Healthcare Ventilation, "High Consequence Spaces"

Healthcare Environments
ASHRAE Madison Chapter
Don MacDonald, Phoenix Controls
March 14, 2016
Healthcare Ventilation, “High Consequence Spaces”

Presentation Outline

I. Industry Challenges
II. Standards and Guidelines
III. Energy Management Trends
IV. Applications
V. Optimizer Software Demo
VI. Summary

Presented by:
Don MacDonald
Northern Regional Manager
Phoenix Controls
Cell: 519-212-3341
dmacdonald@phoenixcontrols.com
www.phoenixcontrols.com
Presentation and Discussion

INDUSTRY CHALLENGES
Energy Challenges

• Escalating Demand
  – HVAC 44% of cost
  – 43% charged higher rates
  – $1.5 M per hospital per year
  – $25 per bed per day
  – 28% pay $3 to $4 per ft²
  – 21% pay $5 to $6 per ft²
  – Cost to double in 20 years

Energy costs

Typical In-Patient Healthcare Energy Consumption

插图

2011 Hospital Energy Management Survey, HFM Magazine
Energy Challenges

• HVAC Code Requirements
  – Outside Air Demands
  – Spaces with 20 to 30 ACH
  – Ventilation Systems
  – Emergency Power
  – Temperature/Humidity

<table>
<thead>
<tr>
<th>Space</th>
<th>ACH Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Rooms</td>
<td>20</td>
</tr>
<tr>
<td>Caesarean delivery</td>
<td>20</td>
</tr>
<tr>
<td>Fracture Room</td>
<td>12</td>
</tr>
<tr>
<td>Cardiac Cath</td>
<td>20</td>
</tr>
<tr>
<td>AI Isolation Rms</td>
<td>12</td>
</tr>
<tr>
<td>Diagnostic Imaging CT, MRI, X-Ray, Ultrasound</td>
<td>9-20</td>
</tr>
<tr>
<td>Burn unit</td>
<td>15</td>
</tr>
<tr>
<td>Laboratory</td>
<td>12</td>
</tr>
<tr>
<td>Pharmacie (QC)</td>
<td>30</td>
</tr>
</tbody>
</table>
Energy Challenges

• Operation Compromises
  – Deferred services
    • No time, no budget
  – Budget cuts
    • Low cost material selection
  – 24/7 Equipment Operation
    • Control limitations
    • Fear of performance failure in unoccupied setback
  – High Demand Use Cost
    • 15% avg. use of profits
Energy Challenges

• Measurement and Verification Processes
  – No commissioning or retro-commissioning in place
    • Lack of standardization and processes
  – Lack of equipment operation verification
    • Equipment performs below specification or code
    • Poor functionality over time
      – 80% of issues are O&M
      – 20% design, install, or replacement issues
  – Failure to benchmark energy data
  – Knowledge gaps regarding energy savings return

Ventilation Design Challenges

• Evidence: Energy Waste
  – Reynolds Army Hospital Final Report
    • Pitot tube assemblies clogged
    • Blockage causing averaging sensor to send skewed signal to transducer
    • Energy waste due to false signals causing supply and return fans to operate at maximum conditions
    • Recommend ongoing maintenance and re-calibration
    • Current standards require that maintenance area be enclosed.
Presentation and Discussion

STANDARDS & GUIDELINES
• Set energy efficiency goals-strategies
• Consider total Life Cycle Cost
• Mechanical control systems should optimize consumption to the minimum needs of the building
• Use energy-saving mechanisms such as variable-air-volume (VAV) systems and programmed controls for spaces in unoccupied periods
Codes and Guidelines
Energy Efficiency

FGI 2010
ASHRAE 90.1, 2013

• **Energy Standard: Buildings Except Low-Rise Residential Buildings**
  - Minimum requirements
  - Energy efficient design and construction
    - Mechanical equipment efficiencies
    - Occupant-sensing controls
    - Expanded modeling requirements
  - Energy demand efficiency.
    - Reduces consumption 30% over 2004
Overview of the currently adopted commercial energy code in each state
as of March 1, 2016

http://www.energycodes.gov/states/index.stm
Codes and Guidelines
Energy Efficiency

ASHRAE Table 7-1

- Pressurized rooms: Air changes may be reduced when room is unoccupied.
- Number of air changes indicated must be re-established when occupied.
- Pressure relationship must be maintained.
- Areas requiring no continuous directional control, ventilation systems may be shut down when unoccupied.
- If any form of VAV system is used for energy conservation it shall not compromise the pressure relationships or the minimum air changes required by the table.
Codes and Guidelines
Energy Efficiency

ASHE
Operating Room HVAC Setback Strategies

• Night setback or Unoccupied setback
  – OR’s have high ACH rates (20-30)
  – ACH may be reduced if pressure held
  – OR’s may be unoccupied 40%
  – Staff usage profile
  – Temperature setback?

