Hilton Hotel at BWI Airport

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Architectural Engineering – Mechanical Option

Presentation Outline

- Project Background Info
- Existing Mechanical Systems
- Design Objectives
- Mechanical Systems Design
- Energy Analysis
- Overall Cost Analysis
- Acoustical Analysis
- Lighting Analysis
- Conclusions

Project Background Info

Project Background Info

Hilton Hotel

- Location: Linthicum Heights, MD
- Less than 2 miles from BWI Airport)

BWI Airport

Project Background Info

Project Information:

- Function: Full-service hotel
- Project Cost: $27 million (estimated)
- Size: 277,000 sq ft (gross)
- Delivery Method: Design-Build
- Construction Dates: June 2005 - October 2006

Existing Mechanical Systems

Existing Mechanical Systems

Condenser water – boiler loop:

- (2) induced-draft cooling towers
- (3) natural gas boilers
- WSHPs in all 279 guest rooms
- (4) VAV AHUs
- VAV boxes with hot water reheat
- (6) CAV RTUs

Existing Mechanical Systems

Value Engineering:

- Eliminated (2) ACUs for guest room ventilation
  - Approved variance: transfer air from corridors into guest rooms and operable windows
- Eliminated (2) chillers
  - AHUs and RTUs operate like heat pumps on condenser water loop

Design Objectives

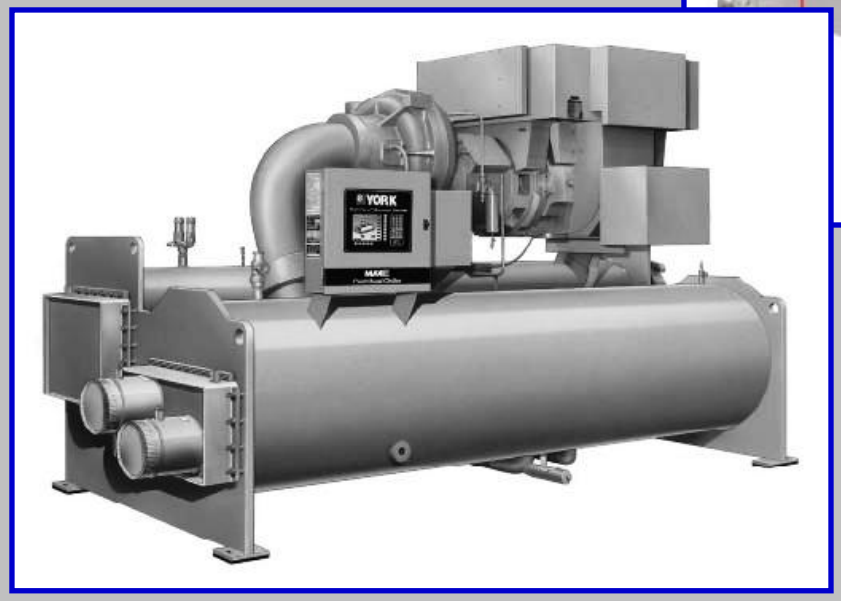
Design Objectives

Main Goal → Increase Energy Efficiency

Other goals:

- Decrease life cycle costs
- Decrease annual energy consumption
- Reduce emissions
- Improve indoor air quality of guest rooms
- Incorporate sustainability
- Use design innovation

Mechanical Systems Design



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Hilton Hotel at BWI Airport

Spring 2006

Mechanical Systems Design

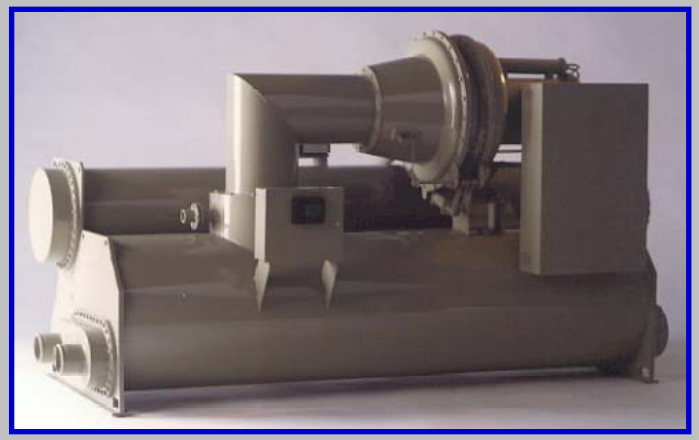
- Chilled water plant design
  - Chilled water and condenser water systems
  - System characteristics
- Water-side free cooling savings
- Impact on air-side equipment
- Guest room indoor air quality
- Equipment selection

