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Underfloor Air Conditioning in North America

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Troup Bywaters + Anders/

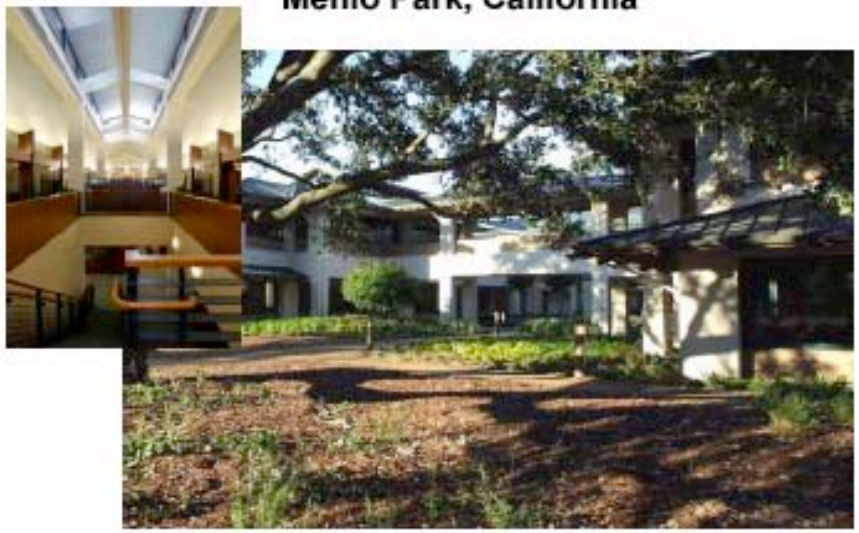
Director and Regional Chair ASHRAE Region at Large

UFAC/UFAD in North America

- Earliest systems date from mid 80s
- Interest re-fuelled by increased use of raised access floors mid 90s on
- Design practice differs from Europe and UK
- Featured in LEED low energy projects
- Increasingly popular at ASHRAE meetings

Hewlett Foundation Headquarters

Menlo Park, California



Owner:	The William and Flora Hewlett Foundation	
Project Team:	Architect:	*B.H. Bocook AIA Architect, Inc. Hawley Peterson & Snyder Architects*
	Manager:	*Bennington/Conover & Assoc.*
	Landscape:	*The Office of Cheryl Barton*
	Contractor:	*Vance Brown Builders*
	Consultant:	*Simon & Associates*
Building Statistics:		
Completion Date:	*May 2002*	
Cost:	*$*	
Size:	48,000 *gross square feet*	
Footprint:	*24,500 square feet*	
Construction Type:	New Construction, Type V Office Building	
Use Group:	*Non-profit*	
Lot Size:	*6.8 acres*	
Annual Energy Use:	*96.45 kBtu/sf/year*	
Occupancy:	*110 Staff*	

LEED

LEADERSHIP IN ENERGY & ENVIRONMENTAL DESIGN

Version 2.0

Gold

❑ Sustainable Sites

- **Alternative Transportation:** *Served by three bus lines within ¼ mile, linking building to fixed rail station; bike racks and shower facilities for bicycle commuters; preferred carpool parking in underground garage*
- **Reduced Site Disturbance:** *60% of site retained as open space*
- **Stormwater Management:** *Bioswales and detention pond ensure no net increase in stormwater runoff, storm drains are filtered to remove TSS & TP*
- **Reduced Heat Islands:** *Light colored, non-petroleum based paving surfaces.*

❑ Water Efficiency

- **Water Efficient Landscaping:** *Native and drought tolerant vegetation with drip irrigation reduce water usage over 50%*

❑ Energy and Atmosphere

- **Optimize Energy Performance:** *Exceeds CA Title 24 by 35%; strategies include underfloor HVAC, thermal energy storage, photovoltaic roof panels, and daylighting. Additional commissioning further optimized systems.*
- **Ozone Depletion:** *No HCFCs or Halon*
- **Measurement & Verification:** *Continuous measurement at device/system level.*

❑ Materials and Resources

- **Construction Waste Management:** *69% of debris recycled*
- **Recycled Content:** *64% of materials (by cost) contain recycled content*
- **Local/Regional Materials:** *40% of materials (by cost) is manufactured within 500 miles of project site.*
- **Certified Wood:** *82% of total wood is FSC certified (exemplary performance)*

