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• Summary
Section 1

Introduction
Energy Consumption

- Industry: 25%
- Transport: 30%
- Buildings: 45%

source DTI
Energy Use in Buildings

Differences in energy systems

<table>
<thead>
<tr>
<th>Natural Vent</th>
<th>Typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buoyancy / Wind</td>
<td>Fans</td>
</tr>
<tr>
<td>Insulation / Mass / Night Cooling</td>
<td>Chillers</td>
</tr>
<tr>
<td>Solar / Occupants / Recycling heat</td>
<td>Heaters</td>
</tr>
<tr>
<td>Natural Lighting</td>
<td>Electric</td>
</tr>
</tbody>
</table>

(Shallow plan)

Source: Baker and Steemers
Section 2

Traditional Natural Ventilation
Advantages and Disadvantages

**Advantages**

- Driven by buoyancy or wind – FREE
- Low energy

**Disadvantages**

- Lack of control
- Cold draughts
- Increased heating required
- Noise ingress
- High max temperatures

Most of these disadvantages can be overcome through design and control !!
## Insufficiency of manual windows

### 8 schools, all post-1995 BRE/DfES study


<table>
<thead>
<tr>
<th>School</th>
<th>N</th>
<th>Ventilation rates (L/s per person)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>&lt; 3</td>
<td>&lt; 8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(%)</td>
<td>(%)</td>
</tr>
<tr>
<td>West Grove</td>
<td>10</td>
<td>3 (30)</td>
<td>9 (90)</td>
<td>8.7</td>
</tr>
<tr>
<td>Moorside</td>
<td>10</td>
<td>2 (20)</td>
<td>10 (100)</td>
<td>6.5</td>
</tr>
<tr>
<td>Wavendon Gate</td>
<td>9</td>
<td>4 (44)</td>
<td>9 (100)</td>
<td>7.7</td>
</tr>
<tr>
<td>Bramingham</td>
<td>10</td>
<td>9 (90)</td>
<td>9 (90)</td>
<td>12.1</td>
</tr>
<tr>
<td>Baltonsborough</td>
<td>7</td>
<td>4 (57)</td>
<td>6 (85)</td>
<td>20.9</td>
</tr>
<tr>
<td>Gallions</td>
<td>8</td>
<td>4 (50)</td>
<td>7 (87)</td>
<td>8.6</td>
</tr>
<tr>
<td>Bounds Green</td>
<td>10</td>
<td>3 (30)</td>
<td>10 (100)</td>
<td>7.9</td>
</tr>
<tr>
<td>Victoria</td>
<td>8</td>
<td>7 (87)</td>
<td>8 (100)</td>
<td>3.6</td>
</tr>
<tr>
<td>All results</td>
<td>72</td>
<td>35 (49)</td>
<td>67 (93)</td>
<td>20.9</td>
</tr>
</tbody>
</table>

- Every classroom had periods with less than 3l/s/person
- In total, 50% of measurements were below 3l/s/person
Section 3

Examples of Natural Ventilation
Examples – Buoyancy Driven

- Hot air driven out at top
- Cold air driven in at base

Pressure vs. Height

Interior air
Exterior air

Interior air
Exterior air
Examples – Wind Driven

Zeus Building, Cambridge – increasing wind driven ventilation using venturi stacks
Section 4

Designing Natural Ventilation
Houghton Hall

Which way does the air flow?
Water bath modelling

Mode 1

Mode 2

Two different steady states can evolve.
Multiple modes can be obtained with numerical modelling ... but
• You need to know what you are looking for!
• Time consuming!

