Margaret M. Alkek Building for Biomedical Research

Justin Mulhollan – Mechanical Option

Baylor College of Medicine
Houston, TX

Spring 2006
Senior Design Project

PRESENTATION OUTLINE

- Project Background
- Building Information
- Existing Mechanical Systems
- Redesign Considerations
- Mechanical Redesign
    - Air System Zoning
    - Energy Recovery System Study
        - Structural Breadth
        - Recommendation
    - Demand Controlled Ventilation
    - Recommendation
- Acknowledgements
- Questions

PROJECT BACKGROUND

- Baylor College of Medicine's "strategic plan" discusses the need for new research laboratory space to support various interdisciplinary research program initiatives.

- Goals of the strategic plan is to expand current faculty's research programs and to recruit other top researchers, as well as to invest in technology related to biomedical research.

- The Albert and Margaret Alkek Foundation donates $31.25 million dollars to fund biomedical research, the largest single donation in the college's history.

- Donation led to the newest research tower being constructed by called the Margaret M. Alkek Building for Biomedical Research.

- Building will support various research programs in cardiovascular sciences, diabetes and metabolic disease, cancer, etc, etc. As well as allow for mental health and neurosciences research to be expanded.

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BUILDING INFORMATION

- Groundbreaking occurred on September 15, 2005.
- Total Project Cost: $110 Million
- 8 Story - 175,000 ft^2
- Research Facility
- Project Team
  - Owner Rep – Flour Enterprises, Inc.
  - Architect – Lord, Aeck & Sargent, Inc.
  - CM – Vaughn Construction
  - MEP – Bard, Rao + Athanas Consulting Engineers
  - Structural – Walter P. Moore

- Building is being constructed on existing underground transgenic mouse facility
- Levels 1 & 2 consist of vivarium spaces (animal holding rooms, procedure rooms, cagewash, etc.)
- Level 3 houses a majority of the buildings' mechanical equipment
- Levels 4-8 are about a 35/65 split between office spaces and general research laboratories

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EXISTING MECHANICAL SYSTEMS

- Level 3 contains the air handling units that serve all the spaces on levels 1&2 and levels 4-8.

- Baylor College of Medicine required redundancy in critical systems such as air handling unts.

- (4) 25,000 CFM air handling units serve the vivarium on levels 1 and 2 with 100% outdoor air (System 1).

- (2) 50,000 CFM air handling units serve the laboratory spaces on levels 4-8 with 100% outdoor air (System 2).

- (2) 50,000 CFM air handling units serve the office side and a portion of the laboratory spaces on levels 4-8. These units are 75% outdoor air (System 3).

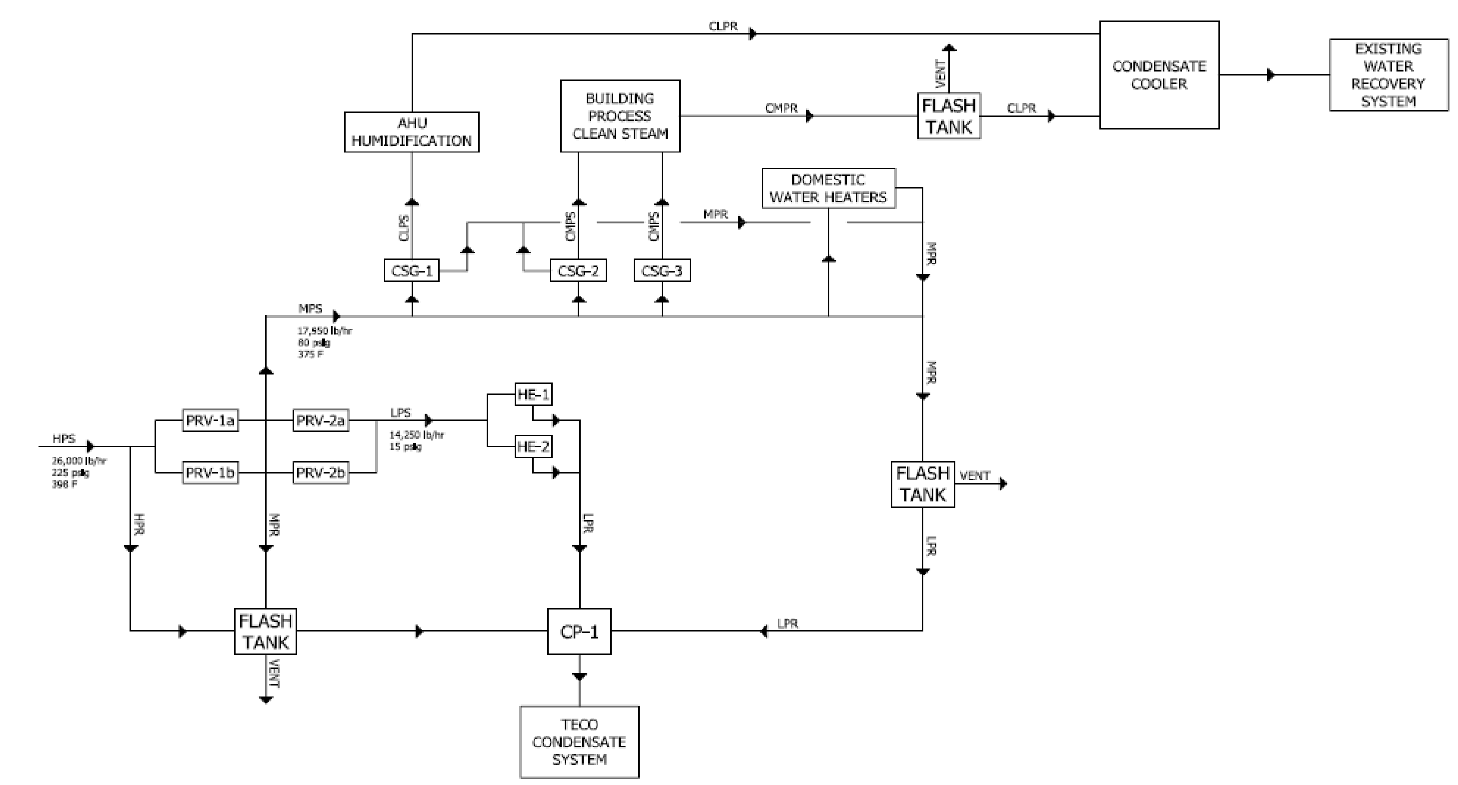
- Seperate exhaust systems within the building for laboratory spaces, vivarium spaces, biological safety cabinets, stainless steal wet exhaust for cagewash and toilet exhausts.