❑ Indoor Environmental Quality

- **Construction IAQ Management Plan:** *Two week flush-out after construction and before occupancy*
- **Low-Emitting Materials:** *Low/no VOC adhesives, sealants, paints, carpet and composite wood.*
- **Controllability of Systems:** *Operable windows, task lighting, motion sensors and underfloor air diffusers.*
- **Daylight & Views:** *All regularly occupied spaces have access to exterior views; strategies include skylights, glazed partitions and doors, lightwells and celestory windows.*

❑ Innovation & Design Process

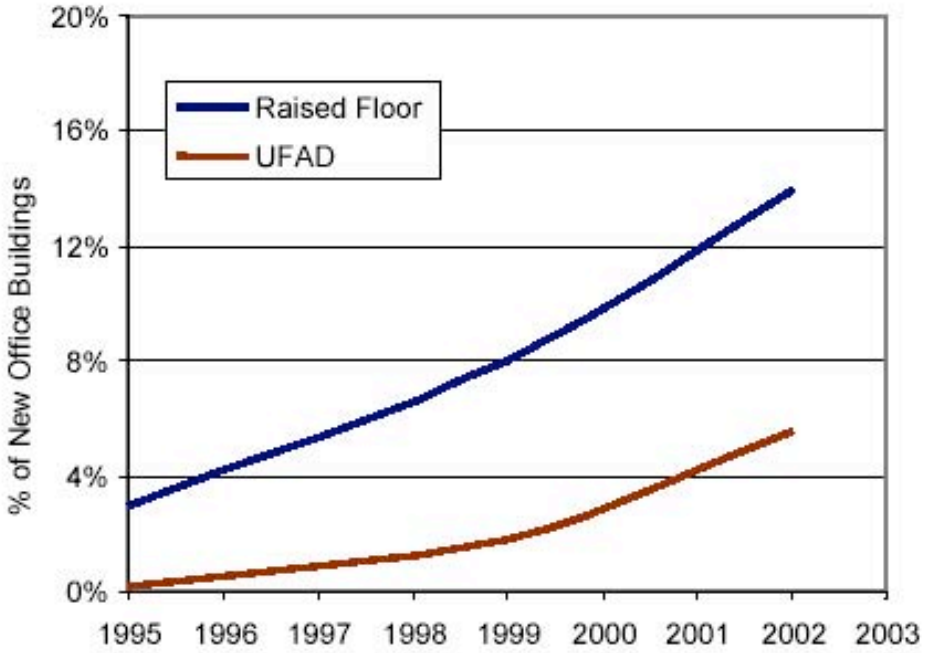
- **Innovation in Design:** *Green housekeeping; green building presentation and tour as a teaching tool; used asphalt alternative for over half of total paving.*

