COURTNEY MILLETT

Mechanical Option Class of 2015

The Pennsylvania State University

April 14, 2015

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MORTON HOSPITAL EXPANSION

Taunton, MA

Advisor: Dr. Bahnfleth



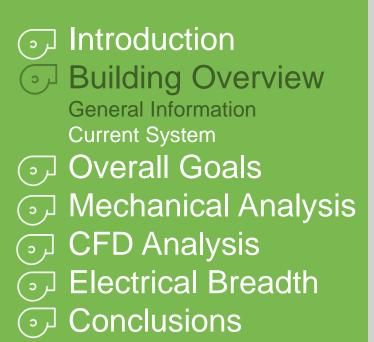
J Introduction Building Overview • Overall Goals Mechanical Analysis • CFD Analysis • Electrical Breadth • Conclusions

Image: Section 1.

MORTON HOSPITAL EXPANSION

• Building Overview • Overall Goals • Mechanical Analysis OFD Analysis • Electrical Breadth • Conclusions





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Owner:

Occupancy: Hospital

Location: Taunton, MA

MORTON HOSPITAL EXPANSION

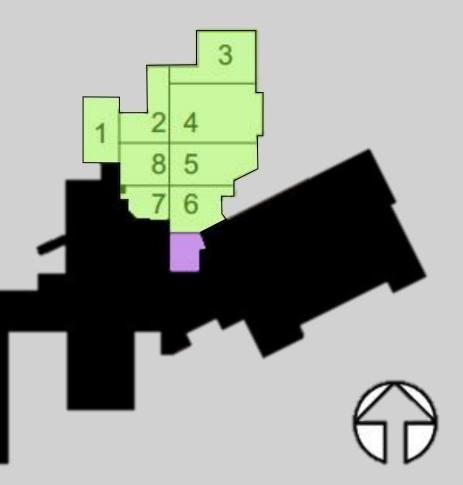
General Information:

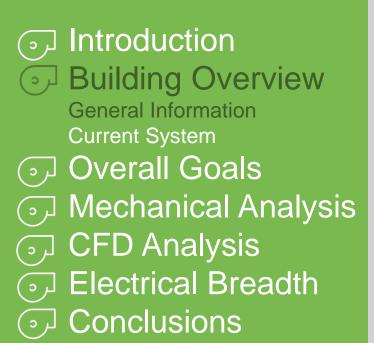
- **Steward Healthcare**

Existing Building Area: 100,000 SF

Expansion Area: 40,000 SF





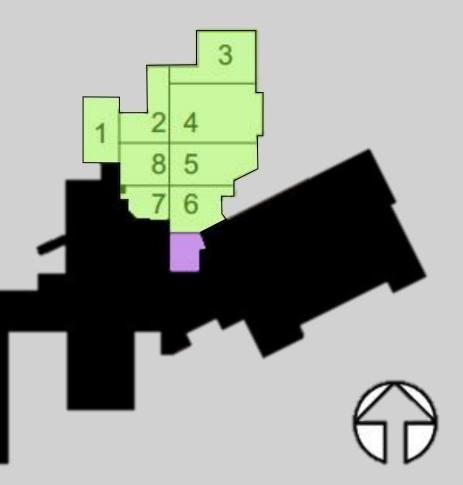


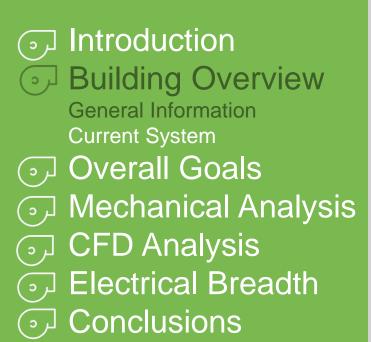
MORTON HOSPITAL EXPANSION



General Information:

- Phase 1:
 - MRI





General Information: Phase 1:



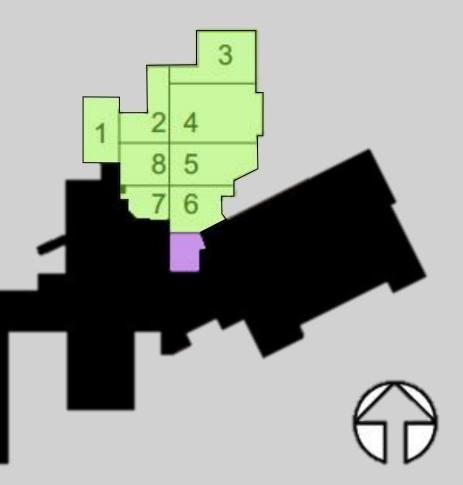
MORTON HOSPITAL EXPANSION

- MRI

Phase 2:

- **Emergency Department**
- Patient Treatment Rooms
- **Psychiatric Ward**
- **Isolation Rooms**





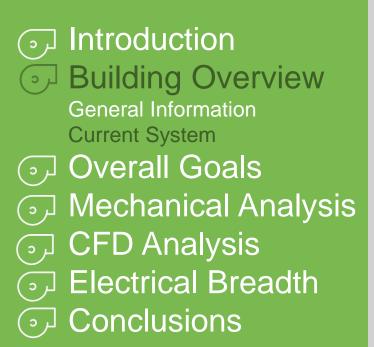
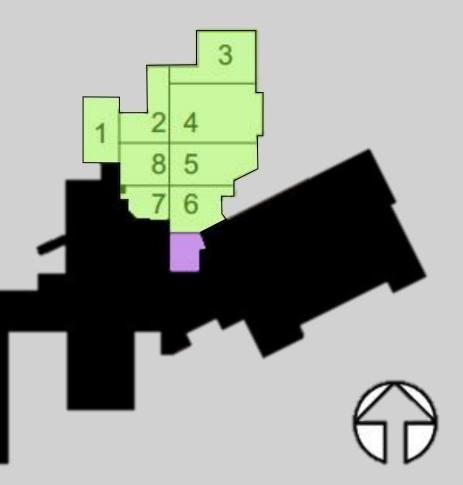


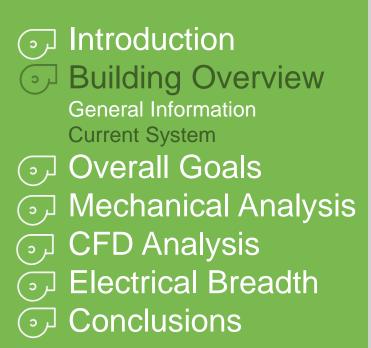
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Current System: Phase 1: AHU-1:

MORTON HOSPITAL EXPANSION

- 2500 CFM **Steam Preheat Coil** DX Cooling Coil
- **Electric Reheat**





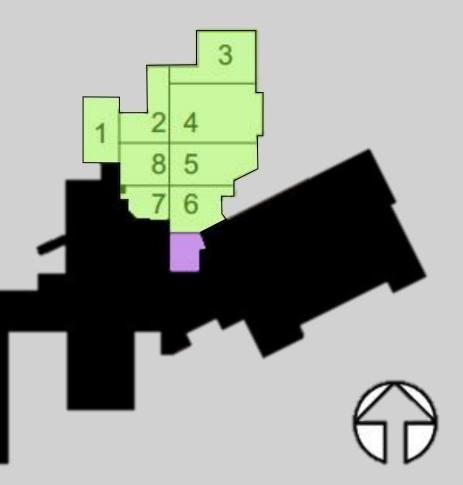
Current System:

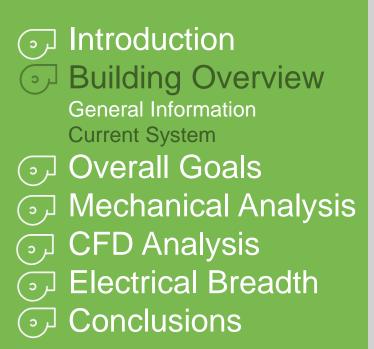


MORTON HOSPITAL EXPANSION

- Phase 1:
 - AHU-1: 2500 CFM **Steam Preheat Coil** DX Cooling Coil
 - **Electric Reheat**
 - Phase 2:
 - 35,000 CFM Hot Water Preheat Coil Chilled Water Cooling Coil
 - VAV Box Hot Water Reheat







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Current Heating System:

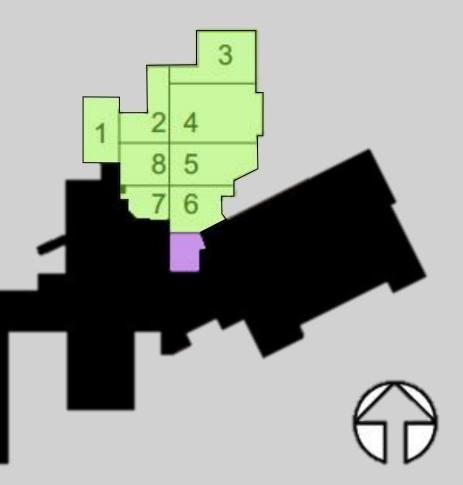
MORTON HOSPITAL EXPANSION

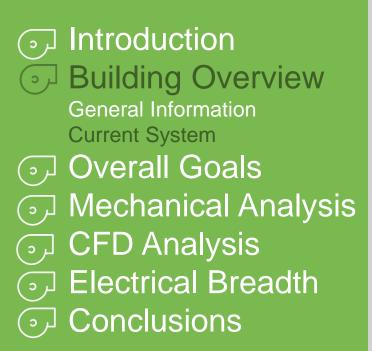
Existing Building Steam Plant

LPS to Steam to HW Heat Exchangers

- 180° F HW Supply
- 140° F HW Return







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Current Heating System:

Current Cooling System:

