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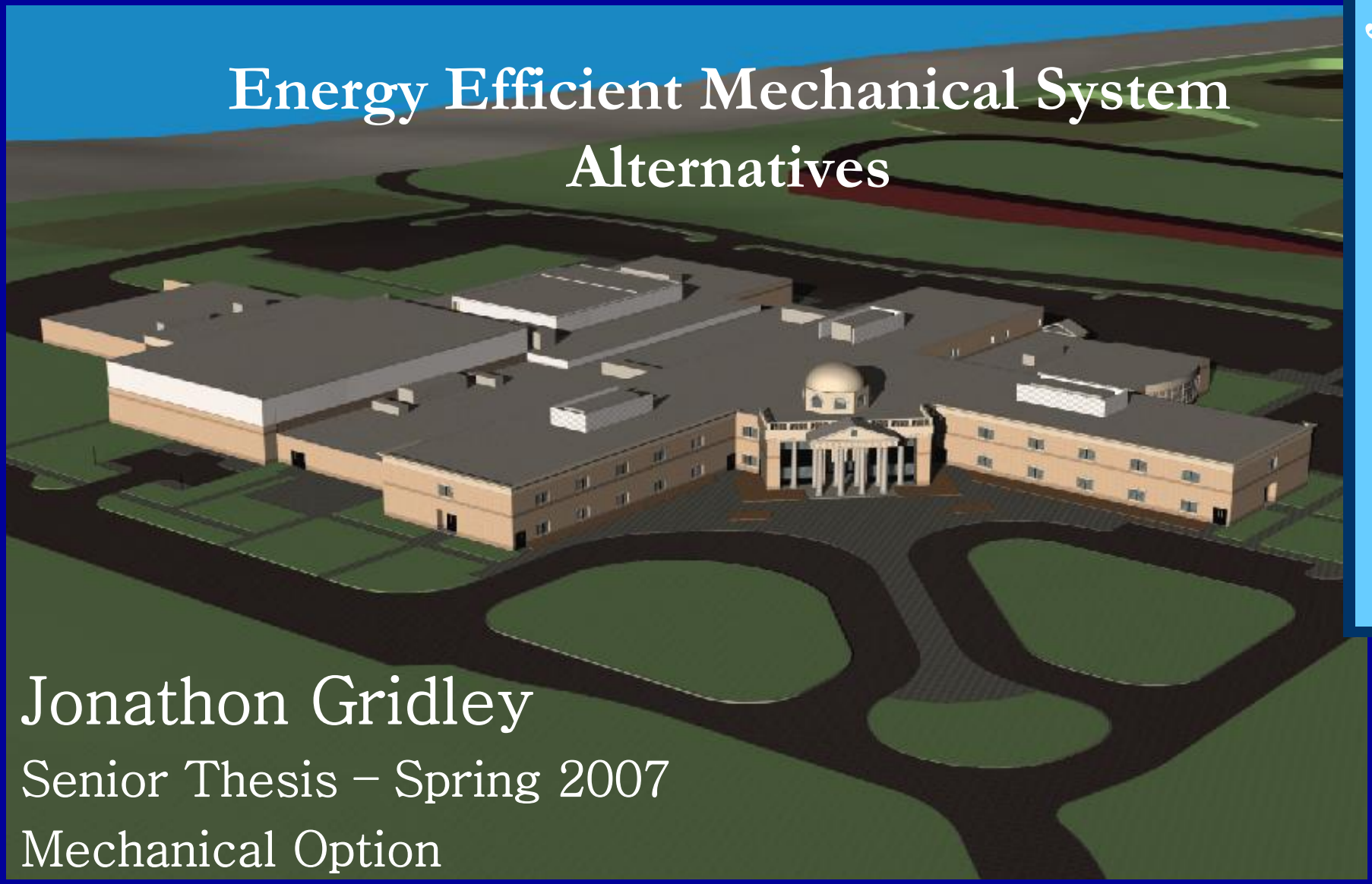
South Jefferson High School

Energy Efficient Mechanical System Alternatives



Jonathon Gridley

Senior Thesis – Spring 2007

Mechanical Option

South Jefferson High School

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PRESENTATION OUTLINE

South Jefferson High School

- BUILDING BACKGROUND
- EXISTING SYSTEMS
- DESIGN OBJECTIVES
- MECHANICAL SYSTEM REDESIGNS
  - VAV System with Chilled Water Plant
  - Ground Source Heat Pump
  - Air-to-Air Heat Recovery and Humidity Control
  - Energy and Cost Analysis
  - Emissions
- BREADTH TOPICS
  - Lighting
  - Construction Management
- CONCLUSIONS AND RECOMMENDATIONS
- ACKNOWLEDGMENTS
- QUESTIONS

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BUILDING BACKGROUND

South Jefferson High School

Location and Site: Charles Town, WV 25414

Occupancy : 1200 students

Size: 199,717 sq.ft.

