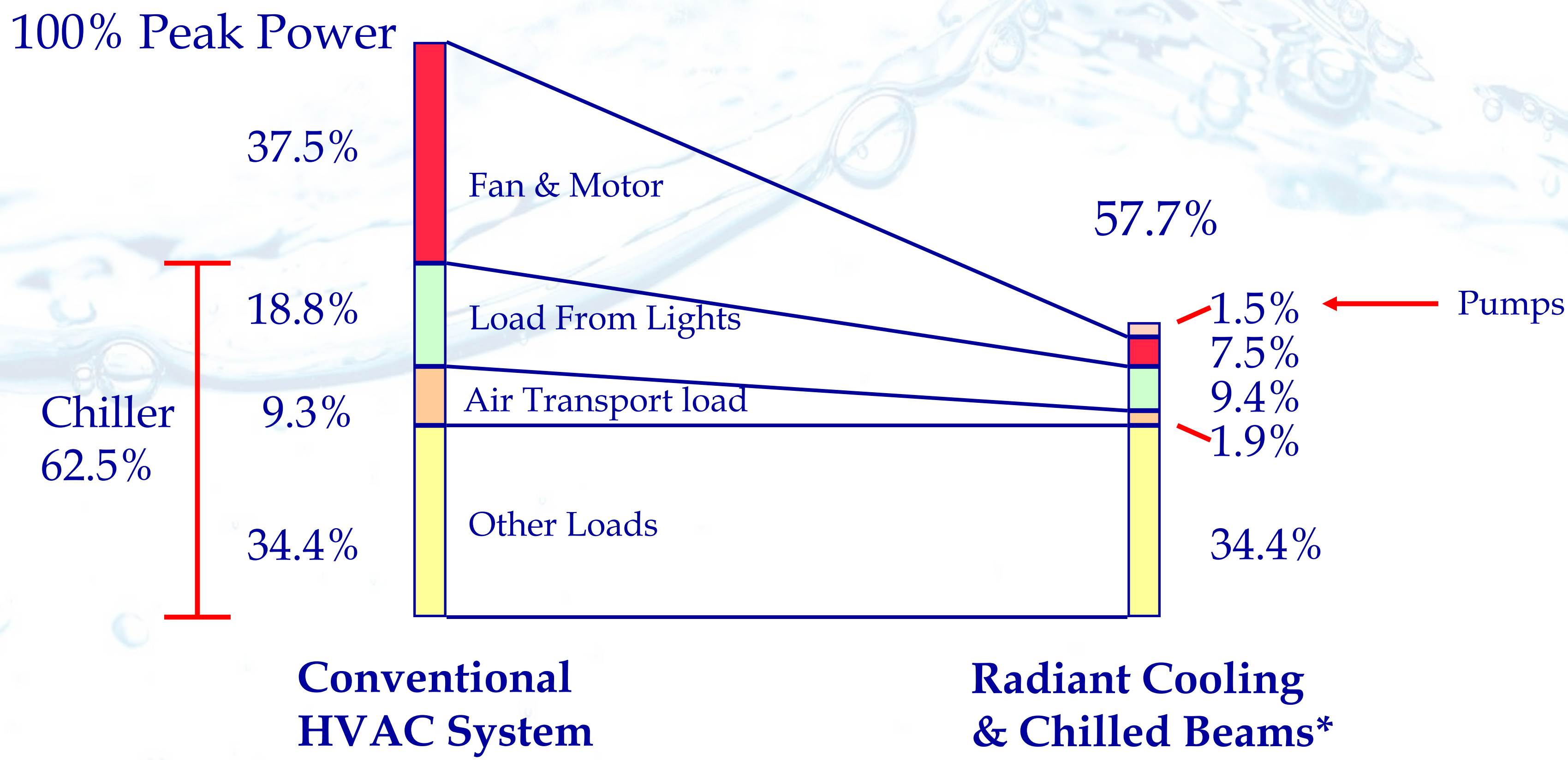
Modular Active Chilled Beams

Current System Solutions



- Fan Coil Units -
  Medium/High energy, medium noise solution.
  Output = 100-200 w/m^2 (32-64 Btuh/ft^2)
  Adaptable solution.
- VAV system -
  Low energy, low/medium noise solution.
  Output = 100-200 w/m^2 (32-64 Btuh/ft^2)
  Most efficient all air system.
- VRV system (Variable Refrigerant Volume) -
  High energy, medium noise solution.
  Output = 150-200 w/m^2 (48-64 Btuh/ft^2).
  Potential for high maintenance costs.
- Chilled Beams -
  Low energy, low noise solution.
  Output = 100-394W/m^2 (32-125 Btuh/ft^2)
  Extremely low maintenance costs.

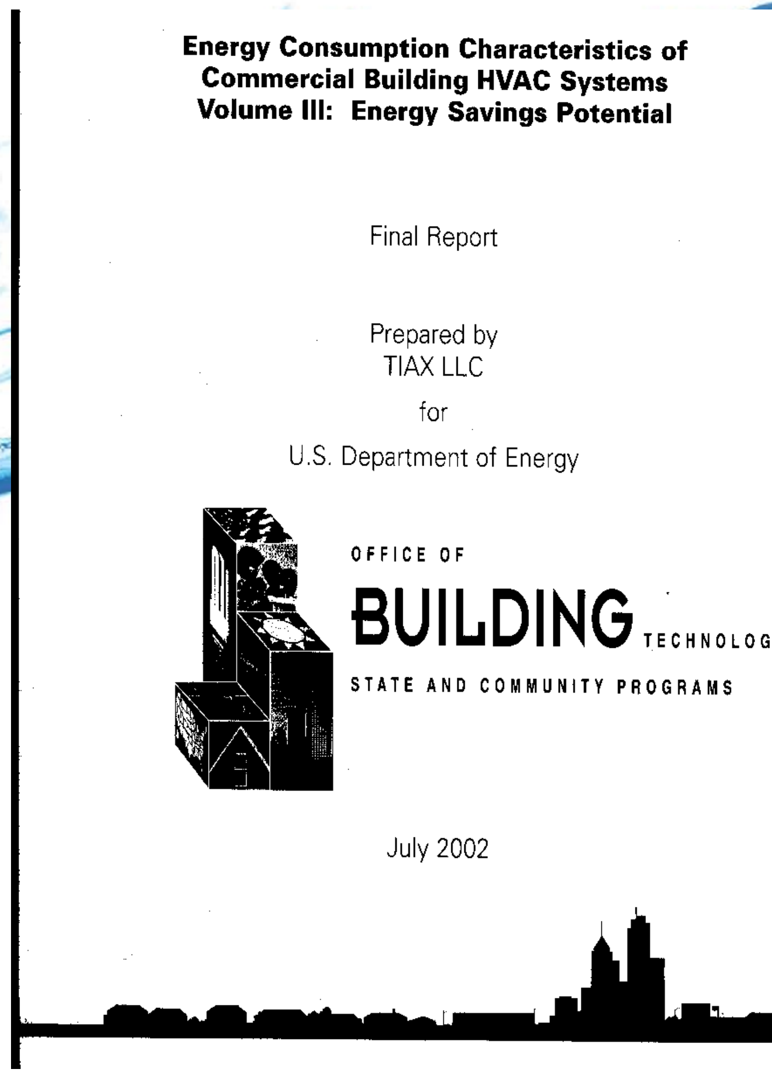
Reduction In Overall System Power



Percentages relative to overall peak power for the conventional system

Figure from: Centre For Building Science News, Lawrence Berkeley Laboratory, "Hydronic Radiant Cooling Systems", Fall 1994.
* Figure does not include additional fan energy associated with developing pressure for active chilled beam operation.