MORTON HOSPITAL EXPANSION

Existing Building Steam Plant

LPS to Steam to HW Heat Exchangers 180° F HW Supply

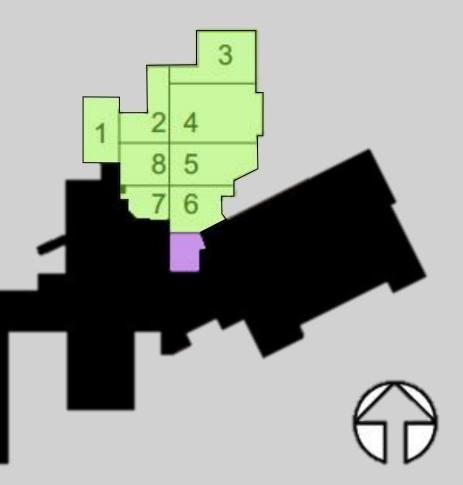
140° F HW Return

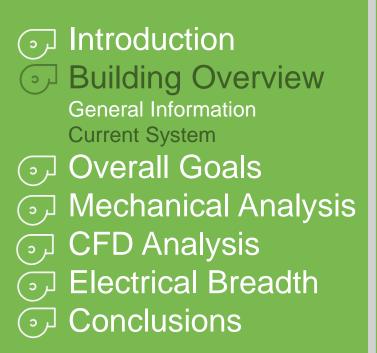
New 155 Ton Air Cooled Chiller

55° F CHW Supply

43° F CHW Return







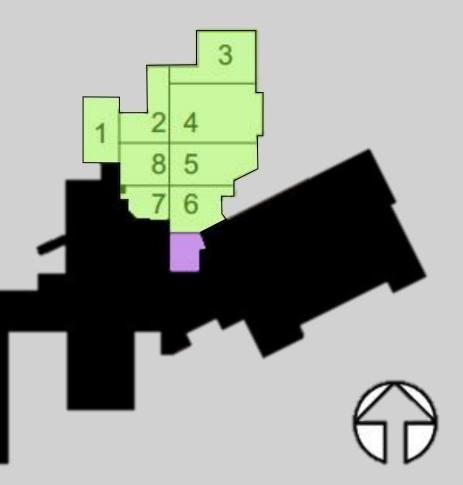
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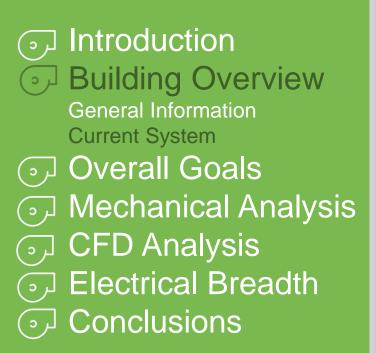
MORTON HOSPITAL EXPANSION ASHRAE 90.1 - 2010:

TAE
Zone
3B, 3C, 4B, 4C, 5B
1B, 2B,5C
6B
1A, 2A, 3A, 4A, 5A, 6A
7,8
NR—Not required

ABLE 6.5.6.1 Exhaust Air Energy Recovery Requirements											
	% Outdoor Air at Full Design Airflow Rate										
	≥30% and < 40%	≥40% and < 50%	≥50% and < 60%	≥60% and < 70%	≥70% and < 80%	≥80%					
	Design Supply Fan Airflow Rate (cfm)										
	NR	NR	NR	NR	≥5000	≥5000					
	NR	NR	≥26000	≥12000	≥5000	≥4000					
	≥11000	≥5500	≥4500	≥3500	≥2500	≥1500					
	≥5500	≥4500	≥3500	≥2000	≥1000	>0					
	≥2500	≥1000	>0	>0	>0	>0					





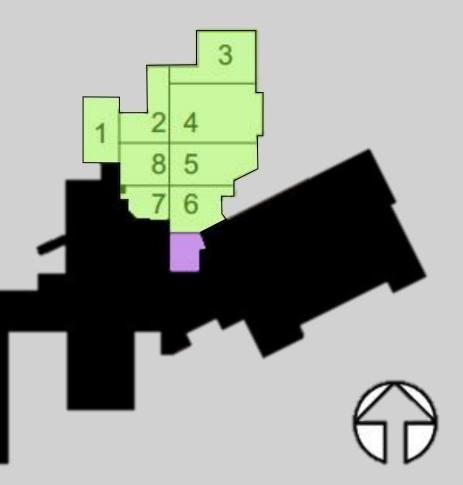


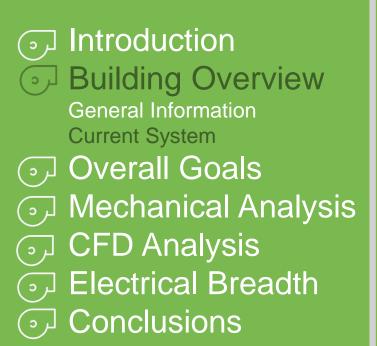
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MORTON HOSPITAL EXPANSION ASHRAE 90.1 - 2010:

TABLE 6.5.6.1 Exhaust Air Energy Recovery Requirements									
	% Outdoor Air at Full Design Airflow Rate								
Zone	≥30% and < 40%	≥40% and < 50%	≥50% and < 60%	≥60% and < 70%	≥70% and < 80%	≥80%			
	Design Supply Fan Airflow Rate (cfm)								
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	≥5000	≥5000			
1B, 2B,5C	NR	NR	≥26000	≥12000	≥5000	≥4000			
6B	≥11000	≥5500	≥4500	≥3500	≥2500	≥1500			
1A, 2A, 3A, 4A, 5A, 6A	≥5500	≥4500	≥3500	≥2000	≥1000	>0			
7,8	≥2500	≥1000	>0	>0	>0	>0			
NR—Not required									

27% Outdoor Air

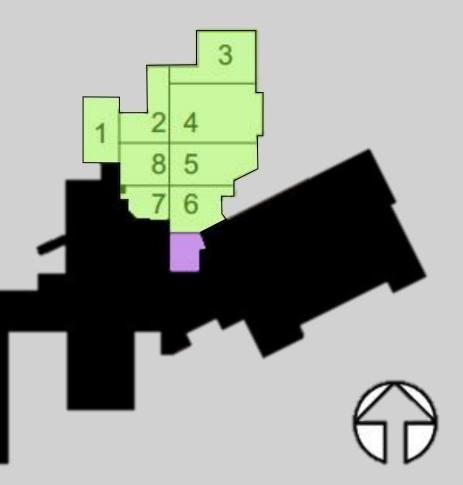




MORTON HOSPITAL EXPANSION ASHRAE 90.1 - 2013:

	% Outdoor Air at Full Design Airflow Rate								
Zone	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and < 80%	≥80%	
	Design Supply Fan Airflow Rate, cfm								
3C	NR	NR	NR	NR	NR	NR	NR	NR	
1B, 2B, 3B, 4C, 5C	NR	≥19,500	≥9000	≥5000	≥4000	≥3000	≥1500	>0	
1A, 2A, 3A, 4B, 5B	≥2500	≥2000	≥1000	≥500	>0	>0	>0	>0	
4A, 5A, 6A, 6B, 7, 8	>0	>0	>0	>0	>0	>0	>0	>0	





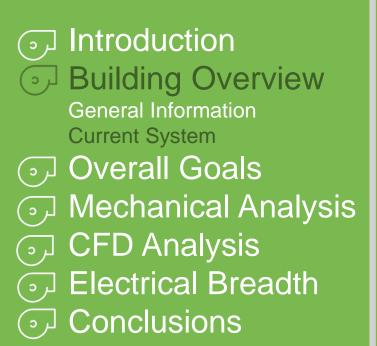
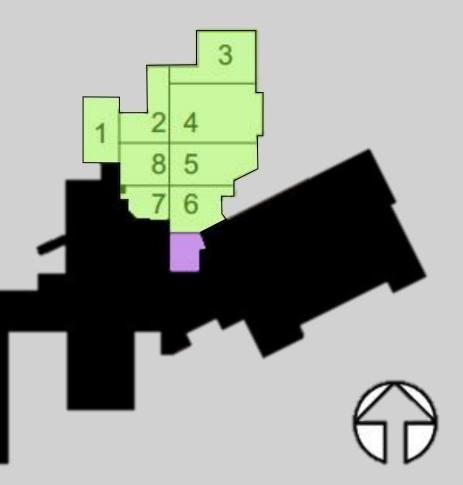


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MORTON HOSPITAL EXPANSION ASHRAE 90.1 - 2013:

TABLE 6.5.6.1-2 Exhaust Air Energy Recovery Requirements for Ventilation Systems Operating Greater than or Equal to 8000 Hours per Year										
% Outdoor Air at Full Design Airflow Rate										
Zone	≥10% and <20%	≥20% and <30%	≥30% and <40%	≥40% and <50%	≥50% and <60%	≥60% and <70%	≥70% and < 80%	≥80%		
	Design Supply Fan Airflow Rate, cfm									
3C	NR	NR	NR	NR	NR	NR	NR	NR		
1B, 2B, 3B, 4C, 5C	NR	≥19,500	≥9000	≥5000	≥4000	≥3000	≥1500	>0		
1A, 2A, 3A, 4B, 5B	≥2500	≥2000	≥1000	≥500	>0	>0	>0	>0		
4A, 5A, 6A, 6B, 7, 8	>0	>0	>0	>0	>0	>0	>0	>0		
							-			

27% Outdoor Air



J Introduction Building Overview • Overall Goals Mechanical Analysis CFD Analysis Electrical Breadth





MORTON HOSPITAL EXPANSION



System Feasibility

→ Building Overview • Overall Goals Mechanical Analysis CFD Analysis • Electrical Breadth • Conclusions







MORTON HOSPITAL EXPANSION



System Feasibility

Energy Consciousness

J Introduction Building Overview • Overall Goals Mechanical Analysis ○ CFD Analysis • Electrical Breadth • Conclusions











MORTON HOSPITAL EXPANSION



System Feasibility

Energy Consciousness

Economically Practical

J Introduction Building Overview • Overall Goals Mechanical Analysis • CFD Analysis • Electrical Breadth • Conclusions

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MORTON HOSPITAL EXPANSION



System Feasibility

Energy Consciousness

Economically Practical

(U) Thermal Comfort



Image: Second Second



MECHANICAL SYSTEM ANALYSIS

Key Considerations: Equipment First Cost System Feasibility Life Cycle Cost **Energy Consumption**



(7)

() ALTERNATIVE 1: Water-Cooled Chiller & **Air-to-Air Heat Recovery**





MECHANICAL SYSTEM ANALYSIS

Key Considerations: Equipment First Cost System Feasibility Life Cycle Cost **Energy Consumption**

 Introduction
 ■ **Building Overview** • Overall Goals Mechanical Analysis Alternative 1 Alternative 2 Overall Comparison CFD Analysis • Electrical Breadth • Conclusions

() ALTERNATIVE 2: Variable Refrigerant Flow



ALTERNATIVE 1: Water-Cooled Chiller & **Air-to-Air Heat Recovery**





MECHANICAL SYSTEM ANALYSIS

Key Considerations: Equipment First Cost System Feasibility Life Cycle Cost **Energy Consumption**



