- Introduction
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- Mechanical Depth
  - DOAS with Active Chilled Beams
  - Solar Thermal Water Heating System
- Structural Breadth Study
- Credits and Acknowledgements

Slippery Rock University Student Union

Slippery Rock, PA

By Gary Haffely

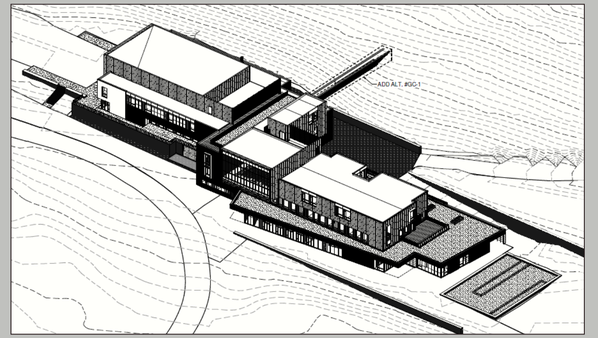
April 12, 2011

Option: Mechanical

Advisor: Dustin Eplee

Project Information

Building Name:	SRU Student Union
Location:	Slippery Rock, PA
Occupancy type:	Student Center, Office
Size:	105,000 SF
Total Cost	$32,000,000
Number of Stories:	3 Floors
Project Start	July 2010
Project Finish	November 2011



Project Goals

- **Achieve LEED Silver Certification**
- **Create a center gathering space for students, faculty and visitors**
- **Demonstrate the benefits of green building design and sustainability**
- **Provide enhanced comfort and control to occupants**

Existing Mechanical System – Air Side

- Introduction
- **Existing Mechanical System Design Overview**
  - **Air Side**
  - Heating
  - Cooling
- Proposed Redesign Overview
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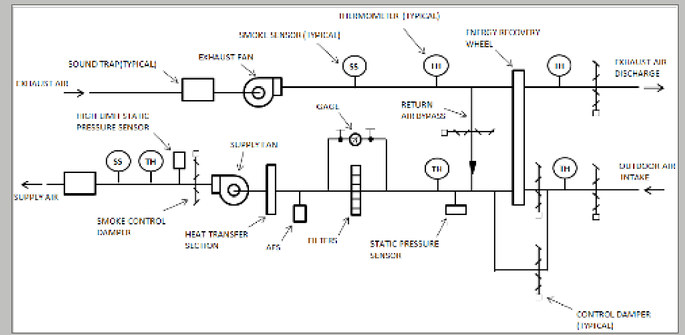
- **(5) VAV Air Handling Units with energy recovery wheel, heat pump, and variable frequency drives**
- **(3) Make-up Air Units**
- **Ductless Split System**

Utility Rates:

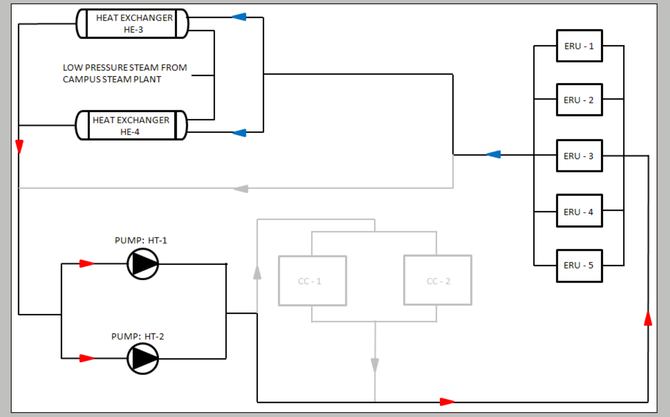
- **Electricity: $0.0462/kWh**
- **Natural Gas: $1.16/therm**
- **Steam: $1.057/therm**



