PENN PLACE:
LUZERNE COUNTY COURTHOUSE ANNEX

Wilkes-Barre, PA

"Introducing Contaminant Sensors in a Government Building to Control Air System Safety for Occupants while Minimizing Operating Cost & Energy Use"

A Mechanical Option Thesis Presentation

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OUTLINE

1. General Building Information
2. Mechanical System Description
3. Mechanical System Troubleshooting
4. Goals & Approach for Mechanical Improvements
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7. Possibilities for Future Work
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GENERAL BUILDING INFORMATION

Penn Place renovation took place between August 2000 and August 2002.

The Primary Project Team:

Architect	Quad Three Group, Inc.	**Wilkes-Barre, PA**
Engineers	Quad Three Group, Inc.	**Wilkes-Barre, PA**
	Luzerne County Engineering Dept.	**Wilkes-Barre, PA**
Construction Manager	Apollo Group, Const. Mgmt. Division	**Wilkes-Barre, PA**

GENERAL BUILDING INFORMATION

Site

- located in the middle of a small city on a corner lot
- footprint of the building extends to the ends of the lot
- parking along the other sides and underneath half of the building
- The building is 3 stories, all above-grade
- 88,000 sq.ft. office space with 22,000 sq.ft. under-parking

Use

- courthouse annex, home to County Government Offices and Courts

GENERAL BUILDING INFORMATION

Actual Cost Information

Property Acquisition	$ 2,455,000.00
Professional Fees	$ 726,334.59
Construction Contracts	$ 4,526,085.87
Additional Contracts	$ 449,889.94
Furniture	$ 531,997.06
Total Project	***$ 8,689,307.46***
Cost per Square Foot	$ 98.74

Project Delivery Method: Design-Bid-Build w/Separate Primes
Luzerne County Engineering Department acting as Owner

GENERAL BUILDING INFORMATION

Architecture

- International Style: concise form, attention paid only to functional details
- simple brick façade is divided by rows of ribbon windows
- appropriate authoritative appearance
- two larger sections of building wrap around a central courtyard
- steel and concrete structure allows for large open courtroom spaces inside

Building Envelope

- typical brick veneered cavity wall system
- double-glazed, in an aluminum sill system.
- main entrance is a set of double aluminum doors **with 1" insulated tempered glass**

Major National Model Codes

BOCA Building Code 1996 Edition

Zoning and Historical

- Commercial. Re-zoning was not necessary for renovation.
- renovation: converted from a multi-tenant building to owner-occupied County building

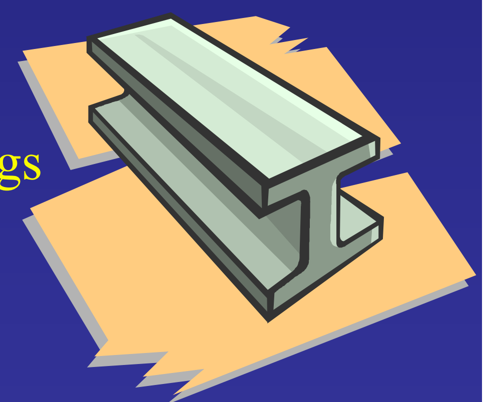
GENERAL BUILDING INFORMATION

Systems

Lighting and Electrical

- Recessed fluorescent luminaires, 32W-T8 lamps
- main electrical distribution is 3000A, 408Y/277V, three-phase, four wire
- 2 transformers are 150kVA and 300kVA, 480V to 208Y/120V

Structural



- load-bearing concrete foundation, columns on spread footings
- concrete slab on metal decking
- steel-framed cavity wall envelope
- roof is a flat, concrete slab on metal decking