() ALTERNATIVE 1: Water-Cooled Chiller & **Air-to-Air Heat Recovery**





MECHANICAL SYSTEM ANALYSIS



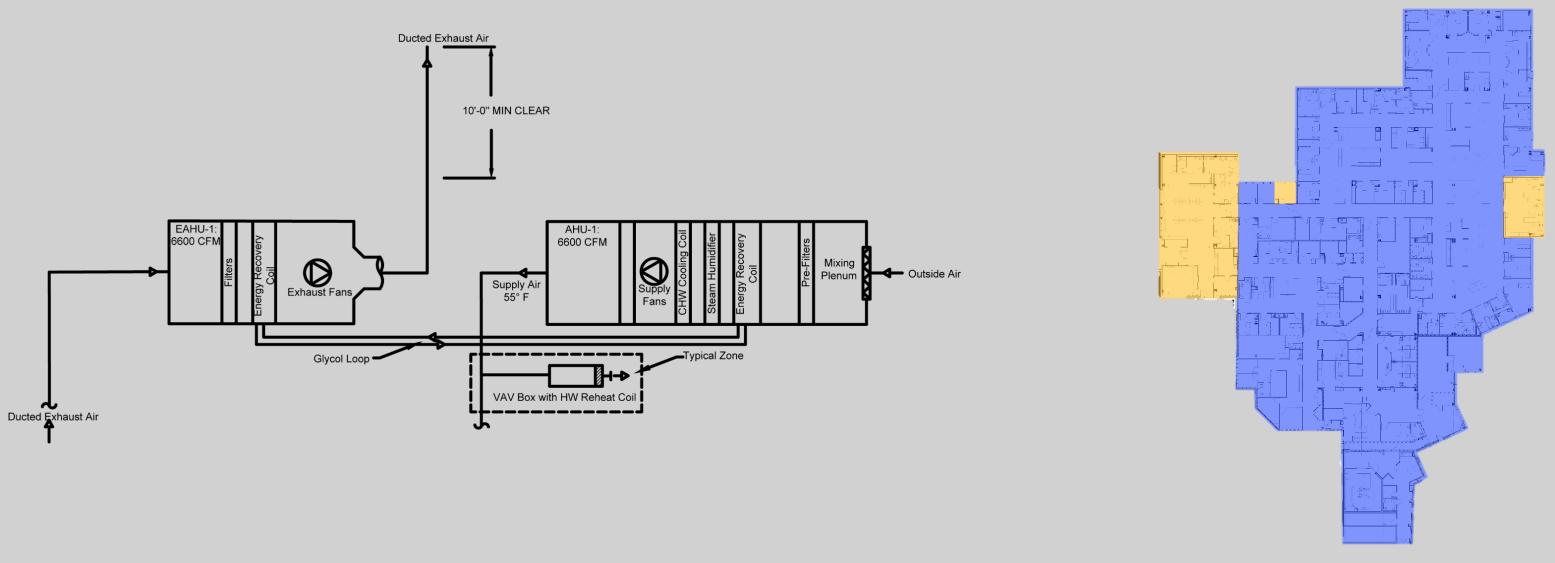
Air-to-Air Energy Recovery





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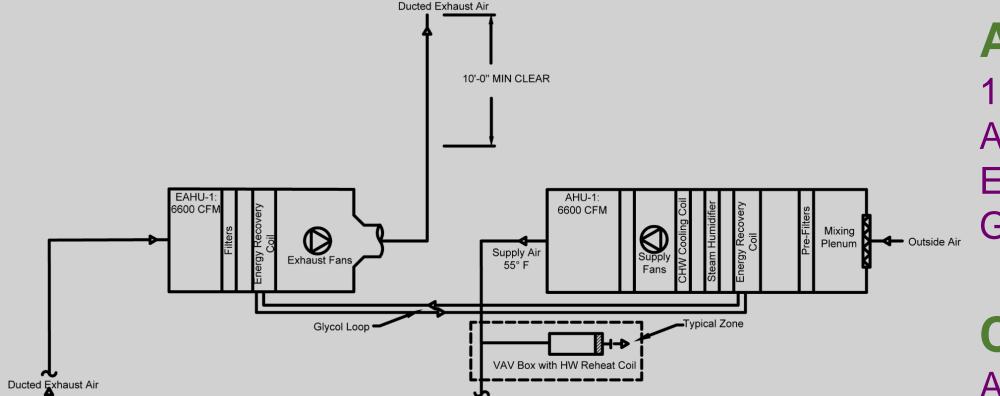
Air-to-Air Energy Recovery







Air-to-Air Energy Recovery





AHU-1 System Features:

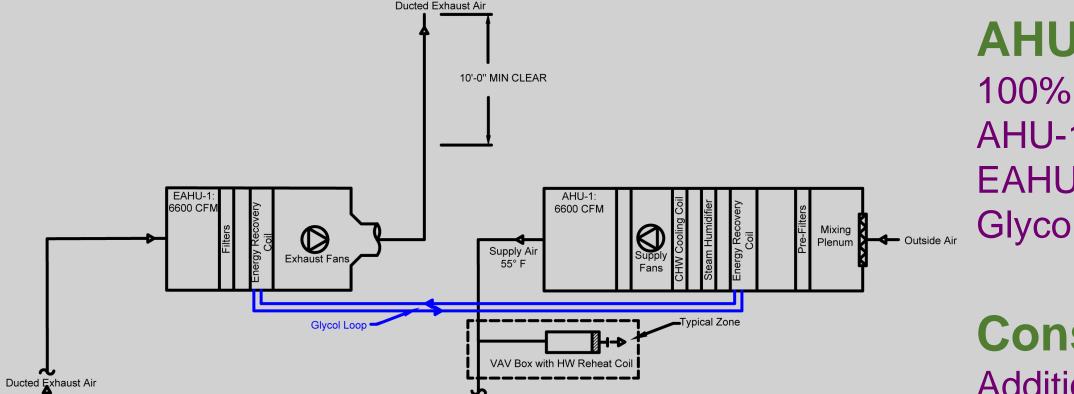
100% Outside Air AHU-1: 6600 CFM EAHU-1: 6600 CFM **Glycol Solution Loop**

Considerations:

Additional Equipment Cost ASHRAE 90.1 – 2013 Compliance **Cross-Contamination**



Air-to-Air Energy Recovery





AHU-1 System Features:

100% Outside Air AHU-1: 6600 CFM EAHU-1: 6600 CFM **Glycol Solution Loop**

Considerations:

Additional Equipment Cost ASHRAE 90.1 – 2013 Compliance **Cross-Contamination**

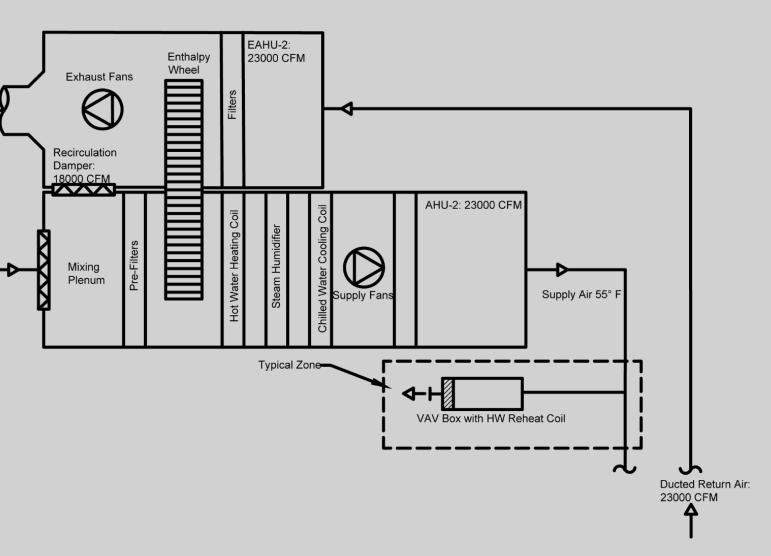


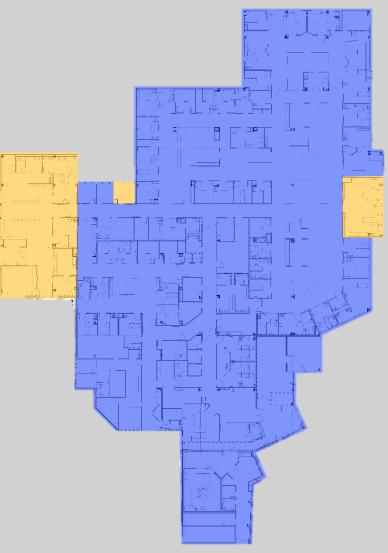
Air-to-Air Energy Ducted Exhaust Air: 5000 CFM Recovery

10'-0" MIN CLEAR

Outside Air: 5000 CFM







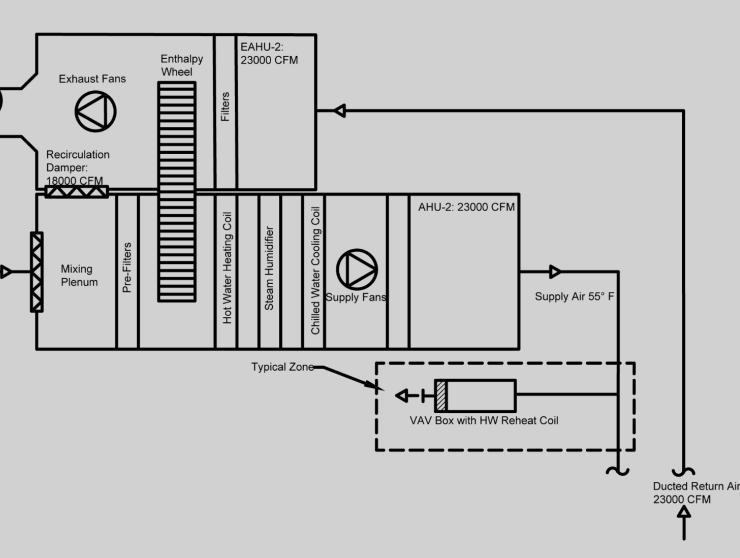


Air-to-Air Energy Ducted Exhaust Air: 5000 CFM Recovery

10'-0" MIN CLEAR

Outside Air: 5000 CFM





AHU-2 System Features: AHU-2: 23,000 CFM EAHU-2: 23,000 CFM Enthalpy Wheel

Considerations: Additional Equipment Cost ASHRAE 90.1 – 2013 Compliance



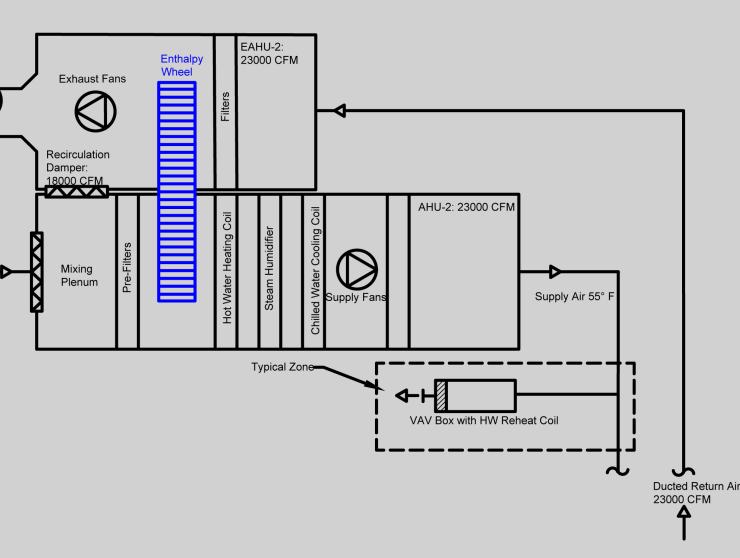
Air-to-Air Energy Recovery

Outside Air:

Ducted Exhaust Air: 5000 CFM

10'-0" MIN CLEAR





AHU-2 System Features: AHU-2: 23,000 CFM EAHU-2: 23,000 CFM Enthalpy Wheel

Considerations: Additional Equipment Cost ASHRAE 90.1 – 2013 Compliance

() Introduction Building Overview Overall Goals J Mechanical Analysis Alternative 1 Overall System Energy Consumption **Operating Cost** Alternative 2 Overall Comparison CFD Analysis Electrical Breadth • Conclusions

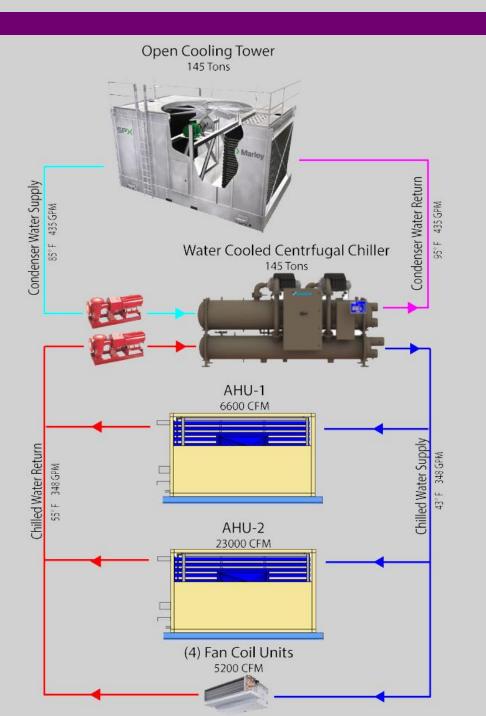
Chilled Water and Condenser Water Loop



(J Introduction Building Overview Overall Goals Mechanical Analysis Alternative 1 **Overall System** Energy Consumption **Operating Cost** Alternative 2 Overall Comparison G CFD Analysis Similar Strength (□) Electrical Breadth • Conclusions

(E)

Chilled Water and Condenser Water Loop



MECHANICAL SYSTEM ANALYSIS ALTERNATIVE 1

System Features:

145 Ton Water Cooled Centrifugal Chiller 1,726,200 Btu/hr Open Cooling Tower 43° F Chilled Water Supply 85° F Condenser Water Supply

Considerations:

Additional Equipment Cost **Re-evaluation of Roof Structure**



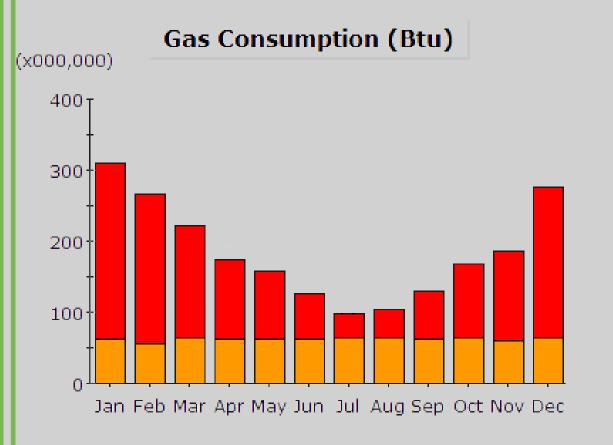
In \$

Electric & Natural Gas Consumption





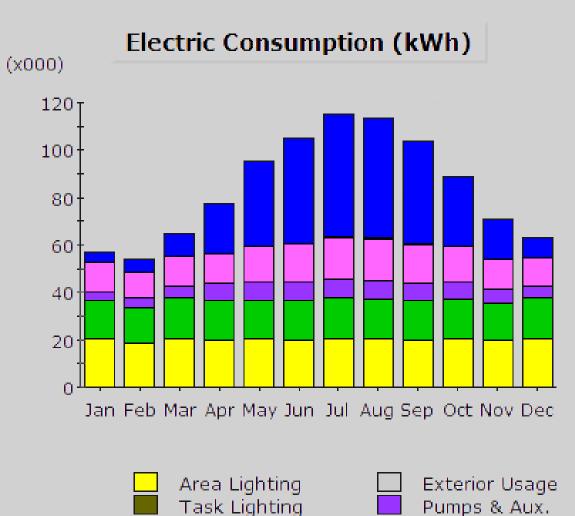
Electric & Natural Gas Consumption



Water Heating Ht Pump Supp. Space Heating

Refrigeration Heat Rejection Space Cooling

MECHANICAL SYSTEM ANALYSIS ALTERNATIVE 1



Misc. Equipment

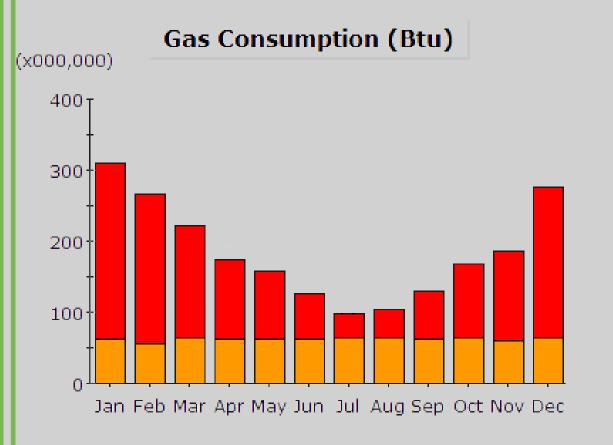
Ventilation Fan

Total Energy Savings: 10% Savings in Electrical Consumption 34% Savings in Natural Gas Consumption



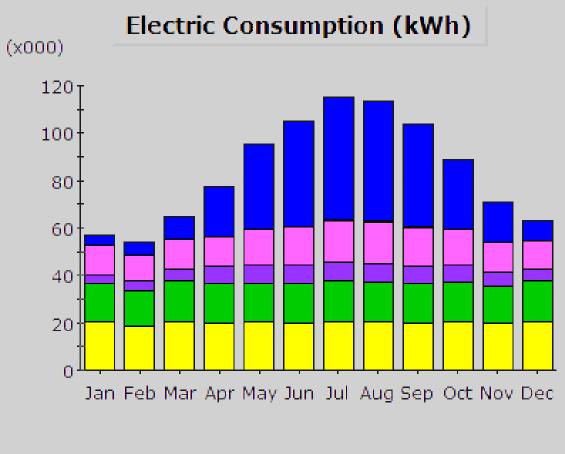
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Electric & Natural Gas Consumption



Water Heating Ht Pump Supp. Space Heating Refrigeration
 Heat Rejection
 Space Cooling

MECHANICAL SYSTEM ANALYSIS ALTERNATIVE 1



Exterior Usage

Pumps & Aux.

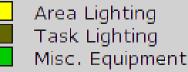
Ventilation Fan

Reductions:

8.5% Reduction in Space Cooling41% Reduction in Fan Energy44% Reduction in Space Heating

Increases:

83% Increase in Pump Energy



() Introduction Building Overview Overall Goals J Mechanical Analysis Alternative 1 Overall System Energy Consumption Operating Cost Alternative 2

Overall Comparison CFD Analysis S Electrical Breadth • Conclusions

Annual Operating Cost

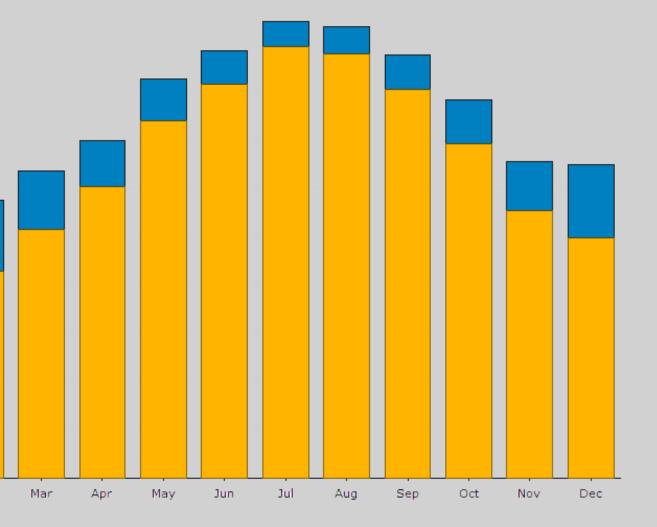


Annual Operating Cost





MECHANICAL SYSTEM ANALYSIS ALTERNATIVE 1



Custom Gas Rate (annual bill: \$ 24,400)

Total Cost Savings:

15% Total Annual Savings 10% Savings in Electrical Costs 34% Savings in Natural Gas Consumption \$4.47/SF

Total Annual Bill Across All Rates: \$ 182,169

Custom Elec Rate (annual bill: \$ 157,769)

Monthly Utility Bills (\$)



Solution → ALTERNATIVE 2: **Variable Refrigerant Flow**





MECHANICAL SYSTEM ANALYSIS

Building Overview Overall Goals J Mechanical Analysis Alternative 1 Alternative 2 **Overall System** ASHRAE 15 Compliance Energy Consumption Operating Cost