- Office side of levels 4-8 are the only spaces within the building that are returned.

EXISTING MECHANICAL SYSTEMS

❖ BCM's campus steam loop provides the building with heating hot water through 2 shell & tube heat exchangers. The campus loop also feeds 3 clean steam generators for humidification in the AHU's, domestic hot water and building process steam (i.e. for the cagewash).

BUILDING STEAM SYSTEM



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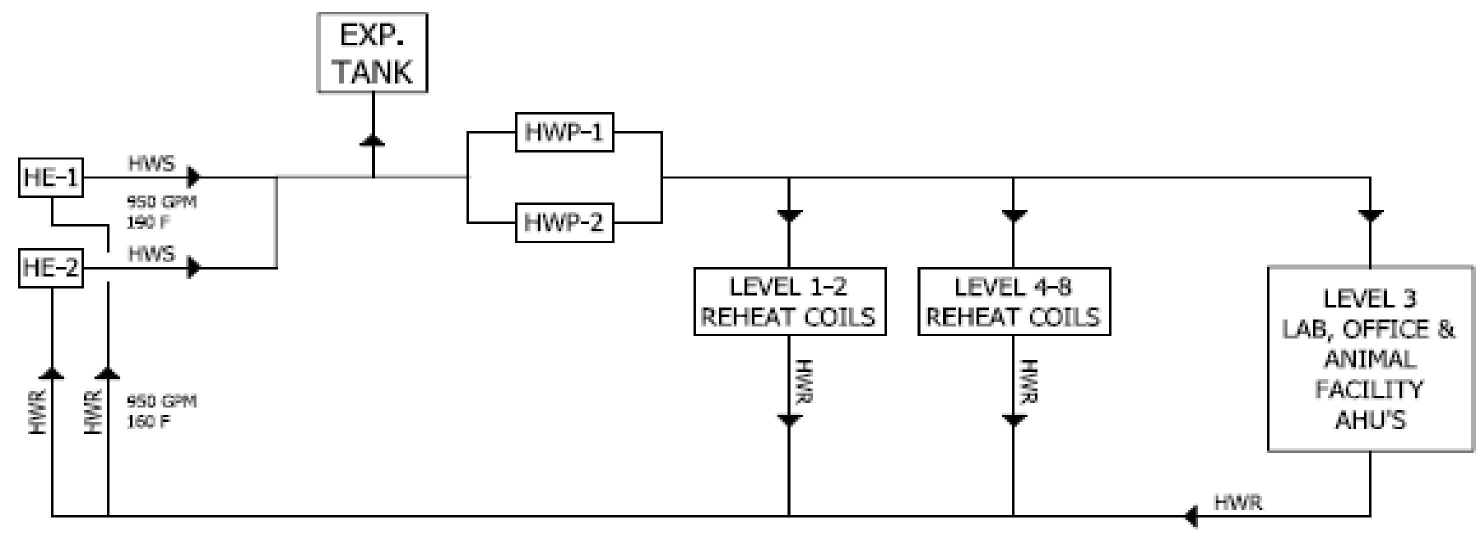
EXISTING MECHANICAL SYSTEMS