Existing Mechanical System – Heating

Water Source Heat Transfer System

- Primary heating



Existing Mechanical System – Heating

Water Source Heat Transfer System

- Primary heating

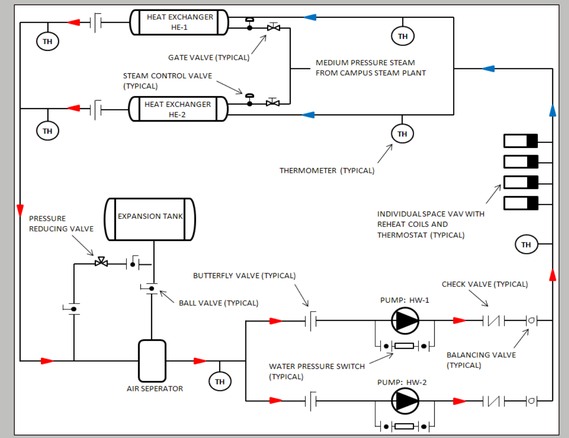
Hot Water Heating System

- Secondary heating

Peak Heating Load

-6,630 Mbh peak heating load

$16,425.00/year



Existing Mechanical System – Cooling

-(2) 175 ton Closed Circuit Coolers

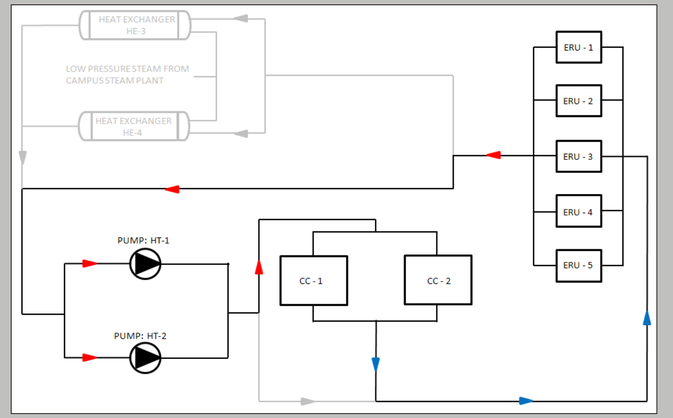
Water Source Heat Transfer System

- Primary cooling

Peak Cooling Load

- 293 ton peak cooling load

$9,900.00/year Cooling



Redesign Goals

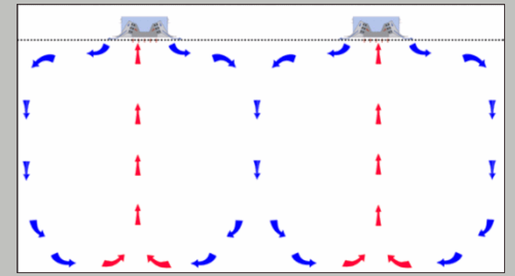
Overall Redesign Goals:

- **Apply alternative space heating and cooling techniques**
- **Incorporate renewable energy sources**
- **Reduce energy consumption**

DOAS Objectives

DOAS with Active Chilled Beams Objectives:

- **Use a dedicated outdoor air system with active chilled beams to adequately heat, cool and ventilate spaces**
- **Maintain space comfort and control**
- **Reduce the number of AHU's**
- **Decrease amount of sheet metal from ductwork**



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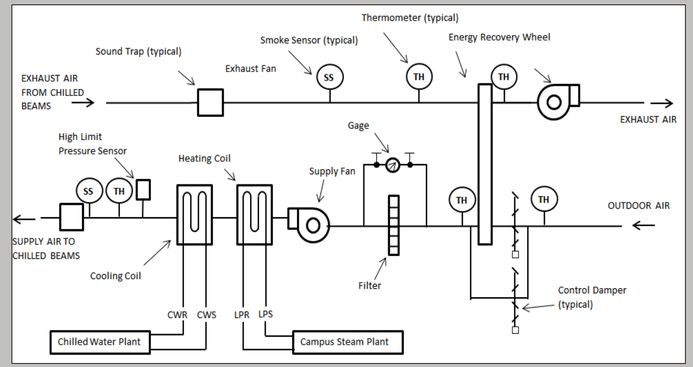
Redesign Energy Saving Techniques:

1. **Dedicated Outdoor Air System**

– Uses minimum ventilation required

– Decouples latent and sensible loads

– Consumes less building materials



Redesign System Components

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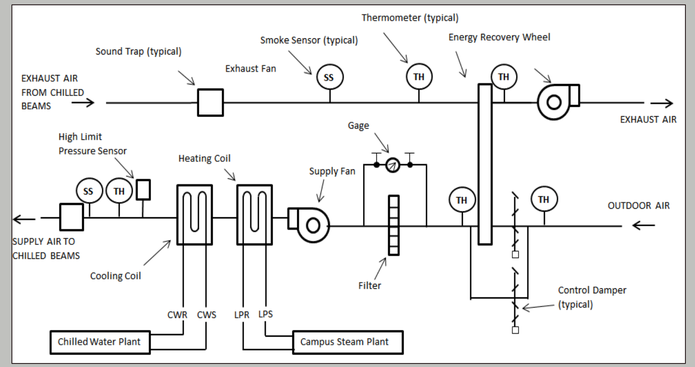
Redesign Energy Saving Techniques:

1. **Dedicated Outdoor Air System**
2. **Enthalpy Wheel**

– Recovers otherwise wasted energy from exhaust air

– Preheats and preconditions incoming outdoor air reducing load on coils



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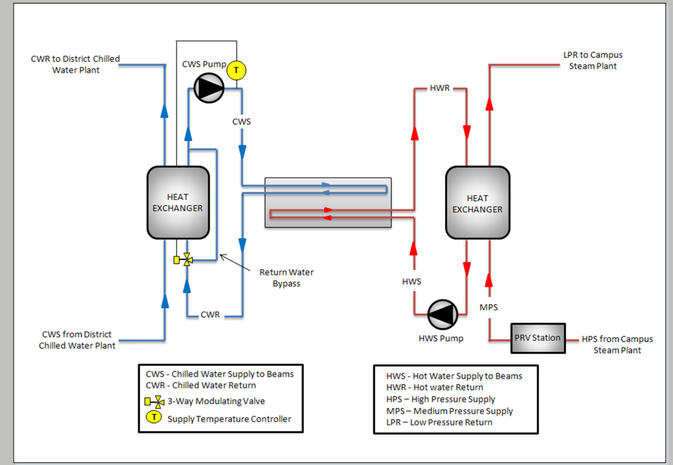
Redesign Energy Saving Techniques:

1. **Dedicated Outdoor Air System**
2. **Enthalpy Wheel**
3. **Active Chilled Beams**

– Treats sensible space loads
– Uses simple space controls
– Reduces fan energy consumption



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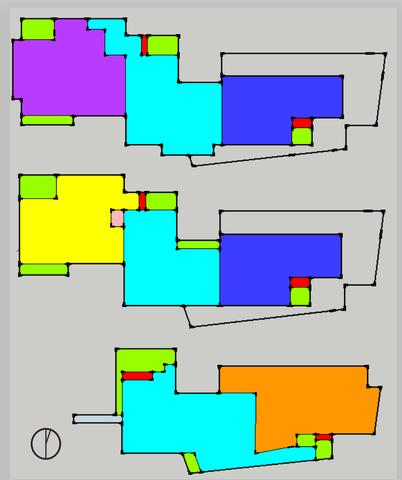
Green: Heating Only - Stairs
Light Blue: ERU 1 - Theater, lounges
Yellow: ERU 2 - Dining, corridors
Dark Blue: ERU 3 - Meeting rooms
Purple: ERU 4 - Ballrooms
Orange: ERU 5 - Bookstore
Pink: MUA - Kitchen
Red: Ductless Split System - Electrical, IT



Existing Layout

Green: Heating Only - Stairs
Purple: ERU 4 - Ballroom
Yellow: ERU 2 - Dining, corridors
Dark Blue: DOAS - Bookstore, meeting, offices
Pink: MUA - Kitchen
Red: Ductless Split System - Electrical, IT

