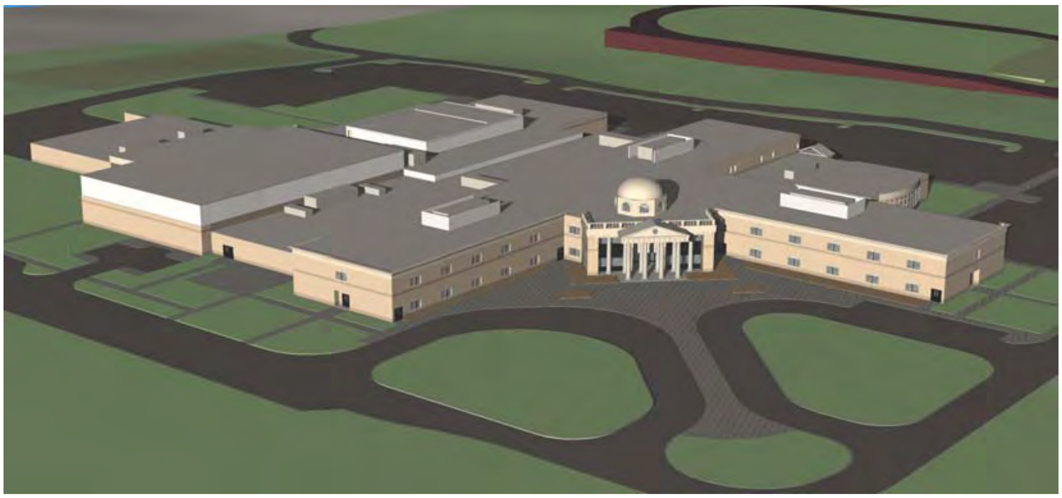
Architectural Engineering Senior Thesis

Energy Efficient Mechanical System Alternatives for South Jefferson High School



South Jefferson High School

Huyett Road
Charles Town, WV 25414

Prepared for Dr. William Bahnfleth
The Pennsylvania State University

By
Jonathon Gridley
Mechanical Option

Thursday April 12, 2007

South Jefferson High School

Huyett Road Charles Town, WV 25414

General Building Data

Building Name: South Jefferson High School

Location and Site: Huyett Road Charles Town, WV 25414

Building Occupant Name: Jefferson County Schools

Occupancy or function types: High School/ Educational

Size: Total Square Footage – 232,705 ft2

Number of Stories: 2 stories

Total Building Cost - $33 Million

Project Delivery Method: Design-Bid-Build

South Jefferson High School

Project Team:

Owner - Jefferson County Schools - http://boe.jeff.k12.wv.us/

Architect - Alpha Associates, Incorporated - http://www.alphaaec.com/

MEP - H.F. Lenz Company - http://www.hflenz.com/

CM - Turner Construction - http://www.turnerconstruction.com/

Architecture:

Zoning: R-1 Residential

Exterior walls are brick veneer applied to heavy duty metal stud framing or brick veneer applied to pre-cast concrete panels.

Mechanical System:

14 Air handling units ranging from 6,000 to 25,500 CFM
- (6) VAV System with Fan Powered Boxes and VFD
- (8) Constant Volume Air Handlers

Heating System:

Two 4,717 MBH Electric Boilers
- Primary-Secondary Variable Volume Pumping

Structural System:

Foundation is reinforced concrete with reinforced concrete retaining walls as needed.

Main substructure is steel framing with Cast-in-place concrete floor slabs.

Roof is supported by metal joists.

Electrical System:

480/277 V, 3-phase electric service
480 to 208/120V Transformers
Emergency 125 kW Diesel Fueled Generator

Lighting: Generally recessed fluorescent lighting fixtures with acrylic lenses

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http://www.arche.psu.edu/thesis/eportfolio/2007/portfolios/JAG432/

The Pennsylvania State University

Architictural Engineering

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Dad, I credit you with my desire to become an engineer in the first place. You have had to deal with questions after questions from me in the past years. I thank you for helping me always and providing me with the skills to be successful in college and in life.

Mom, I thank you for all the motivational support and all the goodies to keep me going. I also thank you for helping me develop my writing skills. I am so fortunate to have you as my mother.

Amy, you make everything worthwhile. I thank you for sticking with me through thick and thin. You are my best friend and my true love. I am graciously humbled by you. After experiencing college and engineering with you, I couldn’t imagine doing it any other way. I can’t wait to accomplish so much more together with you.

Lastly, I would like to thank God for blessing me with the opportunity to attend Penn State and surrounding me with such wonderful people.

3.0 Executive Summary:

This thesis report develops redesigns for South Jefferson High School. The high school is a two story 200,000 square foot secondary education facility. The main objective of the redesigns is green design. The focal point of green design is to utilize mechanical systems that reduce energy consumption and emission, while maintaining a short life cycle payback. A secondary objective is to improve the building's indoor air quality, providing conditions that will increase student performance.

The mechanical depth portion of this report includes detailed analysis on several energy efficient design alternatives. The design alternatives include replacing existing direct expansion equipment with a more energy efficient VAV system utilizing a chilled water system. This system ends up being more expensive in first cost and maintenance costs, the energy savings are minimal, and the system does not payback in either a simple payback or life cycle payback. A ground source heat pump system is the second alternative, and an extensive change to the existing mechanical system. When comparing the ground source heat pump system to the existing VAV system, the ground source heat pump system deems much better results. The system saves approximately $20,000 in maintenance, $73,551 per year on energy consumption, and generates returns in 18.7 years. The ground source heat pump system also improves indoor air quality.

In addition to the main depth area of the report, two breadth areas have been developed. The breadth topics of this report cover lighting and construction management. The objective of the lighting breadth is to utilize more efficient luminaires and lighting controls to decrease the amount of energy consumption while still providing adequate task lighting. The construction management portion analyzes the added cost and scheduling concerns derived from installing chillers and a ground source heat pump well field and loop.

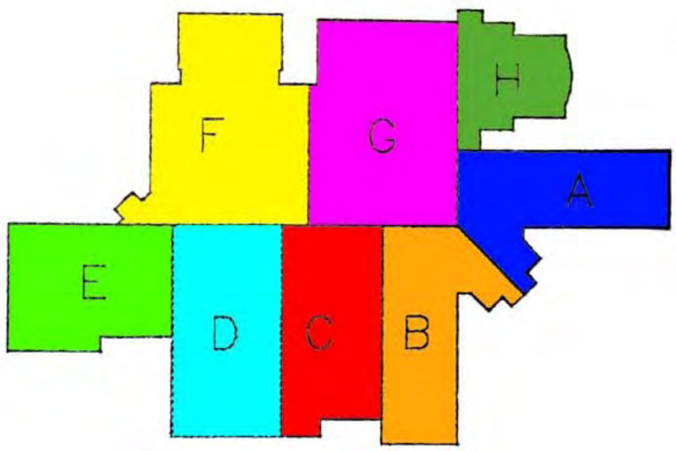
In order to provide orientation and makeup of the building, a short summary of the general building background is provided at the beginning of the report followed by information on the original mechanical systems. The analysis of the existing mechanical systems shows specific areas in which the building can be improved with possible redesign or modification. After the existing systems summary, several proposed redesigns are described and analyzed.