Active Chilled Beams



Energy Consumption Characteristics of Commercial Building HVAC Systems
Volume III: Energy Savings Potential

Final Report

Prepared by
TIAX LLC
for
U.S. Department of Energy

OFFICE OF
BUILDING TECHNOLOGY
STATE AND COMMUNITY PROGRAMS

July 2002

Potential Energy Savings

Table 4-1: Energy Savings Potential Summary for 15 Options

Technology Option	Technology Status	Technical Energy Savings Potential (quads)
Adaptive/Fuzzy Logic Controls	New	0.23
Dedicated Outdoor Air Systems	Current	0.45
Displacement Ventilation	Current	0.20
Electronically Commutated Permanent Magnet Motors	Current	0.15
Enthalpy/Energy Recovery Heat Exchangers for Ventilation	Current	0.55
Heat Pumps for Cold Climates (Zero-Degree Heat Pump)	Advanced	0.1
Improved Duct Sealing	Current/New	0.23
Liquid Desiccant Air Conditioners	Advanced	0.2 / 0.06[12]
Microenvironments / Occupancy-Based Control	Current	0.07
Microchannel Heat Exchanger	New	0.11
Novel Cool Storage	Current	0.2 / 0.03[13]
Radiant Ceiling Cooling / Chilled Beam	Current	0.6
Smaller Centrifugal Compressors	Advanced	0.15
System/Component Diagnostics	New	0.45
Variable Refrigerant Volume/Flow	Current	0.3

Potential Energy Savings

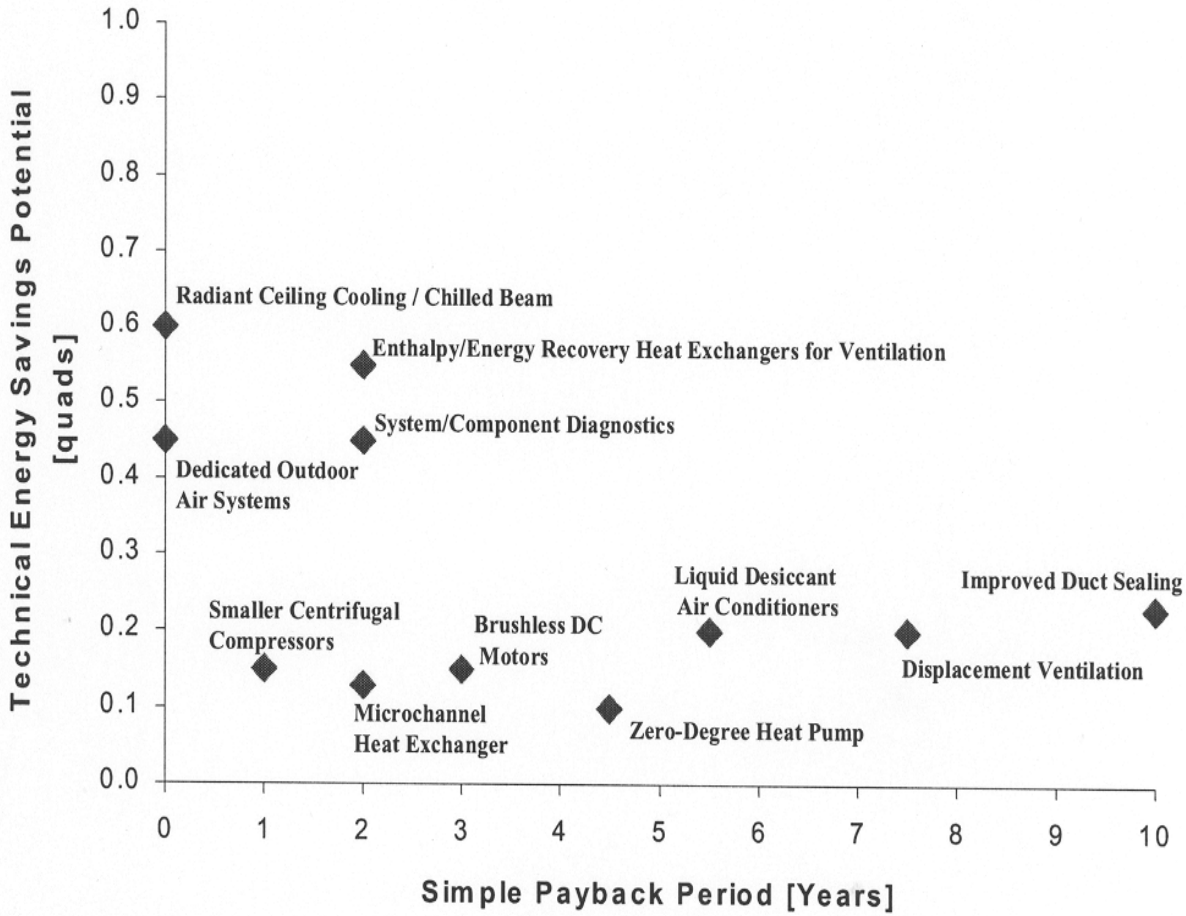
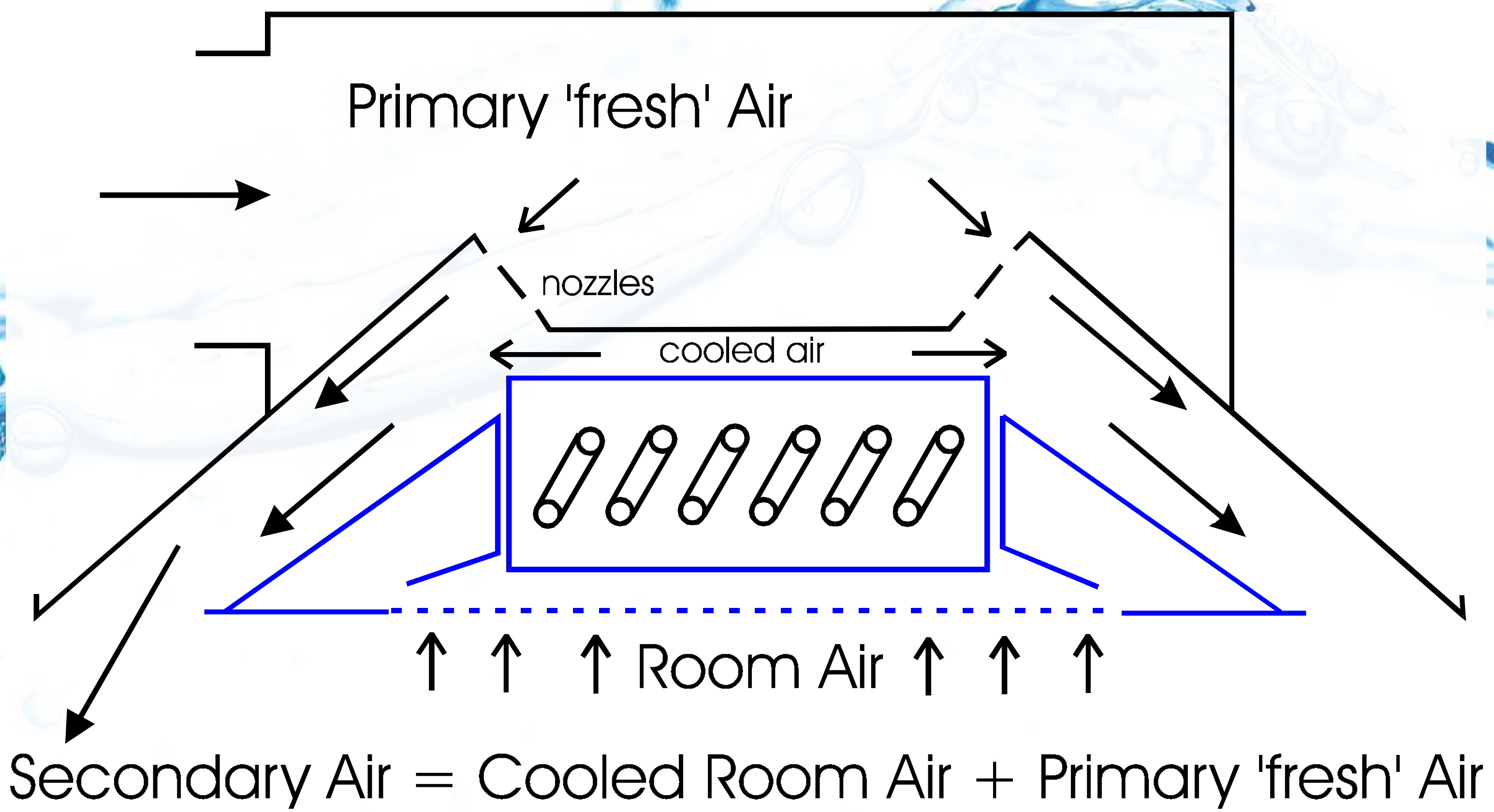