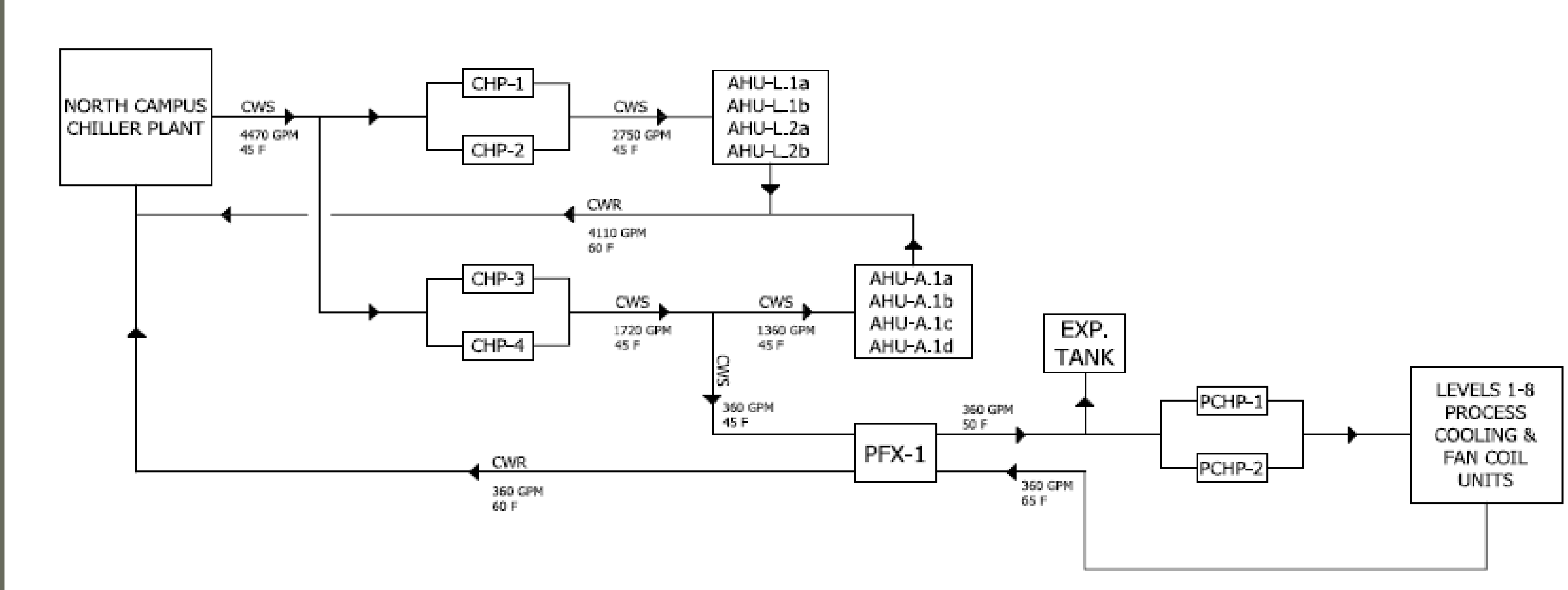
BUILDING HEATING HOT WATER SYSTEM



EXISTING MECHANICAL SYSTEMS

- BCM's campus chilled water loop provides the building with all the chilled water for the air handling units as well as some process cooling.

BUILDING CHILLED WATER SYSTEM



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REDESIGN CONSIDERATIONS

- Major issues with laboratory designs
  - Indoor Air Quality – Typical solution, use 100% outdoor air systems
  - Energy Consumption
  - Redundancy in Critical Systems
- Redesign Questions
  - Can active air quality monitoring in Vivarium/Laboratory spaces ensure indoor air quality while allowing for energy savings through recirculation?
  - What type of energy recovery system is most appropriate for laboratory/vivarium air systems?

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MECHANICAL REDESIGN

AIR SYSTEM REZONING

- Owner's Design Narrative
  - Laboratory Spaces and Support to receive 100% outdoor air at a rate of 6 air changes per hour
  - Office spaces to be designed for 20 CFM of outdoor air per person
- Original System Design
  - Laboratory and Office spaces on the same air system that supplies 75% outdoor air
  - Laboratory's not receiving desired 100% outdoor air system
  - Office spaces being over-ventilated
- Redesign
  - Put laboratory spaces onto System 2 so that labs will receive desired 100% outdoor air
  - Offices will not be over-ventilated
  - No redundancy or HEPA filtration needed in System 3 (simpler air handling unit can be used)

MECHANICAL REDESIGN

ENERGY RECOVERY SYSTEM STUDY

- Four Types of Energy Recovery Systems Common to Laboratories/Vivariums
  - Runaround Loop
  - Heat Pipe
  - Plate Exchanger
  - Total Energy Wheel

- Cross-Contamination a major concern in selecting an energy recovery system

- Location of exhaust and outdoor air ductwork is a factor in determining which system is appropriate (runaround loop can handle any length, where as total energy wheel they must be adjacent to each other)

- Heat Pipe, Plate Exchanger and Total Energy wheel require 3rd floor mechanical to be moved to 8th floor to allow for outdoor and exhaust air streams to be near each other (still not adjacent though).

- Need to check if switching the 3rd floor with the 8th floor is possible, structurally speaking.