Background

Background

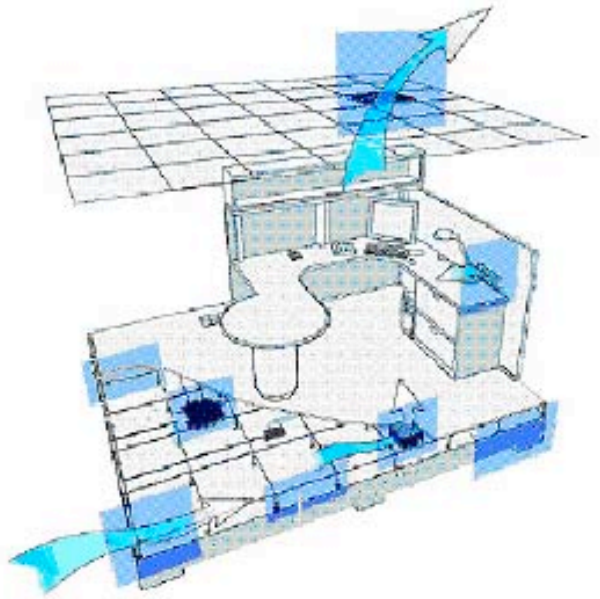
Raised floor and UFAD adoption

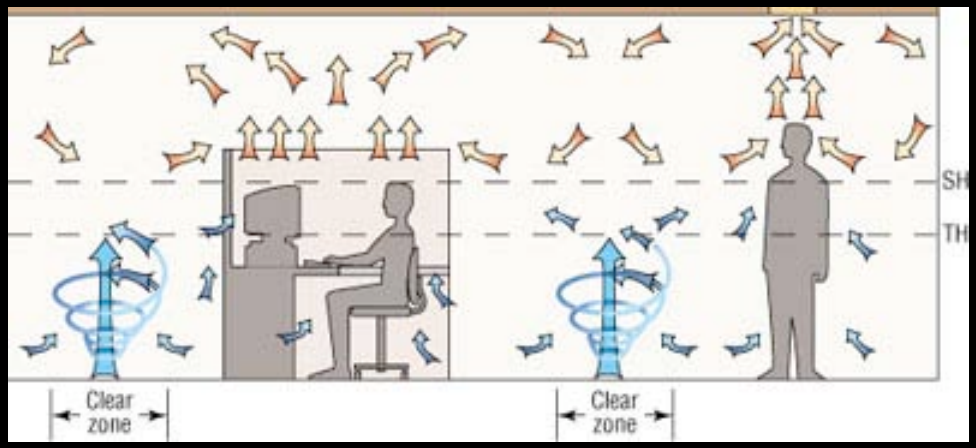
- **1995:** Less than 3% of new office buildings had raised floors, UFAD a "fringe" element
- **1999:** 8% of new offices used raised floors, 20-25% of these with UFAD systems.
- **2002:** 12% -15% have raised floors, +/- 40% of these with UFAD systems.



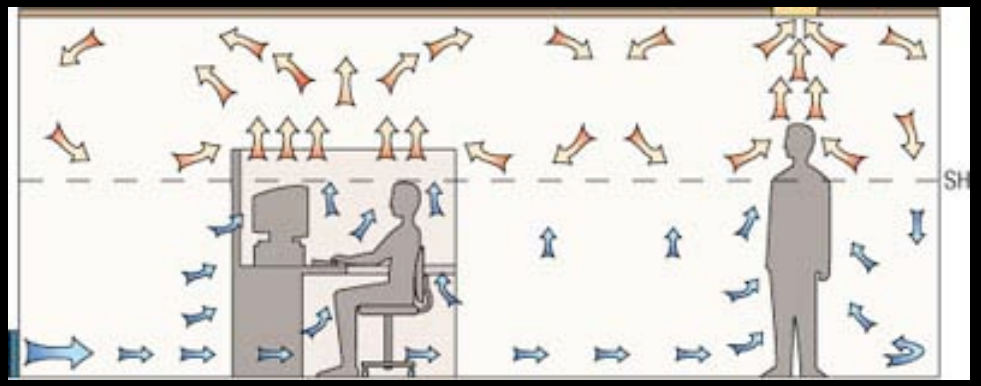
Hype vs. reality

"UFAD systems provide improved flexibility for building services, allowing for fast and inexpensive reconfigurations, and accommodating the high churn rates of the modern workplace."





Underfloor Mixing Supply



Sidewall displacement supply

Reality v. Hype (J. Woods)

- ✓ 65 buildings identified with UFAD systems
- ✓ Size from 2K to 3M sq ft, but % UFAD generally less than total floor area
- ✓ 30% new construction
- ✓ Non-compliance with relative humidity and air movement frequently reported,
- ✓ System problems included insufficient latent heat capacity, lack of controllability of temperature, pressurization, and compartmentalization,
- ✓ Energy and first cost justifications were not validated,

Types and Variations of Current UFAD Systems

Supply Air

Positive Pressure Plenum

- Unducted, "Push" Type
  - ✓ Diffusers & Grilles
  - ✓ VAV Units

"Neutral" Pressure Plenum

- Ducted to VAV or FC Units
- Unducted, "Pull" Type
  - ✓ Fan-powered VAVs
  - ✓ Fan Coil Units
  - ✓ Fan-powered diffusers & Grilles