Chilled Water Plant Design

Design Process:

- Determine building cooling load

1. CHW flow distribution
2. CHW system characteristics
3. CW system characteristics
4. Chiller selection
5. Adjust cooling tower selection
6. Optimize piping design and pumps
7. Optimize control sequences
8. Calculate life cycle costs



Chilled Water System

- 700 ton peak cooling load
- Variable primary flow with parallel pumping
- CHWS = 44 F, ΔT = 12 F
- 2.0 gpm/ton → 1400 gpm
- (2) parallel centrifugal chillers with VSDs
- 50/50 loads, 350 tons each
- R-123 or R-134A refrigerant choices

ΔT (F)	CHW gpm/ton	CW gpm/ton	CHW Btuh/gpm	CW Btuh/gpm
10	2.4	3.0	5000	5000
12	2.0	2.5	6000	6000
14	1.71	2.14	7018	7009
15	1.6	2.0	7500	7500
16	1.5	1.88	8000	7979
18	1.33	1.67	9023	8982
20	1.2	1.5	10,000	10,000

Flow Characteristics

Refrigerant	Type	Global Warming Potential	Ozone Depletion Potential	Heat of Vaporization (Btu/lbm)	Safety Group
R-11	CFC	4000	1	81	A1
R-12	CFC	7100	1	65	A1
R-22	HCFC	1700	0.055	86	A1
R-123	HCFC	93	0.016	66	B1
R-134A	HFC	1300	0	83	A1
R-718	Water	0	0	1070	A1

Refrigerants

Condenser Water System

- 2-cell, induced-draft cooling towers
- CWS = 85 F, ΔT = 10 F
- 3.0 gpm/ton → 2100 gpm
- Fan control with VSDs
- Efficiency > 70 gpm/hp
- 1200 or 1800 rpm fan motor speed choices

ΔT (F)	CHW gpm/ton	CW gpm/ton	CHW Btuh/gpm	CW Btuh/gpm
10	2.4	3.0	5000	5000
12	2.0	2.5	6000	6000
14	1.71	2.14	7018	7009
15	1.6	2.0	7500	7500
16	1.5	1.88	8000	7979
18	1.33	1.67	9023	8982
20	1.2	1.5	10,000	10,000

Flow Characteristics

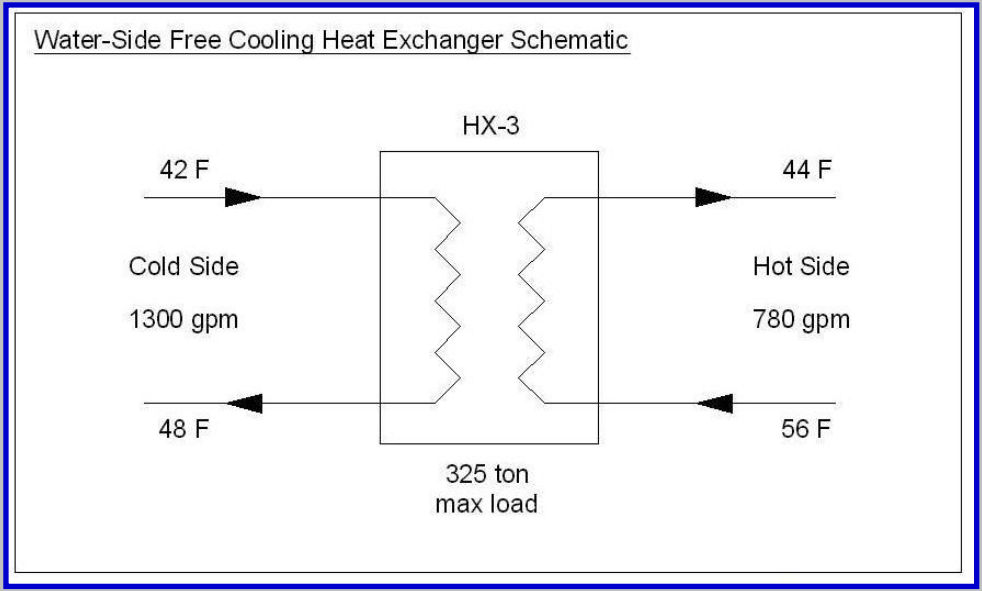
Water-Side Free Cooling

Advantages:

- Decreases chiller energy usage
- Reduces operating costs

Disadvantages:

- Uses more cooling tower fan energy
- Limited operating hours



No of hr WB </= 30F	
January	432
February	312
March	184
April	45
May	3
June	0
July	0
August	0
September	0
October	0
November	75
December	306
Total	**1357**
% of yr	15.49%

Water-Side Free Cooling

Component	With Free Cooling Site Energy (kBtu)	No Free Cooling Site Energy (kBtu)	Savings with Free Cooling (kBtu)	% Savings
Air System Fans	3,423,614	3,423,614	0	0.00%
Cooling	3,452,357	4,255,716	803,359	18.88%
Heating	17,442,574	17,442,574	0	0.00%
Pumps	1,605,084	1,604,931	-153	-0.01%
Cooling Towers	759,293	686,163	-73,130	-10.66%
HVAC Sub-Total	**26,682,921**	**27,412,998**	**730,077**	**2.66%**

Component	With Free Cooling Annual Cost	No Free Cooling Annual Cost	Savings with Free Cooling	% Savings
Air System Fans	$70,297	$70,209	-$88	-0.13%
Cooling	$79,914	$93,363	$13,449	14.41%
Heating	$36,124	$36,121	-$3	-0.01%
Pumps	$33,274	$33,232	-$42	-0.13%
Cooling Towers	$17,486	$16,247	-$1,239	-7.63%
HVAC Sub-Total	**$237,094**	**$249,172**	**$12,078**	**4.85%**

- Saves almost 3% of HVAC energy usage
- Saves $12,000 or 5% of annual operating costs

Air-Side Equipment Impact

Changes:

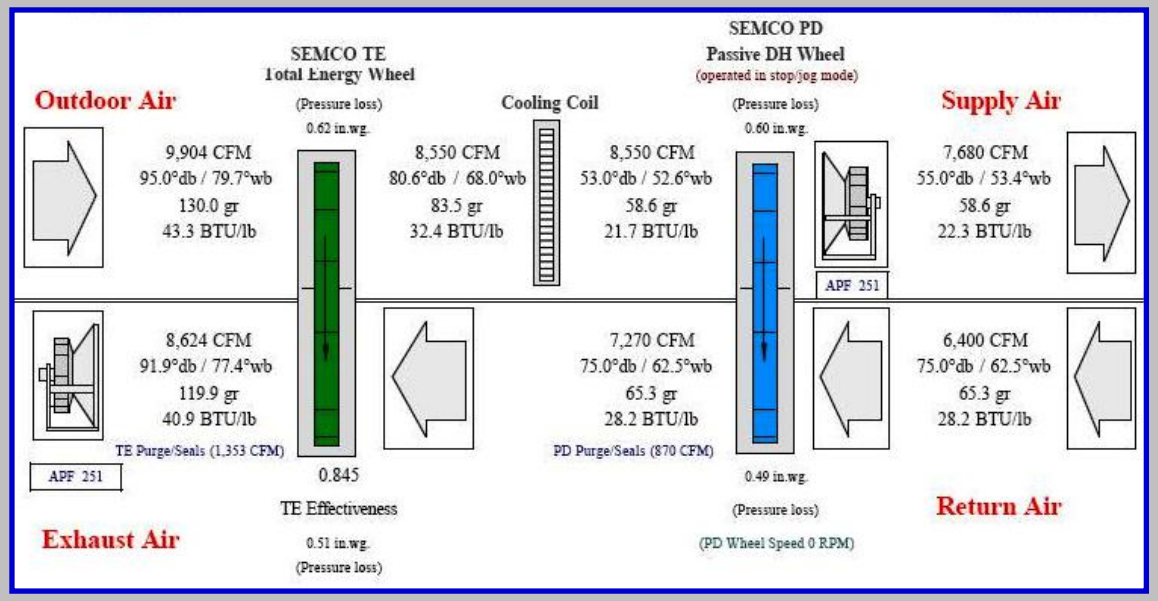
- (4) AHUs changed to CHW cooling coils
- (5) RTUs changed to CHW cooling coils and HW preheat and reheat coils

Stayed the Same:

- Space zoning
- Ventilation sizing
- VAV box layout
- Duct sizing

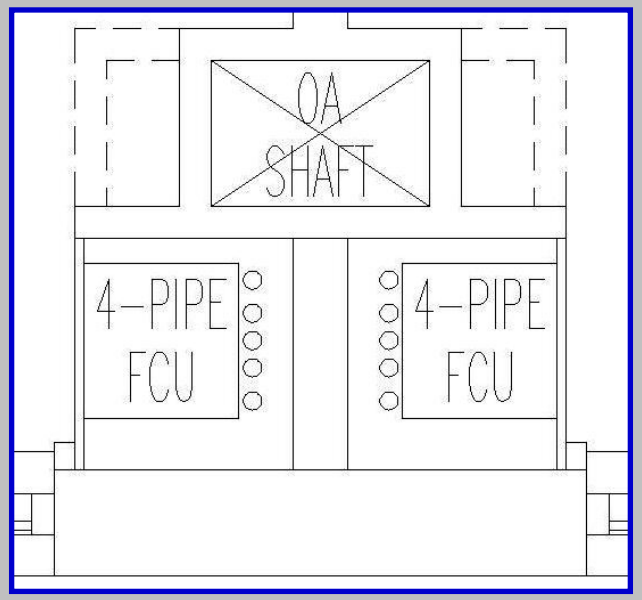
Guest Room IAQ

- (2) new DOAS units - 60 cfm per room
- (2) energy recovery wheels, VSDs on both
  - Enthalpy wheel: 3A molecular sieve, desiccant coating
  - Passive dehumidification wheel: adsorbent desiccant



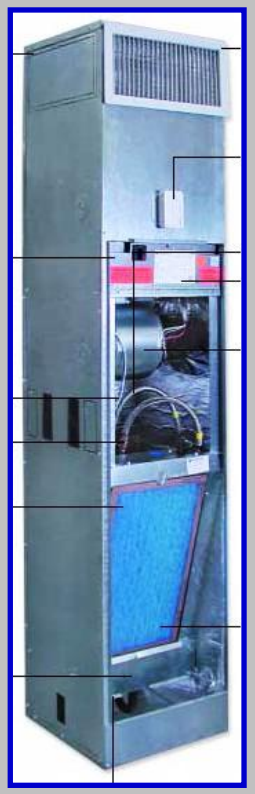
Guest Room IAQ

- 4-pipe FCUs instead of WSHPs or 2-pipe FCUs
  - No compressor at each unit
  - No seasonal changeover
  - Increased flexibility
  - Increased energy efficiency
- 60 cfm of direct ventilation air
  - From DOAS units



Equipment Selection

- (2) Trane CenTraVac centrifugal chillers
- (2) Marley NC-Class induced-draft cooling towers
- (4) Bell & Gossett 1510 series end-suction pumps
  (2) for CHW system and (2) for CW system
- (288) Carrier Airstream fan coil units
- (4) Carrier Aero air handling units
- (5) Carrier Aero CAV rooftop units
- (1) plate-and-frame heat exchanger



Energy Analysis

Energy Analysis

Energy Usage Comparison

- Uses 82% less electric, but 28% more natural gas
- Uses 53% less total energy

Component	Base Case	New Design	Difference	% Diff
HVAC Components				
Electric (kWh)	13,813,310	2,457,286	11,356,024	82.21%
Natural Gas (Therm)	76,290	173,622	-97,332	-127.58%
Non-HVAC Components				
Electric (kWh)	3,682,840	3,682,840	0	0.00%
Natural Gas (Therm)	0	0	0	0.00%
Totals				
Electric (kWh)	17,496,150	6,140,126	11,356,024	64.91%
Natural Gas (Therm)	76,290	173,622	-97,332	-127.58%

Component	Base Case (kBtu)	New Design (kBtu)	Difference (kBtu)	% Diff
Air System Fans	1,611,165	3,423,614	-1,812,449	-112.49%
Cooling	9,513,890	2,735,189	6,778,701	71.25%
Heating	8,101,048	17,442,574	-9,341,526	-115.31%
Pumps	33,564,252	1,527,502	32,036,750	95.45%
Cooling Towers	1,966,906	618,064	1,348,842	68.58%
HVAC Sub-Total	54,757,261	25,746,942	29,010,319	52.98%
Lights	3,954,558	3,954,558	0	0.00%
Electric Equipment	8,611,752	8,611,752	0	0.00%
Non-HVAC Sub-Total	12,566,310	12,566,310	0	0.00%
Grand Total	67,323,571	38,313,252	29,010,319	43.09%