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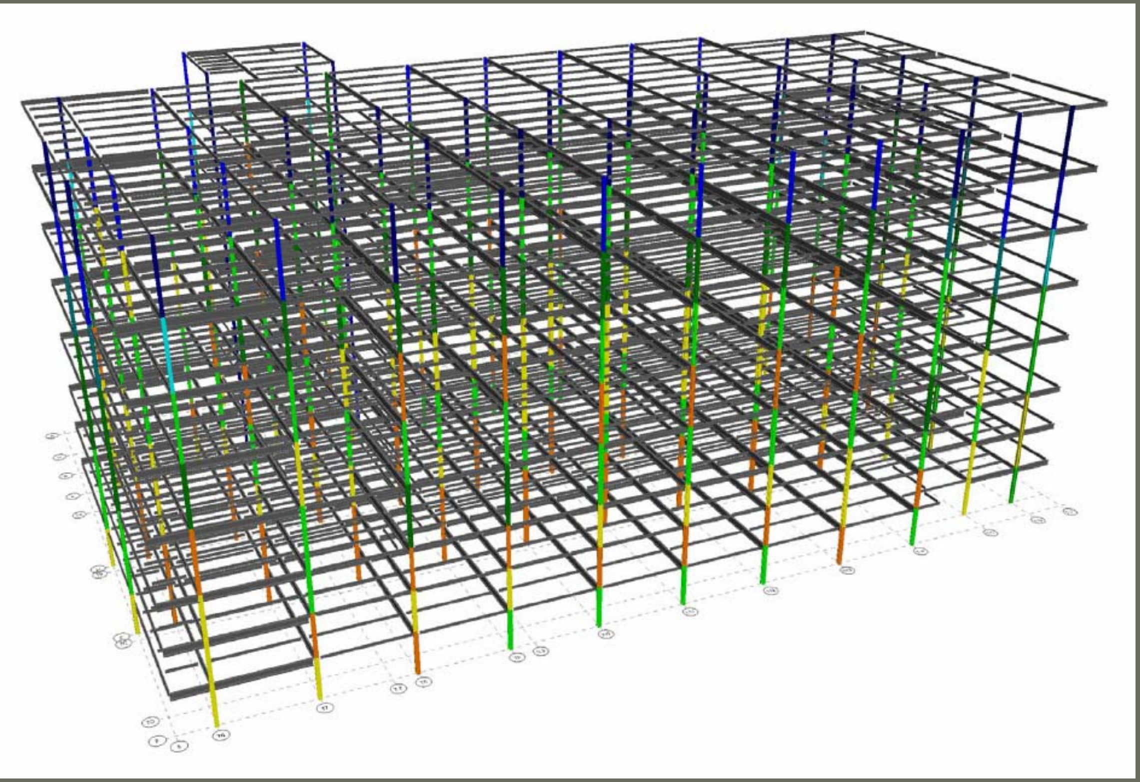
MECHANICAL REDESIGN

ENERGY RECOVERY SYSTEM STUDY

- The research tower was modeled using RAM to check if the current structural system could support switching the 3rd and 8th floor loads.



MECHANICAL REDESIGN

ENERGY RECOVERY SYSTEM STUDY

- Results from RAM showed that current structural system could support switching the 3rd floor with the 8th floor.

- Total Energy Wheel, Plate Exchanger and standard Heat Pipe require the air streams be adjacent to each other. However, Split-Case Heat Pipe could pump over a vertical of up to 50 feet.

- Total Energy Wheel and Plate Exchanger have possibility of cross-contamination without going through an elaborate set up process.

- Cost analysis was set up for Runaround Loop Vs. Split Case Heat-Pipe System (effectiveness of each device is approximately the same).

MECHANICAL REDESIGN

ENERGY RECOVERY SYSTEM STUDY

- It was found that the Split-Case Heat Pipe System was much more expensive than a runaround loop. Also there was extra costs involved with moving the 3rd floor to the 8th floor.

- Final recommendation is to leave the mechanical systems on the 3rd floor and install a runaround loop.

Split Case Heat Pipe Installation Costs

Item	Quantity	Total Cost
Duct Work	170 feet	$ 19,496
Chilled Water Piping	200 feet	$ 10,914
Process Chilled Water	190 feet	$ 3,032
Hot Water Piping	170 feet	$ 5,950
Steam Main Piping	85 feet	$ 7,225
Condensate Return	125 feet	$ 2,125
Laboratory Heat Pipe	1 system	$ 366,000
Vivarium Heat Pipe	1 system	$ 190,000
	Total:	$ 604,742

Runaround Loop Installation Costs

Item	Quantity	Total Cost
Laboratory Coils	6 coils	$ 18,738
Vivarium Coils	6 coils	$ 18,738
Piping (2.5")	190 feet	$ 4,465
Piping (3")	190 feet	$ 7,505
Pump (Vivarium)	1 pump	$ 3,893
Pump (Lab)	1 pump	$ 3,793
Glycol Ethylene	96 Gallons	$ 1,114
	Total:	$ 58,246

* Pricing for all piping per linear foot was taken from original estimate done for the research tower
**Split case heat pipe system estimated byRick Galie at Air Tectonics

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MECHANICAL REDESIGN

DEMAND CONTROLLED VENTILATION

- Original idea was to monitor indoor air quality in Vivarium and Laboratory system exhausts and return when air was at acceptable levels.
  - Vivarium would have to be monitored for mouse emissions and contaminants involved with procedures.
  - Laboratory would have to be monitored based on experiments going on in each room.

- Monitoring indoor air quality in Vivarium and Laboratory spaces would be a difficult task
  - Laboratory spaces would have different experiments going on in each space; multiple sensors for the same exhaust system.
  - Laboratory sensors would have to be changed because research and experiments typically only last 5-7 years; sensors would have to be changed and replaced for each research set up.
  - Vivarium is an extremely critical space; failure of a sensor could ruin an entire research set up.
  - 3^{rd} and higher generations of mice in an experiment can be worth up to $600+ a piece.