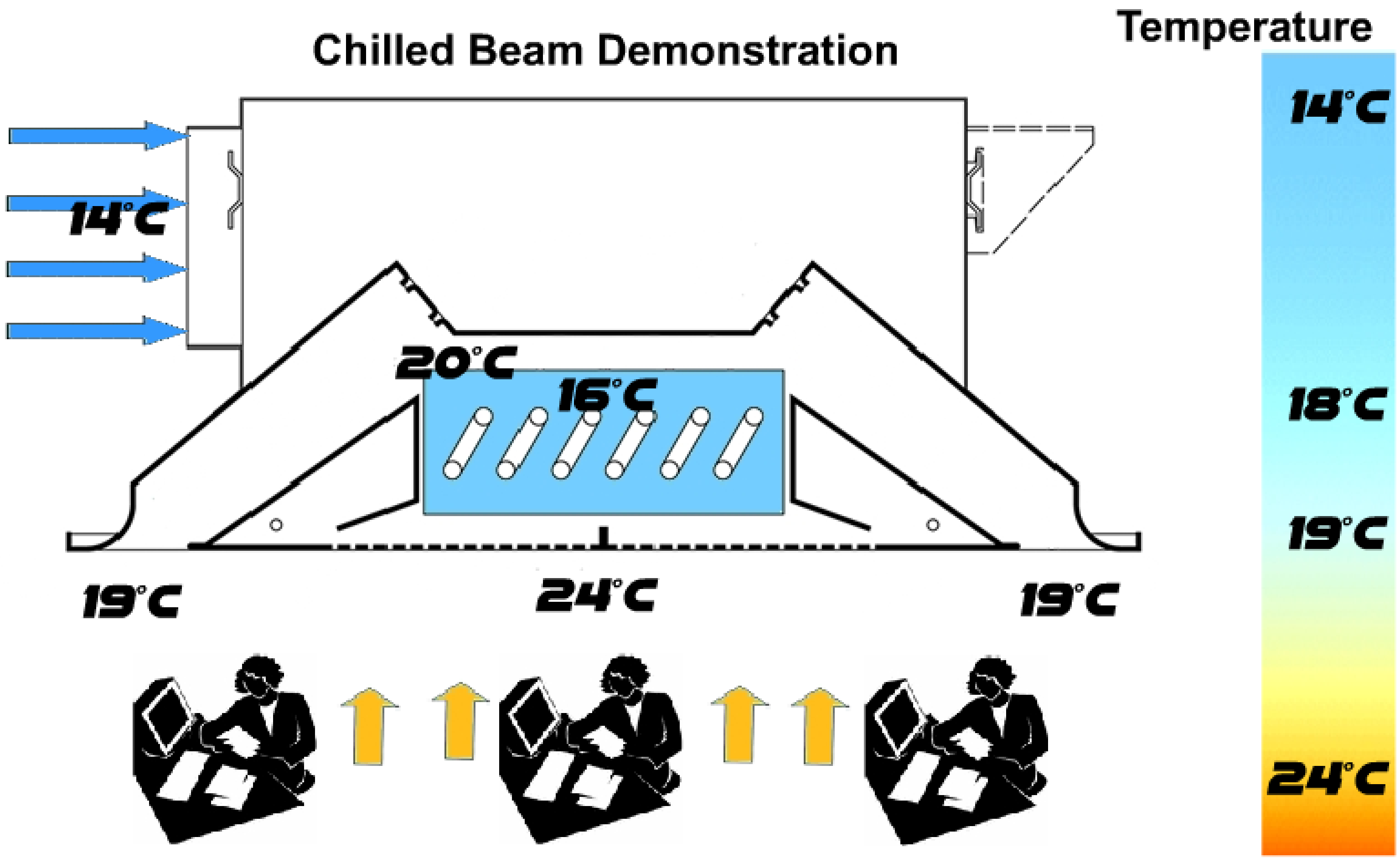
Figure 5-2: Estimated Technical Energy Savings Potential and Simple Payback Periods for the 15 Options

Operation

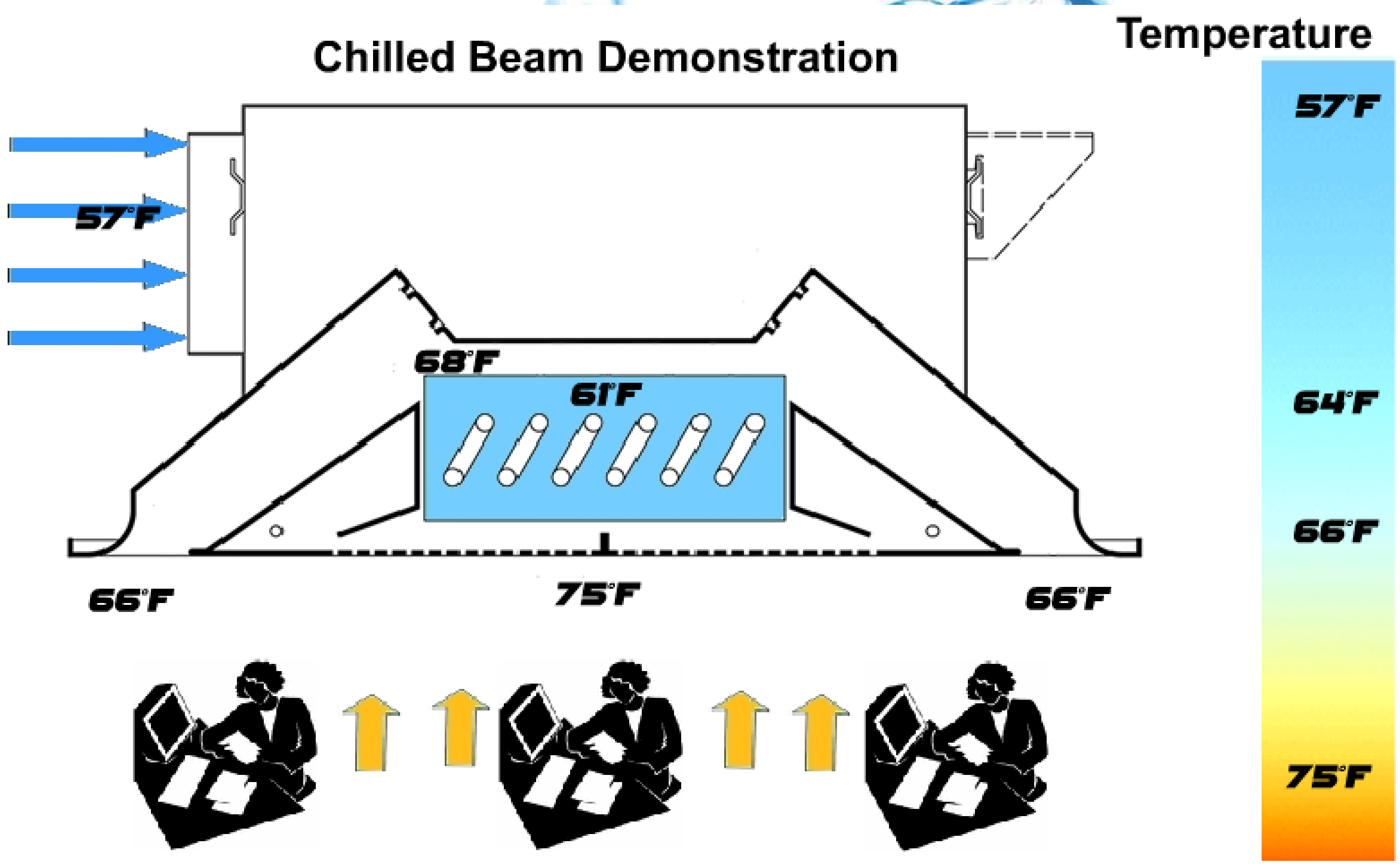


Primary 'fresh' Air
nozzles
cooled air
Room Air
Secondary Air = Cooled Room Air + Primary 'fresh' Air

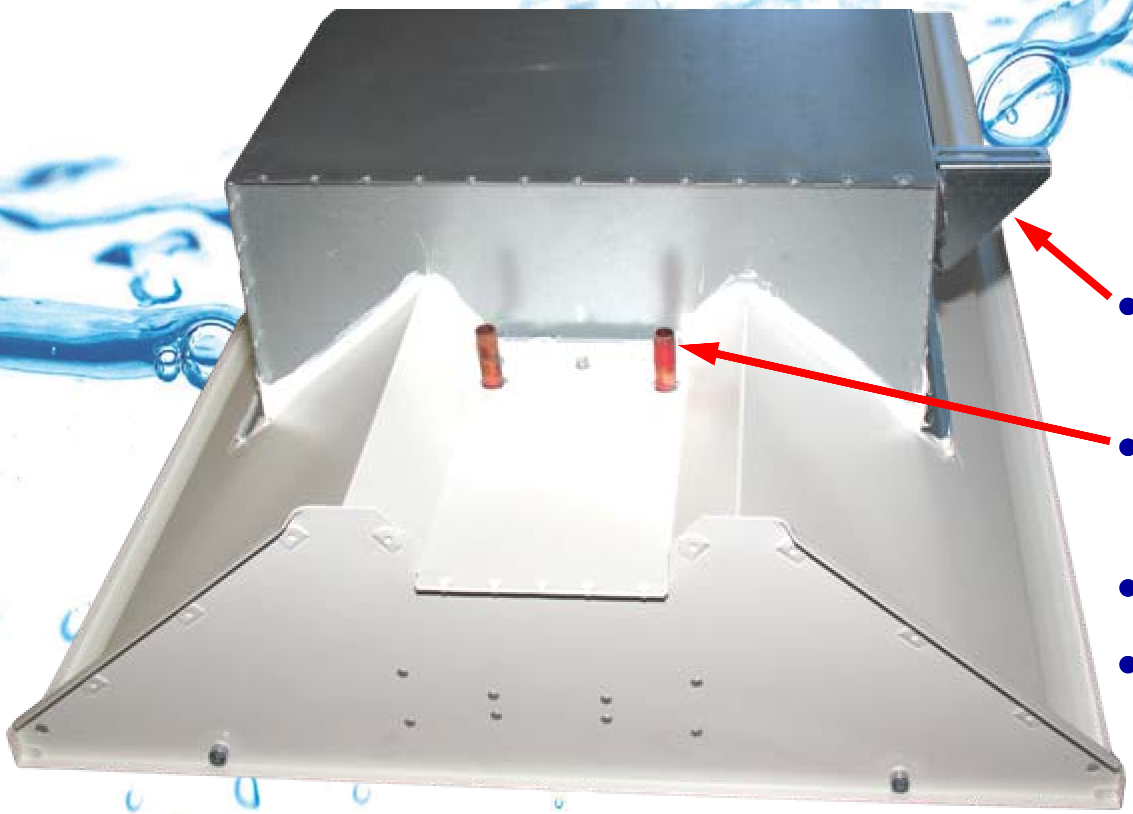
Operation


Chilled Beam Demonstration
Temperature
14°C
20°C
16°C
19°C
24°C
19°C
14°C
18°C
19°C
24°C