Number of Stories: 2 stories

Total Building Cost: $34 Million

Dates of Construction: February 2006 – August 2007

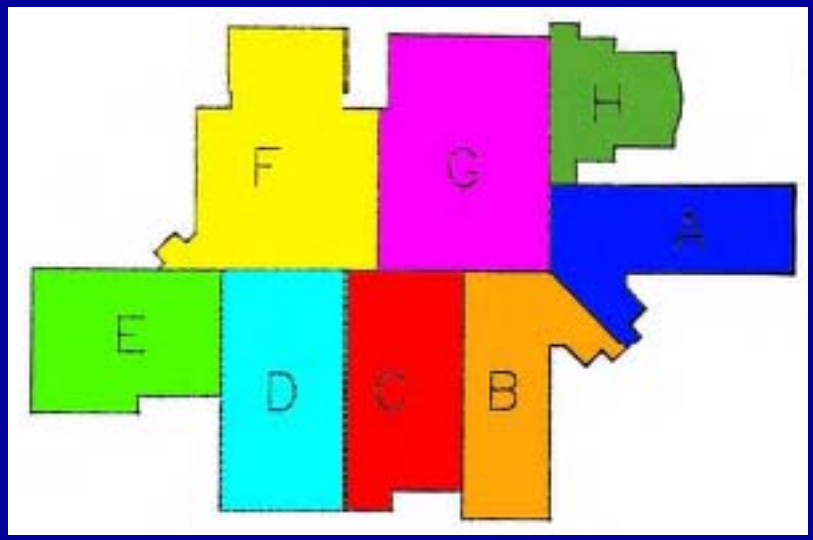
Project Delivery Method: Design-Bid-Build

BUILDING BACKGROUND

South Jefferson High School

BUILDING LAYOUT AND USES:

- Academic Wings and Administration Area
- Learning Resource Center and Science and Technology
- Dining
- Kitchen/Servery
- Physical Education
- Creative Arts
- Library



Building Zone Designations

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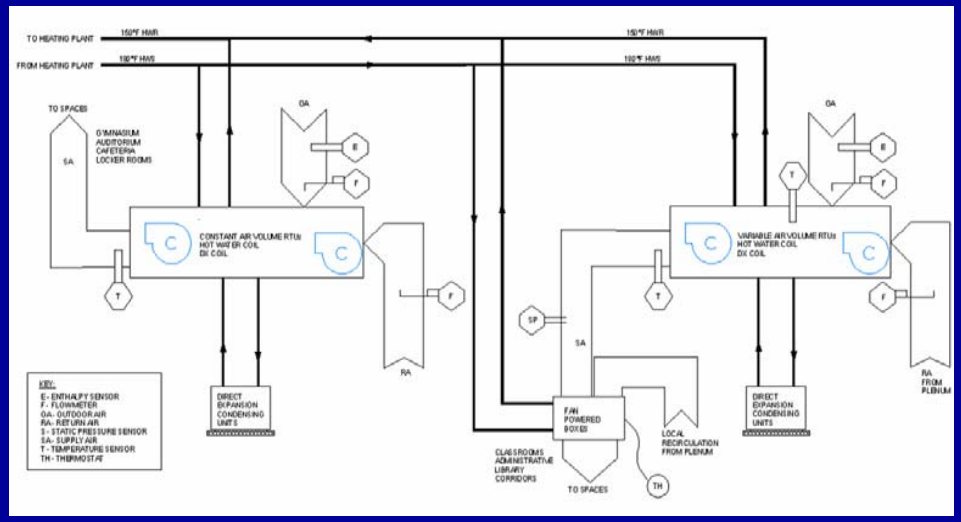
EXISTING SYSTEMS

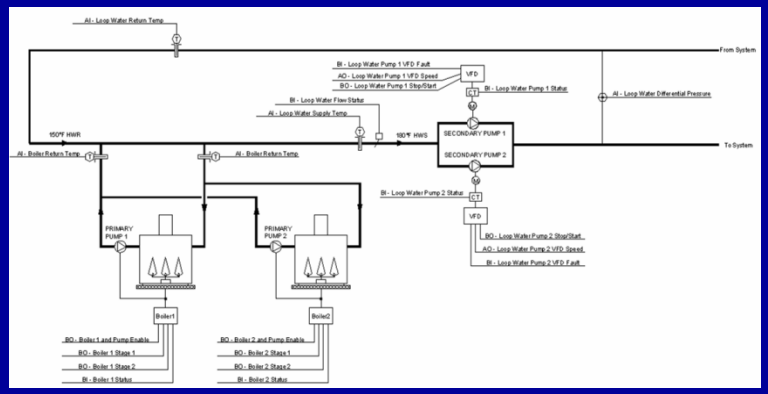
SOUTH JEFFERSON HIGH SCHOOL

MECHANICAL SYSTEM:

- **AIR SIDE**
  - **14 Packaged Roof Top Units ranging from 6,000 to 25,500 CFM**
    - **(6) VAV System with Fan Powered Boxes and VFD**
    - **(8) Constant Volume Air Handlers**
- **WATER SIDE**
  - **Two 4,717 MBH Electric Boilers**
    - **Primary-Secondary Variable Volume Pumping**