Redesign Layout

- Introduction
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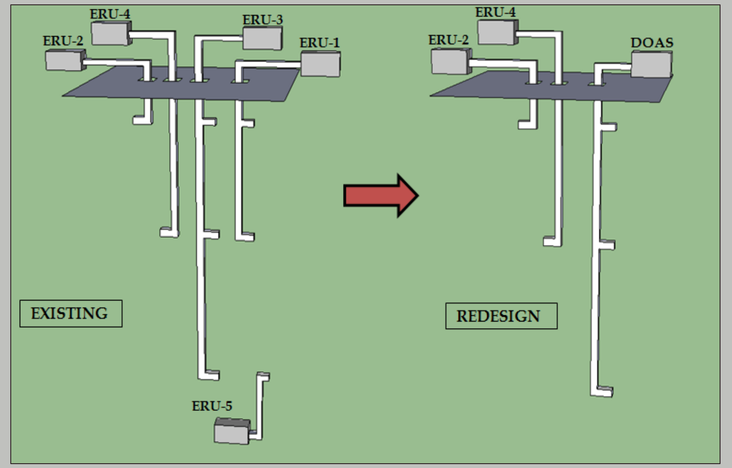

Energy and Cost Evaluation

- Introduction
- Existing Mechanical System Design Overview
- Proposed Redesign Overview
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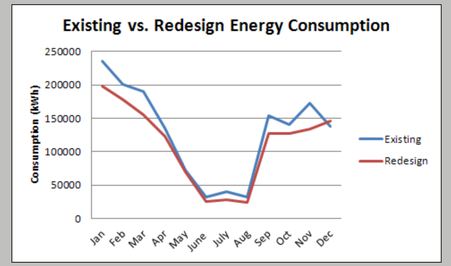

Energy Consumption (kWh)	
Existing	1544209
Redesign	1338466
Net Savings	205743

Estimated Payback: 7 years

Existing Annual Energy Cost				
Natural Gas ($)	Electricity ($)	Steam ($)	Water ($)	Total ($)
8712.60	67894.99	12636.45	0.00	89244.04
Redesign Annual Energy Cost				
Natural Gas ($)	Electricity ($)	Steam ($)	Water ($)	Total
12067.58	63629.73	5135.97	2425.05	83258.33

Annual Cost Savings = $5,985.71

Existing Total of Takeoffs		Redesign Total Takeoffs	
VAV Boxes	$110,081.00	Chilled Beams	$378,678.00
Air Handlers	$515,000.00	Piping	$144,664.60
Diffusers	$17,152.30	Air Handlers	$209,000.00
Sheet Metal	$394,018.08	Sheet Metal	$300,960.42
		CW Pumps	$20,822.00
		CW Heat Exchangers	$24,061.60
Total	$1,036,251.38	Total	$1,078,186.62

Additional Cost = $41,935.24

DOAS with Active Chilled Beams Conclusions:

- **Meet heating, cooling and ventilation requirements while reducing energy consumption**
- **Successfully reduced the amount of sheet metal and total number of air handlers used in the system**
- **Maintained space comfort and control**

Solar Collector Objectives

Solar Thermal Water Heating System Objectives:

- **Utilize solar collectors to reduce steam consumption used for domestic hot water**
- **Maximize system performance**
- **Determine system feasibility**