- Recommendation is to leave vivarium at the owner requested 15 air changes per hour. Laboratory space is much less critical but due to the change nature of the spaces air quality monitoring would not be appropriate.

MECHANICAL REDESIGN

DEMAND CONTROLLED VENTILATION

- The Concordia University Science Complex is a laboratory building in Montreal that utilizes a set back based off of occupancy sensors.

- The laboratories were designed for 10 ACH but when the sensors show the building is unoccupied during day time hours the air change rate drops to 6, similarly if the building is unoccupied at night hours the lab drops to 3 air changes.

- Occupancy sensors are installed in the laboratory spaces on levels 4-8 to control the lighting. A strategy similar to what was described above could be utilized.

- Laboratory is designed for 6 ACH (owner's request, less critical than Concordia University), occupancy sensors would set back to 3 ACH when unoccupied.

- Fume Hood rooms would be changed from constant volume to variable volume. Phoenix Medium Pressure Accel II Venturi Valves would be used as well as Phoenix sash monitors to monitor sash position and adjust valve position.

MECHANICAL REDESIGN

DEMAND CONTROLLED VENTILATION

- CO_2 based demand controlled ventilation is the most popular form of DCV.
- Ventilation Rates found from ASHRAE Standard 62.1 change based on concentration of CO_2.
- Why CO_2?
    - CO_2 generation is proportionate to odorous bioeffluents
    - ASHRAE Standard 62.1 attempts to control the levels of odorous bioeffluents
    - As CO_2 levels increase so does odorous bioeffluents, thus more ventilation air is needed
- Appropriate for spaces with variable occupancy such as office spaces on levels 4-8.
- Office spaces in the tower consist of private offices, open offices, 2 meeting rooms, a conference room and a break area for each floor.
- The meeting rooms, conference room and break area have high design occupancies but are typically not occupied most of the time. These areas would be appropriate areas to monitor CO_2 levels and adjust the Ventilation rate accordingly.
- Office air system will be set up for CO_2 based demand controlled ventilation.

MECHANICAL REDESIGN

DEMAND CONTROLLED VENTILATION

- A CO_2 sensor will also be duct mounted in the outdoor air intake for the Office side's air handling unit. This will give the ambient CO_2 concentration.

- The conference room, break area and 2 meeting rooms on each floor will have wall mounted sensors installed. The sensor in the rooms and the ductwork will be Air Test Technologies model #TR9290.

- Each room will send a CO2 signal back (in ppm) to the controller which will determine the Vou level for each space and then add to the minimum value and calculate Vot for the entire system.

MECHANICAL REDESIGN

DEMAND CONTROLLED VENTILATION

- First step is to do ASHRAE Standard 62.1's ventilation rate procedure with each zone to be sensored unoccupied to determine minimum amount of outdoor air required (V_{ot}).

Standard 62.1 - Office DCV AHU

Level		Room #'s	Box	CFM Max	CFM Min	Design Occupancy (ft^2/person)	Area (ft^2)	P_z Occup.	R_p (cfm/per)	R_a (cfm/ft^2)	V_{bz} (cfm)	E_z	V_{oz} (cfm)	Z_p
1	Lobby + Elevator Lobby	R100,R100B	S2	1350	675	250	1350	5	5	0.06	108	1	108	0.160
1	Corridor	R1C1	S40	1225	625	250	855	3	5	0.06	68	1	68	0.109
4-8	Meeting Room		S1	950	475	25	240	0	5	0.06	14	1	14	0.030
4-8	Office (3)	R402-R404	S2	675	350	100	385	4	5	0.06	42	1	42	0.121
4-8	Interaction space/Elevator Lobby	R400B,R400A	S3,S12	1250	625	250	1250	5	5	0.06	100	1	100	0.160
4-8	Office (4)		S4	1100	550	100	490	5	5	0.06	54	1	54	0.098
4-8	Conference Room	R408	S5	975	500	25	630	0	5	0.06	38	1	38	0.076
4-8	Corridor/Open Office	R4C7.R421,R 4C1	S6	675	350	150	555	4	5	0.06	52	1	52	0.148
4-8	Corridor/Open Office	R4C6	S7	725	375	100	700	7	5	0.06	77	1	77	0.205
4-8	Office (3)	R411-R413	S8	825	425	100	350	4	5	0.06	39	1	39	0.091
4-8	Meeting Room	R414	S9	950	475	25	240	0	5	0.06	14	1	14	0.030
4-8	Office (3)	R415-R417	S10	975	500	100	345	3	5	0.06	38	1	38	0.076
4-8	Men's Restroom/Women's Restroom	R418,R419	S11	325	325	N/A	320	0	0	0.06	19	1	19	0.059
4-8	Interaction space/Break Area	R422,R400C	S12	1100	550	100	1100	0	5	0.06	66	1	66	0.120

Max Z_p =	0.205
V_{ou} =	730
E_v =	0.9
Per Floor V_{ot} =	811
System $V_{ot,min}$ =	4054

MECHANICAL REDESIGN

DEMAND CONTROLLED VENTILATION

- Tables were set up to find equations for each space based on CO2 levels Vs. V_{ou} values as occupancy goes up