Air Side Schematic



Heating Plant Schematic

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DESIGN OBJECTIVES

South Jefferson High School

Green Design Initiative:

- Reduce energy consumption and emission
- Low Operating and Maintenance Costs
- Short life cycle payback
- Improve indoor air quality

Alternative Mechanical Systems:

-VAV System with Chilled Water Plant

- Ground Source Heat Pump System

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MECHANICAL SYSTEM REDESIGNS:

VAV System with Chilled Water Plant

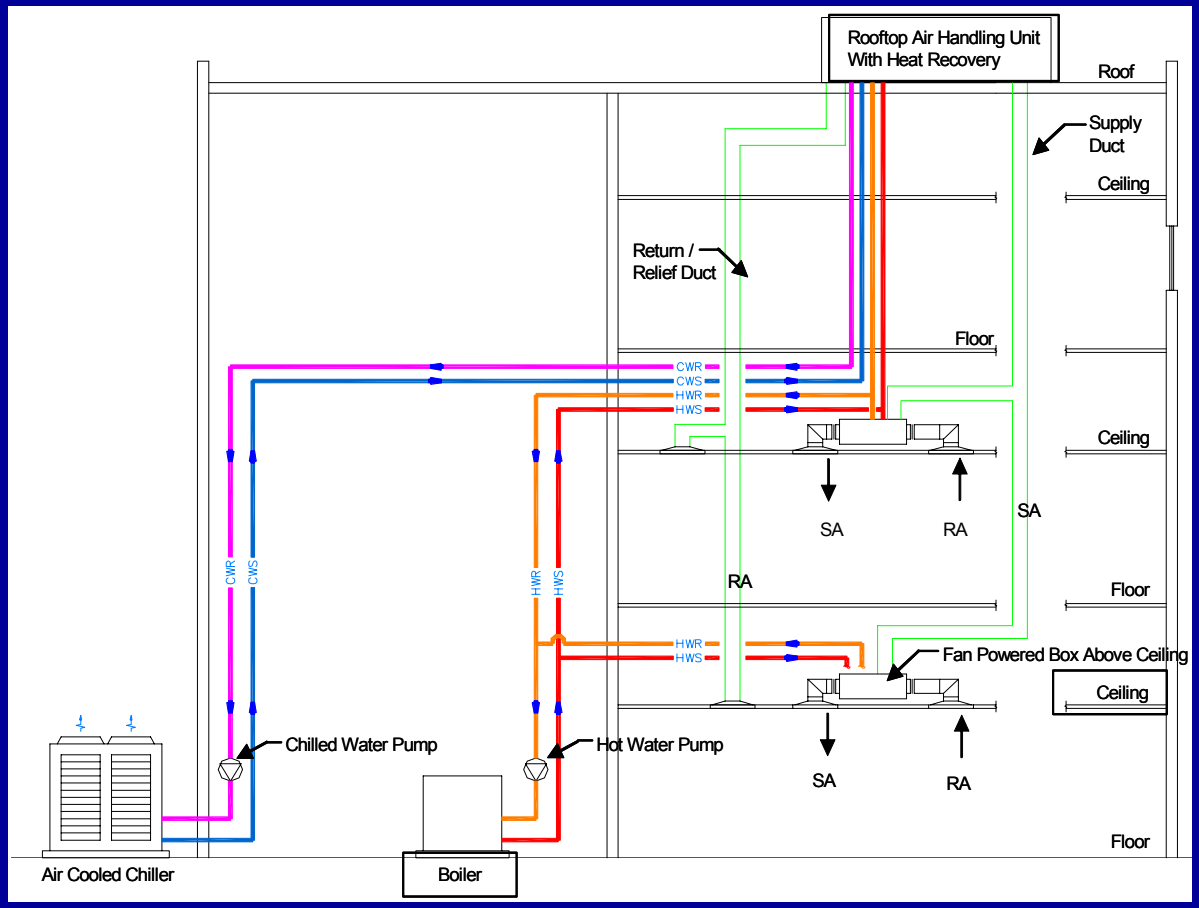
SOUTH JEFFERSON HIGH SCHOOL

Advantages:

- Lower Noise Levels
- Local Control of Temperature
- Better Dehumidification
- Longest Service Life
- Good Energy Conservation
- Energy Reclaim

Disadvantages:

- Higher First Cost
- Filter Maintenance
- Requires More Space Above Ceiling
- Air Cooled Chiller On-Site



VAV with Chilled Water Plant Diagram

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MECHANICAL SYSTEM REDESIGNS:

VAV System with Chilled Water Plant

SOUTH JEFFERSON HIGH SCHOOL

- Two 300 ton air-cooled chillers replace DX condensing units
- 4-pipe system adds chilled water piping to building
- External site for plant by kitchen loading docks surrounded by screen wall to reduce noise
- Enthalpy Wheels added to Roof Top Units