GENERAL BUILDING INFORMATION

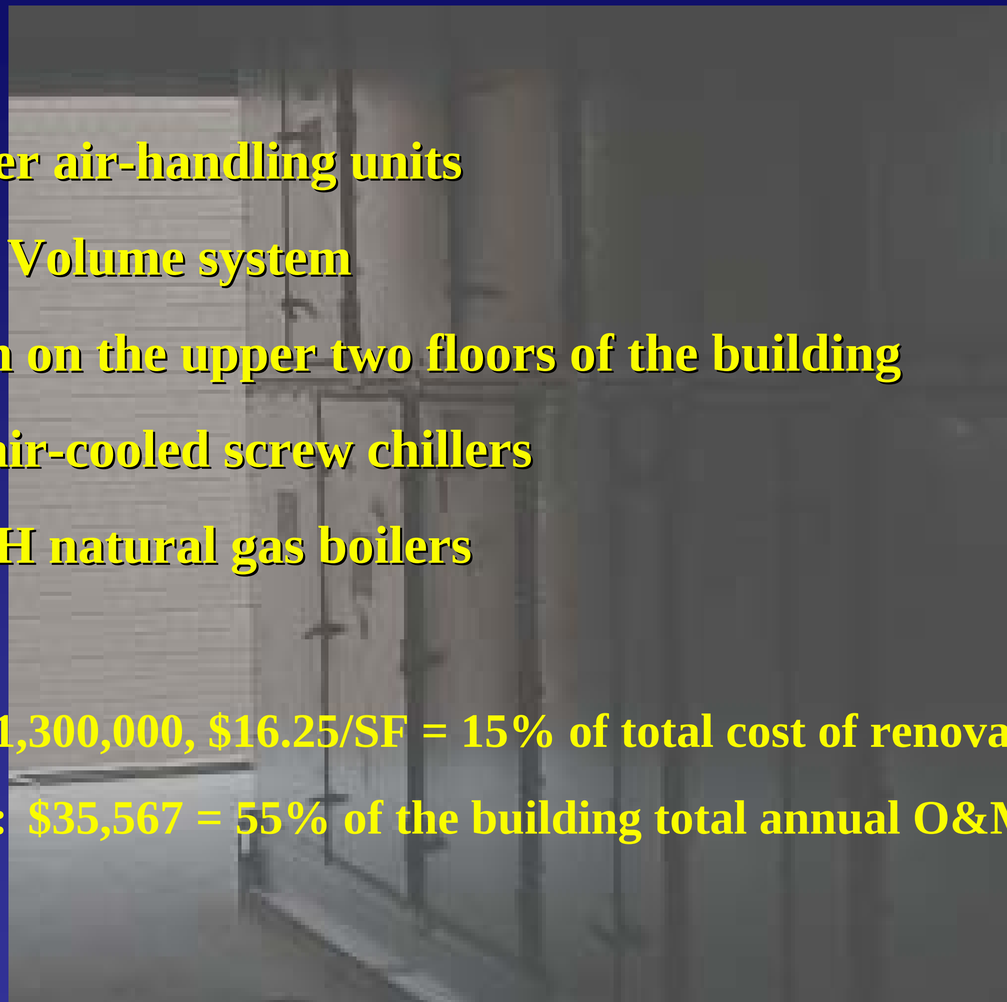
Plumbing

- ❑10GPM pump to lavatories
- ❑ 90gal. gas-fired water heater, 199,000Btu/hr
- ❑ 2 1550rpm, 20GPM sump pumps.

Fire Protection

- ❑ wet-pipe sprinkler system
- ❑ two 2,000 s.f. storage areas protected

MECHANICAL SYSTEM



EQUIPMENT

- 5 chilled water air-handling units
- Variable Air Volume system
- 42 zones each on the upper two floors of the building
- two 182 ton air-cooled screw chillers
- two 2448MBH natural gas boilers

FIRST COST: $1,300,000, $16.25/SF = 15% of total cost of renovation

ANNUAL COST: $35,567 = 55% of the building total annual O&M cost

MECHANICAL SYSTEM TROUBLESHOOTING

Standard 62, Minimum Outdoor Air Rate Compliance

	Results based on Std. 62n Table 6.3					
SYSTEM		**System Ventilation Efficiency based on Max. Critical Value, Z_P**	**Percent Outdoor Air Intake**	**Required Outside Air CFM**	**AHU Capacity for supplying OA**	**Meets Requirement**
AHU-1		0.5	17	3047	12600	Yes!!
AHU-2		0.5	26	3405	12600	Yes!!
AHU-3		0.6	20	3602	12600	Yes!!
AHU-4		0.5	27	4457	12800	Yes!!
AHU-5		0.7	18	537	2400	Yes!!
ENTIRE		0.56	21.6	15048	53000	Yes!!
BUILDING*						

MECHANICAL SYSTEM TROUBELSHOOTING

The Potential Problem: OVER-VENTILATION??