Energy Analysis

Energy Cost Comparison per Year

- New HVAC design cost 78% less than original
- Lights and electric stayed about the same

Component	Base Case (/yr)	New Design (/yr)	Difference (/yr)	% Diff
HVAC Components				
Electric	$959,905	$181,074	$778,831	81.14%
Natural Gas	$17,113	$34,616	($17,503)	-102.28%
HVAC Sub-Total	$977,018	$215,690	$761,328	77.92%
Non-HVAC Components				
Electric	$255,027	$256,782	($1,755)	-0.69%
Non-HVAC Sub-Total	$255,027	$256,782	($1,755)	-0.69%
Grand Total	$1,232,045	$472,472	$759,573	61.65%

Component	Base Case	New Design	Difference	% Diff
Air System Fans	$32,896	$70,277	($37,381)	-113.63%
Cooling	$196,738	$63,402	$133,336	67.77%
Heating	$26,381	$36,124	($9,743)	-36.93%
Pumps	$681,147	$31,683	$649,464	95.35%
Cooling Tower Fans	$39,921	$14,213	$25,708	64.40%
HVAC Sub-Total	$977,082	$215,698	$761,384	77.92%
Lights	$80,260	$80,812	($552)	-0.69%
Electric Equipment	$174,777	$175,979	($1,202)	-0.69%
Non-HVAC Sub-Total	$255,037	$256,791	($1,754)	-0.69%
Grand Total	$1,232,119	$472,490	$759,629	61.65%

Overall Cost Analysis

Overall Cost Analysis

(288) Water-Source Heat Pumps	$430,000
(4) AHUs, (6) RTUs,(43) VAVs, (70') FTRs, and other equipment	$507,100
(2) Cooling Towers	$61,315
(2) Heat Exchangers	$31,810
(4) HW Boilers	$61,000
(23) Pumps	$33,686
(2) HW Generators	$46,430
(2) Water Heaters	$38,548
(43) Fans	$65,200
(5) Sump Pumps	$29,800
(1131) Diffusers	$26,971
(3) Valves and (3) Traps	$30,873
Plumbing Fixtures	$192,896
Sheetmetal Specialties	$25,785
Pipe Fitting Specialties	$17,418
Plumbing Specialties	$61,556
Misc. Equipment	$40,949
Grand Total	**$1,701,337**
Total Used	**$491,315**

Original First Costs

New First Costs

Equipment Costs	Option No	Manufacturer	Model No	Qty	Total Price
Chillers	7	Trane	CTV-AFD	2	$274,372
Cooling Towers	2	Marley	NC8306EL2	2	$92,300
Fan Coil Units	1	Carrier	42S	288	$386,880
Air Handling Units	1	Carrier	39MN	4	$90,900
Rooftop Units	1	Carrier	39MW	5	$79,300
DOAS Units	1	Semco	PVS	2	$193,186
Pumps	1	Bell & Gossett	1510	4	$30,750
Heat Exchanger	1	Bell & Gossett	P41	1	$28,150
Mechanical System Total Equipment First Cost:					**$1,175,838**

Original Equipment Costs	
(288) Water-Source Heat Pumps	$430,000
(2) Cooling Towers	$61,315
Total	**$491,315**

Used First Costs

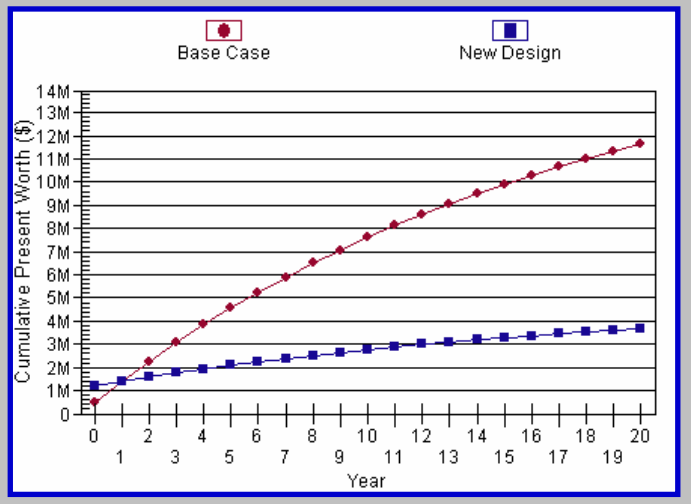
Overall Cost Analysis

Design Case Name	Design Case Short Name	Total Present Worth ($)	Annual Operating Cost ($/yr)	First Cost ($)
Base Case - Original Design	Base Case	$11,623,441	$977,018	$491,315
Chilled Water Plant Design	New Design	$3,673,588	$215,690	$1,175,838
Difference	-	$7,949,853	$761,328	($684,523)
% Diff	-	68.40%	77.92%	-139.32%