York Air-Cooled Screw Chiller

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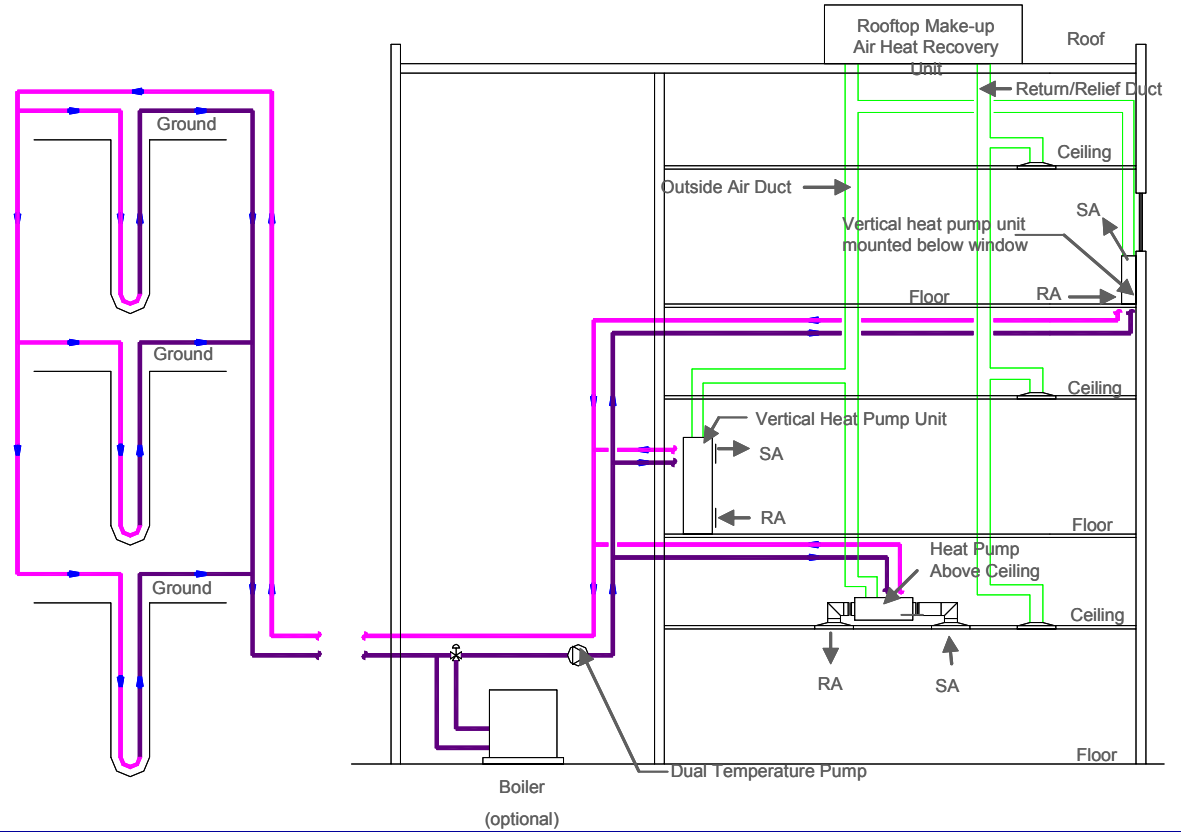
MECHANICAL SYSTEM REDESIGNS:

Ground Source Heat Pump

SOUTH JEFFERSON HIGH SCHOOL

Advantages:

- "Green" Concept
- No Cooling Tower or Chiller
- Good Dehumidification
- Low Maintenance Cost
- Better Indoor Air Quality
- Longer Life



Ground Source Heat Pump Diagram

Disadvantages:

- Higher First Cost
- On-Site Area Required to Bury Piping
- Dependant on the Quality of Electricity

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MECHANICAL SYSTEM REDESIGNS:

Ground Source Heat Pump

South Jefferson High School

- Independent 2-Pipe Ground Source Heat Pump System
- High Efficiency Heat Pumps
- 240 Boreholes, 475 ft deep, located under the future football and soccer practice fields
- Dedicated Outdoor Air Units replace multiple space RTU's

Florida Ground Source Heat Pumps

American Standard Inc. Packaged DOAS

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MECHANICAL SYSTEM REDESIGNS:

Air-to-Air Heat Recovery and Humidity Control

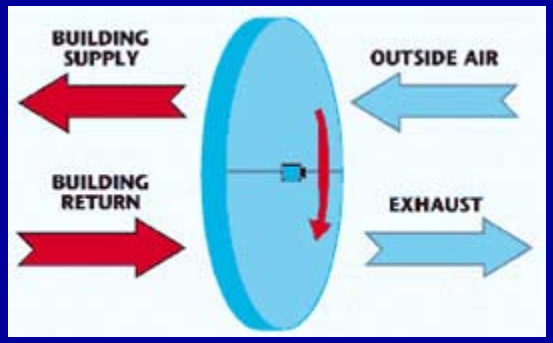
South Jefferson High School

ENTHALPY WHEELS:

- Transfer heat and moisture between EA and OA stream
- Incorporated in RTU's and DOAS units

HUMIDITY CONTROL:

- Densely Populated Spaces – Require Humidity Control
- Maintain RH Levels Between 30% and 50%