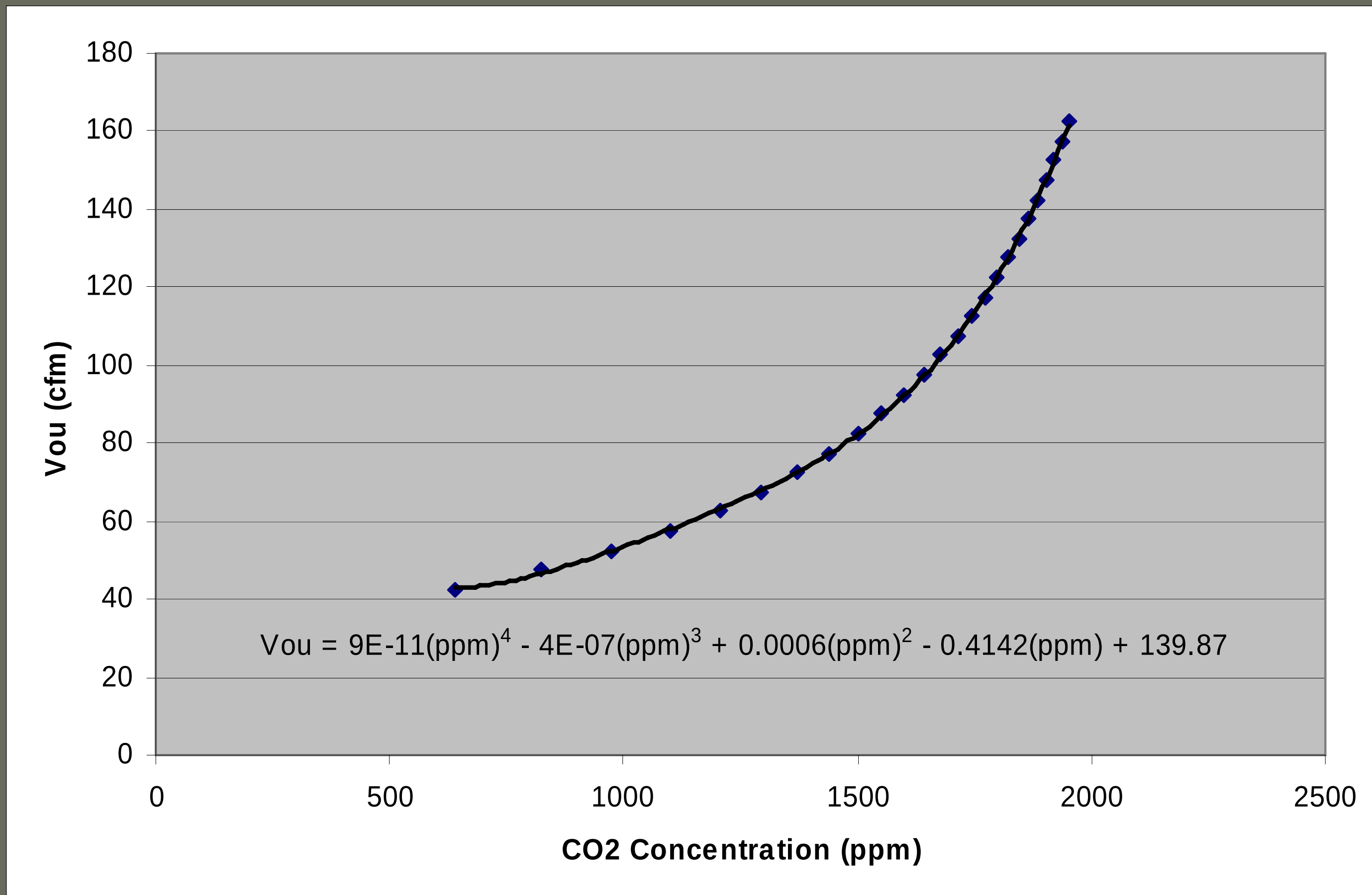
- The following equation from the Standard 62.1 user manual to determine the CO2 concentrations as a function of occupancy (where m is the metabolic rate, m=1.2 for office work).

$$C_{room} = C_{oa} + \frac{8400 \cdot E_z \cdot m}{R_p + \frac{R_a \cdot A_z}{P_z}}$$

- The conference room will be looked as a graphical example.

MECHANICAL REDESIGN

DEMAND CONTROLLED VENTILATION



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MECHANICAL REDESIGN

RECOMMENDATION

- Trane's TRACE 700 was used to put together an energy model for the research tower's base design and the redesign.
- The trace analysis for the research tower showed a 20.6% (2,205,025 kWh) reduction in annual source energy consumption.
- A cost analysis was then set up for the addition of new equipment to implement this design and to show what the payback period would be.