- due to lower than designed occupancy levels
- equipment may adjusted to operate at capacity during the day

Result:

Flow Rates too high = Wasted Energy and $$$

Q: Can ventilation rates be adjusted according to what is actually needed (demand) to save energy and $$?

Goals & Approach for Mechanical Improvements

"Introducing Contaminant Sensors in a Government Building to Control Air System Safety for Occupants while Minimizing Operating Cost & Energy Use"

Goals & Approach for Mechanical Improvements

Goals:

1. Monitor CO_2 levels, and determine occupancy levels from readings

2. Use CO_2 information as initial indication of how to regulate outdoor air intake to zones

3. Less ventilation needed = less money and energy spent

Goals & Approach for Mechanical Improvements

APPROACH:

- ❑ **CO2 Compliance**
- ❑ **Adjusting Flow Rates: Mass Balance**
- ❑ **Fulfilling Standard 62 Ventilation Requirements**
- ❑ **Energy Utilization and Cost Analysis**

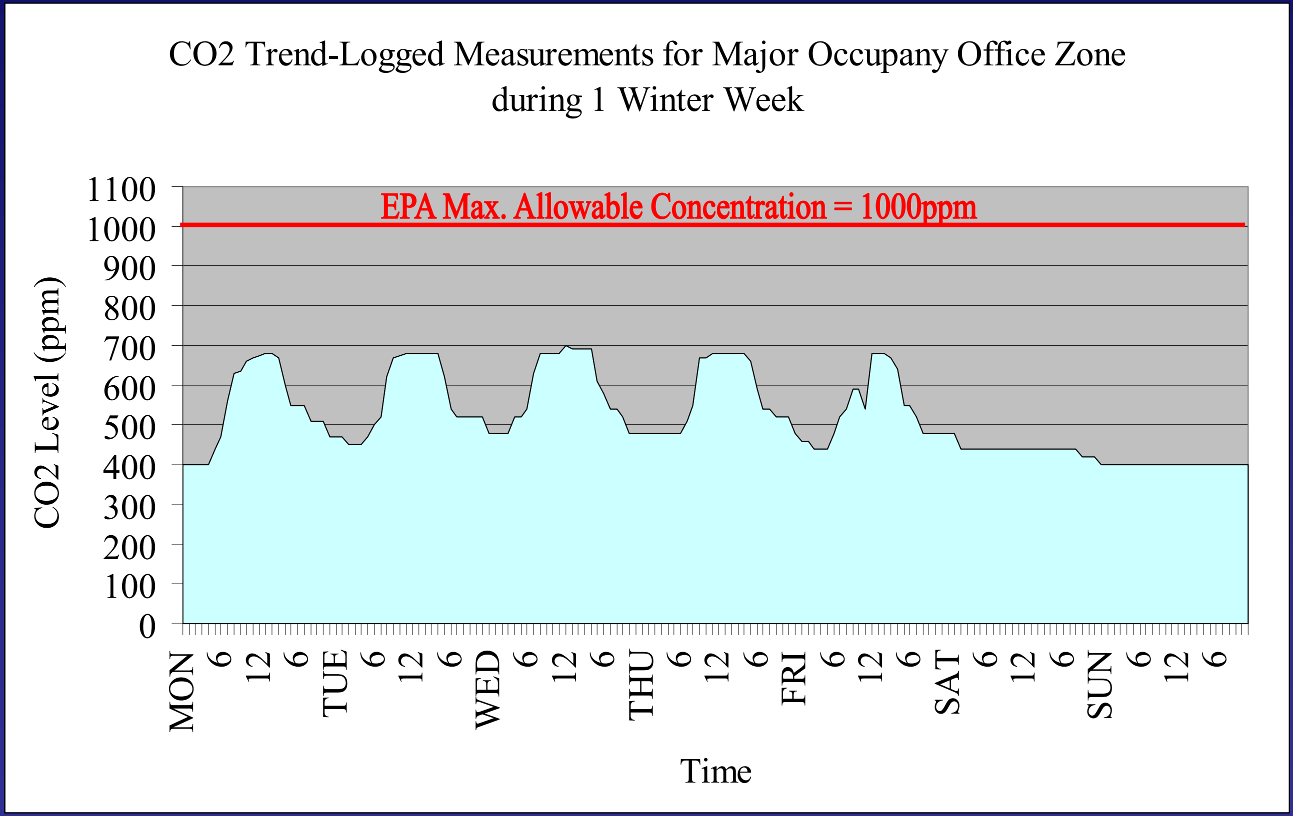
Goals & Approach for Mechanical Improvements