Enthalpy Wheel

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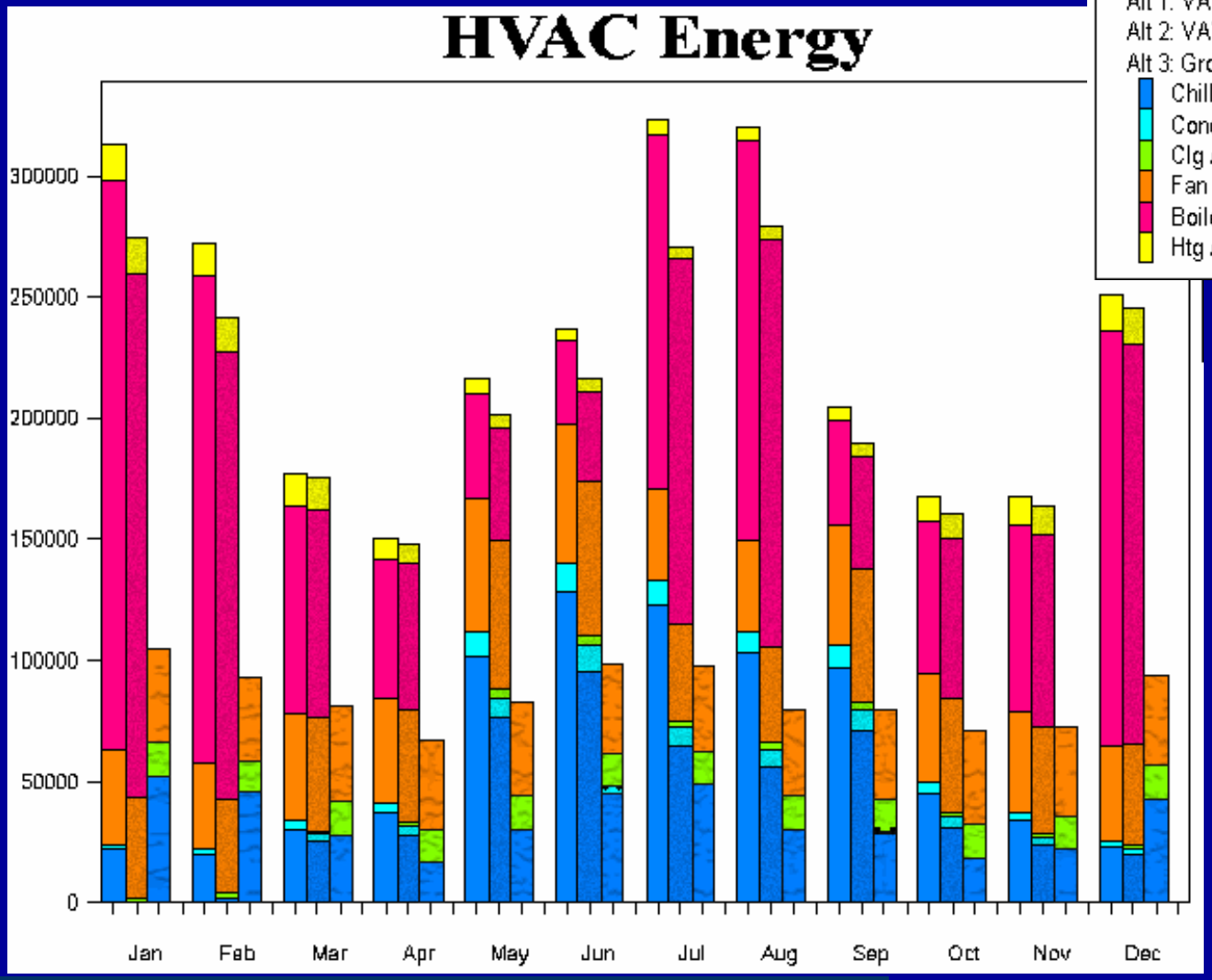
MECHANICAL SYSTEM REDESIGNS:

Energy and Cost Analysis

SOUTH JEFFERSON HIGH SCHOOL



VAV with CWP: Saves 6% in total building energy consumption

GSHP: Saves 25% of total building energy

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MECHANICAL SYSTEM REDESIGNS:

Energy and Cost Analysis

SOUTH JEFFERSON HIGH SCHOOL

VAV with CWP: Cost More in 1st Cost and Maintenance Cost

GSHP: Saves $38,278 in Life Cycle Cost

Alternative	Installed Cost	1st Year Utility Cost	20th Year Utility Cost	1st Year Maint. Cost	20th Year Maint. Cost	Life Cycle Cost
VAV with DX	$4,222,200	$215,145	$455,386	$55,003	$96,448	$7,226,134
VAV with Chiller	$4,532,793	$202,850	$427,374	$80,826	$141,729	$7,657,171
Ground Source HP	$5,234,266	$142,594	$300,424	$33,593	$58,906	$7,187,856

Alternative to Alternative	1st Cost Difference	Simple Payback	Net Present Value	Life Cycle Payback	Internal Rate of Return
Chiller to DX	$310,593	No pay back	-$431,038	No pay back	No pay back
GSHP to DX	$1,012,066	10.7 years	$38,278	18.7 years	10.5%
GSHP to Chiller	$701,473	6.5 years	$469,316	9 years	17.7%

VAV with CWP: Does Not Payback in 20 years

GSHP: Pays back in 18.7 years.