• Moderate Cost and Control strategy
  – Airflow control:
    • pressure independent air valves
    • Supply and exhaust pair
    • Controlled to set-point to maintain offset
    • Volumetric control to maintain pressure differential or direct pressure control
    • Requires minimal maintenance
Airflow Control
Code Requirements
Operation Maintenance Planning

ASHRAE 170
Maintenance, Informative
Appendix A O&M in Health Care Facilities

• Operating Rooms (OR)
  – Tested for positive pressure semi-annually
  – Preventative maintenance schedule

• Protective Environment Rooms (PE)
  – Remain positive to adjacent space whenever an immuno-compromised patient is present
  – Tested daily when occupied

• Airborne Infection Isolation Room (AII)
  – Remain negative to adjacent space whenever an infected patient is present
  – Tested daily when occupied
Presentation and Discussion

ENERGY MANAGEMENT TRENDS
Energy Management Trends

• HVAC Equipment and Processes
  – High-efficiency systems
  – Replacement systems
  – Variable Air Volume (VAV)
  – Static-pressure reset
  – Temperature reset
  – New DDC controls
  – Occupancy sensors
  – Maintenance plans
  – Adjusted control schedules

GOING GREENER Hospitals continue to make sustainability a priority BY JEFF FERENC, December 24, 2010 HFM Magazine.com
Increasing the Bottom Line Through Energy Efficiency, N O V E M B E R — D E C E M B E R 2 0 0 9 | INSIDE ASHE
How Do You Increase Energy Efficiency in Your Health Care Facility? Strategies and Best Practices
VENTILATION APPLICATIONS
78 Critical Spaces
59 Pressurized Spaces
AVG 8.5 ACH
Operating Rooms

- .01” wc positively pressurized space
- 20 ACH when in use
- 4 ACH minimum outside air
- typically runs at constant volume
- during surgery temperature range 68–75°F
- humidity 20–60%
- operates 24 hours a day
- Supply diffusers unidirectional downward and average velocity 25-35 cfm/sqft
- Area of diffusers shall extend a minimum of 12" beyond the surgical table
- Exhaust grills, at least 2 low level approx 8" above floor as far apart as possible
Operating-Surgery Rooms

Supply / Exhaust Tracking Pairs

- VAV or 2-Position
- Occupancy modes
- Temperature
- Humidity
- Pressure monitor
- Remote monitoring
- Duct temp sensor
- Decontamination
Operating-Surgery
Clean / Dirty Corridor
Supply / Exhaust Tracking Pairs
All Airborne Infections Isolation room

- maintain continuous air pressure negative .01” wc
- ensure rooms well-sealed/no leakage
- 70-75 Deg F design temperature
- 12 ACH, 2 ACH of minimum outdoor air
- Calculate ACH based on exhaust flow
- If not occupied pressure relationship is maintained and min ACH 6
- Switching controls for reversible airflow (pressure relationship) shall not be permitted (note t)
- self-closing devices on exit doors
- direct exhaust air outside, away from intake
All Airborne Infections Isolation room

- Retrofit can use HEPA filtration recirc system for ACH
- When All room has an ante room: All room negative to ante room, ante room negative to corridor
- Monitoring device between room and the corridor alarm when pressurization not maintained
- Exhaust grills located in ceiling or wall at the head of the patient bed.
All Airborne Infectious Isolation room

Isolation Rooms w anteroom

Supply / Exhaust Tracking Pairs

- .01” wc
Isolation Room Ventilation Design

ASHRAE 170-2013

PE Protective Environment Isolation room

- 12 ACH, 2 ACH of minimum outdoor air
- ACH for positive room calc on supply airflow
- Pressure positive .01 " wc. 2.5 pa
- Switching controls for reversible airflow (pressure relationship) shall not be permitted (note t)
- 70-75 Deg F design temperature
- maintain continuous positive air pressure
- Ensure rooms well-sealed/no leakage
- When PE room has an ante room: PE room positive to ante room, ante room positive to corridor
- Monitoring device between room and the corridor alarm when pressurization not maintained
- Supply diffusers located at the head of the patient bed.
- Exhaust grills located near the patient room door.
Isolation Rooms w anteroom

Supply / Exhaust Tracking Pairs

PE Protective Environment Isolation room

Isolation Rooms w anteroom

Supply / Exhaust Tracking Pairs

+ .01” wc
Combination AII/PE Isolation room

- 12 ACH, 2 ACH of minimum outdoor air
- maintain continuous positive air pressure
- ensure rooms well-sealed/no leakage
- self-closing devices on exit doors
- 70-75 Deg F design temperature
- Monitoring device(s) between AII/PE room and the ante room and ante room to corridor alarm when pressurization not maintained
- Supply diffusers located at the head of the patient bed.
- Exhaust grills located near the patient room door