Return Air

Ceiling Plenum

- Ducted
- Partially Ducted
- Unducted

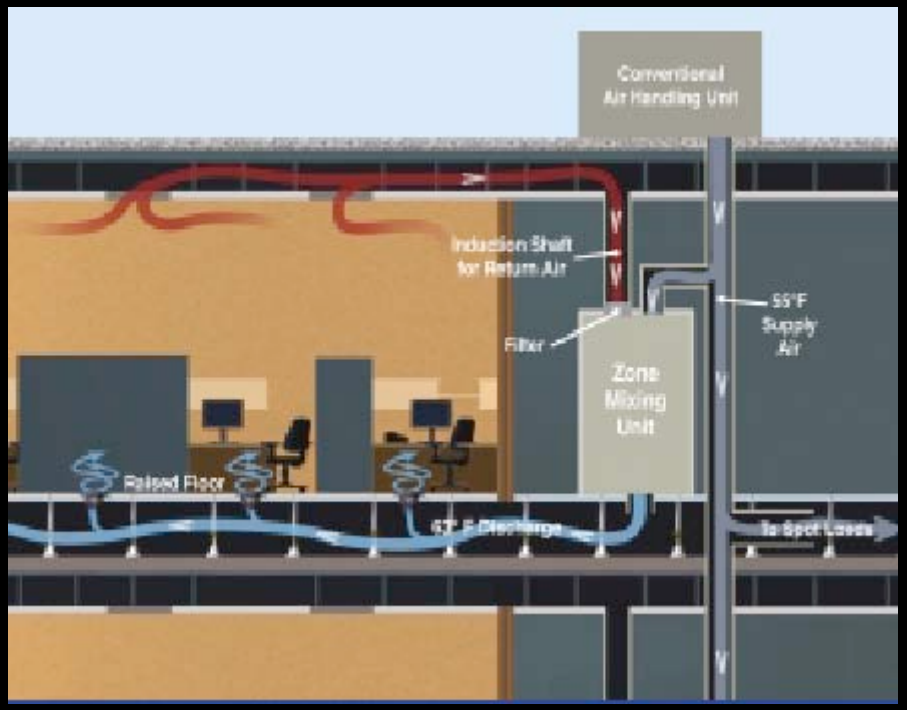
High Sidewall Grilles

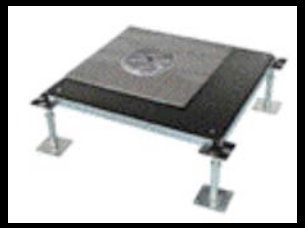
- Ducted or unducted to Ceiling
- Ducted to VAV or FCU in Floor

Floor Plenum

- Ducted from Kiosk to VAV or FCU
- Ducted from Grille to VAV or FCU
- Membrane to separate floor plenum for supply and return

Hardware in N. America





Design Process

- http://www.cbe.berkeley.edu/underfloorair/Default.htm

- *Underfloor air distribution (UFAD) design guide*. Bauman, F. (2003). Atlanta: American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

Design Process

- Building Design Considerations
- Select System Configuration
- Space Cooling and Heating Loads
- Zoning
- Ventilation Air Requirements
- Zone Supply Air Temperature & Flow Rate
- Return Air Configuration
- Cooling Coil Load
- Layout ducts and plenum configuration
- Select Primary HVAC Equipment

Building Design Considerations

- Slab floor to floor heights
- Ceiling void required?
- Plenum depth available
- Air tightness of building