CO2 Compliance

Readings taken over 1 week, 15 minute increments

Major Occupied Zone Monitored

Concentration much less than EPA requirement



Goals & Approach for Mechanical Improvements

Adjusting Flow Rates: Mass Balance

Let's Start with the SIMPLEST CASE

Necessary Assumptions:

1. **Steady-State**
2. **Outdoor Air concentration constant, 400ppm**
3. **No sampling error**
4. **Human respiration, activity level same for all occupants**

Goals & Approach for Mechanical Improvements

Adjusting Flow Rates: Mass Balance

From ASHRAE Standard 62-2001,

$$Vo = N / (Cs - Co)$$

Where, Vo = Outdoor air flow rate per person
N = CO_2 generation rate per person
Cs = CO_2 concentration in the space
Co = CO_2 concentration in outdoor air

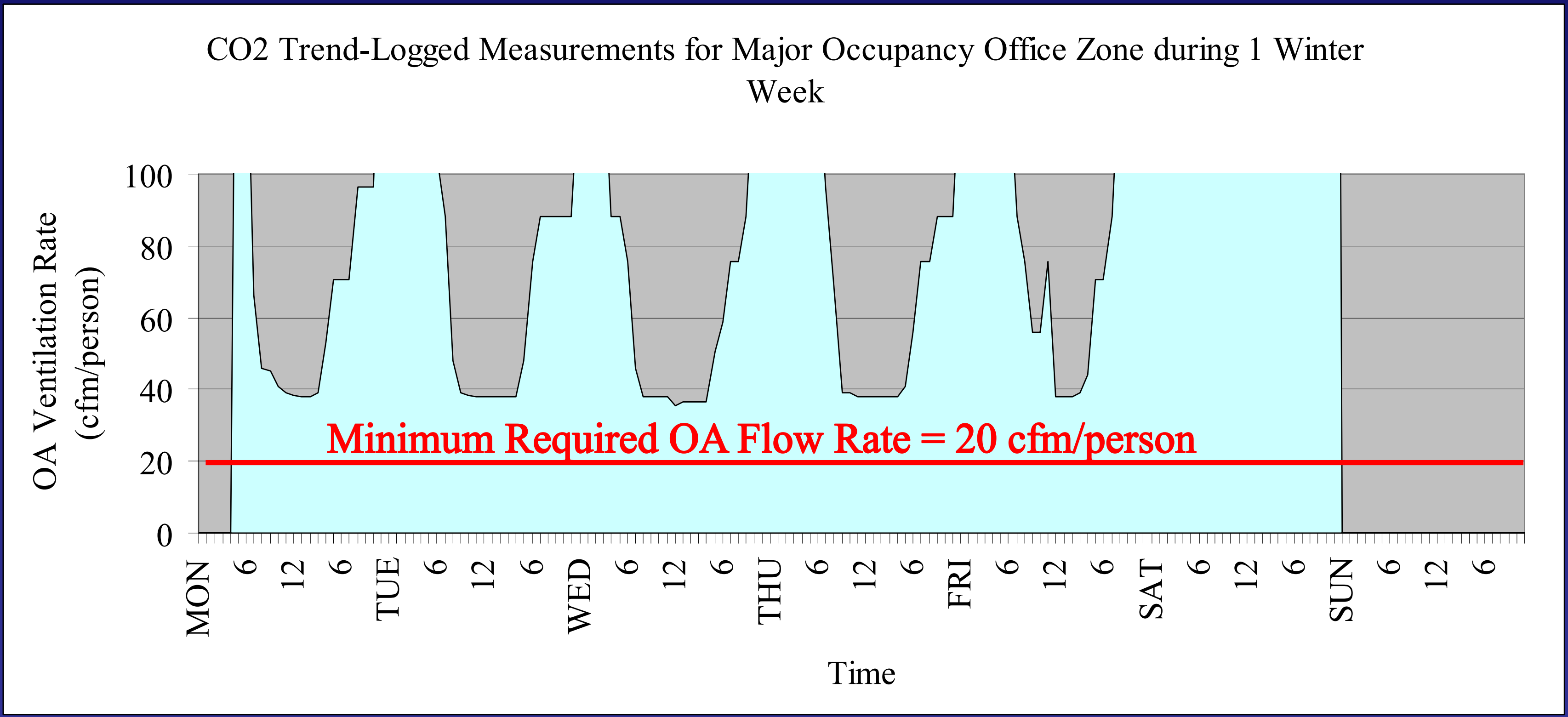
Converting to units of CFM and concentrations in ppm, and assuming an outdoor air CO_2 concentration of 400ppm, the equation is