Operation

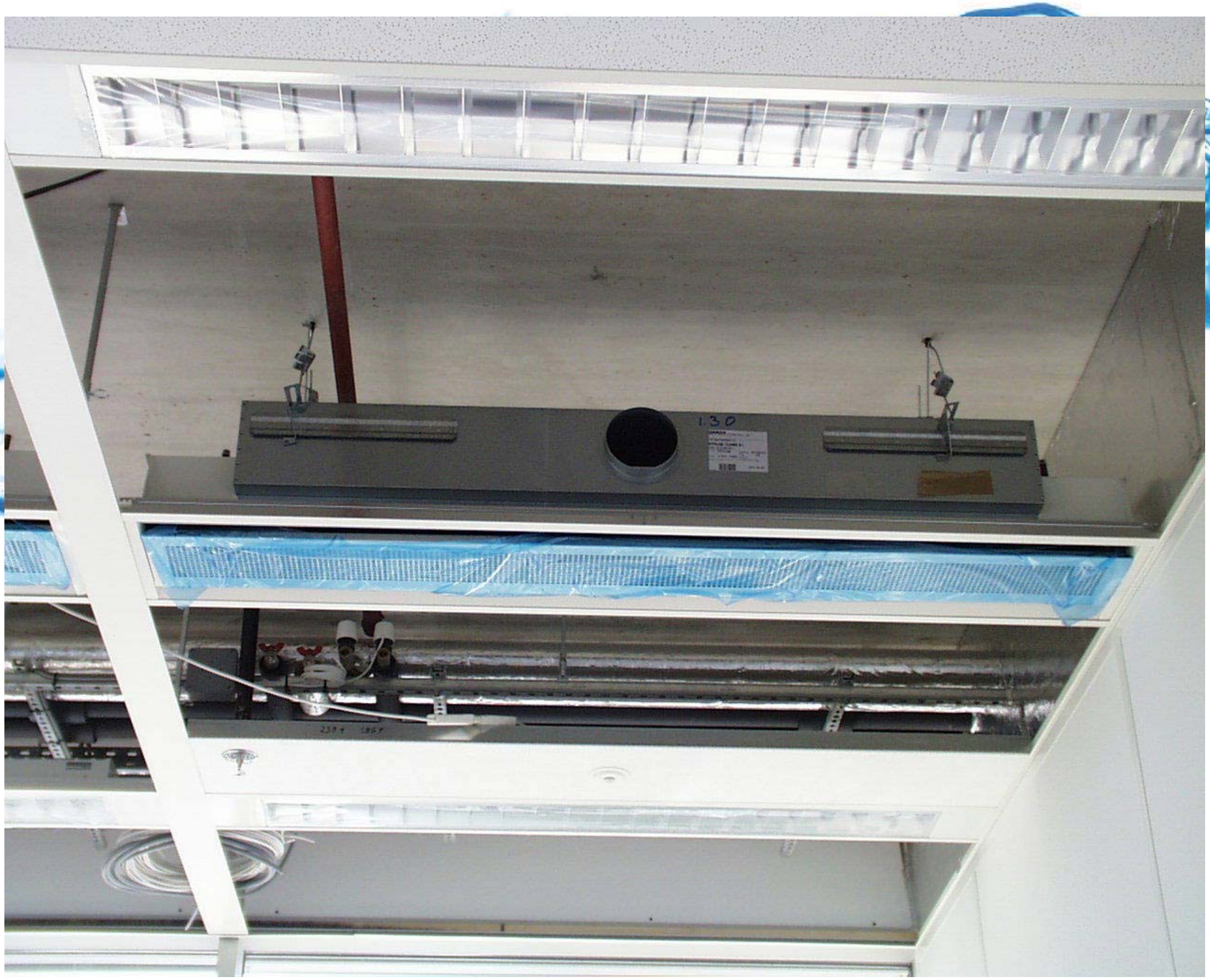

Chilled Beam Demonstration
Temperature
57°F
68°F
61°F
66°F
75°F
66°F
57°F
64°F
66°F
75°F

Operation



- Hanging rails with brackets for easy mounting
- 12mm (0.5”) water connections
- No moving parts
- Easy access from front, where room air enters

Operation



Operation - Benefits

- Higher chilled water temperatures: 14°C-16°C (57°F-61°F).

- Lower hot water temperatures: Select beams for cooling duty, then choose appropriate hot water temperature for heating.

  (i.e. usually less than 45°C (120°F)). Beam discharge air should be less than 8^{o}C (15^{o}F) warmer than room design temperature to prevent stratification.

- Suitable for use with water-to-water heat pumps, and has the potential to double the COP of a dedicated chiller loop.

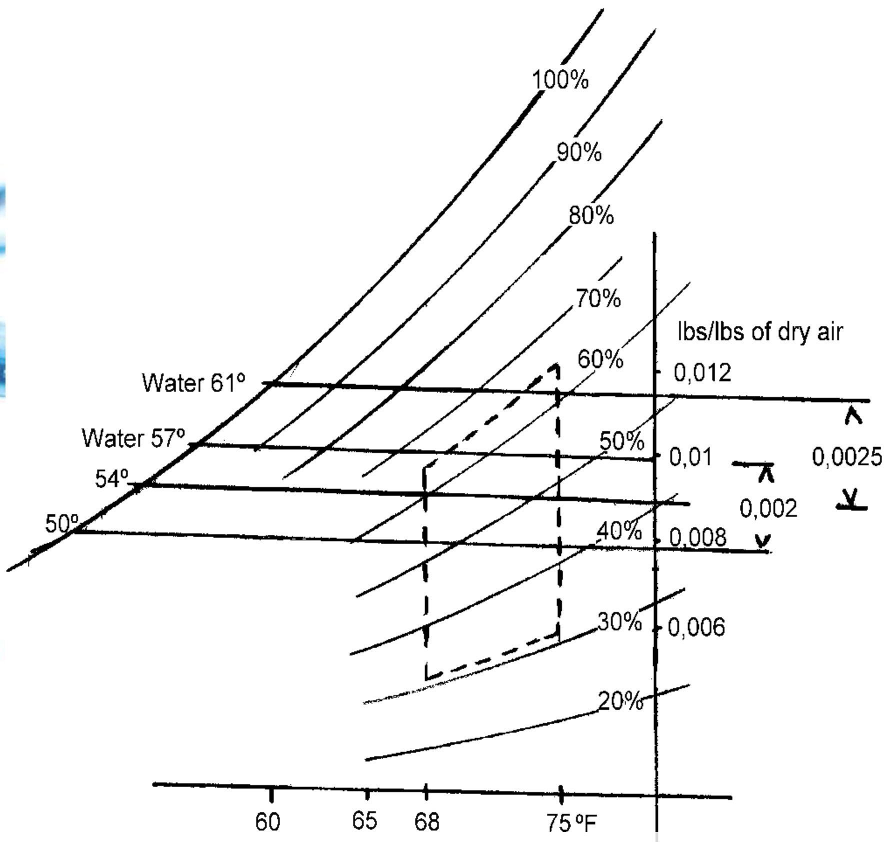
- Self regulating secondary capacity.

  Approach = Room Temperature - Supply water temperature

- VAV control can be used to strictly limit room air velocity, provide linear temperature control, and additional fan energy savings for areas with highly variable latent loads.

  i.e. Boardrooms, coffee rooms, classrooms, etc...

