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Office Dedicated Outdoor Air System with Parallel VAV
Energy and Cost Analysis of Proposed Design
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General Information

- Biomedical Laboratory with mixed office/classroom space
- Location: Buffalo, NY
- Size: 73,000 ft²
- Project Cost: $24,000,000
- Procurement Type: Cost-Plus Fee
- Project Completion: May 2005
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Architect:
Merhdad Yazdani,
Yazdani Studio of Cannon Design
(Los Angeles, CA)

Architects and Engineers:
Cannon Design (Buffalo, NY)

Construction Manager:
Ciminelli Development
(Buffalo, NY)

Merhdad Yazdani discussing the building plan design at HWI
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Architecture

• Aluminum Curtain Wall with varied casement windows and solar shading

• Laboratory Fritted Glass wall Assembly

• 3 story central atrium unifying building

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Existing Conditions

**Lighting/Electrical Systems**
- 480/277V 3phase, 4 Wire Primary
- 120V and 277V Luminaries provide task and accent lighting
- 1.46 W/ft² Lighting Power Density
- 450kW/563kVA Fuel-Fired Emergency Generator

**Structural System**
- 5” Slab-On-Grade Construction
- 4’ poured concrete footings
- Structural Steel Building Skeleton
- Oversized members to provide rigidity
- King-Post Truss System in atrium provides roof and skylight support
Existing Conditions

**Mechanical**

- (2) DX Rooftop AHU’s provide 42,000cfm to office
- (2) 100% Outdoor AHU’s provide 58,000cfm to Lab
- (1) 300 Ton Air Cooled Screw Chiller for AHU Cooling Coils
- VAV Reheat for all Systems
- (6) 2,0000 MBH Hot Water Boilers for building heat
- Laboratory Run-Around Heat Recovery Loop

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Existing Conditions

**Mechanical (cont’d)**

- Dedicated Laboratory Exhaust System for hood contaminant control
- Atrium Smoke Exhaust System with linked exhaust and makeup air fans

- Design Air Conditions

<table>
<thead>
<tr>
<th>Indoor Design Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Summer</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Occupied</td>
</tr>
<tr>
<td>DBT (°F)</td>
</tr>
<tr>
<td>% RH</td>
</tr>
</tbody>
</table>
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**Mechanical Redesign**

- Lab Dedicated Outdoor Air System with Parallel Chilled Beams
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Proposed Redesign

Dedicated Outdoor Air Systems

- Replace DX Units with DOAS System/Parallel VAV
- Replace 100% Outdoor Air Units with DOAS/Parallel Chilled Beams

Justification

- Reduced Required Mechanical Space
- Reduced First Cost
- Reduced Annual Utility Costs
- Improved Indoor Air Quality compared to DX Units
- Desiccant Wheels proven reliable in Laboratory Applications

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Proposed Redesign

Parallel Systems
- VAV on Office Side
- Chilled Beams on Lab Side

Laboratory DOAS AHU
- 25 Ton Cooling Coil
- Desiccant Wheel Only
- 6500 cfm ventilation requirement

Office DOAS AHU
- 30 Ton Cooling Coil
- Enthalpy Wheel and Sensible Wheel
- 10,500 cfm ventilation requirement
Laboratory System

- Exposed Ceilings in lab can easily accommodate chilled beams

DOAS Cooling Capacity:
\[ Q_{SA} = 1.08 \times 6500 \text{ cfm} \times (72^\circ\text{F} - 62^\circ\text{F}) \]
\[ Q_{SA} = 70,200 \text{ Btu/hr} \]

Parallel System Cooling Capacity
\[ Q_{\text{PARALLEL}} = Q_{\text{SENSIBLE}} - Q_{SA} \]
\[ Q_{\text{SENSIBLE}} = 643,000 \text{ Btu/hr} \]
\[ Q_{\text{PARALLEL}} = 643,000 - 70,200 \text{ Btu/hr} = 572,800 \text{ Btuh} \]
\[ 572,800 \text{ Btuh} \times 1\text{W/3.4112 Btuh} = 167,878\text{W} \]

Total Beam Length: \( 167,878 \text{ W} / 510 \text{ W/m} = 329.2 \text{ m} \)

\# of Beams \[ = \text{Total Length} / \text{Spec Beam Length} \]
\[ = 329.2 \text{ m} / 1.21 \text{ m} \]
\[ = 272 \text{ Chilled Beams required} \]
Laboratory System

• Drastic reduction in supply air as compared to 100% outdoor air system

<table>
<thead>
<tr>
<th>System</th>
<th>Existing SA (cfm)</th>
<th>Redesign SA (cfm)</th>
<th>Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHU-1,2</td>
<td>58,000</td>
<td>9,400</td>
<td>83.8%</td>
</tr>
</tbody>
</table>

Contamination Issues?