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MECHANICAL SYSTEM REDESIGNS:

Emissions

South Jefferson High School

Emission Reduction:

VAV with CWP:

Reduces Emissions 7%

GSHP:

Reduces Emissions 30%

lbm Pollutant$_j$/ kWh U.S.					
Fuel	% Mix U.S.	Particulates/kWh	SO_2/kWh	NO_x/kWh	CO_2/kWh
Coal	55.7	6.13E-04	7.12E-03	4.13E-03	1.20E+00

Variable Air Volume with Direct Expansion Roof Top Units					
Fuel	kWh	Particulates	SO_2	Nox	CO_2
Coal	3,448,083	2.11E+03	2.45E+04	1.42E+04	4.13E+06

Variable Air Volume with Chiller Water Plant					
Fuel	kWh	Particulates	SO_2	Nox	CO_2
Coal	3,219,302	1.97E+03	2.29E+04	1.33E+04	3.86E+06

Ground Source Heat Pump					
Fuel	kWh	Particulates	SO_2	Nox	CO_2
Coal	2,409,015	1.48E+03	1.71E+04	9.94E+03	2.88E+06

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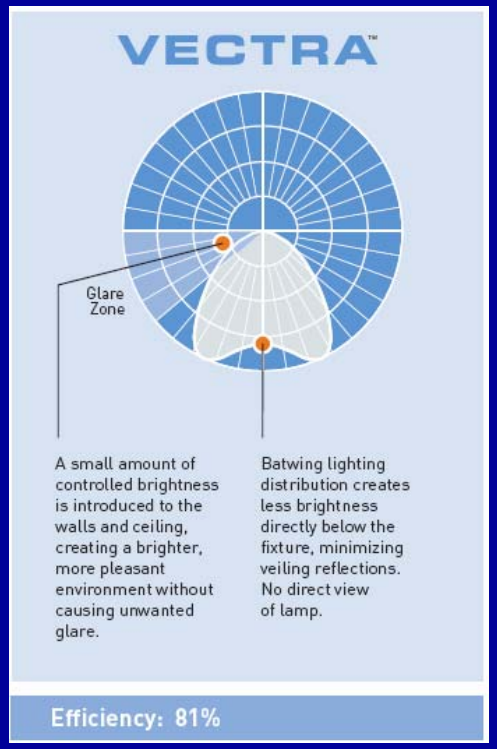
BREADTH TOPICS:

Lighting



- Replace existing fixtures in Classrooms and Corridors with High Efficiency fixture, lamp, and ballast combination
- Maintain proper task lighting
- Reduced lighting fixture power density from:
  - 1.07 to 0.97 W/S.F.
  - Saves $133,000 Annual