- First costs: 40% more
- Annual costs: 78% less

Life Cycle Cost Comparisons

Challenger	Base Case	Additional First Cost ($)	NPW Savings ($)	IRR (%)	Payback Period (yrs)
New Design [Winner]	Base Case	$684,523	$7,949,854	114.23	1.0



Acoustical Analysis

Chiller Acoustical Analysis

Sound Pressure Levels

Original Mech Room	Sound Pressure Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
(1) Pump	80	82	87	86	80	77
(6) Pumps	88	90	95	94	88	85
(1) Boiler	92	89	86	83	80	77
(3) Boilers	95	92	89	86	83	80
Total	**96**	**94**	**96**	**94**	**89**	**86**

New Mech Room	Sound Pressure Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
(1) Centrifugal Chiller	70	72	74	74	78	79
(2) Centrifugal Chillers	73	75	77	77	81	82
(1) Pump	80	82	87	86	80	77
(6) Pumps	88	90	95	94	88	85
(1) Boiler	92	89	86	83	80	77
(3) Boilers	95	92	89	86	83	80
Total	**96**	**94**	**96**	**95**	**90**	**87**

Space	RC Level Range	RC Level Used
Restaurant	35-40	35

Chiller Acoustical Analysis

Transmission Loss Calculations

Original Mech System Design	Sound Pressure Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Mech Room Noise	96	94	96	94	89	86
RC-30 Background Noise	50	45	40	35	30	25
Required NR (dB)	46	49	56	59	59	61
$10*\log(a_2/S)$	-3	-2	0	0	0	0
Required TL (dB)	43	48	56	60	59	61
12 in Concrete Slab Ceiling	44	49	58	65	73	78

New Mech System Design	Sound Pressure Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Mech Room Noise	96	94	96	95	90	87
RC-30 Background Noise	50	45	40	35	30	25
Required NR (dB)	46	49	56	60	60	62
$10*\log(a_2/S)$	-3	-2	0	0	0	0
Required TL (dB)	43	48	56	60	60	63
12 in Concrete Slab Ceiling	44	49	58	65	73	78

FCU Acoustical Analysis

Sound Power Calculations

Typical Guest Room	Octave Band Center Frequency					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
RC-30 Sound Pressure Level (dB)	45	40	35	30	25	20
Sabine Absorption (α_{SAB})	0.33	0.10	0.09	0.12	0.22	0.23
Room Constant (R_T)	587.87	141.02	113.02	164.49	336.83	358.75
Max Sound Power Level (dB)	67	55	50	46	44	40

Typical Guest Room	Sound Power Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Max Sound Power Level	67	55	50	46	44	40
FCU-1: 42SGA03	65	57	53	49	41	39
FCU-1 Compliance?	Yes	No	No	No	Yes	Yes
FCU-2: 42SGA04	69	60	56	51	42	40
FCU-2 Compliance?	No	No	No	No	Yes	Yes