Overall Comparison CFD Analysis Electrical Breadth • Conclusions

VRF Refrigerant Loop



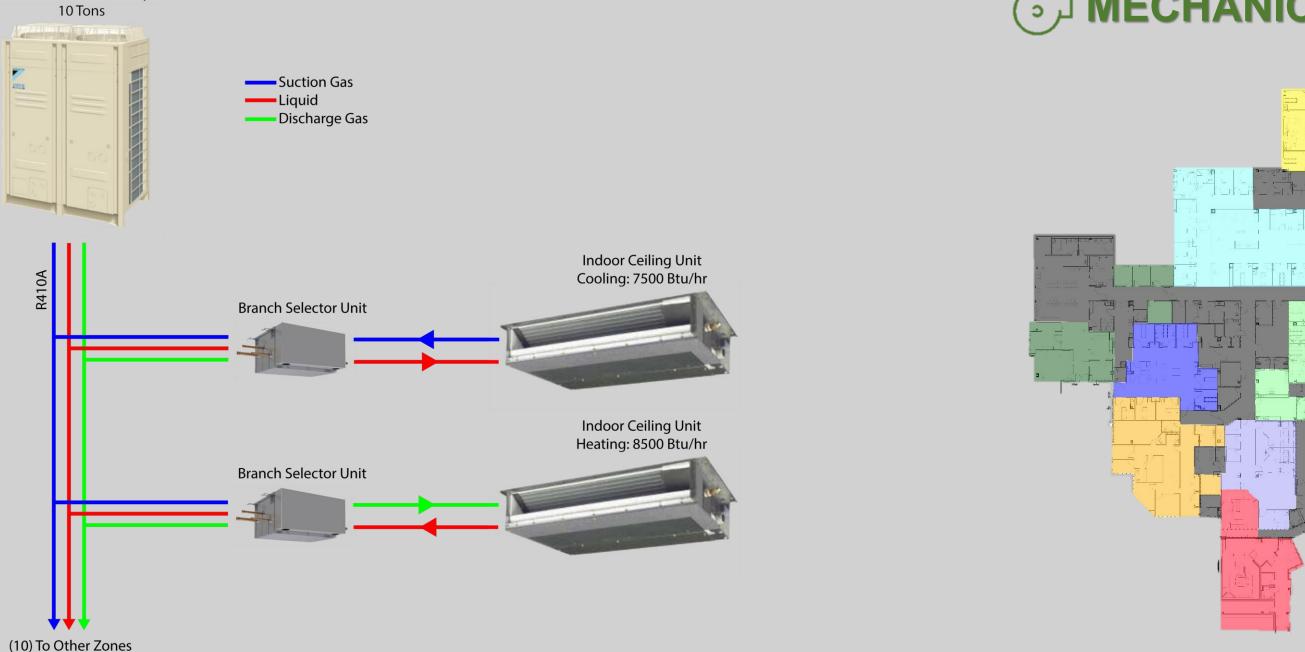
 Introduction
 ■ Building Overview • Overall Goals Mechanical Analysis Alternative 1 Alternative 2

Overall System ASHRAE 15 Compliance Energy Consumption Operating Cost Overall Comparison CFD Analysis Electrical Breadth • Conclusions

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VRF Refrigerant Loop

(8) Outdoor Heat Recovery Unit 10 Tons



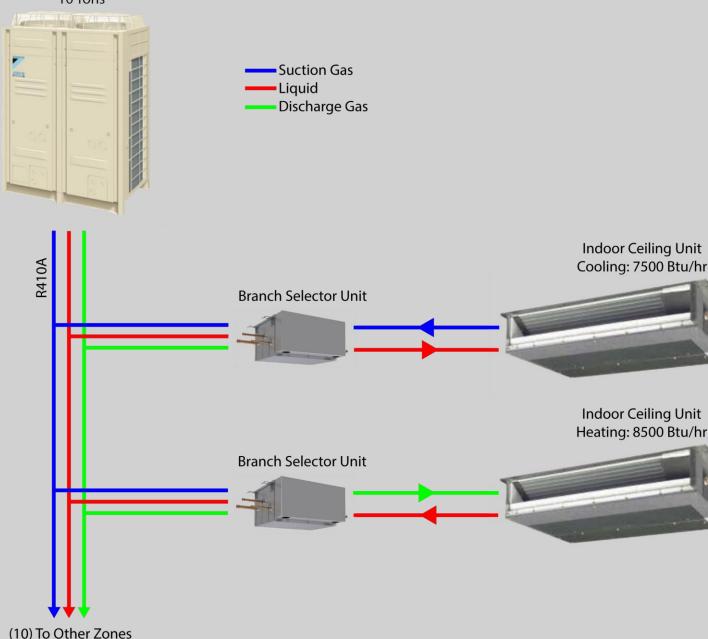


(J Introduction **Building Overview** • Overall Goals Mechanical Analysis Alternative 1 Alternative 2

Overall System ASHRAE 15 Compliance Energy Consumption **Operating Cost** Overall Comparison G CFD Analysis • Electrical Breadth • Conclusions

VRF Refrigerant Loop

(8) Outdoor Heat Recovery Unit 10 Tons





MECHANICAL SYSTEM ANALYSIS ALTERNATIVE 2

System Features: (8) 10 Ton Outdoor Units **Refrigerant R410A** Heat Recovery

Considerations: Additional Equipment Cost ASHRAE 15 – 2013 Compliance

DOAS Ventilation

Building Overview Overall Goals J Mechanical Analysis Alternative 1 Alternative 2 **Overall System** ASHRAE 15 Compliance Energy Consumption Operating Cost Overall Comparison CFD Analysis Electrical Breadth • Conclusions

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○ Introduction Building Overview Overall Goals Mechanical Analysis Alternative 1

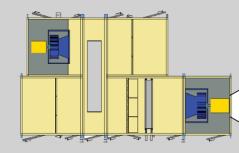
Alternative 2

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Overall System ASHRAE 15 Compliance Energy Consumption **Operating Cost** Overall Comparison G CFD Analysis Sector Secto • Conclusions

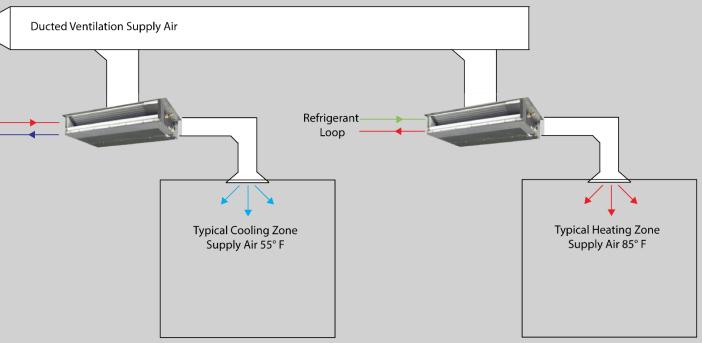
DOAS Ventilation

Dedicated Outdoor Air Unit (DOAS-1)



Refrigerant____ Loop

MECHANICAL SYSTEM ANALYSIS ALTERNATIVE 2



System Features: DOAS-1: 14,500 CFM EAHU-1: 14,500 CFM Enthalpy Wheel Heat Recovery

Considerations: ASHRAE 170 – 2013 Ventilation Requirements



() Introduction Building Overview Overall Goals J Mechanical Analysis Alternative 1 Alternative 2

Overall System ASHRAE 15 Compliance Energy Consumption Operating Cost Overall Comparison CFD Analysis Electrical Breadth • Conclusions

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Chilled Water & Condenser Water Loop



(→ Introduction) Building Overview Overall Goals Mechanical Analysis Alternative 1 Alternative 2

Overall System ASHRAE 15 Compliance Energy Consumption **Operating Cost** Overall Comparison G CFD Analysis Sector Secto • Conclusions

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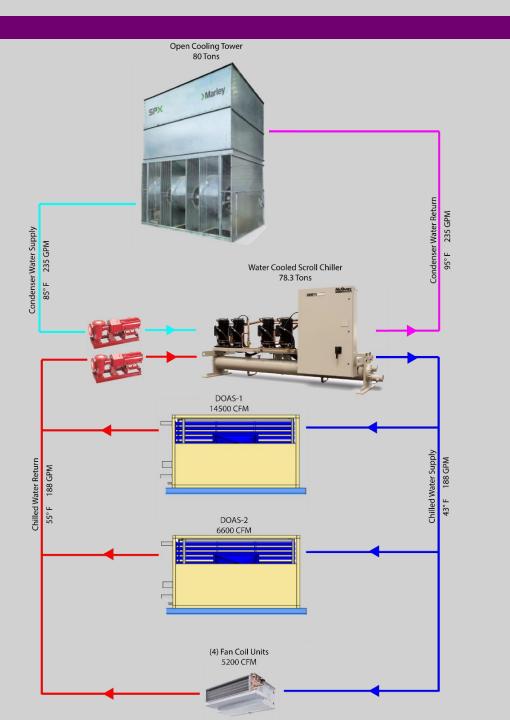
Chilled Water & Condenser Water Loop



System Features: 78 Ton Chiller 970,400 Btu/hr Cooling Tower 43° F Chilled Water Supply 85° F Condenser Water Supply

Considerations:

Reduced Equipment Sizes Reduced Equipment Cost



() Introduction Building Overview Overall Goals J Mechanical Analysis Alternative 1 Alternative 2 Overall System

ASHRAE 15 Compliance Energy Consumption Operating Cost Overall Comparison CFD Analysis Electrical Breadth • Conclusions

ASHRAE 15: **Safety Standard for Refrigeration Systems**



 Introduction
 ■ Building Overview Overall Goals Mechanical Analysis Alternative 1 Alternative 2 Overall System ASHRAE 15 Compliance

Energy Consumption **Operating Cost** Overall Comparison ○ CFD Analysis Electrical Breadth • Conclusions

ASHRAE 15: **Safety Standard for Refrigeration Systems**



		SAFETY GROUP				
F IL NA CM	Higher Flammability	A3	B3			
R M	Lower Flammability	A2	B2			
АВ 5 I		A2_L*	- B2L* -			
IL NI GT Y	No Flame Propagation	A1	B1			
		Lower Toxicity	Higher Toxicity			

INCREASING TOXICITY

* A2L and B2L are lower flammability refrigerants with a maximum burning velocity of ≤3.9 in./s (10 cm/s)

ASHRAE 34: **Refrigerant Safety Group Classifications**

 Introduction
 ■ Building Overview Overall Goals Mechanical Analysis Alternative 1 Alternative 2 Overall System ASHRAE 15 Compliance

Energy Consumption **Operating Cost** Overall Comparison ○ CFD Analysis Electrical Breadth • Conclusions

ASHRAE 15: **Safety Standard for Refrigeration Systems**



_ 1		SAFETY GROUP					
F L NA CM	Higher Flammability	A3	В3				
R M	Lower Flammability	A2	B2				
A B S I I L N I G T Y		A2_L*	- B2L* -				
	No Flame Propagation	A1	B1				
		Lower Toxicity	Higher Toxicity				
		INCREASING TOXICITY					

* A2L and B2L are lower flammability refrigerants with a maximum burning velocity of ≤3.9 in./s (10 cm/s)

ASHRAE 34: **Refrigerant Safety Group Classifications**

(→) Introduction Building Overview Overall Goals Mechanical Analysis Alternative 1 Alternative 2 Overall System ASHRAE 15 Compliance Energy Consumption **Operating Cost** Overall Comparison CFD Analysis S Electrical Breadth