Uniform initial conditions (20°C)

1st floor initially hotter than ground (eg. 1st floor occupancy arrive earlier)

Air enters through 1st floor vents
→ cool interior

Air exits through 1st floor vents
→ hot 1st floor

Mode 1

Mode 2
Section 5

Natural Ventilation Strategies
Traditional approach: Summer

Buoyancy based ventilation strategy: Upwards Displacement
**Stack Based System: Summer**

Increased buoyancy head > increased ventilation rates in summer

Wind helps, but *ventilation still provided on hot still days*

Fan-assisted on hottest days
Traditional approach: Winter

Still operating in upwards displacement ventilation
Cold air in needs preheating
Traditional approach: Winter

<table>
<thead>
<tr>
<th>Heat Source</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupants</td>
<td>32 x 65 = 2 kW</td>
</tr>
<tr>
<td>Lighting</td>
<td>70 x 15 = 1 kW</td>
</tr>
<tr>
<td>IT</td>
<td>0.5 kW</td>
</tr>
<tr>
<td>Solar</td>
<td>0.5 kW</td>
</tr>
<tr>
<td>Fabric loss</td>
<td>-1 kW</td>
</tr>
<tr>
<td>TOTAL</td>
<td>3 kW</td>
</tr>
</tbody>
</table>

\[ Q = \rho \cdot C_p \cdot V \cdot \Delta T \Rightarrow \Delta T = 15 \, \text{degC} \]

Cold Air Needs Preheating to 16 °C

\[ T_{\text{classroom}} = 16 + 15 = 31 \, ^\circ\text{C} \]

Overheat in winter > Increase ventilation rate > Increased preheating

> Increase Energy Usage!
Mixing System: Winter

Mix incoming cold air with hot classroom air
Air into classroom pre-heated by heat gains in space
Removes requirement for pre-heating with radiators
Stack based System: Night Cooling

Automatic night cooling on the hottest days
Night cooling at high level: reduces security risks
Can be fan assisted if target Temp. no achieved by 3am
Section 6

Internal Comfort
Harston Project

Before

- Prototype e-stack system
- Completed September 2006

After

- Monitored for two consecutive winters
Internal Climate Comparison

Alternating days, unit on/off

Max. CO2
BB101

Max. CO2
offices CIBSE Guide A

CO2 (ppm)

0 200 400 600 800 1000 1200 1400 1600 2000

03/03/2008 00:00 06/03/2008 00:00 09/03/2008 00:00 11/03/2008 00:00 13/03/2008 00:00 15/03/2008 00:00
Internal Temperatures in a Classroom in Linton High School between June 1st - July 18th

Linton Village College
- 0 hours for which $T_{room} > 28^\circ C$
- $(T_{room})_{\text{max}} = 27.5^\circ C$
- $(T_{room} - T_{external})_{\text{max}} = 2.4^\circ C$

BB101 Standards
- 120 hours for which $T_{room} > 28^\circ C$
- $(T_{room})_{\text{max}} = 32^\circ C$
- $(T_{room} - T_{external})_{\text{max}} = 5^\circ C$
Section 7

Energy Savings
Theoretical Model

Energy required (W) vs. External Temperature (degC)

- Conventional Upflow Displacement Natural Ventilation
- e-stack (space heating)
- e-stack (electrical)
Theoretical Energy Savings

During occupation, heating over one year:
Conventional natural ventilation: ~ 80-90 kWh/m²/yr
e-stack ventilation: ~ 5-10 kWh/m²/yr

Potential energy savings 70-85 kWh/m²/yr

CIBSE good practice total energy consumption for a secondary school: 135 kWh/m²/yr

Reducing total consumption to: 50 - 65 kWh/m²/yr
Equivalent to approximately: 50 - 60 % reduction
Measured Savings

Fossil Fuels Energy Consumption kWh/m²/yr

Queen Alexandra College, Birmingham

Port Regis School, Dorset
Energy Consumption of a Middle Storey UK Classroom with good practice U-value standards

- Conventional Natural Ventilation
- MVHR with bypass all year
- Winter MVHR with summertime natural ventilation and fan boost
- e-stack ventilation

Total Energy Requirement (kWh/m²/year of gas equivalent)

- Heating
- Fans
Section 8

E-stack systems
System Types

Stack
- R-Series
  - Classrooms
  - Halls (multiple units)
- S-Series
  - Spaces with clerestory
  - Room height >3.5m