• Wheel Purge section
• 3Å Molecular Sieve Desiccant provides “selective absorption”

• Johns Hopkins Ross Research Laboratory Case Study
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Office System

DOAS with Parallel VAV

- Convert Existing DX Systems to DOAS with Parallel VAV?

Required Supply air by Parallel VAV System based on Load

\[
\text{CFM}_s = \frac{Q_s}{1.08 \times (T_{RA} - T_{SA})} = \frac{690,530 \text{ btu/hr}}{1.08 \times (72^\circ F - 55^\circ F)} = 37,528 \text{ cfm}
\]

Reduction of Parallel Systems

- 12% reduction in supply air with DOAS/Parallel VAV compared to DX Rooftop Units

<table>
<thead>
<tr>
<th>System</th>
<th>Existing SA (cfm)</th>
<th>Redesign SA (cfm)</th>
<th>Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTU-1</td>
<td>14,175</td>
<td>12,500</td>
<td>11.8%</td>
</tr>
<tr>
<td>RTU-2</td>
<td>28,300</td>
<td>25,000</td>
<td>11.7%</td>
</tr>
<tr>
<td>Total</td>
<td>42,475</td>
<td>37,528</td>
<td>11.6%</td>
</tr>
</tbody>
</table>
Annual Energy Reduction

- Trane TRACE-700 Energy Analysis

<table>
<thead>
<tr>
<th></th>
<th>Original Design</th>
<th>Proposed Design</th>
<th>Savings</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost ($/yr)</td>
<td>75,166</td>
<td>55,069</td>
<td>20,097</td>
<td>26.74%</td>
</tr>
<tr>
<td>Consumption (kWh/yr)</td>
<td>2,116,058</td>
<td>1,581,585</td>
<td>534,473</td>
<td>25.26%</td>
</tr>
</tbody>
</table>

- Dedicated Outdoor Air Systems Reduce Load by approximately 25%.

- Reduced Life Cycle Cost of approximately 16% over 20 years with 5% inflation.
Emissions Reduction

- New York State Requires that 25% of generated power come from renewable sources by 2013.

<table>
<thead>
<tr>
<th></th>
<th>kWh</th>
<th>lbm Particulates</th>
<th>lbm SO₂</th>
<th>lbm NOₓ</th>
<th>lbm CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>2,107,705</td>
<td>13,658</td>
<td>104,818</td>
<td>188,640</td>
<td>86,368,271</td>
</tr>
<tr>
<td>Redesign</td>
<td>1,859,199</td>
<td>12,048</td>
<td>92,460</td>
<td>166,399</td>
<td>76,185,141</td>
</tr>
<tr>
<td>% Reduction</td>
<td>11.79%</td>
<td>11.79%</td>
<td>11.79%</td>
<td>11.79%</td>
<td>11.79%</td>
</tr>
</tbody>
</table>

- Proposed redesign reduces emissions by approximately 12%.
First Cost Reduction

- R.S. Means Analysis
- The proposed system provided a reduced cost of $248,173 as compared to the existing system

<table>
<thead>
<tr>
<th></th>
<th>Existing System</th>
<th>Proposed DOAS Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller [tons]</td>
<td>300</td>
<td>150</td>
</tr>
<tr>
<td>Boilers [mbh]</td>
<td>10,200</td>
<td>5100</td>
</tr>
<tr>
<td>AHU's</td>
<td>$154,500</td>
<td>$72,025</td>
</tr>
<tr>
<td>Chiller</td>
<td>$163,500</td>
<td>$97,500</td>
</tr>
<tr>
<td>Pumps (Primary)</td>
<td>$10,850</td>
<td>$5,150</td>
</tr>
<tr>
<td>Boilers</td>
<td>$21,000</td>
<td>$10,500</td>
</tr>
<tr>
<td>Pumps (Boiler)</td>
<td>$30,900</td>
<td>$15,450</td>
</tr>
<tr>
<td>Parallel Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VAV</td>
<td>$137,770</td>
<td>$98,070</td>
</tr>
<tr>
<td>Chilled Beams</td>
<td></td>
<td>$187,000</td>
</tr>
<tr>
<td>Pumps (Parallel)</td>
<td></td>
<td>$6,150</td>
</tr>
<tr>
<td>Piping (Parallel)</td>
<td></td>
<td>$7,500</td>
</tr>
<tr>
<td>Ductwork</td>
<td>$304,000</td>
<td>$76,000</td>
</tr>
<tr>
<td>Totals:</td>
<td>$822,520</td>
<td>$574,345</td>
</tr>
</tbody>
</table>