All/PE room has an ante room:

- Ante room shall be positive to both patient room and the corridor OR.....
- Ante room shall be negative to both patient room and the corridor
Combination All/PE Isolation room
Isolation Rooms w anteroom

Supply / Exhaust Tracking Pairs
Combination All/PE Isolation room
Isolation Rooms w anteroom

Supply / Exhaust Tracking Pairs
Sterile Prep & Compounding rooms

- 30 ACH, 15 ACH of minimum HEPA filtered outdoor air. Non hazardous, non radioactive CSPs ** 15 ACH if meet criteria
- 70-75 Deg F design temperature
- Sterile prep, maintain positive air pressure
- Compounding rm: maintain .01” wc negative air pressure
- Hazardous drugs prep in a ISO Class 5 BSC and placed in a ISO Class 7 area
- ISO Class 7 ante room next to prep room
- The BSC should be 100% vented to the outside via HEPA filtration
- rooms well-sealed/no leakage
- A pressure indicator shall be installed that can be readily monitored for correct room pressurization
- Pressure differential between the Class 7 prep and general pharmacy area shall not be less than .02” wc
- Hand motion door activation
Pharmacy App USP797

CSP Clean Rooms

- Doors are represented correctly and are interlocked so only one door can open at any time
- Progressive Offset Control has been implemented with flow rates frozen when doors are open
- All pressures shown as measured with independent Advanced Pressure Monitors APM2

CVV 360 l/s

Prep Area + 15 pA

GEX 287 l/s

MV 350 l/s

POC PPP

POC PPP

Compounding Sterile Prep Preparation

BSC Class II
B2 100% Exhaust

GEX 0 / 450 l/s

BSC EXV 450 / 0 L/S

CVV 350 l/s

30 l/s

30 l/s

73 l/s

Compoundin Room 15 pA

Sterile Prep +30 pA

BSC Class II
A2 100% Recirc

MAV 420 l/s

GEX 320 l/s
Compound Sterile Prep Rooms

Supply / Exhaust Tracking with BSC shutdown

Pharmacy

Shut-Off Containment

• VAV or 2-Position
• High turndown
• Temp/Humidity Sensor
• Pressure monitor
• Remote monitoring
• Duct Temp Sensor
• Occupancy Modes
• BSC driven to shut-off when not in use
• General Exhaust required in the event of BSC failure or shutdown.
Typical patient room

- Approximately 70–80% of hospital space
- Neutral to slightly positive
- Supply unit, ducted exhaust
- 6 ACH with 2 ACH OSA
- Typically CV, but shifting towards VAV
- Temperature range 70–75°F
- Humidity 30–60%
- Bathroom 100% exhaust
Patient Rooms

Supply / Exhaust Tracking Pairs option for Pandemic ready

Patient Room

- VAV or 2-Position
- Temp control
- Occupancy modes
- Pandemic sequences
Surge Capacity Zones

Supply / Exhaust Tracking Pairs

- VAV or 2-Position
- Occupancy modes
- Pandemic sequences
- Room pressure monitors
- Remote monitoring
- Dampers to control sequence and to close for decontamination
Laboratory Rooms

Diagnostic Laboratories
Healthcare

Project Histories

Massachusetts General Hospital
Boston, MA
Building for the Third Century (B3C)
Boston, MA

Occupied
25 ACH
2,800 cfm
65 hr/wk

Unoccupied
4 ACH
448 cfm
103 hr/wk

<table>
<thead>
<tr>
<th>Conditioned Air Cooling</th>
<th>9,420 kWh</th>
<th>$1,413</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditioned Air Heating</td>
<td>25.1 Mbtu</td>
<td>$376</td>
</tr>
<tr>
<td>Reheat Energy</td>
<td>204.1 Mbtu</td>
<td>$3,061</td>
</tr>
<tr>
<td>Fan Energy</td>
<td>16,898 kWh</td>
<td>$2,535</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>26,318 kWh</strong></td>
<td><strong>$7,385</strong></td>
</tr>
</tbody>
</table>

- Procedure Room
  - Reduce air changes during unoccupied periods
  - 20 Procedure Rooms
  - Difference in Air Flow: 2,352 cfm
  - Temp of Conditioned Air (AHU): 55°F
  - Annual Savings $147,700

Healthcare Project Histories

Providence Health & Services
Renton, WA
Providence Everett
Everett, WA

Engineering study
Changing from CV (11.6 ACH) to VAV would provide significant savings
Fan energy and re-heat demand

VAV design
Energy savings

Venturi Valve Technology
Airborne infection control
Enables hospital to respond to pandemic incidents by creating isolation rooms on-demand