$$Vo = 10{,}600 / (Cs - 400)$$

This equation was used to calculate actual outdoor airflow rates in the zone based on measured carbon dioxide levels.

Goals & Approach for Mechanical Improvements

Adjusting Flow Rates: Mass Balance



Goals & Approach for Mechanical Improvements

Adjusting Flow Rates: Mass Balance

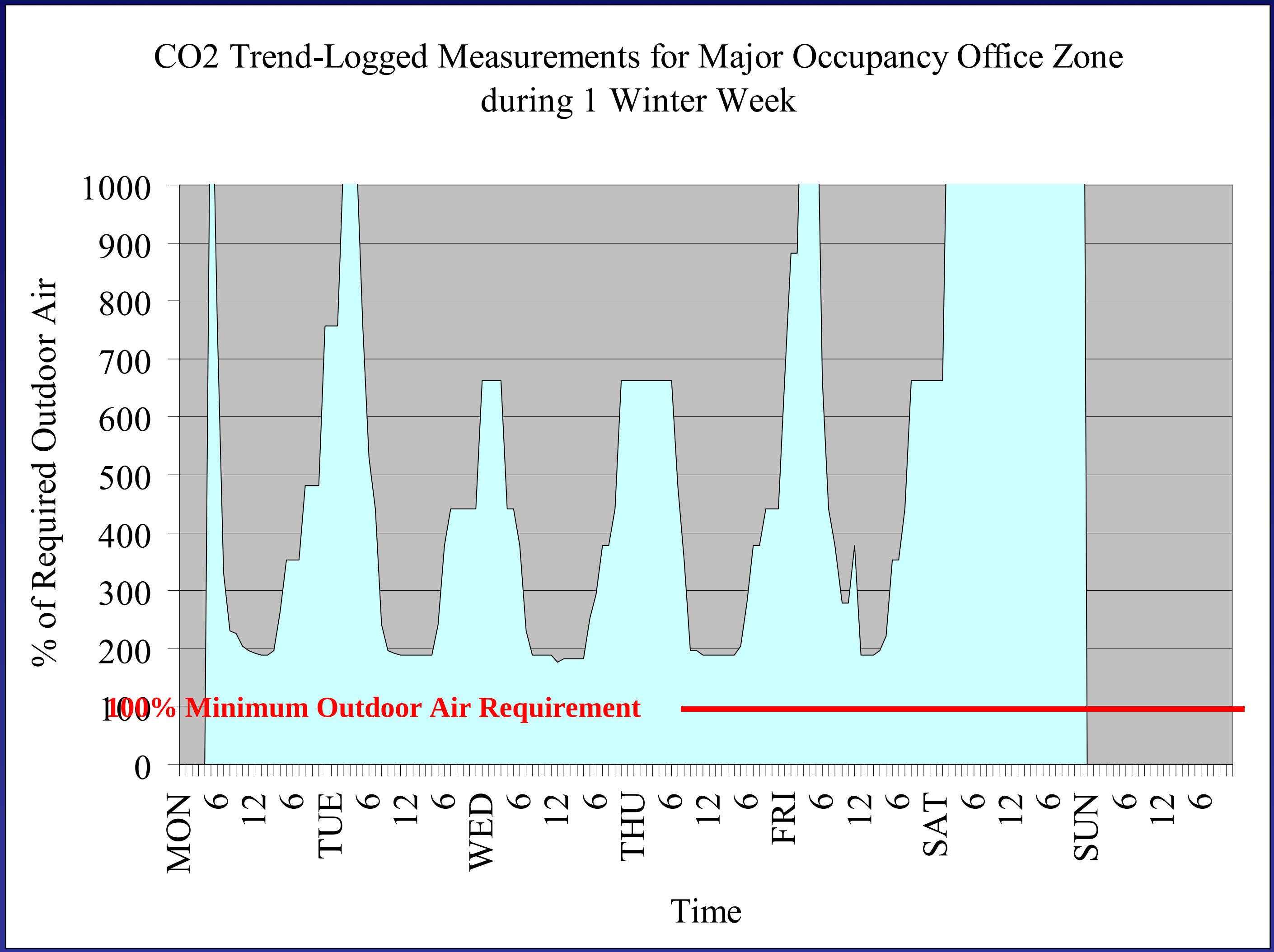
Findings:

Peak levels ~ 680ppm = 38CFM/person
(almost twice the required minimum outdoor air flow rate)

Off-peak hours (2/3 of each work day, weekends, and holidays)
Required Fresh Air = 1.9 and 13.2 times the amount of fresh air required to meet acceptable ventilation guidelines.

Although many assumptions are made using the steady-state equations, these values are justification enough to demonstrate a need for a solution to regulate flow rates more properly for the sake of energy savings.

Goals & Approach for Mechanical Improvements



Goals & Approach for Mechanical Improvements

POINT:

There is a point beyond which the level of safety is fulfilled where there are conditions where the over-design is detrimental concerning energy and resources.

COUNTERPOINT:

This analysis is based solely on representative CO_2 levels in the space. Outdoor air calculations are based on ideal, steady-state conditions, which are unlikely to exist.

RESOLUTION:

However, considering the extremely high levels of fresh air supplied to the spaces, even with a considerable margin of error, demand-control ventilation appears to be a good cure for optimizing air supply to spaces.

Redesign and Alternative Solutions

Redesign

1. Adjust demand loads based on energy simulation of multiple zones

CONTAM was used to determine loads can be adjusted to as much as 2/3 full load during most of peak period and still ssupply 26 CFM/person outdoor air

Hourly load adjustment based on

$$Q_{supply} = \rho C_p \Delta T (V)$$

Redesign and Alternative Solutions

Redesign

Original Demand Load: Full Load 6am-4:30 weekdays

Adjusted to an average of 2/3 capacity

System resized using Carrier's' Hourly Analysis Program (HAP)

Redesign and Alternative Solutions

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Redesign and Alternative Solutions

RESULTS

Energy Savings

	Existing System, without Demand Control	System with Demand Control CO2 Sensor Improvements	Annual Energy Savings
HVAC	200,355kWh	155,485kWh	9.50%

At an average cost of $0.11/kWh, Annual Energy Costs

	$22,039	$17,103	$4,936

Redesign and Alternative Solutions

RESULTS

Cost Analysis

6 CO2 Sensors	$1,500
Installation (union labor)	$13,500
Total First Cost	$15,000

Redesign and Alternative Solutions

RESULTS

Life Cycle Cost Analysis			
	Existing System, without Demand Control	System with Demand Control Improvements	Savings from Demand Control Upgrade
First Cost		$15,000	($15,000)
Future Cost			
Annual Cost of Operation	$64,852	$57,825	+$7,027
Net Savings			
Present Value of non-investment savings			$7,027
Increased Total Investment			$15,000
Savings-to-Investment Ratio			0.47
Simple Payback			2.2 years

Redesign and Alternative Solutions

RESULTS

- ✓ **County engineers would implement the sensors for demand-controlled ventilation**

if the building was not located in Luzerne County (O&M issues)