Possible Operating Conditions

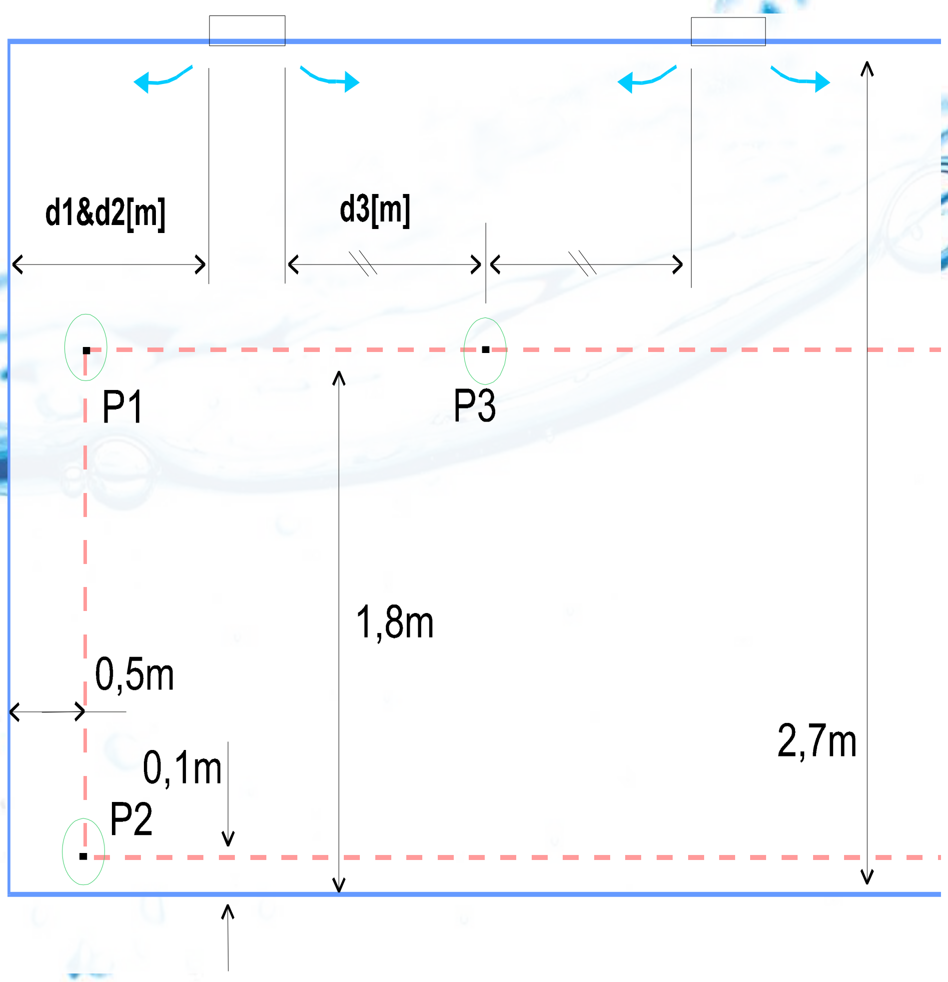


Psychrometric Chart

Air dew point 10°C, (50°F)
Water temperature 14°C, (57°F)
Dehumidification=
0.002 lbs per lbs of dry air

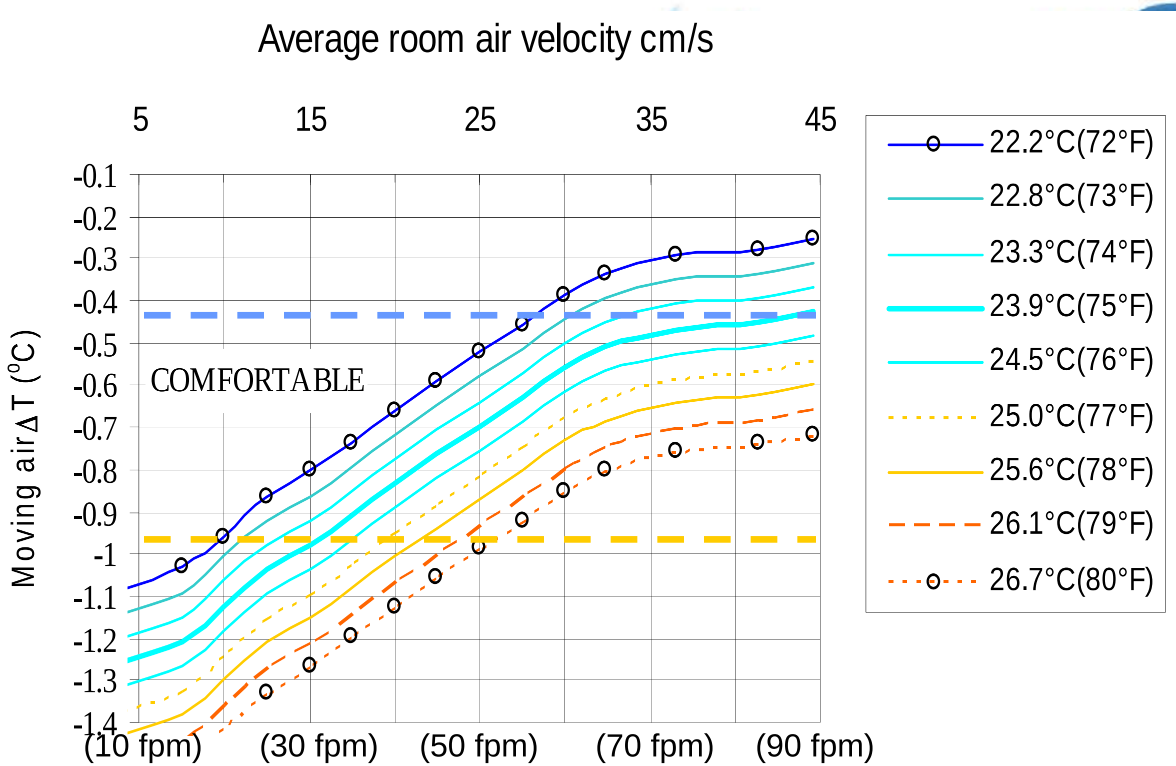
Air dew point 12°C, (54°F)
Water temperature 16°C, (61°F)
Dehumidification=
0.0025 lbs per lbs of dry air

Critical Room Air Velocities



- P1 only critical up against the wall
- P2 drops rapidly moving into the room
- P3 = ½ at 1m height

Air Distribution Chart



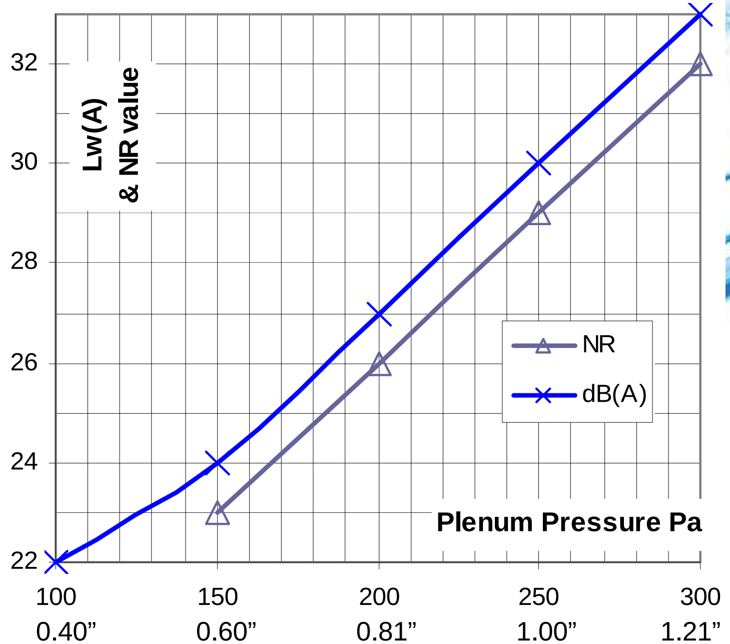
24.5 °C (76.0 °F) Room temperature, at <0.5ΔT allows 0.4m/s room air velocity

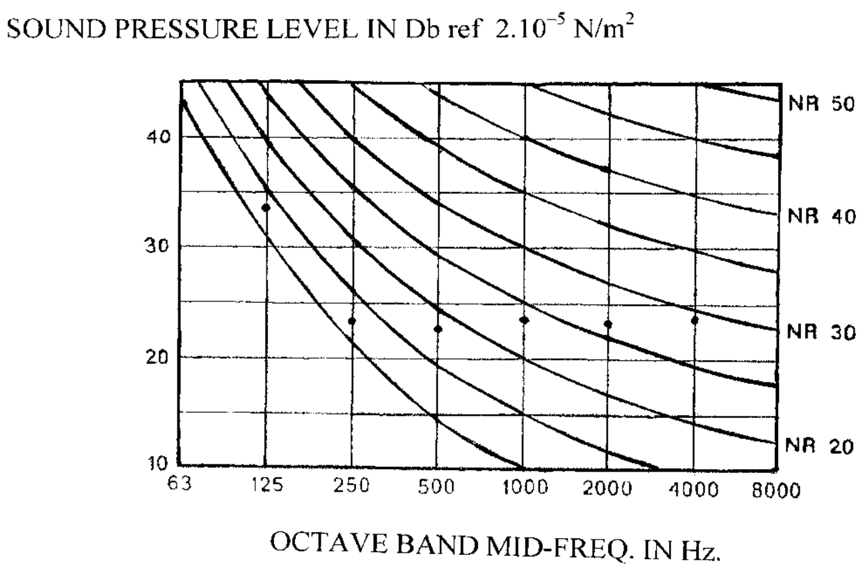
23.9 ° C (75.0 °F) Room temperature, at <0.45ΔT allows 0.4m/s room air velocity