SOUTH JEFFERSON HIGH SCHOOL

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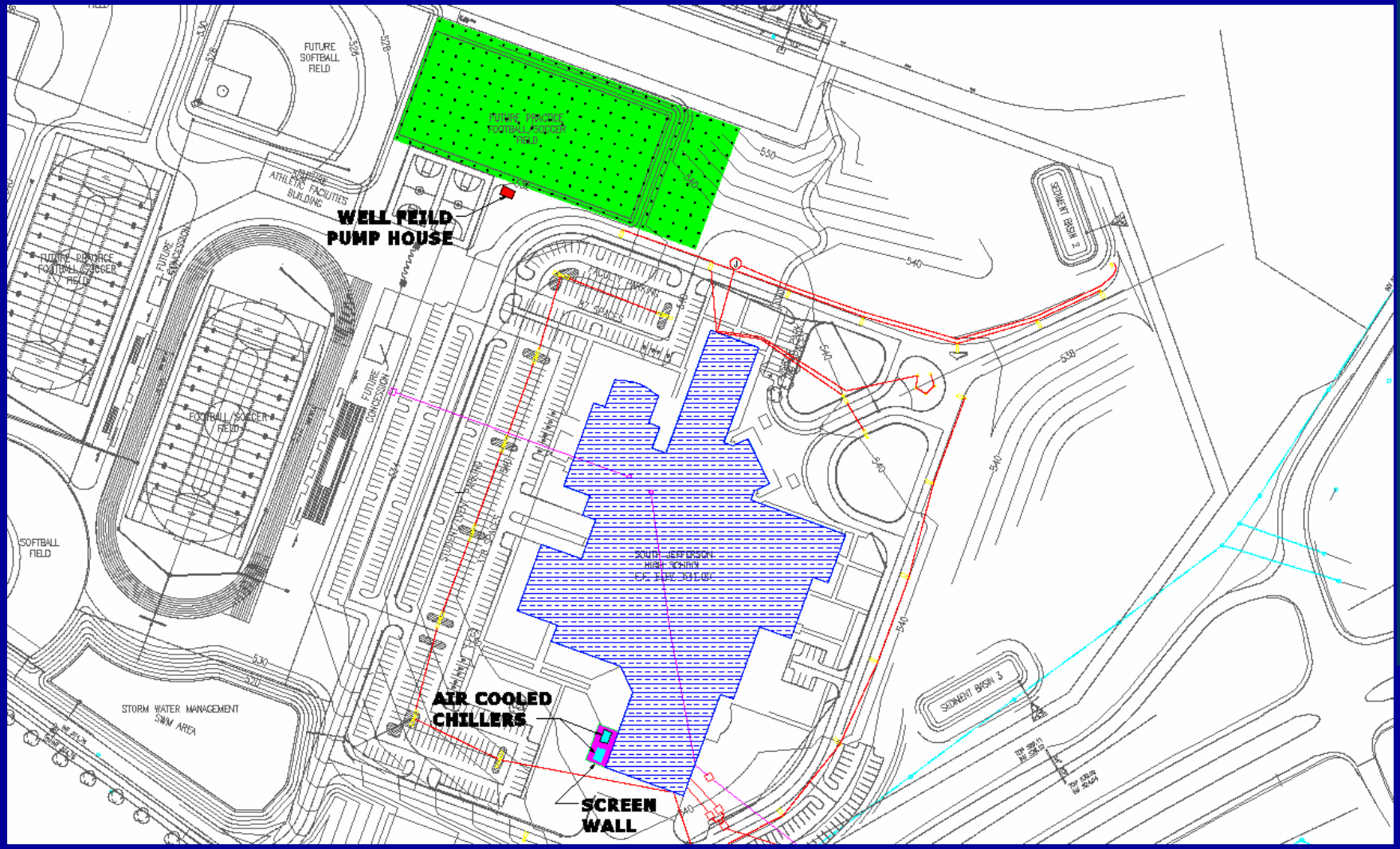
BREADTH TOPICS:

Construction Management

SOUTH JEFFERSON HIGH SCHOOL



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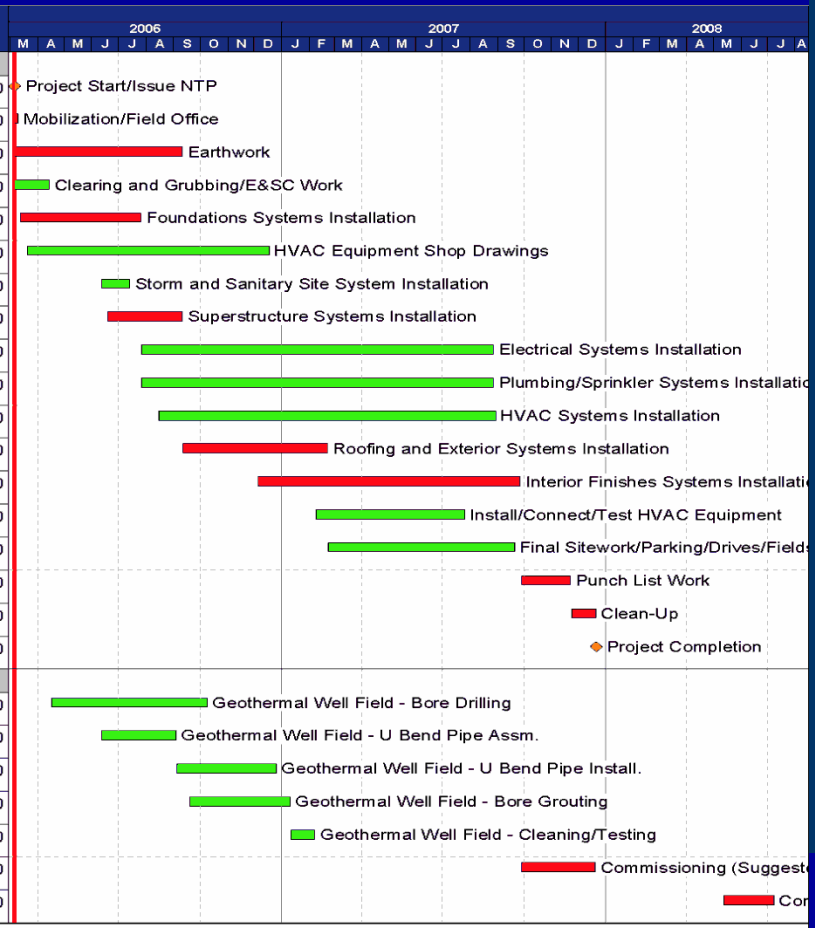
BREADTH TOPICS:

Construction Management

SOUTH JEFFERSON HIGH SCHOOL

Act ID	Description	Orig Dur	Rem Dur	Early Start	Early Finish	Total Float	%
Base Building Systems w/out Geothermal System							
0000	Project Start/Issue NTP	0	0	06MAR06 *		0	0
1000	Mobilization/Field Office	5d	5d	06MAR06	10MAR06	0	0
1040	Earthwork	135d	135d	06MAR06	11SEP06	0	0
1020	Clearing and Grubbing/E&SC Work	30d	30d	06MAR06	14APR06	15d	0
1110	Foundations Systems Installation	97d	97d	13MAR06	26JUL06	0	0
1100	HVAC Equipment Shop Drawings	195d	195d	20MAR06	18DEC06	5d	0
1130	Storm and Sanitary Site System Installation	24d	24d	12JUN06	14JUL06	31d	0
1120	Superstructure Systems Installation	60d	60d	19JUN06	11SEP06	0	0
1140	Electrical Systems Installation	280d	280d	27JUL06	27AUG07	23d	0
1160	Plumbing/Sprinkler Systems Installation	280d	280d	27JUL06	27AUG07	23d	0
1150	HVAC Systems Installation	270d	270d	15AUG06	30AUG07	20d	0
1170	Roofing and Exterior Systems Installation	115d	115d	12SEP06	21FEB07	0	0
1180	Interior Finishes Systems Installation	210d	210d	05DEC06	27SEP07	0	0
1230	Install/Connect/Test HVAC Equipment	120d	120d	08FEB07	26JUL07	45d	0
1250	Final Sitework/Parking/Drives/Fields	150d	150d	22FEB07	20SEP07	5d	0
1200	Punch List Work	40d	40d	28SEP07	22NOV07	0	0
1190	Clean-Up	21d	21d	23NOV07	21DEC07	0	0
1220	Project Completion	0	0		21DEC07 *	0	0
Geothermal System Work (Integrated Schedule)							
1050	Geothermal Well Field - Bore Drilling	125d	125d	17APR06	09OCT06	15d	0
1060	Geothermal Well Field - U Bend Pipe Assm.	60d	60d	12JUN06	04SEP06	15d	0
1070	Geothermal Well Field - U Bend Pipe Install.	80d	80d	05SEP06	26DEC06	15d	0
1080	Geothermal Well Field - Bore Grouting	80d	80d	19SEP06	10JAN07	15d	0
1090	Geothermal Well Field - Cleaning/Testing	20d	20d	11JAN07	07FEB07	15d	0
1210	Commissioning (Suggested/Winter)	60d	60d	28SEP07	20DEC07	0	0
1240	Commissioning (Suggested/Summer)	40d	40d	13MAY08	08JUL08	0	0



Start date	06MAR06
Finish date	08JUL08
Data date	06MAR06
Run date	08APR07
Page number	1A
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South Jefferson High School
Charlestown, West Virginia
Base Building System Schedule
with Integration of Geothermal Well System

Early bar
Progress bar
Critical bar
Summary bar
Start milestone point
Finish milestone point

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CONCLUSIONS AND RECOMMENDATIONS

SOUTH JEFFERSON HIGH SCHOOL

Criteria	Weighting	DX Roof top Units	DX Roof Top Units with Heat Recovery	Ground Source Heat Pump with Dedicated Outdoor Air	Ground Source Heat Pump with Dedicated Outdoor Air and Heat Recovery	Fan Powered Box VAV with CWP	Fan Powered Box VAV with CWP with Heat Recovery
Thermal Comfort	4	2	2	3	3	4	4
Maintainability	3	3	3	4	4	2	2
Indoor Air Quality	5	4	4	5	5	4	4
Energy Usage	5	2	3	4	5	3	4
Space Noise	4	3	3	3	3	4	4
Site Imact	3	4	4	2	2	3	3
Site Noise	3	3	3	5	5	3	3
Equipment Life	3	2	2	3	3	4	4
Refrigerant	2	2	2	3	3	4	4
First Cost	3	5	4	3	2	4	3
Overall Score		105	107	126	128	123	125

5 = Excellent **4 = Above Average** **3 = Below Average** **2 = Below Average** **1 = Poor**

ACKNOWLEDGEMENTS

MECHANICAL PROFESSORS:

Dr. Bahnfleth, Dr. Friehaut, J.J., Dr. Mumma, and Dr. Srebric

PROFESSIONALS:

Ryan Buff, John Weiland, Damion Spahr, and Paul Patrelli

FRIENDS AND FAMILY:

Parents, Dave, Rod, Kevin, Justin, Eric, Krista, Amy

South Jefferson High School

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Questions

VAV with Chilled Water Plant	Ground Source Heat Pump
-Two 300 ton screw air-cooled chillers replace the existing DX condensing units.	-Independant 2-pipe GSHP system
-External site for plant by kitchen loading docks, surrounded by screen wall to reduce noise	-Dedicated outdoor air units with energy recovery replace multiple space RTU's
-Initial cost higher by $310,500	-240 boreholes, 475 deep, located under the future football and soccer practice fields
-Maintenance cost increases because a 4-pipe system	-$1,012,044 increase in first cost
-Improves efficiency 0.26 kW/ton	-Saves over $20,000 dollars in maintenance
-Saves only 6% in total building energy consumption	-Reduces total energy consumption by 25%
	-Life cycle payback of 18.7 year

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