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ASHRAE 15: **Safety Standard for Refrigeration Systems**

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Refrigerant Number	Con
Zeotropes 409A	R-22/124/1
409B	R-22/124/1
410A ⁱ	R-32/125 (
$410B^{i}$	R-32/125 (
411A ^e	R-1270/22
411B ^e	R-1270/22
412A	R-22/218/1
413A	R-218/134

MECHANICAL SYSTEM ANALYSIS ALTERNATIVE 2

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TABLE 4-2 Data and Safety Classifications for Refrigerant Blends

	Composition Tolerances	OEL ^h , ppm v/v	Safety Group	RCL ^a			Highly Toxic
nposition (Mass %)				(ppm v/v)	(lb/Mcf)	(g/m ³)	or Toxic ^f Under Code Classification
142b (60.0/25.0/15.0)	(±2.0/±2.0/±1.0)	1000	A1	29,000	7.1	110	Neither
142b (65.0/25.0/10.0)	(±2.0/±2.0/±1.0)	1000	A1	30,000	7.3	120	Neither
(50.0/50.0)	(+0.5, -1.5/+1.5, -0.5)	1000	A1	140,000	26	420	Neither
(45.0/55.0)	(±1.0/±1.0)		A1	140,000	27	430	Neither
2/152a (1.5/87.5/11.0)	(+0.0, -1.0/+2.0, -0.0/+0.0, -1.0)	990	A2	14,000	2.9	46	Neither
2/152a (3.0/94.0/3.0)	(+0.0, -1.0/+2.0, -0.0/+0.0, -1.0)	980	A2	13,000	2.8	45	Neither
142b (70.0/5.0/25.0)	(±2.0/±2.0/±1.0)	1000	A2	22,000	5.1	82	Neither
a/600a (9.0/88.0/3.0)	(±1.0/±2.0/+0.01.0)	1000	A2	22.000	5.8	94	Neither

ASHRAE 34: Table 4-2 Data and Safety Classifications for Blends

Considerations: Institutional Occupancy: Reduce RCL by 50%

(→) Introduction Building Overview Overall Goals Mechanical Analysis Alternative 1 Alternative 2 Overall System ASHRAE 15 Compliance Energy Consumption **Operating Cost** Overall Comparison CFD Analysis Solution Electrical Breadth

• Conclusions

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ASHRAE 15: Safety Standard for Refrigeration Systems

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Refrigerant Number	Con		
ceotropes 409A	R-22/124/		
409B	R-22/124/		
410A ⁱ	R-32/125 (
410B ⁱ	R-32/125 (
411A ^e	R-1270/22		
411B ^e	R-1270/22		
412A	R-22/218/		
413A	R-218/134		

MECHANICAL SYSTEM ANALYSIS ALTERNATIVE 2

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TABLE 4-2 Data and Safety Classifications for Refrigerant Blends

	Composition Tolerances	OEL ^h , ppm v/v	Safety Group	RCL ^a			Highly Toxic
mposition (Mass %)				(ppm v/v)	(lb/Mcf)	(g/m ³)	or Toxic ^f Under Code Classification
142b (60.0/25.0/15.0)	(±2.0/±2.0/±1.0)	1000	A1	29,000	7.1	110	Neither
142b (65.0/25.0/10.0)	(±2.0/±2.0/±1.0)	1000	A1	30,000	7.3	120	Neither
(50.0/50.0)	(+0.5, -1.5/+1.5, -0.5)	1000	Al	140,000	26	420	Neither
(45.0/55.0)	(±1.0/±1.0)		A1	140,000	27	430	Neither
2/152a (1.5/87.5/11.0)	(+0.0, -1.0/+2.0, -0.0/+0.0, -1.0)	990	A2	14,000	2.9	46	Neither
2/152a (3.0/94.0/3.0)	(+0.0, -1.0/+2.0, -0.0/+0.0, -1.0)	980	A2	13,000	2.8	45	Neither
142b (70.0/5.0/25.0)	(±2.0/±2.0/±1.0)	1000	A2	22,000	5.1	82	Neither
4a/600a (9.0/88.0/3.0)	(±1.0/±2.0/+0.01.0)	1000	A2	22.000	5.8	94	Neither

ASHRAE 34: Table 4-2 Data and Safety Classifications for Blends

Considerations: Institutional Occupancy: Reduce RCL by 50%

() Introduction Building Overview Overall Goals J Mechanical Analysis Alternative 1 Alternative 2 Overall System ASHRAE 15 Compliance Energy Consumption Operating Cost Overall Comparison CFD Analysis Electrical Breadth • Conclusions

Electric & Natural Gas Consumption



(J Introduction Building Overview Overall Goals Mechanical Analysis Alternative 1 Alternative 2

Overall System ASHRAE 15 Compliance Energy Consumption **Operating Cost** Overall Comparison ○ CFD Analysis S Electrical Breadth • Conclusions

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Electric & Natural Gas Consumption

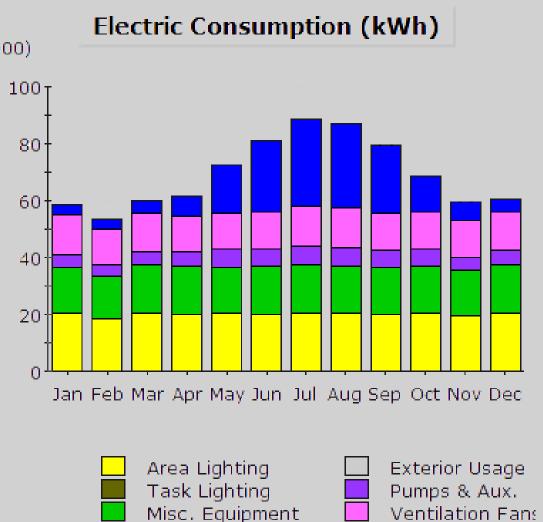
Gas Consumption (Btu) (x000,000) 250_T 200 150 100 50+ Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Water Heating Ht Pump Supp. Space Heating



(x000)

MECHANICAL SYSTEM ANALYSIS ALTERNATIVE 2



Total Energy Savings: 26% Savings in Electrical Consumption 50% Savings in Natural Gas Consumption

(Introduction Building Overview Overall Goals Mechanical Analysis Alternative 1 Alternative 2

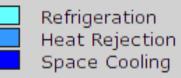
Overall System ASHRAE 15 Compliance Energy Consumption **Operating Cost** Overall Comparison CFD Analysis S Electrical Breadth • Conclusions

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Electric & Natural Gas Consumption

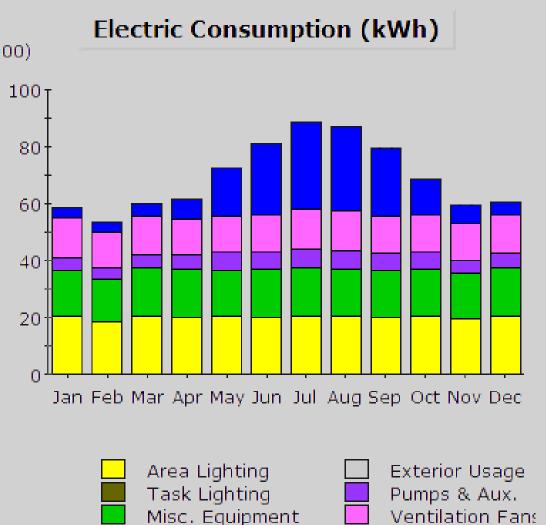
Gas Consumption (Btu) (x000,000) 250_T 200 150 100 50+ Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Water Heating Ht Pump Supp. Space Heating



(x000)





Reductions:

40% Reduction in Space Cooling 44% Reduction in Space Heating

Annual Operating Cost

() Introduction Building Overview Overall Goals J Mechanical Analysis Alternative 1 Alternative 2 Overall System ASHRAE 15 Compliance Energy Consumption **Operating Cost** Overall Comparison CFD Analysis Electrical Breadth • Conclusions

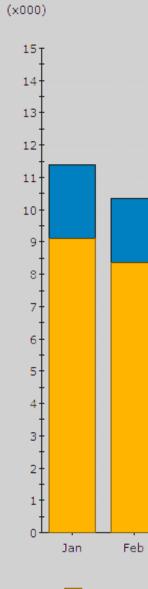
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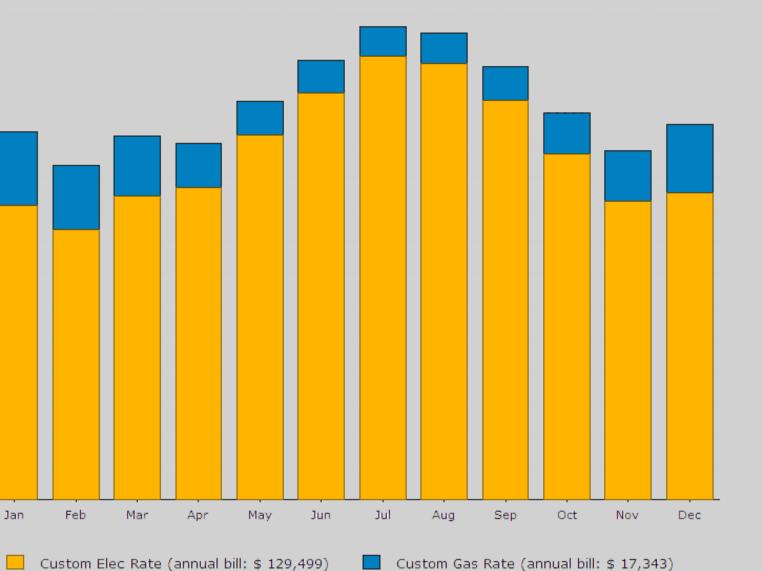
Annual Operating Cost

 Building Overview Overall Goals Mechanical Analysis Alternative 1 Alternative 2 Overall System ASHRAE 15 Compliance Energy Consumption **Operating Cost** Overall Comparison CFD Analysis • Electrical Breadth • Conclusions

(Introduction



Monthly Utility Bills (\$)



MECHANICAL SYSTEM ANALYSIS ALTERNATIVE 2

Total Cost Savings: 32% Total Annual Savings 26% Savings in Electrical Costs 54% Savings in Natural Gas Consumption \$3.60/SF

Total Annual Bill Across All Rates: \$ 146,842









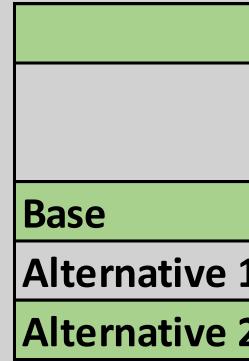


MECHANICAL SYSTEM ANALYSIS Overall Comparison

(J Introduction **Building Overview** • Overall Goals Mechanical Analysis Alternative 1 Alternative 2 Overall Comparison LCC and Payback Energy Analysis • CFD Analysis • Electrical Breadth • Conclusions