Redesign and Alternative Solutions

Implementation

Can easily be retrofitted in compliance with Trane digital controls system

CO_2 Wall Sensor for Demand Control Ventilation

Redesign and Alternative Solutions

Alternative Solution

Direct Electrical Airflow measurement

Considered “more direct” apprach by some professionals, but not based on occupancy demands, other than Standard 62 design rates

Redesign and Alternative Solutions

Continuing Project

"Investigation of New Sensoring Technology and Guidelines for Preparing Existing Variable-Air-Volume (VAV) Systems for Response to Contaminant Dispersion in Moderate-Risk Office Buildings"

ASHRAE Graduate Grant-in-Aid

Breadth Study: Building Security

Design Goal:

Coordinating Systems Security Design:

Guidelines for Designers and Owners in first, planning stages of Project

an "AE" approach to Building Security planning

Breadth Study: Building Security

Problem:

1. Standards not all in one place, hard to find
2. Courthouse buildings more volatile environments than expected
3. No compilation of security technology
4. Cost-Benefit?

Breadth Study: Building Security

Approach:

1. Gather standards
2. 2. Compile security goals that everyone agrees upon
3. Develop model for courthouses/moderate-risk security buildings based on technologies and techniques in practice

Breadth Study: Building Security

Standards

Standards & Guidelines for Building Security

AISC Design Guide on Mitigation of Blast and Progressive Collapse

ASCE

Update to Structural Design for Physical Security

New Standard for Blast-Resistant Design and Construction

ASTM E 54 Homeland Security; Standards for threat assessment, mitigation, design

ASIS (Industry Best Practices)

CDC Pub 2002-139: Protecting Building Environments from CBR attacks

CPTED: Crime Prevention Through Environmental Design (Industry Best Practices)

DOD Unified Facilities Criteria

UFC 4-101-01 Minimum AT Standards for Buildings, Minimum AT Standoff
Distances for Buildings

UFC 4-021-01 Mass Notification Systems

UFC 4-022-01 Entry Control Facilities

Breadth Study: Building Security

Standards

FEMA 428: Primer to Design Safe School Projects in Case of Terrorist

FEMA 429: Insurance, Finance, and Regulation Primer for Risk Management in Buildings

FEMA 430: Primer for Incorporating Building Security Components in Architectural Design

FEMA 452: Risk Assessment: A How-To Guide to Mitigate Potential Terrorist Attacks Against Buildings

FEMA 453: Multi-hazard Shelter (Safe Havens) Design

FEMA 455: Rapid Visual Screening for Building Security

FEMA 459: Incremental Rehabilitation to Improvements Security in Buildings

GAO Critial Infrastructure Protection: Significant Homeland Security Challenges Need to be Addressed

GSA Interagency Security Committee

GSA PBS-100

ISC (Interagency Security Committee) Security Design Criteria

LBNL Pub 51959

NIOSH Publication No.2002-139 Guidelines for Protecting Ventilation Systems in Commercial and Government Buildings from Chemical, Biological, and Radiological Attack

USAF Installation Guide

US Army TM 5-853

Breadth Study: Building Security

Goals

1. Save lives, reduce injuries
2. Protect assets
3. Facilitate safe evacuation, reduce & anticipate recovery
4. Anticipate and not preclude changing security requirements
5. Develop Comprehensive strategy for a balanced approach considering cost effectiveness while accepting some risk
6. Maintain balance between security and clients needs, zoning/codes, culture, community, location, etc.

Breadth Study: Building Security

Technologies based on Trade

Conclusions

Penn Place Mechanical System

A case of over-ventilation and fluctuation in occupancy and operations makes the **Penn Place building an excellent candidate for demand- controlled ventilation based on CO2 levels.**

Renovating the system with sensors and controls can save as much as 10% of energy per year, and about 12% of the current building overall operating cost. Payback would be about 2.2 years, making the solution one worth investigating.

Security

A basic security master plan for Penn Place includes guarded parking lot gated entrance, and smart card readers throughout the building. The most important security tactic for this building, because of its location and level of public use is making occupants aware of who should be in the building and who should not.