4.0 Building Background:

South Jefferson High School is a two story 199,717 s.f. secondary school utilized by 1200 students during the day, and a number of adult learners in the evening. The total capacity of the school is designed to accommodate up to 1500 students. The building is located in Charles Town, WV off Route 340.

South Jefferson High School is broken into 8 separate zones named A thru H. The second floor is also divided into similar zones A, B, and G. The designation of each of these areas can be seen in Figure 1. The school has academic wings (1st Flr A & B, and 2nd Flr A), an administration area (1st Flr A & B), and common facilities (1st Flr C thru H) for use by all students. Common facilities such as the Learning Resource Center (1st Flr G), dining (E), physical education (C & D), and creative arts (F) are accessible from the main corridors. The school's administrative offices and Student Services are located near the main entrance.

Figure 1 – South Jefferson High School Zone Designations



The Science (2nd Flr G) and Technology Center (2nd Flr B) is partially funded by a separate grant, this portion of the building includes the School's Science Department along with various technology oriented subject areas such as technology training labs, technology education, engineering, agricultural technology, and video conferencing. During regular school hours, the center supports the academic curriculum. In the evenings, the facilities will be available for continuing education classes open to the community at large.

The South Jefferson School District plans to make the Learning Resource Center and computer facilities available to the community after normal school hours as well. Thus the community at large will have access to up-to-date facilities for instruction, research, and application that are not currently available in the school district.

4.1 Building Statistics:

Building Name: South Jefferson High School

Location and Site: Huyett Road Charles Town, WV 25414

Building Occupant Name: Jefferson County Schools

Occupancy or function types: High School/ Educational Facility – 1200 students

Size: Total Square Footage – 199,717 ft2

Number of Stories: 2 stories

Project Team:

- Owner – Jefferson County Schools – http://boe.jeff.k12.wv.us/
- Architect – Alpha Associates, Incorporated – http://www.alphaaec.com/
- MEP – H.F. Lenz Company – http://www.hflenz.com/
- CM – Turner Construction – http://www.turnerconstruction.com/

Dates of Construction: Under Construction (February 2006 – August 2007)

Total Building Cost: $34 Million

Project Delivery Method: Design-Bid-Build

Major national model codes:

- International Building Code 2000
- International Mechanical Code 2003
- NFPA 101 Life Safety Code
- Americans with Disabilities Act
- West Virginia State Fire Code

4.2 Building Systems Overview:

Electrical:

The electrical service supplied to South Jefferson High School is 480 volt three-phase electric service with multiple distribution switchboards. Transformers have been installed throughout the building to step the voltage down to 208/120 volts.

The panel boards installed throughout the building have integral surge protection fed from an isolation transformer to be used for computer grade power. These panels serve dedicated computer receptacles.

A diesel fueled emergency generator has been implemented for emergency power distribution throughout the building. The generator serves emergency lighting, exit signs, fire alarm panel, public address system, automatic temperature control system, security system, hot water system pumps, and kitchen refrigeration equipment. The fuel tank is base-mounted and provides a minimum of four hours of operating capacity.

Lighting:

The lighting in classrooms and corridors utilizes recessed fluorescent lighting fixtures with acrylic lenses. Fixtures are switched so that the inner and outer lamps may be energized independently. Fluorescent lighting fixtures are used in the storage rooms. High output fluorescent lighting fixtures are installed in the Gymnasium and Cafeteria. Multiple rows of colored border lights and spot lights are used for the Auditorium stage. All stage lighting is controlled by a theatrical dimmer system. Pole mounted metal halide lighting fixtures are used for all paved areas.

Emergency lighting is installed in the corridors, the boiler room, Multi-Purpose Room, and at the exterior of exits to meet all applicable codes. All emergency lighting is connected to the emergency power panels. L.E.D. type exit signs connected to the emergency power system aid in egress.

Mechanical:

The HVAC system shall primarily consist of variable air volume air handling units serving series-style fan powered boxes at classrooms. The classroom wings have rooftop units with ductwork chased down through rated shafts for outside air to a fan powered box at each classroom. The fan powered boxes serve an overhead distribution system.

The Gymnasium, Auditorium and Cafeteria are served with single-zone air handling units located on the roof. These units incorporate demand-based ventilation controls.

All heating-only equipment such as cabinet unit heaters and horizontal unit heaters are installed in mechanical spaces, entry vestibules, and similar areas.

Structural:

The high school's foundation is reinforced concrete designed to meet subsoil conditions with reinforced concrete retaining walls as needed. The main substructure is steel framing with cast-in-place concrete floor slabs. The roof is supported by metal joists.

Fire Protection:

The building is fully protected with an automatic sprinkler system with all necessary exterior connections for fire department connections. Sprinkler locations are done according to NFPA requirements. Hot and cold water distribution piping is Type "L" copper and is insulated with fiberglass pipe covering. Soil and waste piping and rainwater piping are Schedule 40 PVC piping above ground and PVC SDR-35 pipe in any areas below ground.

Transportation:

South Jefferson High School is directly accessible by the use of West Virginia Route 340 near Charles Town. Two bus drop-off circles are located in front of the school while all parking is located in the rear of the building.

Telecommunications:

South Jefferson uses a combination wireless/wired data network system. The data wiring consists of augmented category 6 data conductors installed from each data outlet in the building to a patch panel located in designated rooms. The augmented category 6 structured cabling system enables 10-gigabit-per-second Ethernet transmission over a full 100 meters. Fiber optic cabling has been run between hub rooms to provide a building wide network.

5.0 Mechanical Systems Summary:

The HVAC system primarily consists of multiple variable air volume rooftop units (RTU) serving series-style fan powered boxes at classrooms. The classroom wings have rooftop units with ductwork chased down through rated shafts for outside air to a fan powered box at each classroom. The fan powered boxes serve ceiling mounted diffusers.

The Gymnasium, Auditorium and Cafeteria are served with single-zone air handling units located on the roof. These units incorporate demand-based ventilation controls in the form of CO_2 sensors.

All heating-only equipment such as cabinet unit heaters and horizontal unit heaters are installed in mechanical spaces, entry vestibules, and similar areas. The heating-only equipment, rooftop unit heating coils, and auxiliary heating coils are served by hot water generated by two electric boilers.

5.1 Air Side Mechanical Systems:

South Jefferson High School is comprised of mostly classrooms. The HVAC systems serving the classroom areas consist primarily of variable air volume roof top units serving series-style fan powered boxes at classrooms. The classroom wings have a total of 5 rooftop units with ductwork chased down through rated shafts for outside air to a fan powered box located in the plenum space above the corridor outside of each classroom. The fan powered boxes are in serve overhead air distribution diffusers. A return plenum is used to return air to the roof top units. The administrative offices are also served in this same method by RTU-3.