Gary Haffely
Mechanical Option

Solar Collector Design

Advisor: Dustin Eplee
SRU Student Union

- Introduction
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  - **Solar Thermal Water Heating System**
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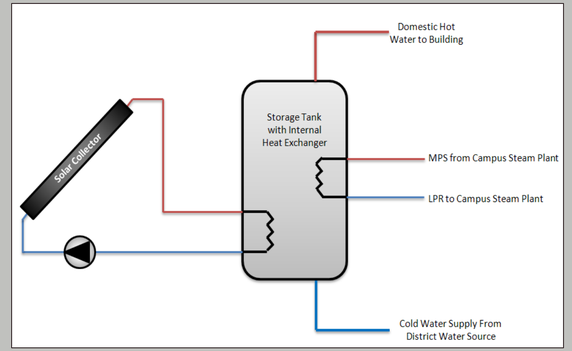
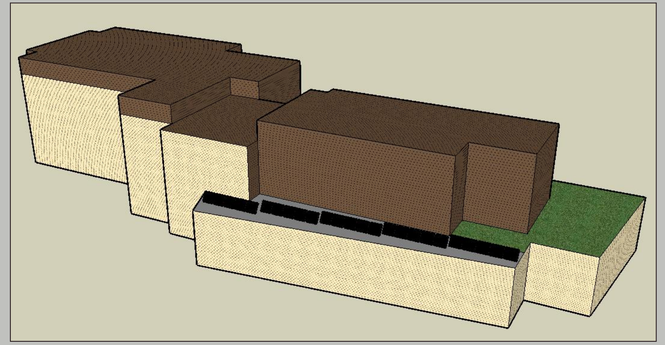
Solar Thermal Water Heating Design:

- Replace 3000 square feet of green roof with 25 evacuated tube arrays
- Orient collectors facing south at a tilt of 40 degrees





Southern Face of SRU Student Union

Gary Haffely
Mechanical Option

Solar Collector Cost Evaluation

Advisor: Dustin Eplee
SRU Student Union

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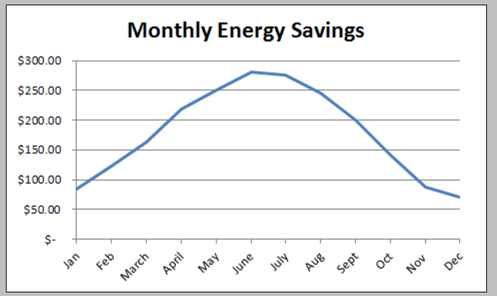
Solar Thermal Water Heating Cost Analysis:

- Total First Cost: **$85,610.00**
- Total Annual Energy Savings: **$2,141.65**
- Green Roof Savings: **$45,300**
- Estimated payback without government incentives: **18.8 years**

Cost Breakdown	
Solar Collector Cost	($85,610.00)
Incentive	$29,963.50
Tax Credit	$25,683.00
Green Roof Savings	$45,300.00
Net Savings	$15,336.50



Solar Collector Design Conclusions

System Conclusions:

- Advantages:
  - Incorporate renewable energy sources
  - Energy savings
- Disadvantages:
  - Collectors affect building aesthetics
  - Partial obstruction of interior office views

- Successfully reduced steam consumption while maximizing possible system performance
- Not worthwhile unless government incentives apply

Structural Redesign Objectives

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Structural Breadth Objectives:

- Change existing composite steel deck floor system to precast hollow core planks in the ballroom
- Resize beam and girder framing based on new load
- Determine total cost and feasibility of new system

Superimposed Dead Load – 15 psf
Dead Load – 15 psf
Live Load (ballroom) – 100 psf

Total Loads – 130 psf

Prestressed Concrete
8"x4'-0" Hollow Core Plank

1 Hour Fire Resistance Rating With 2" Topping

PHYSICAL PROPERTIES
Composite Section

A_c = 301 in.^{2} Precast b_w = 13.13 in.
I_c = 3134 in.^{4} Precast S_{bc}= 616 in.^{3}
Y_{bc}= 5.09 in. Topping S_{tc} = 902 in.^{3}
Y_{tc}= 2.91 in. Precast S_{bp} = 1076 in.^{3}
Y_{ts} = 4.91 in. Precast Wt. = 245 PLF
Precast Wt. = 61.25 PSF

SAFE SUPERIMPOSED SERVICE LOADS — IBC 2006 & ACI 318-05 (1.2 D + 1.6 L)