Facade
- F-Series
  - Spaces onto an Atrium
  - Units include attenuator baffles

Atrium
- A-Series
R-series System

- Air inflow from exterior
- 950.0mm
- 600.0mm
- Warm room air to be used for mixing
- Air outflow from room to exterior
- Mixed air inflow into room
- 130.0mm
- 500.0mm
User Interface

Red/Blue LEDs
- RED = Open Windows
  The system is in summer mode and the room is either getting too warm or CO2 is getting too high.
- BLUE = Close Windows
  The system is in winter mode

KEY SWITCH
- ON = Normal Operation
  The system is almost always on, but is controlled to shut down when the room is unoccupied
- OFF = For yearly maintenance
- TEST = For commissioning and testing
Atrium system

900mm dia. fan

Circular egg-crate grill

Distance between the two units in the room should be as large as possible

Acoustic baffles
Port Regis School, Dorset
Port Regis School, Dorset
Facade system

Effective free area of the damper should be a minimum of 0.4m².

Distance between unit and supplementary window should be as large as possible.

Opening window for Winter outflow and supplementary Summer inflow or outflow.
For classrooms at the top of multi-storey schools or in just one floor where there generally was Breathing Buildings B-Series, a stack unit.

Areas filled with computer equipment such as IT classrooms generate excessive amounts of heat. These rooms can sometimes have even more stringent limits on summertime overheating than BS 1121, and so we offer a hybrid ventilation system to solve these challenges. Once the external temperatures reach a level where free cooling cannot be used, the ventilation system switches to minimum return and a cooling system is turned on, controlled by the B-Series controller.

In larger spaces such as school halls, our S-Series units ensure excellent ventilation and low energy consumption while complying with BS 1121 summer overheating requirements. The number of stack-required stacks on the perimeter area and often works in conjunction with low and high level windows.

Our F-Series unit is ideal for classrooms with sloping roofs or which have a bank of windows looking away from external noise. The F-Series delivers the benefits of stack ventilation without the need to penetrate the roof.

In an atrium with classrooms linked to it our A-Series units provide low cost mixing ventilation in winter and compliance with BS 1121 summer overheating.

The A-Series units provide noise attenuation to manage noise transfer between the atrium and classrooms.

Noise can be a major distraction and affecting noise attenuation while ensuring plentiful ventilation is crucial for rooms near busy roads. In these cases we supply acoustic attenuators within the stack unit and termination which provide up to 30dB of attenuation (certified by Sound Research Laboratories).
Adaptive Thermal Comfort

- Adaptive thermal comfort forming the basis of new overheating standards for schools, firstly through PSBP then a new release of BB101.
- Mixing ventilation and cross-flow ventilation are mandated.
- Nightcooling and thermal mass strongly encouraged.
- Breathing Buildings already able to model to new TM22 guidelines (unlike tools like IES) and currently on board with many main contractors for their bidding process for PSBP.
Adaptive Thermal Comfort

- Adaptive thermal comfort now uses **Operative Temperature** as the parameter to measure designs against.

- Thermal mass has a 2-fold effect on operative temperature; reducing air temperature (conduction) and surface temperature (radiation).

- Importance of a secure, controlled nightcool strategy, getting as close to target temperature overnight as possible.

- The balance between the requirements of the acoustician (suspended ceiling) vs. an exposed concrete soffit. This can be solved with Phase Change Materials which can be incorporated into ceiling tiles or ceiling rafts and is equivalent to approx. 140mm of exposed concrete.
Section 10

Summary
• Natural ventilating buildings can reduce total energy consumption significantly.

• Intelligent control is key.

• Strategies:
  – Winter: Mixing ventilation
  – Summer: Displacement ventilation

• Complex spaces should be modelled:
  - Thinking about natural ventilation from early stages of design can lead to improved performance and better building integration.

• Thermal mass will have increasing importance when CIBSE TM22 released and adaptive thermal comfort becomes the standard.