MECHANICAL REDESIGN

RECOMMENDATION

New/Changed Equipment Cost Information

New Equipment	Quantity	Units	Cost / Unit	Total Cost	Source
CO2 Sensor (Wall)	20	Ea.	$ 900.00	$ 18,000.00	Trane
CO2 Sensor (Duct)	1	Ea.	$ 800.00	$ 800.00	Trane
Lab AHU's	170,000	CFM	$ 5.50	$ 935,000.00	Original Estimate
Vivarium AHU's	90,000	CFM	$ 5.50	$ 495,000.00	Original Estimate
Office AHU's	55,000	CFM	$ 3.12	$ 171,600.00	RS Means
Relays	200	Ea.	$ 90.00	$ 18,000.00	RS Means
Return Fan (19.5K)	1	Ea.	$ 8,625.00	$ 8,625.00	RS Means
Runaround Loop System					
Laboratory Coils	6	Ea.	$ 3,123.00	$ 18,738.00	RS Means
Vivarium Coils	6	Ea.	$ 3,123.00	$ 18,738.00	RS Means
Piping (2.5")	190	LF	$ 23.50	$ 4,465.00	RS Means
Piping (3")	190	LF	$ 39.50	$ 7,505.00	RS Means
Pump (Vivarium)	1	Ea.	$ 3,893.00	$ 3,893.00	RS Means
Pump (Lab)	1	Ea.	$ 3,793.00	$ 3,793.00	RS Means
Glycol Ethylene	96	Gal	$ 11.60	$ 1,113.60	RS Means
			Runaround Loop Subtotal:	$ 58,245.60	
			Total:	$ 1,763,516.20	

Original Equipment Cost Information

Equipment	Quantity	Units	Cost/Unit	Total Cost	Source
Lab AHU's	100,000	CFM	$ 5.50	$ 550,000.00	Original Estimate
Vivarium AHU's	90,000	CFM	$ 5.50	$ 495,000.00	Original Estimate
Office AHU's	100,000	CFM	$ 5.50	$ 550,000.00	Original Estimate
Return Fan	2	Ea.	$ 7,500.00	$ 15,000.00	Original Estimate
			Total:	$ 1,610,000.00	

New Equipment Cost:	$ 1,763,516.20
Old Equipment Cost:	$ 1,610,000.00
Annual Energy Savings (kWh):	2,205,025
Energy Charge ($/kWh):	$ 0.0816
Payback Period (Years):	0.85

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- The trace analysis for the research tower showed a 20.6% (2,205,025 kWh) reduction in annual source energy consumption.
- A cost analysis was then set up for the addition of new equipment to implement this design and to show what the payback period would be.
- The calculation shows a payback period of approximately 1 year. This is very favorable and the redesign suggestions would be very beneficial to implement.

ACKNOWLEDGEMENTS

INDUSTRY

Kurt Shank – BR+A

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Ari Tinkoff – GRG

Brian Peasley – EwingCole

STUDENTS

Matthew Rooke

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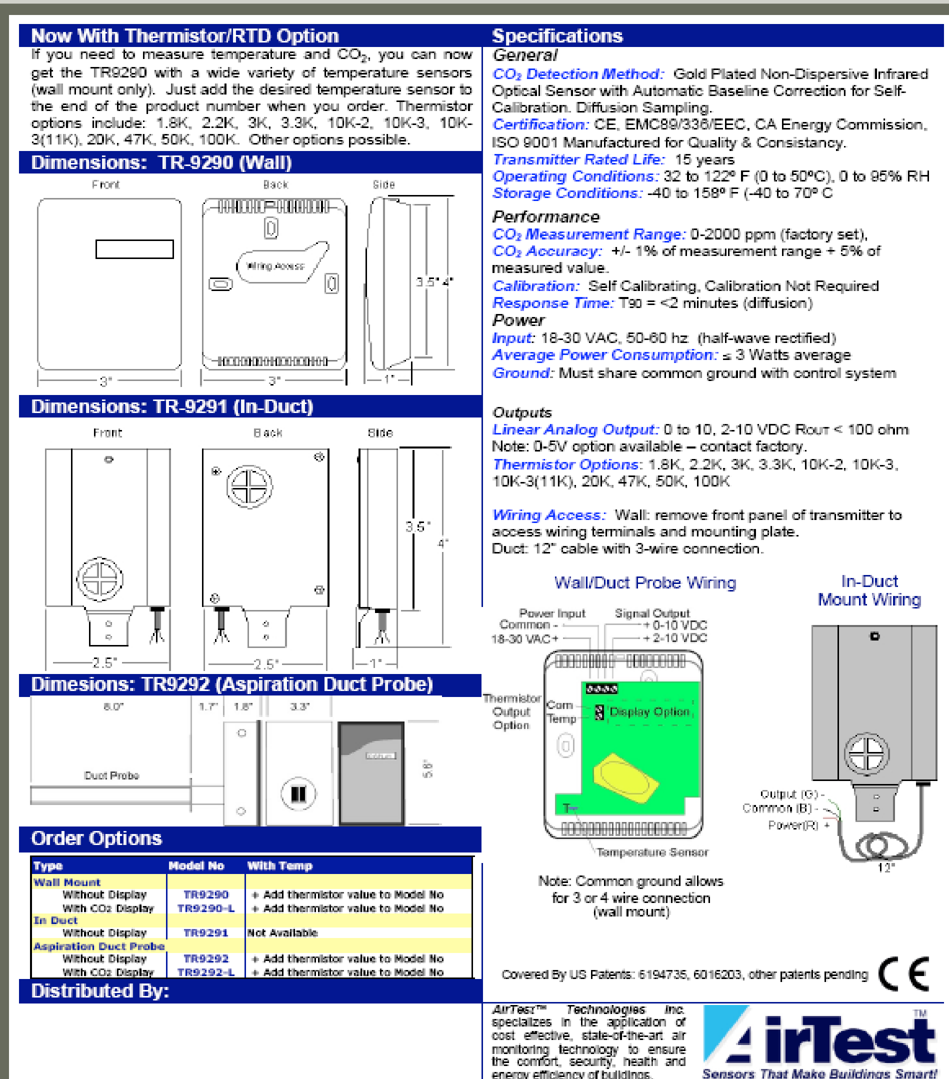
QUESTIONS

?