Typical diffuser comfort line @ 0.9 ΔT moving air

High performance chilled beam comfort line @ 0.45 ΔT moving air

Pressure vs. Sound

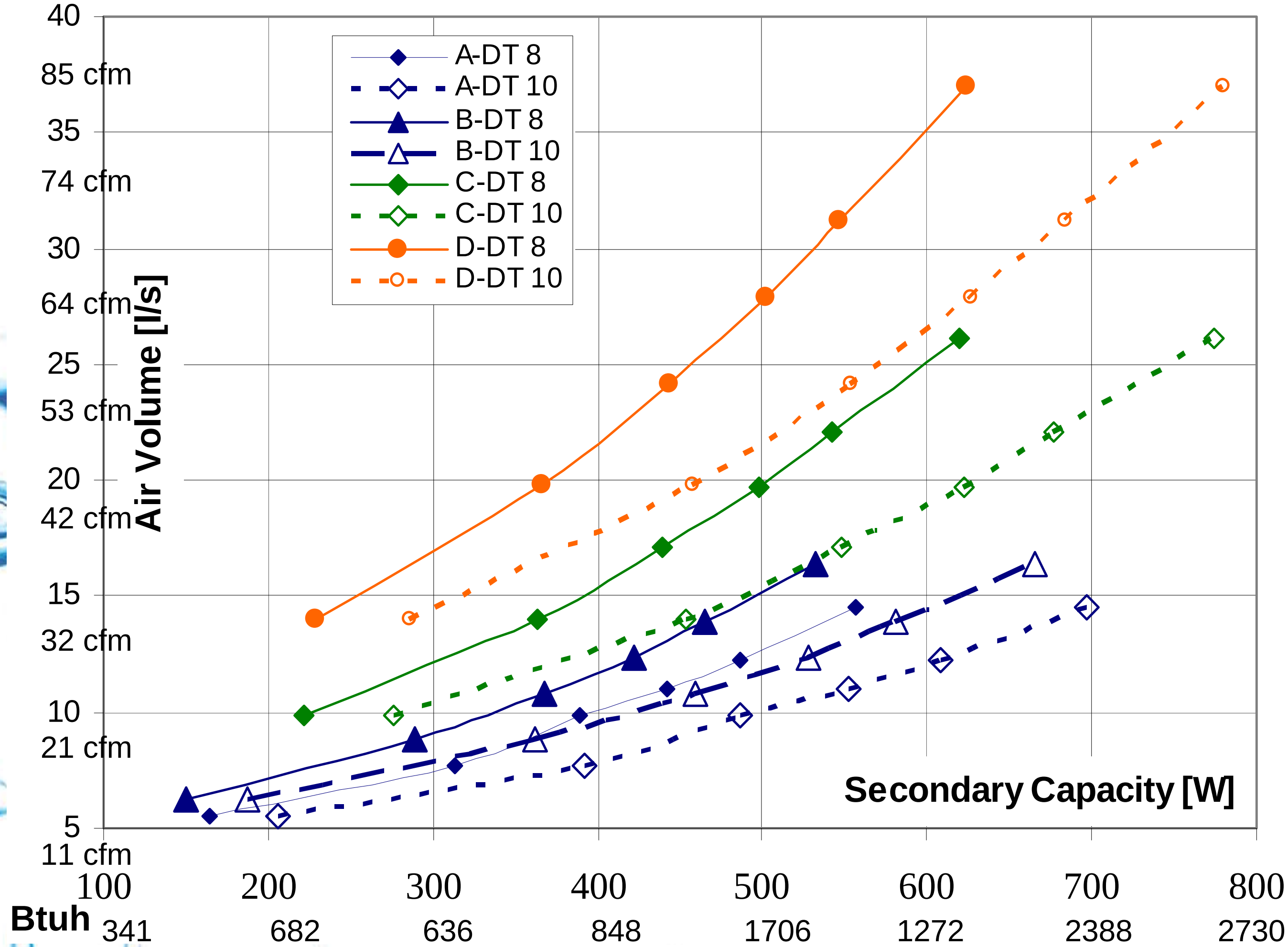




4KHz Band determines the NR value typical room –10dB at 4KHz

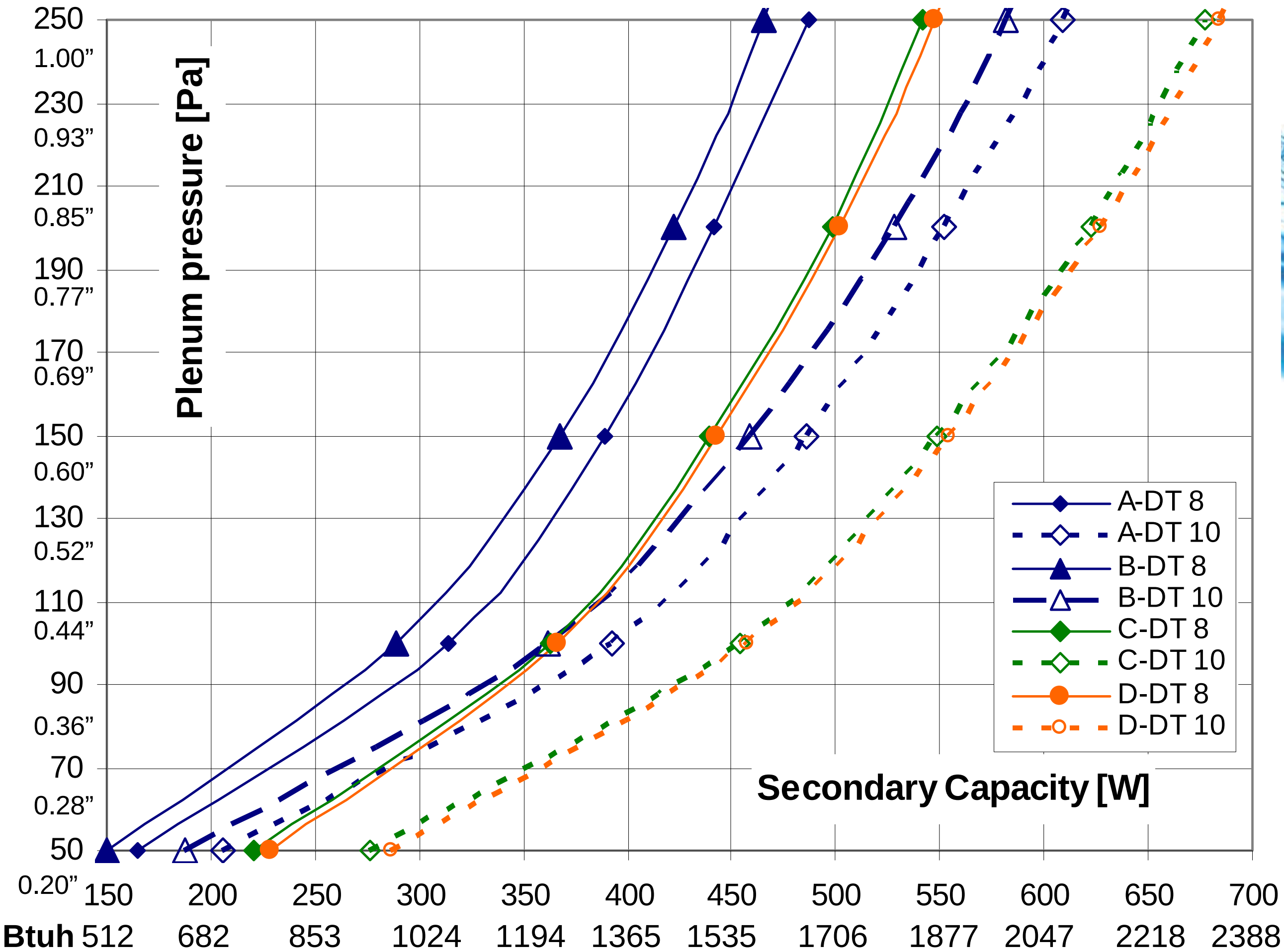
Up to 300Pa (1.2" w.c.) pressure noise is not an issue.