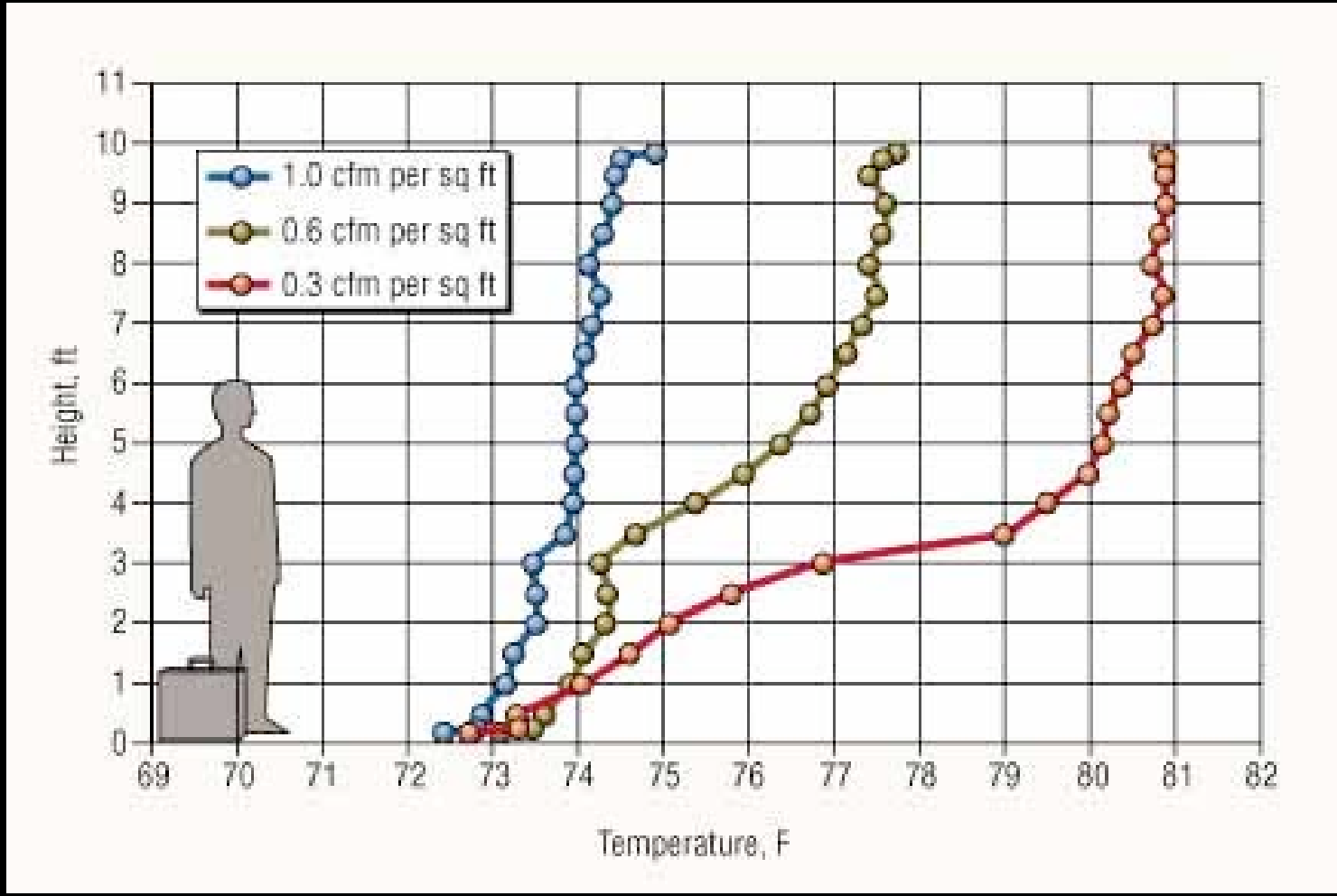
Select System Configuration

- Pressurised plenum - central air handlers
- Low pressure plenum - displacement
- Zero pressure plenum – local fan units
- Ducted outlets

Zoning

- Perimeter < 5.0m x 6m
- Interior < $80m^2$
- Smoke Barriers <$400m^2$

Return Air Configuration



Construction Phase Guidelines

Construction Phase Guidelines

- Underfloor air distribution (UFAD) systems require good coordination between all building trades throughout the design and construction process.
- It is essential that the implications of the raised access floor be considered early in the design process.
- It is important to lay out underfloor equipment requiring regular maintenance to be located in accessible areas, such as corridors, not underneath furniture and partitions.

Construction Phase Guidelines

- Determine areas in the building with no access floor and allow for transitions to areas with access flooring.
- In pressurized underfloor air distribution systems, greater care must be taken during construction to seal the underfloor plenum to prevent uncontrolled air leakage.
- The main structural slab, the traditional working platform, will not be available continuously during construction, and therefore a well coordinated construction sequence is necessary

Testing and Balancing

Testing and Commissioning

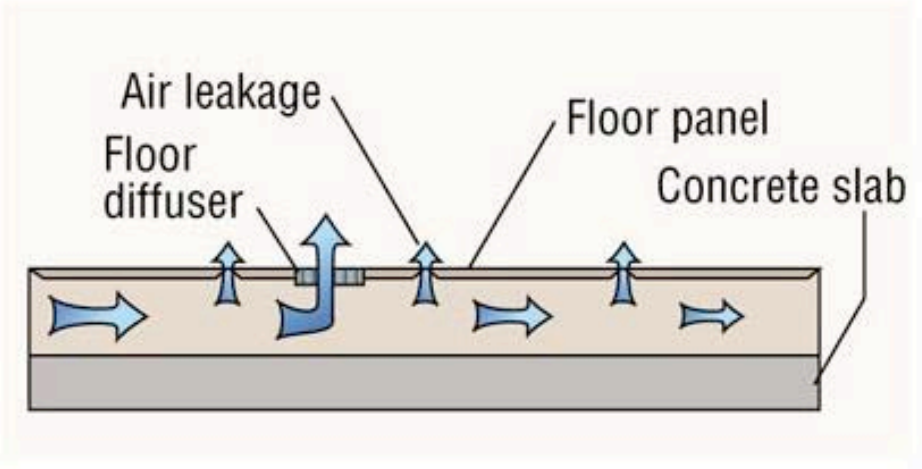
- CIBSE Commissioning Code A: Air distribution systems
- CIBSE Commissioning Code W: Water distribution systems
- CIBSE Commissioning Code W: Water distribution systems
- BSRIA Commissioning HVAC Systems: Guidance on the division of responsibilities
- BSRIA Commissioning air systems. Application procedures for buildings
- BSRIA Air tightness testing