CO_2 SENSOR CUT SHEET



Now With Thermistor/RTD Option

If you need to measure temperature and CO_2, you can now get the TR9290 with a wide variety of temperature sensors (wall mount only). Just add the desired temperature sensor to the end of the product number when you order. Thermistor options include: 1.8K, 2.2K, 3K, 3.3K, 10K-2, 10K-3, 10K-3(11K), 20K, 47K, 50K, 100K. Other options possible.

Dimensions: TR-9290 (Wall)

Dimensions: TR-9291 (In-Duct)

Dimesions: TR9292 (Aspiration Duct Probe)

Order Options

Type	Model No	With Temp
Wall Mount		
Without Display	TR9290	+ Add thermistor value to Model No
With CO2 Display	TR9290-L	+ Add thermistor value to Model No
In Duct		
Without Display	TR9291	Not Available
Aspiration Duct Probe		
Without Display	TR9292	+ Add thermistor value to Model No
With CO2 Display	TR9292-L	+ Add thermistor value to Model No

Distributed By:

Specifications

General

CO_2 Detection Method: Gold Plated Non-Dispersive Infrared Optical Sensor with Automatic Baseline Correction for Self-Calibration. Diffusion Sampling.

Certification: CE, EMC89/336/EEC, CA Energy Commission, ISO 9001 Manufactured for Quality & Consistancy.

Transmitter Rated Life: 15 years

Operating Conditions: 32 to 122° F (0 to 50°C), 0 to 95% RH

Storage Conditions: -40 to 158° F (-40 to 70° C

Performance

CO_2 Measurement Range: 0-2000 ppm (factory set),

CO_2 Accuracy: +/- 1% of measurement range + 5% of measured value.

Calibration: Self Calibrating, Calibration Not Required

Response Time: T90 = <2 minutes (diffusion)

Power

Input: 18-30 VAC, 50-60 hz (half-wave rectified)

Average Power Consumption: ≤ 3 Watts average

Ground: Must share common ground with control system

Outputs

Linear Analog Output: 0 to 10, 2-10 VDC Rout < 100 ohm

Note: 0-5V option available – contact factory.

Thermistor Options: 1.8K, 2.2K, 3K, 3.3K, 10K-2, 10K-3, 10K-3(11K), 20K, 47K, 50K, 100K

Wiring Access: Wall: remove front panel of transmitter to access wiring terminals and mounting plate.

Duct: 12" cable with 3-wire connection.

Wall/Duct Probe Wiring

In-Duct Mount Wiring

Note: Common ground allows for 3 or 4 wire connection (wall mount)

Covered By US Patents: 6194735, 6016203, other patents pending

AirTest™ Technologies Inc. specializes in the application of cost effective, state-of-the-art air monitoring technology to ensure the comfort, security, health and energy efficiency of buildings.

AirTest™ Sensors That Make Buildings Smart!

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Senior Design Project – Spring 2006

MECHANICAL REDESIGN

DEMAND CONTROLLED VENTILATION

- Design Standard 62.1 Calculation

Standard 62.1 - Office DCV AHU

Level		Room #'s	Box	CFM Max	CFM Min	Design Occupancy (ft^2/person)	Area (ft^2)	P_z Occup.	R_p (cfm/per)	R_a (cfm/ft^2)	V_{bz} (cfm)	E_z	V_{oz} (cfm)	Z_p
1	Lobby + Elevator Lobby	R100,R100B	S2	1350	675	250	1350	5	5	0.06	108	1	108	0.160
1	Corridor	R1C1	S40	1225	625	250	855	3	5	0.06	68	1	68	0.109
4-8	Meeting Room		S1	950	475	25	240	10	5	0.06	62	1	62	0.131
4-8	Office (3)	R402-R404	S2	675	350	100	385	4	5	0.06	42	1	42	0.121
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4-8	Conference Room	R408	S5	975	500	25	630	25	5	0.06	164	1	164	0.328
4-8	Corridor/Open Office	R4C7.R421,R 4C1	S6	675	350	150	555	4	5	0.06	52	1	52	0.148
4-8	Corridor/Open Office	R4C6	S7	725	375	100	700	7	5	0.06	77	1	77	0.205
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4-8	Men's Restroom/Women's Restroom	R418,R419	S11	325	325	N/A	320	0	0	0.06	19	1	19	0.059
4-8	Interaction space/Break Area	R422,R400C	S12	1100	550	100	1100	11	5	0.06	121	1	121	0.220

Max Z_p =	0.328
V_{ou} =	1007
E_v =	0.8
Per Floor V_{ot} =	1258
System $V_{ot,design}$ =	6292