- RC-30?
  - No

Space	RC Level Range	RC Level Used
Guest Room	25-35	30

FCU Acoustical Analysis

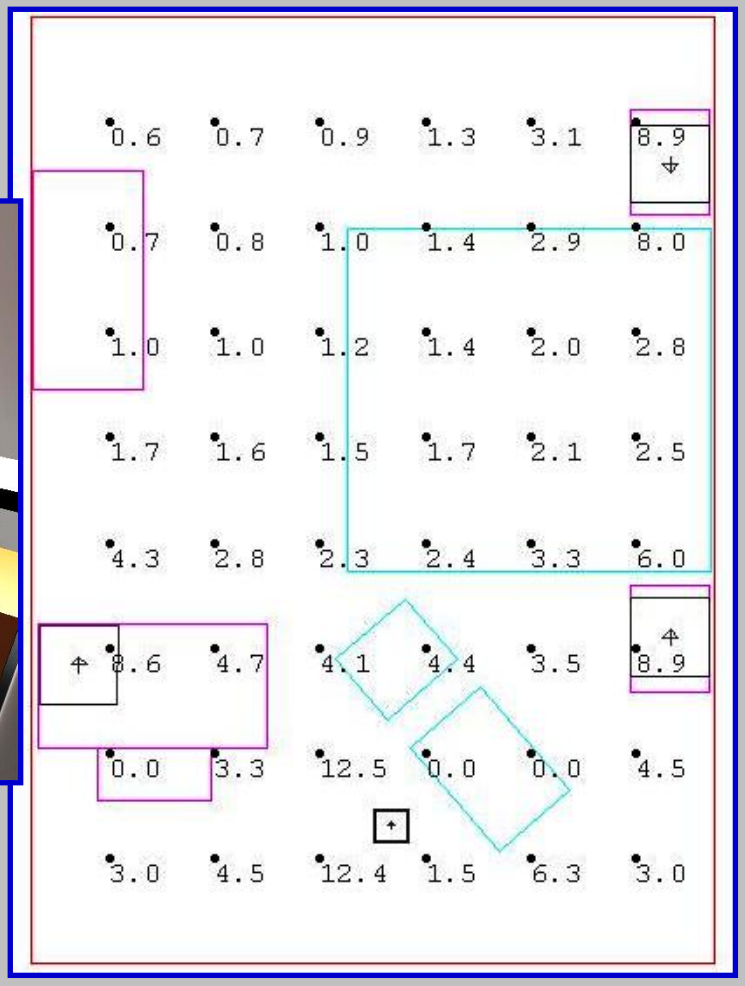
Adjusted Sound Power Calculations

Typical Guest Room	Octave Band Center Frequency					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
RC-35 Sound Pressure Level (dB)	50	45	40	35	30	25
Sabine Absorption (αSAB)	0.33	0.10	0.09	0.12	0.22	0.23
Room Constant (RT)	587.87	141.02	113.02	164.49	336.83	358.75
Max Sound Power Level (dB)	72	60	55	51	49	45

Typical Guest Room	Sound Power Level (dB)					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Max Sound Power Level	72	60	55	51	49	45
FCU-1: 42SGA03	65	57	53	49	41	39
FCU-1 Compliance?	Yes	Yes	Yes	Yes	Yes	Yes
FCU-2: 42SGA04	69	60	56	51	42	40
FCU-2 Compliance?	Yes	Yes	No	Yes	Yes	Yes

- RC-35?
  - Yes

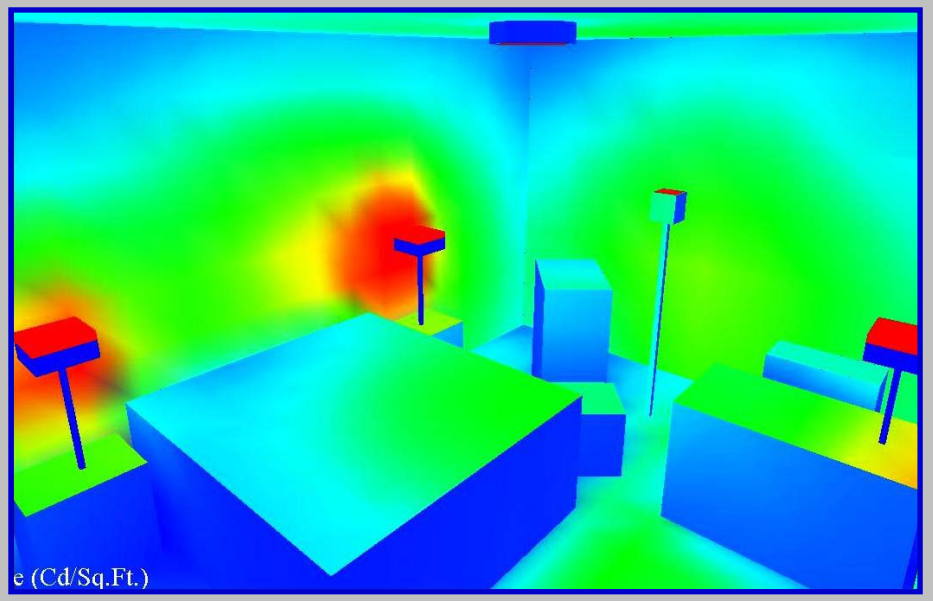
Lighting Analysis



Lighting Analysis

Lighting Options:

- Original incandescent lamps
- Change to compact fluorescent lamps
- (2) surface mounted CFL options
- (2) surface mounted disk options
  - CFL and circular fluorescent
- Combination of SM disk and CFL lamps