The Science Rooms on the 2nd floor Zone G are served by RTU-5. This roof top unit supplies all of its 14,000 cfm as 100% OA in order to reduce the risk of volatile lab chemicals getting into the air. Air distribution systems serving the Science Rooms are designed to maintain a negative pressure in the room with respect to the adjacent areas.

The Locker Room/Athletic Department of the school are located on the 1st floor Zone C. This area is served by RTU-12 a 12,000 cfm 100% outside air unit. The Locker Room areas are fully exhausted to maintain a negative pressure to adjacent spaces. This roof top unit serves as a make-up for 90% of the exhausted air.

The Gymnasium, Auditorium and Cafeteria are served with single-zone air handling units located on the roof. The Gymnasium and Auditorium both utilize two roof top units each, while the Cafeteria only requires a single RTU. All five roof top units incorporate demand-based ventilation controls in the form of CO_2 sensors.

The school's 14 packaged roof top units (RTU), with condensing units, range in size from 4,500 cfm to 25,500 cfm. All refrigeration coils are direct-expansion instead of chilled water. Design airflow quantities for all roof top units can be seen below in Table 1.

Symbol	Variable or Constant Volume	Supply Air (CFM)	Design Outdoor Air (CFM)	OA Percent (%)	Cooling Airflow (CFM)	Heating Airflow (CFM)	Return Airflow (CFM)
RTU-8	CV	4,500	1,200	26.7	3,337	3,337	3,337
RTU-2	VV	25,500	10,600	41.6	20,877	22,605	22,605
RTU-3	VV	13,000	3,600	27.7	10,231	3,069	10,231
RTU-4	VV	24,000	10,500	43.8	18,776	18,840	18,840
RTU-5	CV	14,000	14,000	100.0	11,273	11,276	11,276
RTU-6	VV	12,000	2,700	22.5	6,993	7,156	7,156
RTU-7	VV	15,000	6,400	42.7	12,521	12,979	12,979
RTU-1	VV	22,000	9,600	43.6	1,951	19,741	19,741
RTU-9	CV	9,000	8,000	88.9	7,950	7,950	7,950
RTU-10	CV	13,000	7,500	57.7	9,963	9,963	9,963
RTU-11	CV	6,000	4,670	77.8	3,581	3,581	3,581
RTU-12	CV	12,000	12,000	100.0	7,448	7,448	7,448
RTU-13	CV	9,500	5,500	57.9	9,375	9,375	9,375
RTU-14	CV	9,500	5,500	57.9	9,662	9,662	9,662
Totals:		**184,500**	**100,570**		**130,601**	**143,645**	**150,807**

Table 1 - Design Airflow Quantities

5.2 Boilers and Hot Water Systems:

Heating-only equipment, hot water coils in the RTU's, plus auxiliary heating coils scattered throughout South Jefferson High School are heated hydronically by two identical hot water boilers. These boilers are designed for heating by electric resistance. Electric boiler data can be seen in Table 2.

Symbol	Total KW Input	Total Load Amps	MBH Output	Steps of Control	Elect Char	EWT ºF	LWT ºF
BLR-1	1,440	1,742	4,717	16	460V/3PH/60HZ	150	180
BLR-2	1,440	1,742	4,717	16	460V/3PH/60HZ	150	180

Table 2 – Electric Boiler Data

The heating system also incorporates a primary-secondary pumping system. Two primary and two secondary (building loop) system water pumps were installed. The pumps are provided with variable frequency controllers to offer an energy-saving variable flow system. Pump data can be seen in Table 3 below.

Symbol	Type	System	GPM	FT HD	Efficiency	Motor HP	Impellar Dia.	VFD	Operation
P-1	In Line	HWS/R	310	30	74.6	5	6.875"	No	Primary Duty
P-2	In Line	HWS/R	310	30	74.6	5	6.875"	No	Primary Duty
P-3	Flr Mtd	HWS/R	750	80	78.8	25	10.750"	Yes	Secondary Duty
P-4	Flr Mtd	HWS/R	750	80	78.8	25	10.750"	Yes	Secondary Standby

Table 3 – Pump Data

5.3 Mechanical Systems Controls:

All sequences of controls for the entire building are performed by Direct Digital Controls (DDC). This DDC system monitors all the sensors, and it is able to adjust all the set points and time delays for the equipment. The DDC system also provides start/stop, speed control, monitoring, and alarms for the variable frequency drives (VFD). A few controls can be seen in the schematic diagrams in Appendix B.

6.0 Humidity Concerns:

The humidity levels in the Charles Town area are relatively high. No additional means of removing humidity have been incorporated into the systems design. Only the rooftop units cooling coils provide dehumidification of the air. A desiccant and/or enthalpy wheel should help control humidity in the supply air. Added humidity controls would improve thermal comfort and indoor air quality within the building. It has been shown in recent studies that improving these two areas can increase student performance and lower absenteeism. Table 4 shows humidity profile data for a variety of spaces. There are a number of rooms in need of humidity control, most being densely populated spaces.