Testing and Balancing

- Design Supply air Temperatures 16 to 21^{O}C
- Typical Temperature Pick Up 3 K*
- Range: 1.0 to 3.7K
- Plenum Pressure 10 to 20 Pascal
- Leakage:
  - –5Pa13.5 - 16%
  - –15Pa - 41%

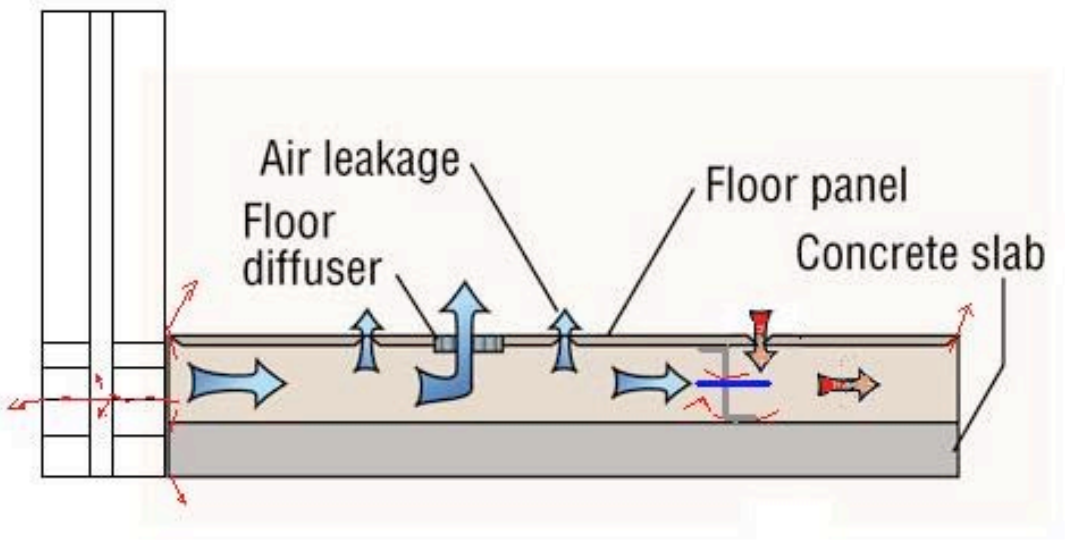
* If supply – return DT = 6K and above temperature pick up and leakage apply then cooling capacity at outlets will be (6 –3)/6 * (100-41)/100 = 29.5% of design.

Plenum Air Leakage



One major cause of uncontrolled air leakage from pressurized plenums is leakage between floor panels.

Plenum Air Leakage



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Plenum Air Leakage

Floor (with carpet)	Linear coefficient	Exponent	Net Leakage at 7 Pa	Net Leakage at 12.5 Pa	Net Leakage at 25 Pa	Normalised leakage at 25 Pa
	a	n	($l.s^{-1}$)	($l.s^{-1}$)	($l.s^{-1}$)	($l.s^{-1}.m^{-2}$)
Hewetson	1.2564	0.7374	5.3	8.1	13.5	0.69
Tate	0.4365	0.8009	2.1	3.3	5.7	0.30

Plenum Air Leakage

	$m^3.h^{-1}.m^{-2}$ at 100 Pa	$m^3.h^{-1}.m^{-2}$ at 50 Pa
HVCA Class A ductwork	0.41	0.29
HVCA Class B ductwork	1.94	1.37
BSRIA very good building	3.54	2.5
BSRIA good building	7.07	5.0
Average UK office building	30.83	21.8

Floor Voids (Ventilation Plenums)

Where floor voids are used for ventilation plenums as used in displacement ventilation systems, the BSRIA recommended air tightness criteria should remain as 1 litre per second per square metre of floor area.