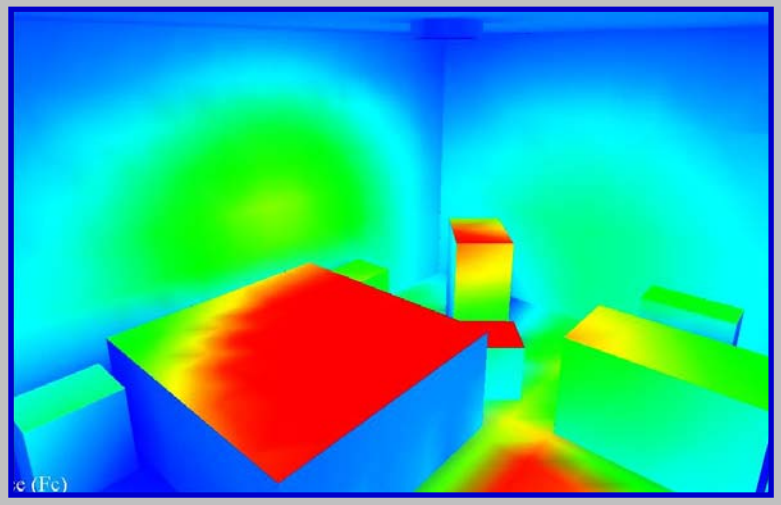


Lighting Analysis

Option No	Option	Watts per Room	Total Elec Use (kW)	Avg hr per day	Avg hr per yr	Total Elec Use (kWh per yr)	Energy Savings (kWh)**
Base	Inc	400	111.60	4	1460	162,936	-
1	CFL	108	30.13	4	1460	43,993	118,943
2	SM 1	104	29.02	4	1460	42,363	120,573
3	SM 2	156	43.52	4	1460	63,545	99,391
4	SM Disk 1	62	17.30	4	1460	25,255	137,681
5	SM Disk 2	72	20.09	4	1460	29,328	133,608
6	Combo	170	47.43	4	1460	69,248	93,688

**vs Base

Energy Savings



Electric Cost Savings

Option No	Option	Avg Elec Cost (per kWh)***	Elec Cost (per yr)	Elec Cost Savings**
Base	Inc	$0.071	$11,568.46	-
1	CFL	$0.071	$3,123.48	$8,444.97
2	SM 1	$0.071	$3,007.80	$8,560.66
3	SM 2	$0.071	$4,511.70	$7,056.76
4	SM Disk 1	$0.071	$1,793.11	$9,775.35
5	SM Disk 2	$0.071	$2,082.32	$9,486.13
6	Combo	$0.071	$4,916.59	$6,651.86

***Calc avg from rates **vs Base

Lighting Analysis

Lamp Cost Savings

Option No	Option	Total Lamp Cost	Avg Relamp Cost (per yr)*	Total Cost (per yr)	Lamp Cost Savings**
Base	Inc	$2.36	$2.30	$640.88	-
1	CFL	$18.36	$2.68	$747.88	-$106.99
2	SM 1	$15.92	$2.32	$648.49	-$7.60
3	SM 2	$23.88	$3.49	$972.73	-$331.85
4	SM Disk 1	$31.98	$2.92	$814.17	-$173.29
5	SM Disk 2	$30.76	$2.81	$783.11	-$142.23
6	Combo	$50.34	$5.60	$1,562.05	-$921.17
			*(Total lamp cost)/(avg life)		**vs Base

Yearly Total Savings

Option No	Option	Yearly Total Cost Savings**
Base	Inc	-
1	CFL	$8,337.98
2	SM 1	$8,553.05
3	SM 2	$6,724.91
4	SM Disk 1	$9,602.06
5	SM Disk 2	$9,343.90
6	Combo	$5,730.70
		**vs Base

Conclusions

Conclusions

Central chilled water plant benefits:

- Increased energy efficiency
- Reduced life cycle costs
- Improved guest room IAQ
- Decreased overall energy usage
- Reduced emissions
- Overall better system

Acknowledgements

- Thank you to everyone for their support!!
- My loving parents and brother, Jared
- Julie – I couldn't have survived without you!!
- Entire AE class of 2006 – you guys are awesome…
  - Big Jay, B-rad, Senk, and Roni
- The entire AE Department
  - Moses, Dr B, and JJ
- Southland Industries, Inc
  - Scott Winkler and Andy Tech
- And most importantly… God

Questions...

...and Answers

Thank you!