SYSTEM HUMIDITY PROFILES

	---- Maximum----				------------- Number of Hours at each Percentage Range -------------											
Room Description	% Rh	Mo	Hr	Day	>70%	70-66	66-62	62-58	58-54	54-50	50-46	46-42	42-38	38-34	34-30	<30 %
CORRIDOR H112	71	8	8	2	176	245	671	449	739	1,237	1,162	1,034	829	628	626	964
VICE PRIN B107	64	1	7	1	0	0	0	8	306	1,128	1,991	2,191	1,050	935	529	622
COMPUTER LAB G103	92	1	11	1	0	0	0	0	337	505	1,590	1,810	1,052	1,172	635	1,659
KEYBOARDING LAB G110	87	1	10	1	0	0	0	118	411	546	1,583	1,696	957	1,166	707	1,576
LAB CADD G116	88	1	11	1	0	0	0	0	213	548	1,516	1,829	1,067	1,086	786	1,715
BUSINESS CLASSROOM G110	100	1	14	1	0	103	462	489	757	1,842	1,602	1,049	1,009	564	374	509
PREP G118A	90	1	18	1	0	0	0	0	0	0	576	2,661	1,631	1,186	1,073	1,633
FORENSICS LAB G118	67	1	9	1	0	0	0	0	0	586	2,144	1,671	913	1,261	602	1,583
VISUAL COMM PRODN LAB G119	57	1	6	1	0	0	0	0	0	293	1,939	1,717	947	1,039	912	1,913
CONTROL ROOM G120	58	1	6	1	0	0	0	0	0	416	2,010	1,616	947	998	943	1,830
OFFICE TECH LAB G109	87	1	10	1	0	0	0	118	411	546	1,583	1,696	957	1,166	707	1,576
SCHOOL STORE G105	100	12	24	2	1,327	4	36	9	50	11	614	3,871	1,449	861	281	247
INFO TECH REPAIR LAB G124	100	1	12	1	0	0	203	479	372	1,025	1,967	1,327	935	890	642	920
OFFICE G104A	71	1	12	1	0	0	0	0	0	0	547	2,543	1,529	942	1,041	2,158
RECEPTION B103C	100	8	7	2	3,276	748	655	524	580	761	762	446	409	206	273	120
CORRIDOR D102	77	8	7	2	948	396	262	591	755	855	971	973	680	717	631	981
CORR H112	72	8	8	2	204	260	651	437	611	1,113	1,253	950	842	746	646	1,047
LOBBY B101	64	9	7	1	0	0	172	290	975	1,242	1,696	1,140	982	644	515	1,104
CORRIDOR A133	77	8	7	2	948	396	262	591	755	855	971	973	680	717	631	981
CORRIDOR B134	77	8	7	2	948	396	262	591	755	855	971	973	680	717	631	981
CORRIDOR B133 AHU3	61	8	13	8	0	0	0	806	751	1,238	1,397	1,164	936	656	725	1,087
FACILITY PLANNING B114	71	7	10	2	10	101	243	1,290	1,673	1,320	1,344	612	888	645	313	321
LOUNGE B114A	81	12	9	2	59	260	700	770	1,443	2,311	1,357	731	554	217	235	123
PHYSICS LAB G207	58	5	14	1	0	0	0	0	36	250	1,163	2,052	1,738	1,462	1,107	952
INSTRUCTOR PLANNING G101	73	1	6	1	114	288	378	537	564	1,450	1,231	918	853	591	519	1,317
CORR G125	59	1	8	2	0	0	0	74	1,747	965	118	814	4,303	680	59	0
STAGE BACKSTAGE F125	58	6	14	1	0	0	0	0	0	126	379	522	890	1,809	1,638	3,396
UNIVERSAL LAB G208	58	5	14	1	0	0	0	0	18	236	1,286	2,161	1,996	1,185	1,074	804
UNIVERSAL LAB G209	58	5	14	1	0	0	0	0	36	280	1,288	2,387	1,741	1,099	1,106	823
UNIVERSAL LAB G210	58	5	14	1	0	0	0	0	36	280	1,288	2,387	1,741	1,099	1,106	823
UNIVERSAL LAB G211	58	5	14	1	0	0	0	0	36	271	1,349	2,382	1,726	1,109	1,052	835
UNIVERSAL LAB G212	58	5	14	1	0	0	0	0	62	326	1,141	2,457	1,721	1,132	1,037	884
PREP ROOM G208A	56	1	7	1	0	0	0	0	0	0	1,179	2,288	1,695	1,832	739	1,027
PREP G210A	56	1	7	1	0	0	0	0	0	36	891	2,341	1,891	1,335	1,151	1,115
PREP ROOM G212A	56	1	7	1	0	0	0	0	0	0	552	2,064	2,241	1,584	1,359	960
UNIVERSAL LAB G213	58	5	14	1	0	0	0	0	62	326	1,141	2,457	1,721	1,132	1,037	884
MARKETING CLASSROOM G104	100	1	14	1	261	414	633	613	1,089	1,888	1,164	941	640	475	373	269
CORR G126	55	1	6	1	0	0	0	0	0	51	204	1,583	2,302	1,353	1,205	2,062
SPL ED OFFICE	88	8	7	2	1,916	544	555	666	891	672	404	810	853	488	365	596
CORR G128	54	1	1	1	0	0	0	0	0	0	0	1,458	2,219	1,183	1,037	2,863

Table 4 – System Humidity Profile

7.0 Design Objectives:

The results of this thesis will suggest alternative solutions to the design of the South Jefferson High School. All modifications are for academic purposes and do not imply flaws in the original design. All modifications are simply alternative solutions which will include one system alteration and one extensive modification to the mechanical system. The alteration will resulting changes to the other building systems.

8.0 Considered Alternatives:

These design alternatives were considered but not selected in the redesign of South Jefferson High School.

- Combustion Air Preheating

Combustion air preheating is for fuel-fired heating equipment, one of the most potent ways to improve efficiency and productivity is to preheat the combustion air going to the burners. The source of this heat energy is from the exhaust gas stream, which leaves the process at elevated temperatures. A heat exchanger, placed in the exhaust stack or ductwork, can extract a large portion of the thermal energy in the flue gases and transfer it to the incoming combustion air. This strategy would provide boilers with a fuel source other than the current electrical fuel source. Although obtaining an alternate fuel source may be possible, material and maintenance costs for this method are too expensive for a school budget. Also, combustion air preheating is typically used for larger scale projects.

- Displacement Ventilation

In displacement ventilation the range of supply air temperatures and discharge velocities is limited to avoid discomfort to occupants. Displacement ventilation has a limited ability to handle high heating or cooling loads if the space served is occupied. The system would require extensive alteration to the architectural design of the building. It is also costly and is not common in schools.

- Night Precooling

There are two variations on night precooling. One, termed night ventilation precooling, involves the circulation of outdoor air into the space during the naturally cooler nighttime hours. This can be considered a passive technique except for any fan power requirement needed to circulate the outdoor air through the space. The night ventilation precooling system benefits the building indoor air quality through the cleansing effect of introducing more ventilation air. With the other variation, mechanical precooling, the building mechanical cooling system is operated during the nighttime hours to precool the building space to a setpoint usually lower than that of normal daytime hours. The location and mass of building are not ideal for this strategy. Thermal comfort is also a concern requiring, building occupants to be more tolerant of slightly cooler temperatures during the morning hours.

9.0 Mechanical System Redesigns:

The approach taken in the mechanical system redesigns of South Jefferson High School is that of the green design initiative. A motivator for green design is lowering the total cost of ownership through resource management and energy efficiency. Sustainable green design is useful in a school project because of tight budgets, close observation within the community, and typically long time periods between renovation or new construction of a school. A secondary benefit associated with green design is the increased productivity from a building that is comfortable and provides healthful conditions. Comfortable students are less distracted, able to focus better on their tasks/activities, and occupants will appreciate the physiological and physical benefits good green design provides.

The first alternative design researched was a VAV system with chilled water plant. The intent of this redesign was to show the improvements of having a central chilled water plant compared to many DX condensing units as the main cooling source for the building's roof top units. This system design alternative required the least amount of redesign because of its similarity to the existing system. Still, adding a chilled water plant required alterations and additions to the current building design.

The second alternative researched was a ground source heat pumps system. This system is a very energy efficient but costly to construct. Implementing a ground source heat pump system for South Jefferson High School required extensive redesign and analysis. The only similarities to the existing mechanical system were the use of a 2-pipe hydronic distribution system and any single space air handling units remained in tact. All other equipment was revamped.