Chilled Beam Capacity vs. Primary Air Volume



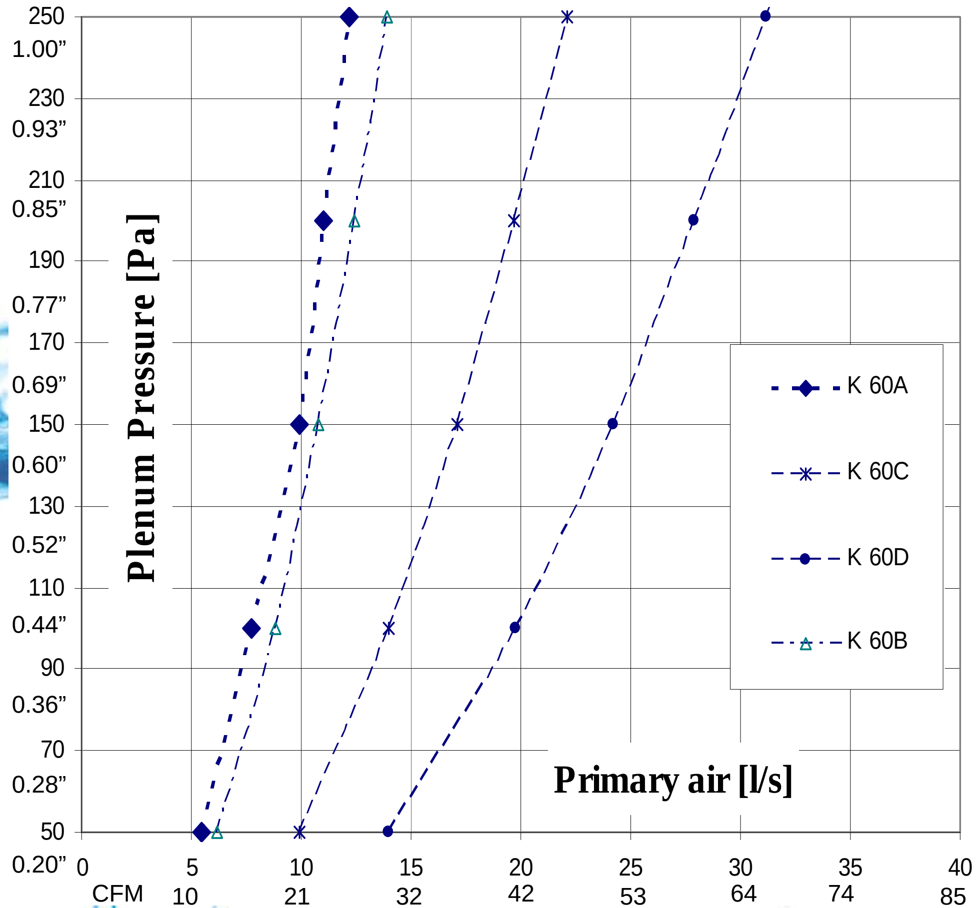
Values for a 600mm x 1200mm (2'x4') Beam

Chilled Beam Capacity vs. Primary Air Volume



Values for a 600mm x 1200mm (2’x4’) Beam

Pressure is the Common Factor



- Adjusting the air volume for each beam is not practical nor possible at these low air volumes.
- Reading plenum pressure with a Magnehelic is easy and reliable.
- Pressure is the common factor.
- A very small hole in the duct is easily covered with duct sealant.

Ducting for Equal Static Pressure

$$Pt = Ps + Pv$$

Pt = total pressure [Pa] (”w.c.)

Ps = static pressure [Pa] (”w.c.)

Pv = velocity pressure [Pa] (”w.c.)

- If velocity pressure is kept negligibly low, then the same static pressure will hold throughout the duct. (i.e. Only if transport loss can be neglected).

$$Pv = 0,5 \times r \times v^2$$

Pv = velocity pressure [Pa] (”w.c.)

r = air density [1.2 kg/m^3] (0.075 lbs/ft^3)

v^2 = air velocity [m/s] (fpm)

At < 3m/s (590 fpm) duct air velocity Pv < 5.4[Pa] (0.02”w.c.)

At < 3m/s (590 fpm) transport

Ø = 125mm (5”) < 1Pa/m (0.001”w.c/ft.)

Ø = 200mm (8”) < 0.6Pa/m (.0007”w.c./ft.)

- Low air volumes required for beams makes using round ducting practical and low air velocity achievable.

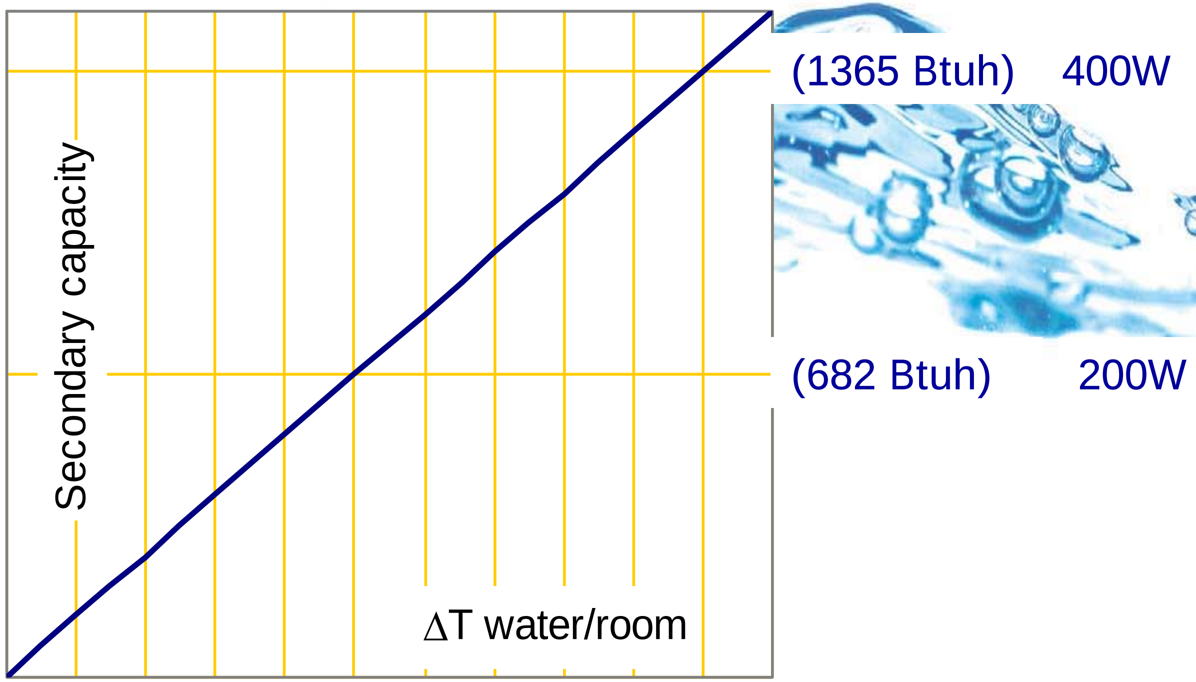
Controls

Water & Air

On/Off Water Control

- Can be used for large zones
- ON/OFF is only for secondary capacity
- Ventilation remains
- Required with interlock for opening windows, or dew point sensor on chilled water supply.

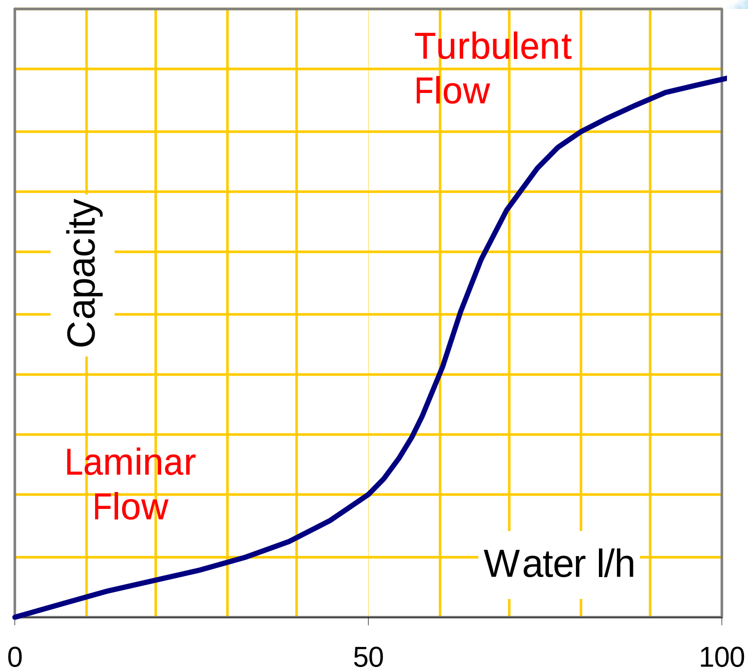
Self-Regulating – Simple Controls!