Strand Pattern		SPAN (FEET)																
		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
4 - 1/2"ø	LOAD (PSF)	280	256	226	199	190	170	151	137	119	106	93	82	72						
6 - 1/2"ø	LOAD (PSF)	366	341	318	299	271	245	223	211	196	176	159	143	129	113	98	85	74	63	53
7 - 1/2"ø	LOAD (PSF)	367	342	320	300	282	265	243	221	202	189	180	165	151	134	118	104	91	80	69

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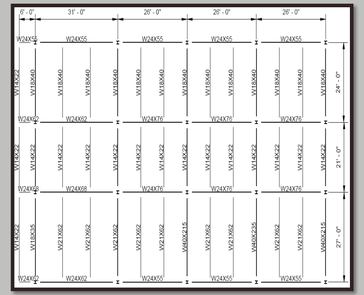
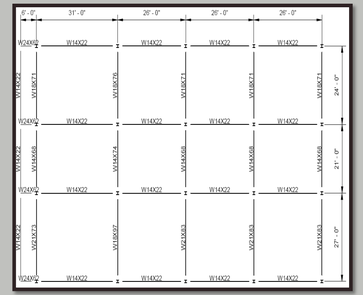


Existing Layout



Redesign Layout

Beam Sizing and Deflection Checks

Beam Tag	W	Length of Beam	Weight of Beam	Trib Width	Inertia (I)	Moment (M_U)	With S-W (M_U)	Capacity	Δ_{LL}	Allowable Δ_{LL}	Δ_{TL}	Allowable Δ_{TL}	Check
	psf	ft	plf	ft	in^4	ft-k	ft-k	ft-k	in	in	in	in	
W14X68	281.5	21	68	26	722	403.5	407.2	431	0.08	0.7	0.11	1.05	✓
W14X74	286	21	74	28.5	795	449.3	453.4	473	0.08	0.7	0.10	1.05	✓
W18X71	281.5	24	71	26	1170	527.0	532.1	548	0.09	0.8	0.11	1.2	✓
W18X76	286	24	76	28.5	1330	586.9	592.3	611	0.08	0.8	0.10	1.2	✓
W18X97	286	27	97	28.5	1750	742.8	751.6	791	0.09	0.9	0.12	1.35	✓
W21X83	281.5	27	83	26	1830	666.9	674.5	735	0.09	0.9	0.12	1.35	✓

Structural Redesign Conclusions

Structural Breadth Conclusions:

- Overall Cost Savings: **$83,287.75**
- Will speed construction time
- Difficult to apply to entire building

Steel Beam Redesign			
Pounds of Steel Beams	Tons of Steel	$/ton	Total Cost $
40153	20.08	3250.00	65248.63
Steel Connections Ratio	Tons of Steel	$/ton	Total Cost $
20.08/158 = x/15.8	2.01	3250.00	6532.50
			Steel Total $
			71781.13

Precast Hollow Core Plank Redesign			
Plank Thickness	Area sf	$/sf	Plank Cost $
8" Planks	5616	7.50	42120.00
10" Planks	2702	8.50	22967.00
	8318		65087.00

Concrete Topping			
Material	Area sf	$/sf	Topping Cost $
2" Topping	8318	2.50	20795.00
			Total Cost $
			157663.13

Existing

Steel Beam Redesign			
Pounds of Steel Beams	Tons of Steel	$/ton	Total Cost $
83611	41.81	3250.00	135867.88
Steel Connections Ratio	Tons of Steel	$/ton	Total Cost $
41.27/158 = x/15.8	4.18	3250.00	13585.00
			Steel Total $
			149452.88

Metal Decking			
Plank Thickness	Area sf	$/sf	Plank Cost $
3" Metal Deck	8318	2.50	20795.00

Concrete Slab on Deck			
Material	Area sf	$/sf	Topping Cost $
2" Topping	8318	8.50	70703.00
			Total Cost $
			240950.88

Redesign

Credits and Acknowledgements

- Herbert Carlson: Slippery Rock University
- Nick Rosko: CJL Engineering
- Dustin Eplee: Thesis Advisor
- Friends and Family