Energy recovery was incorporated into both systems. In the VAV with chilled water plant alternative enthalpy wheels were added into the existing roof top units. This added initial cost and did not lower the size of existing heating and cooling equipment enough to declare the wheels a viable addition to the system. The ground source heat pump system uses dedicated outdoor air units for any units serving multiple spaces. These dedicated outdoor units require energy recovery and utilize enthalpy wheels.

Humidity control was the final step in improving the existing system. Indoor air quality is a major concern in schools. The approach to relieve these concerns was the addition of enthalpy wheels and humidity control into air handling units serving multiple spaces.

Many of the values used in the analysis of the mechanical system redesign were generated using the Trane Trace 700 software package.

9.1 VAV System with Chilled Water Plant:

A chilled water plant contains chillers that generate chilled water to serve cooling coils in equipment. The chilled water is distributed to the cooling coils through schedule 40 steel chilled water piping. A main benefit of using a chilled water plant is the plant's ability to take advantage of load diversity throughout the building. The load can be matched more efficiently with a central cooling system compared to multiple scattered compressors of a direct expansion system. The energy benefits amount to a savings of 0.26 KW/ton compared to distributed systems. Appendix B shows separate schematics for the chilled water plant and how it ties into the airside equipment.

-Air-Cooled versus Water-Cooled:

There are two primary methods of rejecting heat from a chiller, air-cooled and water-cooled. Air-cooled packaged chillers have enjoyed market appeal because of the simplicity of installation. The units are completely factory piped and wired so that the user has only to connect the chilled water piping and power wiring to have a performing chiller system. Higher operating costs and sound levels accompany an air-cooled selection; however, they are still typically more efficient than a direct expansion type system. In addition, most school maintenance staffs are familiar with this type of equipment and can maintain it without requiring outside maintenance contracts.

Conversely, water-cooled chillers are those that employ a cooling tower or fluid cooler heat exchange medium. They are usually the most expensive first cost chiller equipment due to the separation of the chiller and the cooling tower, which is usually located on the roof. Water-cooling is more energy efficient than air -cooling. However, most school maintenance staffs do not have the in-house expertise to deal with the chemical requirements associated with make up water or inhibitors required when the cooling towers are laid up for the winter. Usually water-cooled chillers require a school district to employ some type of outside chiller maintenance contract. Table 5 shows a simple comparison of a quality air-cooled chiller and water cooled chiller providing levels for particular issues.

	Quality Air-Cooled	Water-Cooled
Sound	(-) Loudest (1)	Medium
First Cost	(+) Lowest (2)	(-) Highest
Operating Cost	(-) Medium(3)	Lowest
Size	(-) Largest	Split
Longevity	(-) 15-20 years	(+) 20-25 years
Environmentally Friendly	134A	134A, 123
Electrical Service Size	(-) Highest	Medium

Table 5 – Quality Air-Cooled vs. Water-cooled Chillers

-Chiller Selection:

In order to select chillers for South Jefferson High School, calculated cooling capacities for the existing packaged direct expansion roof top units were developed in the Trane TRACE 700 software (Table 6). This data shows that the total peak load cooling tonnage is 591 tons for a design day. This load is handled completely by the roof top units' condensing units. Installing a central chilled water plant replaces the DX condensing units with air-cooled chillers.

Plant	System	Peak Plant Loads		Block Plant Loads		
		Main Coil ton	Peak Total ton	Time Of Peak mo/hr	Main Coil ton	Block Total ton
Cooling plant - 001		585.9	590.4	7/12	573.2	577.7
	AHU-8	6.4	10.9	7/12	6.4	10.9
	AHU-2	82.4	82.4	7/12	81.5	81.5
	AHU-3	30.2	30.2	7/12	30.2	30.2
	AHU-4	68.1	68.1	7/12	68.1	68.1
	AHU-5	40.7	40.7	7/12	40.7	40.7
	AHU-6	20.5	20.5	7/12	20.5	20.5
	AHU-7	49.3	49.3	7/12	47.5	47.5
	AHU-1	72.7	72.7	7/12	72.7	72.7
	AHU-9	37.1	37.1	7/12	36.6	36.6
	AHU-10	42.2	42.2	7/12	42.2	42.2
	AHU-11	10.0	10.0	7/12	4.5	4.5
	AHU-12	32.6	32.6	7/12	32.6	32.6
	AHU-13	46.1	46.1	7/12	44.4	44.4
	AHU-14	47.6	47.6	7/12	45.4	45.4
Building totals		585.9	590.4		573.2	577.7

Building peak load is 590.4 tons.
Building maximum block load of 577.7 tons occurs in July at hour 12 based on system simulation.

Table 6 – Design Cooling Load

When comparing the number and size for the air-cooled chillers, there were several possibilities to choose between. The first option, which is not very viable with air-cooled chillers, is to use just one chiller to meet the building's full peak load. Since air cooled chillers are typically available only between 150 to 500 tons and the building peak load was 591 tons this was not a viable option.

The second option would be to have two chillers in parallel which each meets half the calculated peak loads or approximately 300 tons each. A third option would be to have two chillers sized at a 60/40 split of the peak load. However, this option was not as lucrative as the regular 50/50 load split when compared to the chiller load profiles developed in Trane TRACE 700. The capacity of the 40% chiller (at 240 tons) would only meet the cooling demands during the winter months. The 60% chiller (at 360 tons) would have to operate for almost the entire year. In comparison, one of the 50% chillers (at 300 tons) could meet the cooling loads of the building for approximately four months out of the year.

Additional options for the chiller plant arrangement include using three chillers, each at one-third of the peak load (at 200 tons each). This was not a feasible solution and only represented a higher first cost with no real benefits in operating efficiency.

After comparing all these possibilities, it was determined that the two air-cooled chillers should operate in parallel and split the load in half at 300 tons each. This way, if one chiller would break down, the second chiller could meet up to half the load of the building. A school is not a critical facility like a hospital or data center, but some redundancy is important and logical.

The next design consideration was the type of chiller to select. Table 7 shows the Department of Energy's recommended chiller types according to tonnage. The type of chiller selected for South Jefferson is a screw chiller which operates well under the specified 300 tons. Under standard operating conditions the chiller achieves an EER of 12.4.

Chiller Size Recommendation	
<= 100 tons	1st choice: Reciprocating 2nd choice: Scroll 3rd choice: Screw
100 – 300 tons	1st choice: Screw 2nd choice: Scroll 3rd choice: Centrifugal
> 300 tons	1st choice: Centrifugal 2nd choice: Screw

Table 7 – Recommended Electric Chiller Types

-Variable Speed Control:

Another design consideration deals with the speed control of the compressors on the air-cooled chillers. It is recommended to use Variable Frequency Drives (VFD) on the chillers to increase the overall energy efficiency. This slightly increases the energy usage at peak loading with the rated kW/ton of the chillers. But in perspective, the chiller plant will only be operating at peak load conditions for a very small percentage (5% or less) of the time during the year. About 95% of the time is spent at part load conditions, which operate more efficiently with the use of VFD controllers on both chillers.