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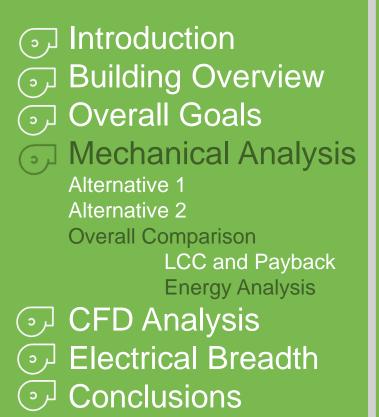
Life Cycle Cost and Payback Period



MECHANICAL SYSTEM ANALYSIS Overall Comparison

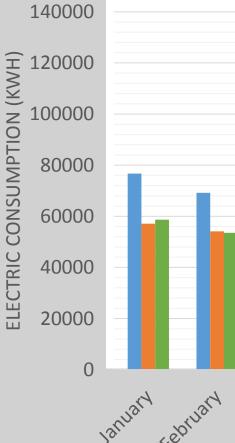
	Life Cycle Cost						
	Total Life Cycle		Payback				
	Cost	Savings	Period				
	\$ 4,726,768.09						
1	\$ 4,157,240.30	12%	1.85				
2	\$ 3,771,892.32	20%	4.98				

Cost Basis: 25 Year Equipment Life First Cost: **RS** Means Mechanical Cost Data 2015 Maintenance Cost: RS Means Facilities Maintenance & Repairs 2015 Utility Cost: eQuest Energy Simulation **Escalation Factors:** NIST Handbook 135



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Energy Analysis





Electric Consumption Comparison

Base Alternative 1 Alternative 2

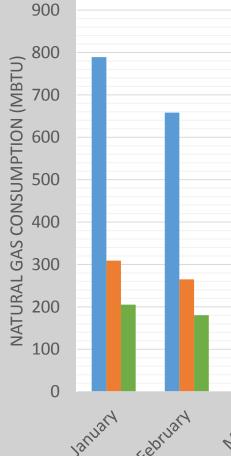


MECHANICAL SYSTEM ANALYSIS Overall Comparison



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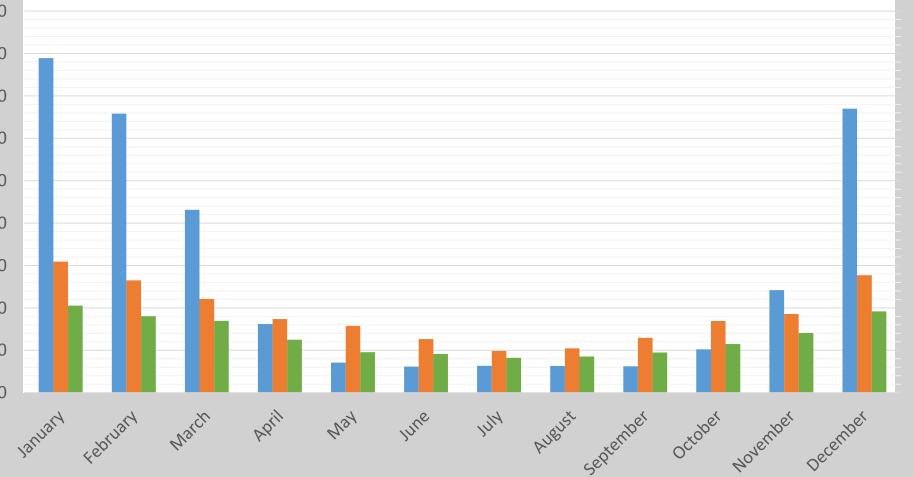
Energy Analysis





Natural Gas Consumption Comparison

Base Alternative 1 Alternative 2



MECHANICAL SYSTEM ANALYSIS Overall Comparison

 Building Overview J Overall Goals Mechanical Analysis G CFD Analysis Electrical Breadth

Image: Section 1.

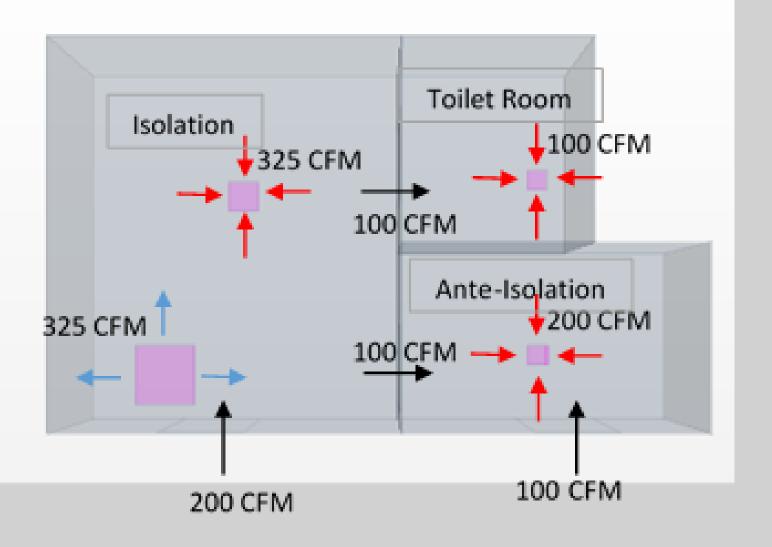


OD Computational Fluid Dynamics Masters Coursework

(J Introduction Building Overview • Overall Goals Mechanical Analysis CFD Analysis Geometry Pressure Gradient Temperature Gradient Age of Air Electrical Breadth • Conclusions

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Isolation Room Geometry





Considerations: ASHRAE 170 All Room Requirements: **Negative Pressure Relationship** 70-75° F Design Temperature 12 Total ACH

Introduction ■ Building Overview Overall Goals Mechanical Analysis G CFD Analysis Geometry **Pressure Gradient** Temperature Gradient Age of Air

J Electrical Breadth • Conclusions

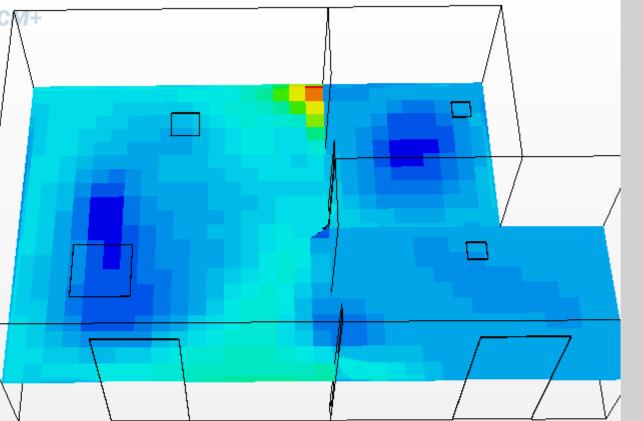
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Pressure Gradient











Considerations: ASHRAE 170 All Room Requirements: **Negative Pressure Relationship** 70-75° F Design Temperature 12 Total ACH

Introduction ■ Building Overview • Overall Goals Mechanical Analysis G CFD Analysis Geometry **Pressure Gradient** Temperature Gradient Age of Air

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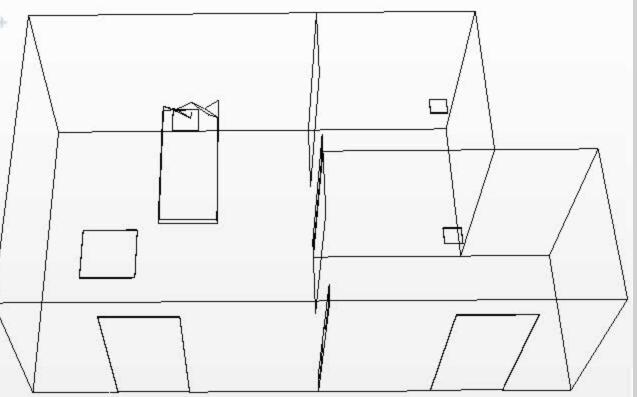
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Pressure Gradient











Considerations: ASHRAE 170 All Room Requirements: **Negative Pressure Relationship** 70-75° F Design Temperature 12 Total ACH

Introduction ■ Building Overview Overall Goals Mechanical Analysis J CFD Analysis

Geometry Pressure Gradient Temperature Gradient Age of Air

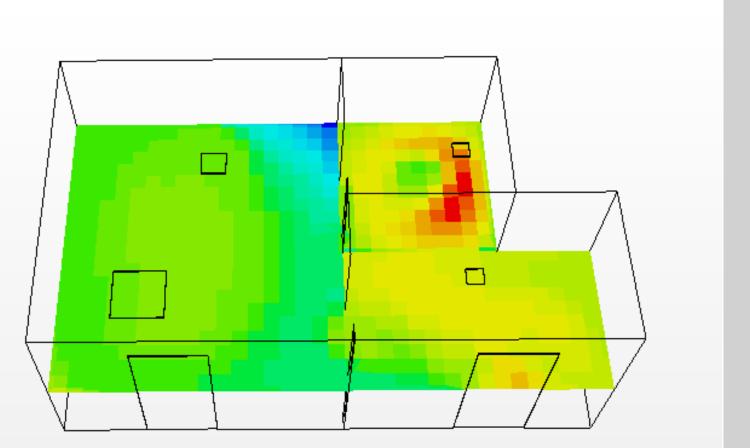
Electrical Breadth • Conclusions

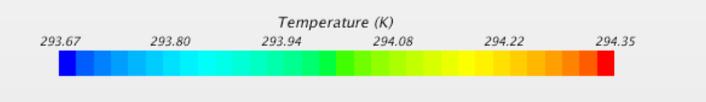
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Temperature Gradient



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Considerations: ASHRAE 170 All Room Requirements: Negative Pressure Relationship **70-75° F Design Temperature** 12 Total ACH

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Pressure Gradient Temperature Gradient Age of Air