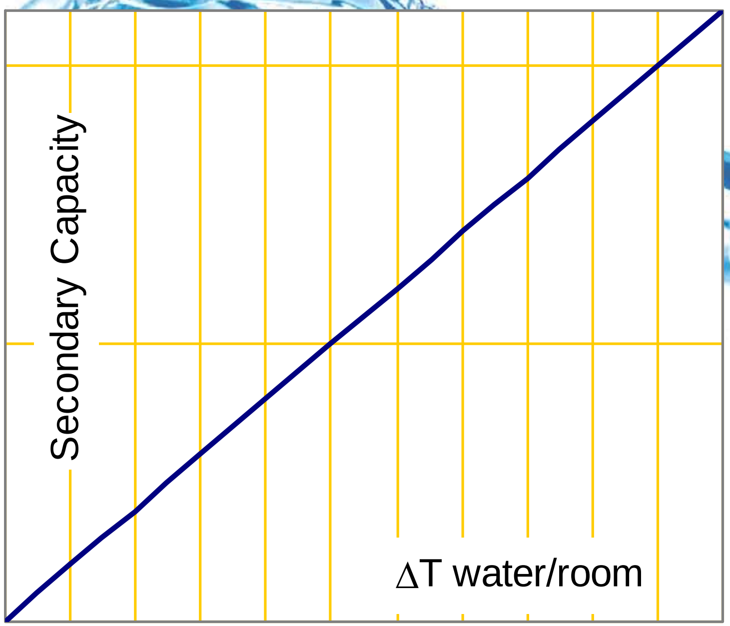


Self Regulating **Approach** = Room Temperature – Supply water temperature.

Example: Room temp 75°F (24°C), Water temperature 61°F (16°C)
Therefore **Approach** = 14ºF (8K), Capacity = X
As Room temp drops to 68°F (20°C), Water temperature 61°F (16°C),
Therefore **Approach** = 7ºF (4K), Capacity = ½ X

Proportional Water Flow Control





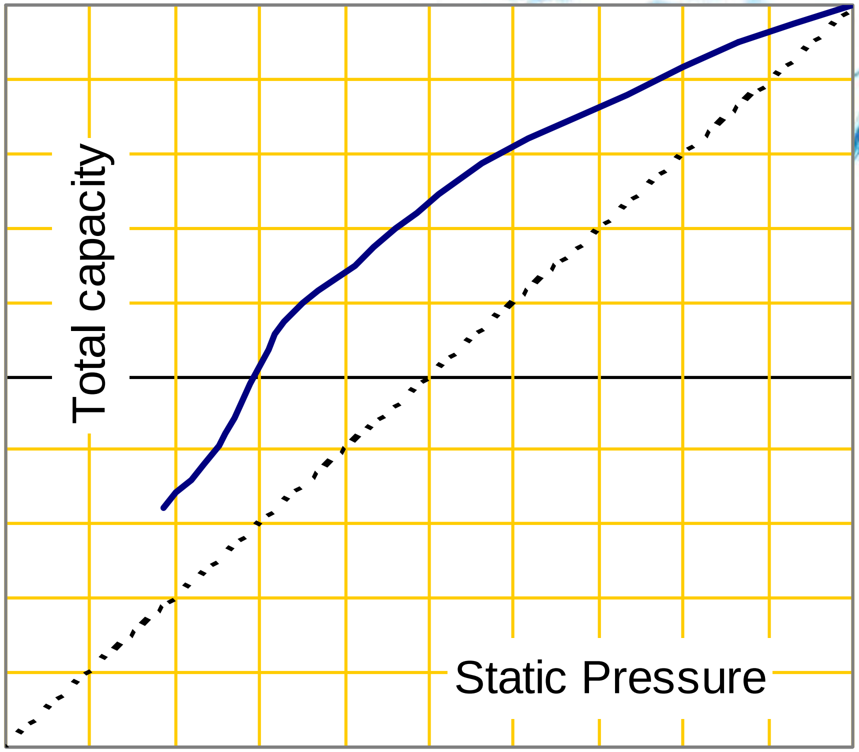
Single Circuit Water Flow

- non-linear, possible operation issues, likely expensive for small circuits.

Temperature Controlled Water

- Usually restricted to floor plates.

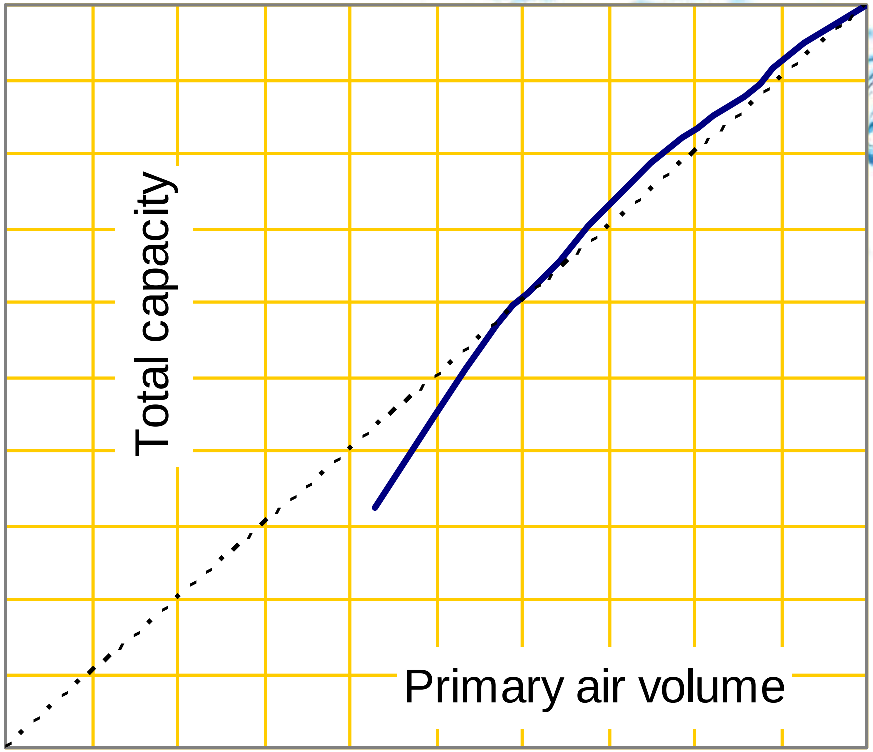
Pressure Control



- Setting up for constant volume control is feasible.
- Using variable static pressure gives non linear control; hence instability, tight control with static pressure is not practical.

VAV Control

- Use duct pressure as velocity pressure
- Min. 0.3” (75 Pa) for all beams



- Max. used to limit room air velocity. Usually no more than 1.2” w.c. (300 Pa)
- Self regulating enables large zones
- VAV only for ‘fresh air’
- VAV diversity advantage retained
- Linear capacity control gives tight temperature control
- P-band allows even more air movement

Installation Cost Comparison
3 kW (1 ton) Nominal

FAN COIL

- Fan Coil Unit + diffuser
- Mounting FCU + diffuser
- 3x spigot connections
- 1x Water connection and insulation
- 1 x Condensation drainage
- 120 V AC connection
- 1 x Unit Controller, 4 port valves, actuators and room temp. sensor

CHILLED BEAMS

- Beams 3 units x 2.1m
- Mounting 3 Beams
- 3x spigot connections
- 3x Water connections return water needs no insulation
- No condensate drainage
- No electrical connections
- Very simple terminal controls

Special duct consideration for beams:
USE LARGER DOWNSTREAM DUCTING TO MAINTAIN STATIC PRESSURE

Installation Cost Comparison
3 kW (1 ton) Nominal

Operational savings with Beams:

- 50% electric power for the chiller with 16ºC (61ºF) water, or ground water, for cooling
- Reduced primary air with VAV
- Tight temperature control where required, with VAV
- No secondary fan power
- No moving parts to maintain
- No filters to change

Installation & Operation

Installation

- Easy mounting with hanging rails and brackets
- No moving parts
- Very little maintenance
- Easy access from the front for coil cleaning.
- No electrical connections
- Inexpensive terminal controls

Operation

- High chilled water temperature 14-16°C (57-61°F)
- Primary 'fresh' air quantity tailored to suit ventilation requirements.
- Self regulating
- VAV for tight temperature control

Installation & Operation

Installation & Operation

Installation & Operation

Conclusions

- Chilled beams are the ultimate low energy, low noise air conditioning solution.
- High standards of indoor climate can be achieved with excellent air distribution and control.
- Highly variable loads can be addressed using VAV on the Primary air supply.
- Simple commissioning of both air and water.
- Practically no maintenance required.
- DOAS Information: http://doas-radiant.psu.edu.leed.html

Documentation

- Air diffusion colour printed documentation
- Selection program for 600mm wide (24”)
- PDF product documentation for 600mm (24”) wide beams
  - Features benefits & operations
  - Drawings
  - Primary capacity graph
  - Secondary capacity graph
  - Static pressure graphs
  - Water pressure drop values
  - Sound power levels at various pressures
  - Distances to observe for room air velocity

Documentation

- Engineering Documentation
  - Terminology and basics
  - Performance comparison tables
  - Air movement chart
  - Critical velocities
  - Noise
  - Water supply
  - Various types of control
  - Design for room air velocity 0.25, 0.3 , 0.4 m/s
    (50, 60, 80 fpm)
  - Design capacity tables
  - Examples of room layout and capacity available
  - 600mm (24") beam up to 394W/m^2 + (125 Btuh/ft^2 +)