9.2 Ground Source Heat Pump:

Ground source heat pump (GSPH) systems take advantage of the earth's relatively constant temperatures just below its surface (53° in Charles Town, WV). The system uses a refrigeration cycle to extract and transfer heat to and from the ground. This system circulates a fluid (usually an antifreeze solution) through a subsurface loop (well field) of pipe to a heat pump. The subsurface loop typically consists of polyethylene pipe, which is placed horizontally in a trench or vertically in a bore hole. This thin-walled pipe is a heat exchanger, transferring heat to and from the earth. Fluids inside the pipe circulate to the heat exchanger of an indoor heat pump where they exchange heat with the refrigerant. The refrigerant loop typically consists of copper pipes that contain a refrigerant. The ground source heat pump system typically utilizes the earth as a source of heat in the winter and as a source of cooling in the summer.

System Variations:

Hybrid or independent, two-pipe and one pipe ground source heat pump systems were all considered in the redesign of South Jefferson High School.

-Two-Pipe versus One-Pipe:

In comparison of two-pipe versus one-pipe hydronic distribution systems, operating cost and first costs associated with each will differ. The overall cost of piping is better in the one-pipe system, but it also requires more pumps due to its distributed secondary pumping scheme. Since conserving energy is the main approach, a two-pipe system was selected.

-Hybrid versus Independent:

A hybrid GSHP system uses the aid of an additional heat exchanger other than the ground to reject heat, while the independent GSHP system uses only the ground. Both the hybrid and independent GSHP systems require a well field to be sized. The well field was modeled in the GHLEPro software package. The results, as seen in Appendix F, showed that all heat rejection could be done by the ground without the aid of any supplemental heat exchangers. In total, 240 boreholes at 20 foot intervals were required with each bore hole being 8 inches in diameter and drilled to a depth of 475 feet. The entire 480 x 200 foot well field can be constructed under the football and soccer practice fields at South Jefferson, and space still remains to construct a pump house containing two 25 horsepower pumps and all associated data collection equipment. This outcome makes an independent 2-pipe ground source heat pump system feasible for the redesign of South Jefferson.

9.3 Air-to-Air Heat Recovery:

Energy recovery was incorporated into both alternative systems. Both alternatives recover energy in the building's air distribution system, through the use of air-to-air heat recovery. Enthalpy or total energy wheels are used to transfer heat and moisture between a leaving exhaust air stream and entering outdoor air stream. In the VAV with chilled water plant alternative enthalpy wheels were added to the existing roof top units. This added first cost and did not significantly lower the size of existing heating and cooling equipment enough to declare the wheels a necessary addition to the system.

The ground source heat pump system uses dedicated outdoor air units for any units serving multiple spaces. The dedicated outdoor air units require energy recovery and utilize enthalpy wheels.

9.4 Humidity Control:

The density of the school's population results in large amounts of outdoor air that must move through the building to assure proper ventilation. If the air is not properly conditioned, small amounts of moisture in the outdoor air can lead to too much indoor moisture and moisture-related problems during the varying seasons.

One of the drawbacks to using ground source heat pumps in lieu of the other systems is that humidity control is not as good with heat pumps. In order to aid with this problem, dedicated outdoor air units have been used in place of the existing roof top units serving multiple spaces (Appendix B).

In each redesign, humidity controls are incorporated with the use of enthalpy wheels in the air handling equipment. The goal in using humidity controls is to maintain humidity levels below 60%, ideally between 30% and 50%. Simulations of both systems show that most spaces fell within the ideal humidity range. A few exceptions did exist in spaces with increased activity levels, such as the weight room and dance studio.

9.5 Cost Analysis:

Initial Cost:

The addition of a chilled water plant did not drastically increase first cost compared to the existing mechanical system. The difference between the existing system and VAV with chilled water plant is a just over $310,000. A detailed unit cost estimate of the VAV with chilled water system can be seen in Appendix D.

The ground source heat pumps system cost estimate was derived from the existing mechanical system cost estimate. Adjustments to the cost estimate were taken into account by having dedicated outdoor air units replacing the roof top units serving multiple spaces, fan powered boxes were replaced by less expensive heat pumps, and boilers were eliminated. These changes resulted in a reduction in cost, but this system requires a geothermal well field which can be very expensive. The cost for the well field and pump house accounts for an additional $1,807,847 to the project's cost. The cost estimation for the geothermal well field can be seen in Appendix D. These differences amount to a $1,012,044 increase in first cost between the existing and ground source heat pump system (Appendix D).

Maintenance Cost:

Maintenance costs were calculated using the ASHRAE HVAC Applications Handbook, 2003 mechanical maintenance cost estimation. Calculated results can be seen in Appendix D.

The VAV system with chilled water plant's maintenance cost is the highest of the alternative designs. Even though maintenance would be more centralized, and the number of compressors is reduced significantly with a plant. The increased cost of a 4-pipe system compared to a 2-pipe system significantly outweighs any other factor in the calculation. This also causes the maintenance cost for VAV system with chilled water plant to be more than the DX system. Not as surprising, is the result of the ground source heat pump system saving over $20,000 dollars annually over the DX system.

Life Cycle Cost:

The VAV system with chilled water plant does not yield returns in either life cycle payback or simple payback within 20 years. The ground source heat pump system starts to generating returns in 18.7 years within the 20 year life expectancy of a school (Table 8). The well field is the main element effecting first cost of the ground source heat pump system. If a hybrid GSHP system were designed it may have generated returns sooner. Reducing the well field size could influence cost more than adding a fluid cooler and boiler to the system. A hybrid system was not designed because it is not as energy efficient as an independent system.