### Anticipated Annual Energy Savings

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
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</thead>
<tbody>
<tr>
<td>Fan Energy Savings</td>
<td>$35,509.00</td>
</tr>
<tr>
<td>Reduced Reheat</td>
<td>$17,885.00</td>
</tr>
<tr>
<td>Reduced Hot Water Pumping</td>
<td>$110.00</td>
</tr>
<tr>
<td>Reduced Cooling</td>
<td>$2,301.00</td>
</tr>
<tr>
<td>Reduced Chilled Water Pumping</td>
<td>$122.00</td>
</tr>
<tr>
<td><strong>Total Projected Annual Savings</strong></td>
<td><strong>$55,926.00</strong></td>
</tr>
</tbody>
</table>

### Benefits of Switching To VAV

<table>
<thead>
<tr>
<th>Utility</th>
<th>Energy Savings/yr</th>
<th>Rebate Amount</th>
<th>Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric</td>
<td>7,560,000 Kwh</td>
<td>$1,405,000</td>
<td>-</td>
</tr>
<tr>
<td>Gas</td>
<td>2,800,000 Kwh</td>
<td>$375,523</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10,360,000 Kwh</strong></td>
<td><strong>$1,780,523</strong></td>
<td><strong>3.16 yrs</strong></td>
</tr>
</tbody>
</table>
Presentation and Discussion

OPTIMIZER SOFTWARE DEMO
Optimizer Software

• Airflow energy and lifecycle software (FREE)
  – Wizard Style User Interface
  – Accurate VAV modeling
  – Alignment with various commercial building types
  – Flexibility for quick simple or more detailed energy analysis
  – What if scenarios
  – Utilizes TMY3 and WMO weather data
  – Flexible Reporting on Energy, Sustainability, and ROI
  – Built in room types for quicker modeling
    • https://www.phoenixcontrols.com/resource-pc-optimizer.htm
### Annual Energy Usage

<table>
<thead>
<tr>
<th>Control Type</th>
<th>Energy Cost (US$)</th>
<th>Savings (US$)</th>
<th>Cooling Energy (kWh)</th>
<th>Heating Energy (mcf)</th>
<th>Reheat Energy (mcf)</th>
<th>Supply Fan Energy (kWh)</th>
<th>Exhaust/Return Fan Energy (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV VAV Box</td>
<td>$86,566</td>
<td>$0</td>
<td>323,622.9</td>
<td>0.0</td>
<td>2,913.7</td>
<td>213,559.3</td>
<td>128,135.6</td>
</tr>
<tr>
<td>VAV Boxes</td>
<td>$39,992</td>
<td>$40,374</td>
<td>197,470.5</td>
<td>3.7</td>
<td>1,915.0</td>
<td>60,181.6</td>
<td>36,123.3</td>
</tr>
<tr>
<td>VAV Venturi Valves</td>
<td>$25,671</td>
<td>$60,885</td>
<td>114,042.6</td>
<td>317.4</td>
<td>804.6</td>
<td>47,019.3</td>
<td>28,704.9</td>
</tr>
</tbody>
</table>

### Financial Analysis (US$)

**Inflation = 3%, Analysis Period = 10 Years, Hurdle Rate = 5%**

<table>
<thead>
<tr>
<th>Control Type</th>
<th>NPY</th>
<th>IRR</th>
<th>SIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV VAV Box</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>VAV Boxes</td>
<td>$350,565</td>
<td>181.3 %</td>
<td>15.5</td>
</tr>
<tr>
<td>VAV Venturi Valves</td>
<td>$555,278</td>
<td>313.8 %</td>
<td>27.19</td>
</tr>
</tbody>
</table>

### Annual Greenhouse Gas Emissions Equivalency

<table>
<thead>
<tr>
<th></th>
<th>CV VAV Box</th>
<th>VAV Boxes</th>
<th>VAV Venturi Valves</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 yr</td>
<td>(3.56)</td>
<td>(2.58)</td>
<td>(3.28)</td>
</tr>
</tbody>
</table>

- **10 ORs**
- **8 Operating 25 ACH**
  - M-F 8am-6pm, 6 ACH RoD
- **2 Operating 25 ACH**
  - Su-Sa 8am-6pm, 6 ACH RoD

**10 Year Life Cycle Cost ($USD) and Payback**

- Energy Costs
- O & M Costs
- Product Initial Costs
- HVAC Initial Costs
Presentation and Discussion

SUMMARY
Why Improve Ventilation in the Hospital Environment?

- **Energy efficiency**
  - Ability to implement setback strategies during unoccupied periods without compromising environmental integrity.

- **Hospital-acquired infections**
  - Better airborne infection control

- **Operational efficiency**
  - Flexibility of switching from a normal patient room to a negative surge capacity room.

- **Healing environment for patient**
  - More effective comfort control for faster patient recovery
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Healthcare Environments

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March 14, 2016
Thank you!