NB. This rate of air leakage is ten times that allowed for low pressure ductwork in DW 144

Plenum Air Leakage

- Testing plenums once installed is relatively easy.
- This may be too late in practical terms – the Building Leakage should be satisfied before the raised access floor is laid

Temperature Pick up

- Temperature pick up in underfloor voids is largely related to distance.
- US advice varies between maximum distances of 7 to 15m. The shorter the distance the better.
- When the underfloor void is an air duct the temperature rise can be calculated easily.
- In open plenums it is more difficult to predict. CFD could be used.
- Rule of thumb – 1 to 2K per 10m

Who is responsible?

- Specifying ventilation related performance requirements of plenum?
- Management of sequence of installation?
- Construction quality of underfloor plenums and air pathways?
- Testing and Balancing underfloor plenums and air pathways?

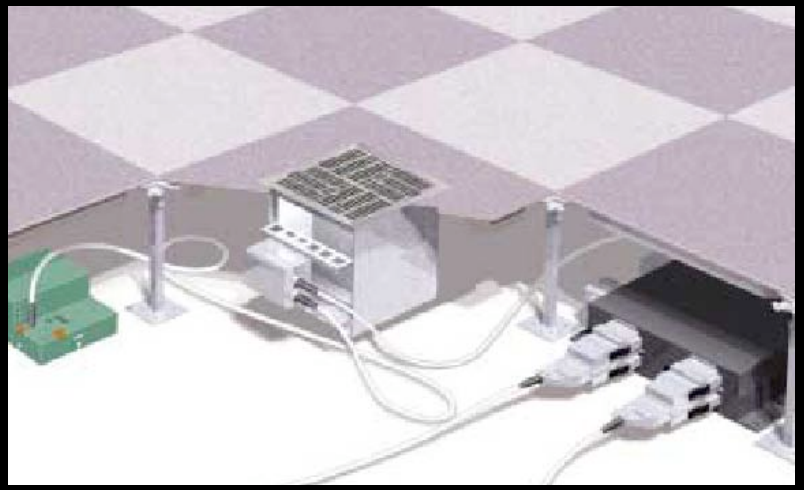
Maintenance of UFAD

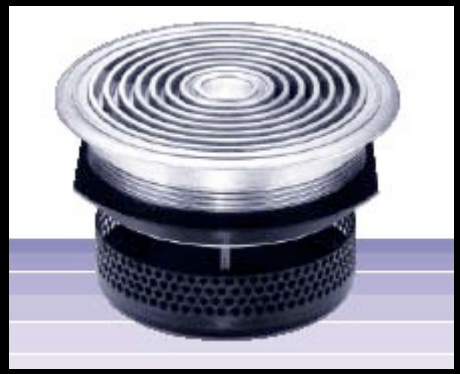
- Duct Hygiene
  - Dirt traps
  - Higher rate of dust collection

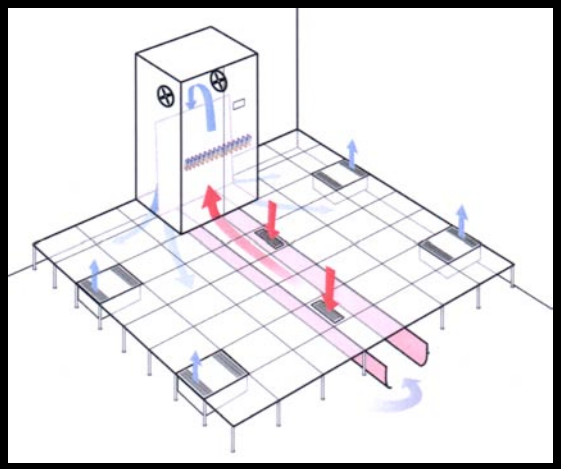
Energy Efficiency

- Lower fan energy
- Higher mean temperature in space
- Thermal storage (exposed ceiling)
- Overnight cooling?
- Plenum losses?

UFAD in the UK







Reality v. Hype (D.Arnold)

Potential UFAD benefits

1. Improved flexibility for building services
2. Improved ventilation efficiency and indoor air quality
3. Improved occupant comfort, productivity and health
4. Reduced energy use
5. Reduced life-cycle building costs
6. Reduced floor-to-floor height in new construction