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Wind Energy Feasibility

- 70% of total funding eligible to be subsidized by NYSERDA

- Area known for high winds, could be justifiable with state funding

- Wind Map
Wind Energy Feasibility

- PROVEN 6kW Turbine Output

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Proven Energy, Ltd.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Output @ 12.5 m/s</td>
<td>6 kW</td>
</tr>
<tr>
<td>Rated Output @ 5.5 m/s (Buffalo, NY)</td>
<td>1 kW</td>
</tr>
<tr>
<td>Rotor Diameter</td>
<td>5.5 m</td>
</tr>
<tr>
<td>Total Weight</td>
<td>860 kg</td>
</tr>
</tbody>
</table>
Wind Energy Feasibility

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proven 6kW Wind Turbine w/Grid Connect</td>
<td>$18,160</td>
</tr>
<tr>
<td>Isolation and Rectification Controller</td>
<td>$1,090</td>
</tr>
<tr>
<td>Tilt-up self-supporting mast (9m)</td>
<td>$6,860</td>
</tr>
<tr>
<td><strong>Total Cost per Turbine</strong></td>
<td><strong>$26,110</strong></td>
</tr>
<tr>
<td><strong>Total Installed Cost</strong></td>
<td><strong>$52,220</strong></td>
</tr>
<tr>
<td><strong>Total Cost with 70% NYSERDA discount</strong></td>
<td><strong>$15,666</strong></td>
</tr>
</tbody>
</table>

Payback Period (years) = \( \frac{\text{Initial Cost}}{\text{Annual Savings}} \)

Assume Annual Savings at Peak Electric Rate:
Annual Savings = 12,000 kWh * $0.0095/kWh = $1,140

Payback Period = \( \frac{$15,700}{\$1,140} \) = **14 years = POSSIBLE**
Lighting Concerns

Proposed Scope

• Evaluate typical office lighting
• Retrofit Fixtures without Negative Impact
• 50 Private offices plus general office space

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Watts</th>
<th>Length</th>
<th>Lumens (25°C)</th>
<th>2 lamp fixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>39W T5</td>
<td>45.2&quot;</td>
<td>3100</td>
<td>78W</td>
</tr>
<tr>
<td>Retrofit</td>
<td>28W 75</td>
<td>45.2&quot;</td>
<td>2900</td>
<td>58W</td>
</tr>
</tbody>
</table>

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Lighting Concerns

- Redesign implemented while preserving integrity of original design
- Higher initial bulb cost
- Reduction in Cooling Load by 2.95 tons
- Reduction in overall LPD from 1.48 W/ft² to 1.33 W/ft²

- Cost Reduction
  - Phillips F28W/T5/830 - $8.50

- Savings $1.49 x 200 bulbs = $298 initial savings
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Conclusions and Thoughts

Summary
• Dedicated Outdoor Air Systems to replace DX and 100% OA VAV Units
• **Reduced Electrical Load** by 26% annually
• **Reduced annual utility Costs** by approx $20,000/yr
• **Reduced Initial cost** of mechanical system by $248,173
• **Wind Power** possible, with funding
• **Reduced Lighting Power Density** with reduced-watt bulbs saves energy and first costs

Recommendations
• Redesign considerations a viable alternative to existing design

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Acknowledgements

• Eric Lindstrom and the rest of the Cannon Design Team

• Walt Pangborn at the Hauptman-Woodward Institute

• All of the AE Faculty, especially Dr. Freihaut

• Friends and Family

• Finally, the AE class of 2007 ... we did it!!

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Questions?