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

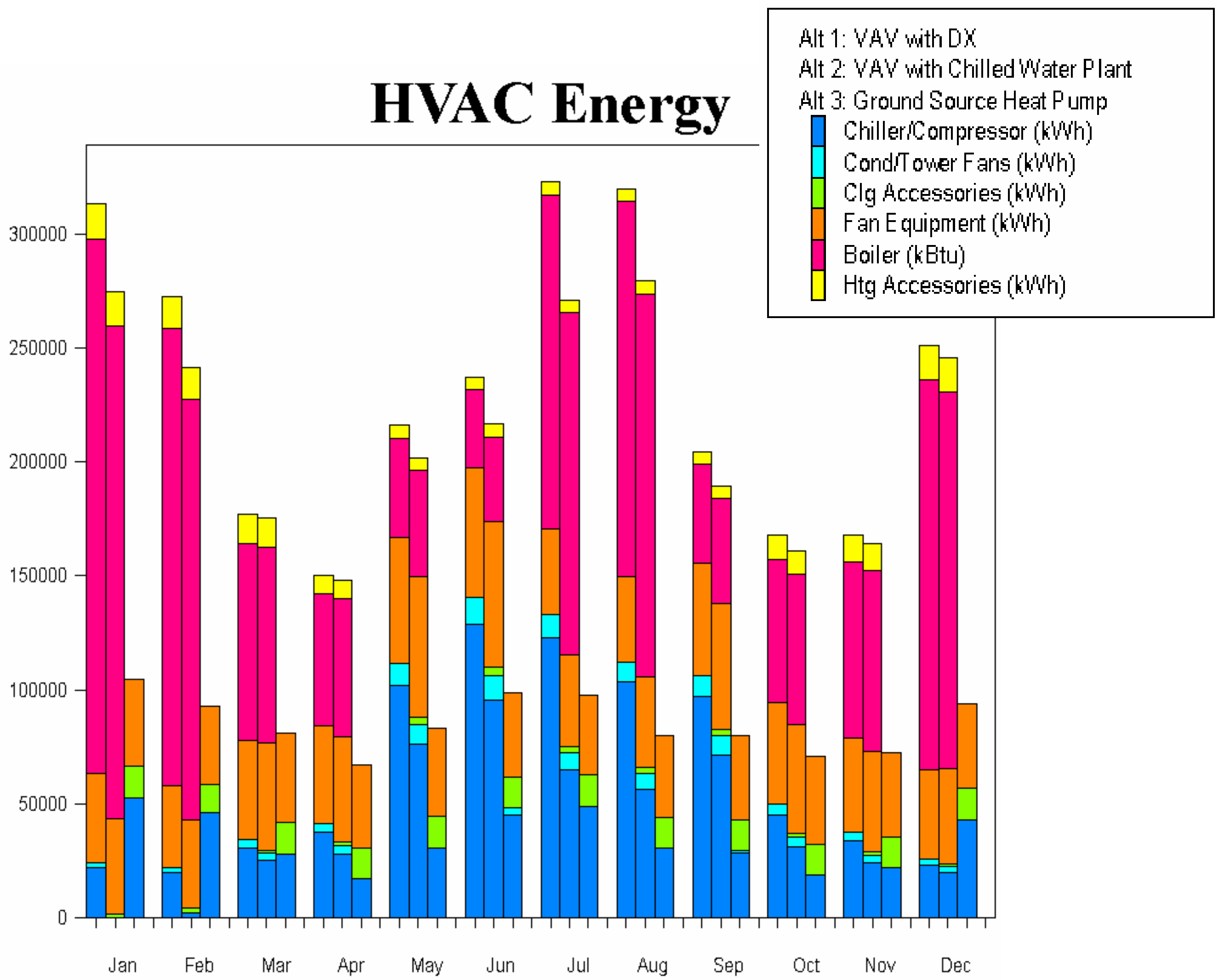
Altern. to Altern.	1st Cost Difference	Simple Payback	Net Present Value	Life Cycle Payback	Internal Rate of Return
Chiller to DX	$310,593	No pay back	-$431,038	No pay back	No pay back
GSHP to DX	$1,012,066	10.7 years	$38,278	18.7 years	10.5%
GSHP to Chiller	$701,473	6.5 years	$469,316	9 years	17.7%

Table 8 – Economic Comparison

9.6 Energy Analysis:

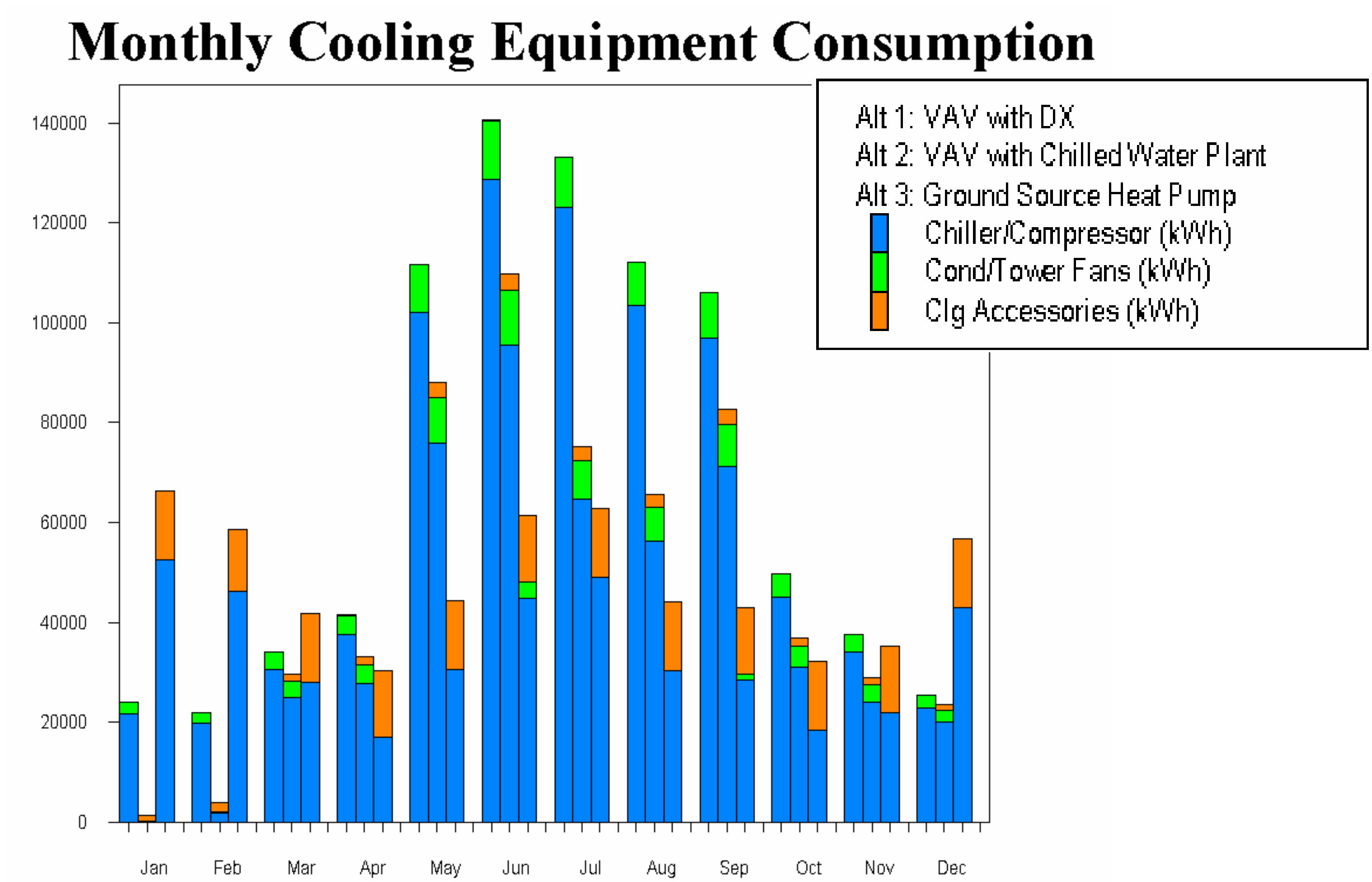
The VAV with chilled water plant alternative saves only a marginal amount of energy over the existing DX system. Most of the energy savings did show in space cooling and heat rejection, but the pump energy doubled (Appendix C) resulting in only 6% reduction in total building energy consumption. This reduction amounts to a $13,295 savings per year. The energy savings the air-cooled chiller has over the existing system is a direct result of the reduced KW/ton of the chiller and the energy recovered from the roof top units enthalpy wheels. Monthly HVAC energy consumption can be seen in Figure 2 to see system energy usages. One of the main reasons that the chilled water plant does not save more energy over the existing system is because the cooling equipment in both cases is air-cooled. If the chillers were to be water-cooled the energy savings would be much more noticeable, because of a higher COP. The counter to the water-cooled chiller is that the initial costs and maintenance costs for the system would be much higher.