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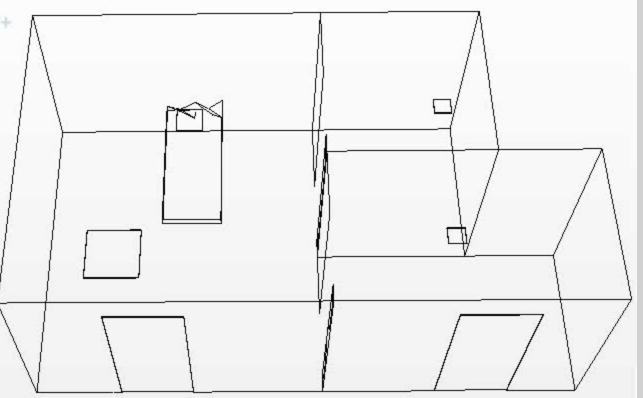
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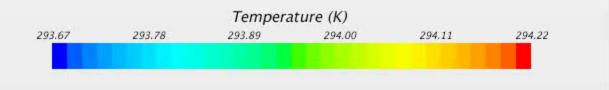
Temperature Gradient



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Considerations: ASHRAE 170 All Room Requirements: Negative Pressure Relationship **70-75° F Design Temperature** 12 Total ACH

Age of Air



Pressure Gradient Temperature Gradient Age of Air

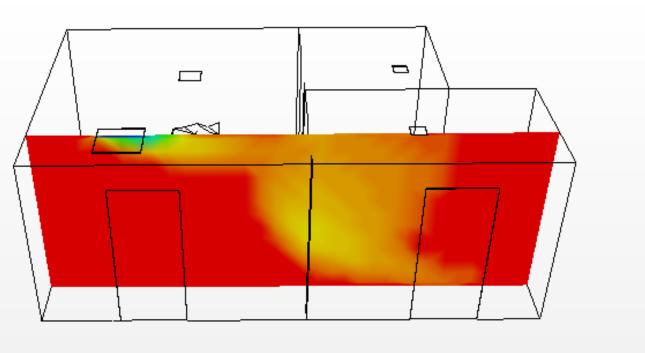
Electrical Breadth • Conclusions

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Considerations: ASHRAE 170 All Room Requirements: Negative Pressure Relationship 70-75° F Design Temperature **12 Total ACH**

Age of Air

 Introduction
 ■ Building Overview J Overall Goals Mechanical Analysis G CFD Analysis Geometry

Pressure Gradient Temperature Gradient Age of Air

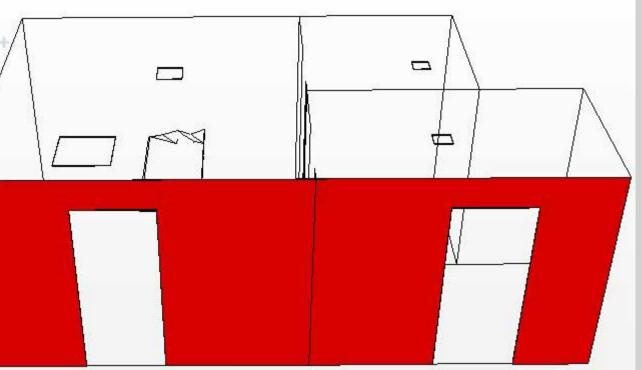
Electrical Breadth • Conclusions

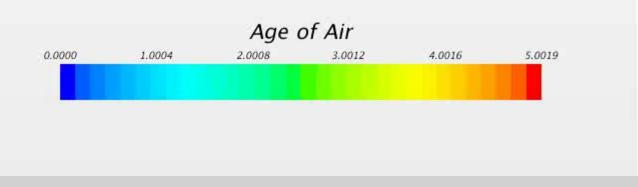
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Considerations: ASHRAE 170 All Room Requirements: Negative Pressure Relationship 70-75° F Design Temperature **12 Total ACH**



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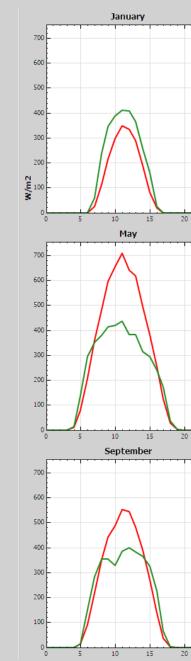


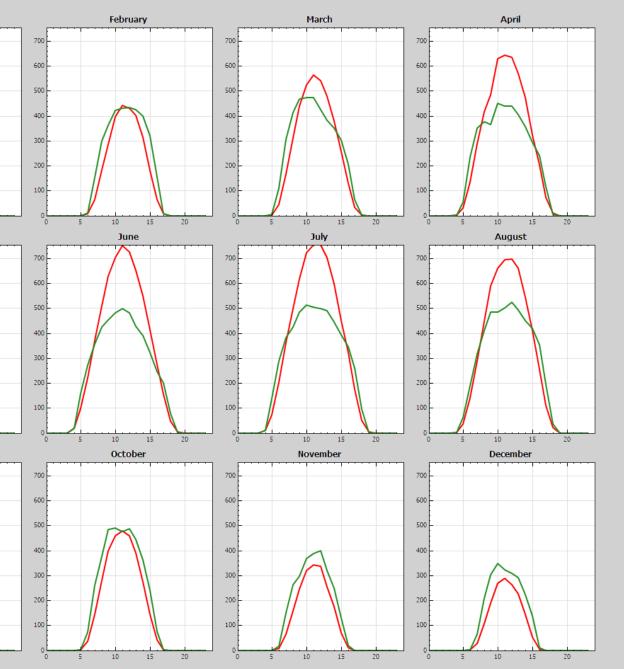


Electrical Breadth Photovoltaic Array

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 Electrical Breadth Site Information Electric Generation Economics
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Site Information





Considerations:

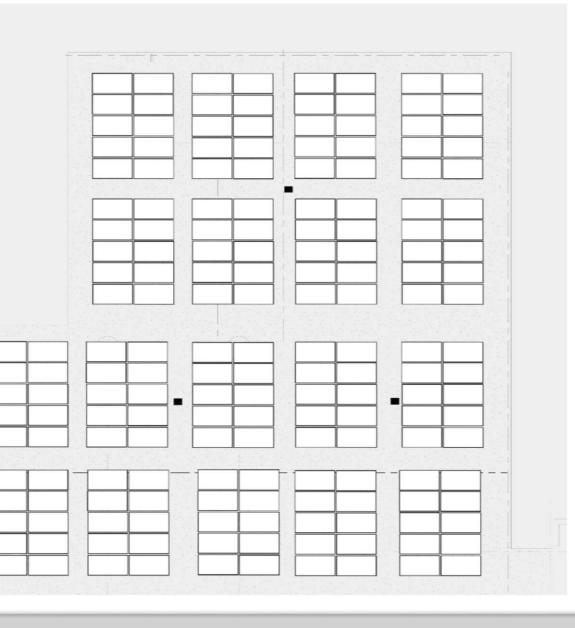
Annual Beam Normal Radiation: 1388.7 kWh/m² Annual Diffuse Radiation: 1454.4 kWh/m²

Electrical Breadth Photovoltaic Array

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Site Information





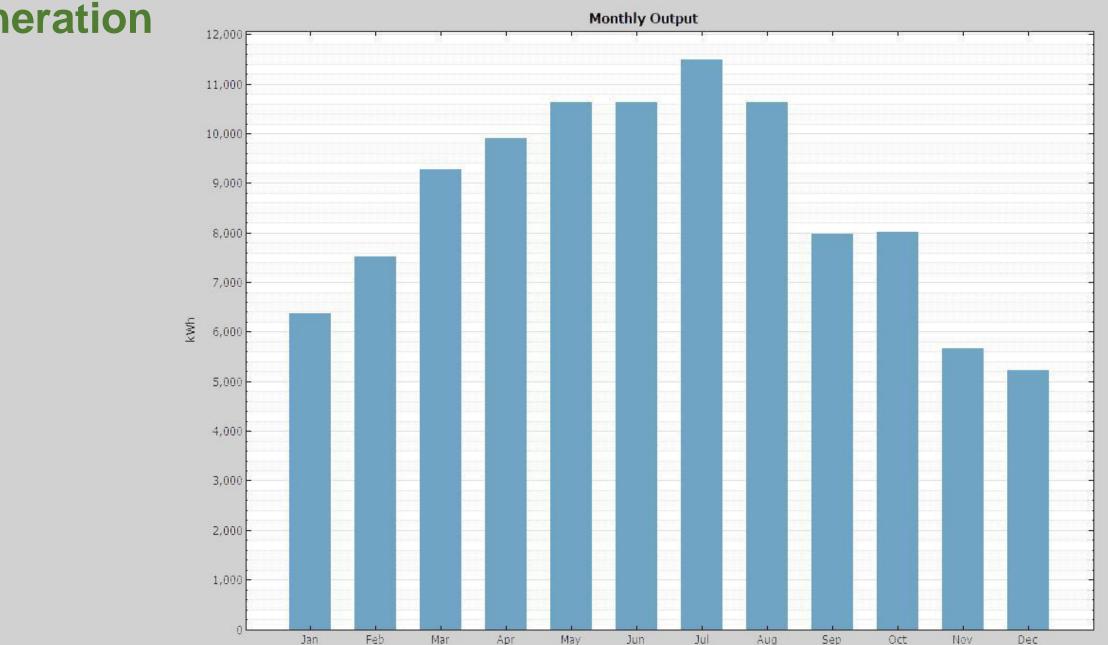
Considerations: Latitude: 41.7° Total Area: 3800 SF

Sector Electrical Breadth Photovoltaic Array

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Electric Generation



Considerations:

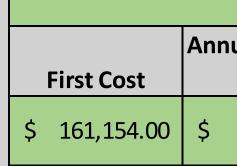
Total Site Electric Consumption: 831,450 kWh Total Generated by Panels: 103,349 kWh Remaining 88% produced by the grid

Electrical Breadth Photovoltaic Array



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Photovoltaic Panels Payback					
nual Consumption	Annual Consumption				
Savings Savings		Payback Period (year)			
11,022.58	9%	14.62			

Payback Period:

Initial Investment

Cash Inflow per Period

Sector Electrical Breadth Photovoltaic Array

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Recommendations

Alte 26% 3 50% 3 32% 7 23% 0 1.5 Ye

Alternative 2: VRF

- 26% Savings in Electrical Consumption
- 50% Savings in Natural Gas Consumption
- 32% Total Annual Utility Cost Savings
- 23% Cost Savings over the Equipment Life4.5 Year Payback





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Pho 12% I 9% R 14.5 `

Photovoltaic Array

- 12% Reduction in Electrical Grid Generation
- 9% Reduction in Annual Cost
- 14.5 Year Payback





Or Conclusions





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Senior Associate BR+A Consulting Engineers, LLC

Engineering Account Executive - Stebbins Duffy, Inc.

n Assistant Professor – Penn State AE Department



PSU Architectural Engineering Department Faculty and Staff AE Class of 2015 Friends & Family

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MORTON HOSPITAL EXPANSION

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MORTON HOSPITAL EXPANSION

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