Figure 2 – Monthly HVAC Energy Consumption



The ground source heat pump system produced much better results, saving nearly 25% of the total building energy consumption. This reduces the operating cost $73,551 per year. Considering that the school is located in West Virginia, this outcome is comparable to results found in other case studies for ground source heat pump systems in northern schools. The only area where the ground source heat pump system consumes more energy than the existing system is in pump energy. The pump energy is higher because of the added 25 hp pumps needed to pump water through the geothermal well field. The ground source heat pump's 22.8 EER for cooling and 4.6 COP for heating help account for most of the energy consumption savings. Heating consumption is reduced 51% and cooling consumption is reduced 69%. The cooling reduction can be seen on a monthly basis in Figure 3.

Figure 3 – Monthly Cooling Equipment Energy Consumption



9.7 Emissions:

Both redesign alternatives reduce total building energy consumption over the existing building mechanical system. Therefore, the alternatives also reduce the amount of pollutants emitted into the air. Electricity is used for power at South Jefferson creating no on-site emissions. Still, generating the electricity at a power plant and transferring it to the site is only 33% efficient and the plant produces its own emissions. South Jefferson High School uses a national power plant to generate its electricity; the mix of national power plant according to fuel types is shown in Table 9. Calculated pounds of harmful emissions can also be seen in the table. Assuming the plant that serves South Jefferson is a coal plant, the VAV with CHP reduces emissions be 7% and the ground source heat pump system reduces emissions by 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
Oil	2.8	3.03E-05	4.24E-04	7.78E-05	5.81E-02
Nat. Gas	9.3	0.00E+00	1.26E-06	2.36E-04	1.25E-01
Nuclear	22.8	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hydro/Wind	9.4	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Totals	100.0	6.43E-04	7.54E-03	4.44E-03	1.38E+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
Oil	3,448,084	1.04E+02	1.46E+03	2.68E+02	2.00E+05
Nat. Gas	3,448,083	0.00E+00	4.33E+00	8.14E+02	4.30E+05
Nuclear	3,448,083	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hydro/Wind	3,448,083	0.00E+00	0.00E+00	0.00E+00	0.00E+00

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
Oil	3,219,302	9.74E+01	1.36E+03	2.51E+02	1.87E+05
Nat. Gas	3,219,302	0.00E+00	4.04E+00	7.60E+02	4.01E+05
Nuclear	3,219,302	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hydro/Wind	3,219,302	0.00E+00	0.00E+00	0.00E+00	0.00E+00

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
Oil	2,409,015	7.29E+01	1.02E+03	1.87E+02	1.40E+05
Nat. Gas	2,409,015	0.00E+00	3.02E+00	5.68E+02	3.00E+05
Nuclear	2,409,015	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hydro/Wind	2,409,015	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Table 9 – Emissions Comparison

9.8 Conclusions and Recommendations:

The main goal in the redesign of South Jefferson High School's mechanical systems is green design. The focus in green design is lowering the total cost of ownership through resource management and energy efficiency and secondly increasing healthful benefits.

The first alternative (VAV with chilled water plant) does not meet these demands and is not a recommended design for South Jefferson. The system does not pay back in a 20 year life cycle and only has a marginal improvement in energy efficiency and indoor air quality.

The second alternative redesign (ground source heat pump system) is a recommended system redesign. The alternative yields returns in 18.7 years, while significantly reducing energy consumption and costs, cutting back on source emissions, and improving indoor air quality by alleviating humidity concerns.

10.0 Breadth Areas:

The two main breadth analysis areas proposed for the South Jefferson High School redesign were chosen because of the direct effect the analyses have on one another. The results of improving some of the lighting systems will directly affect the mechanical systems by decreasing cooling loads and building energy consumption. Also, the redesign of the mechanical systems at South Jefferson High School will have effects on some of the building's cost and scheduling concerns.

10.1 Lighting:

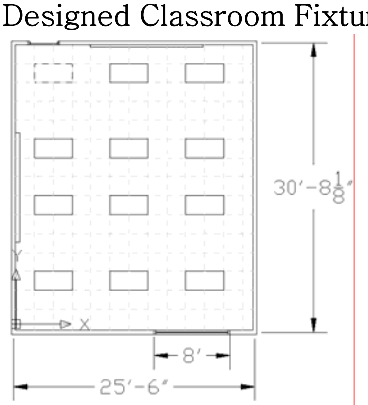
Research has shown that information presented visually is absorbed faster and retained more reliably than information presented orally. In order to promote learning, the classroom environment must be designed so that teachers and students can perform their visual tasks comfortably, quickly and accurately. Lighting is a main component that impacts the performance of teachers and students. High quality, energy effective lighting is great way to help improve a school.

Efficient Classroom Lighting Fixtures:

A significant amount (approximately 20%) of the annual HVAC energy consumption is conditioning of lighting. Classrooms and corridors lighting fixtures account for over half of South Jefferson's total lighting fixtures. Providing the classrooms and corridors energy efficient light fixtures to maintain lower watt per square foot values would consequently reduce cooling loads and considerably help annual energy costs. A summary of the existing total lighting fixture wattage is provided in Appendix G.

The highly efficient lighting fixture, lamp, and ballast combination chosen for each classroom and corridor are designed to guarantee enough illuminance for proper task lighting. The lighting calculations in Appendix G were generated for a typical South Jefferson classroom to ensure adequate task lighting. A layout of the lighting fixtures for the typical classroom can be seen in Figure 4.

Figure 4 – Designed Classroom Fixture Layout



The reduction in energy generated by the classroom and corridor lighting fixtures resulted in 0.10 W/S.F. decrease for the entire building. This will save 19,971 W in electrical service and would likely downscale electrical equipment. The energy to condition the lighting is reduced by 474.2 x 10^6 BTU's per year. The reduced loads effectively reduce HVAC equipment size. If the high efficiency lighting is used in the ground source heat pump alternative, the total building energy cost is $133,348. The result is nearly a $9000 per year savings over a ground source heat pump system with the existing light fixtures.

10.2 Construction Management:

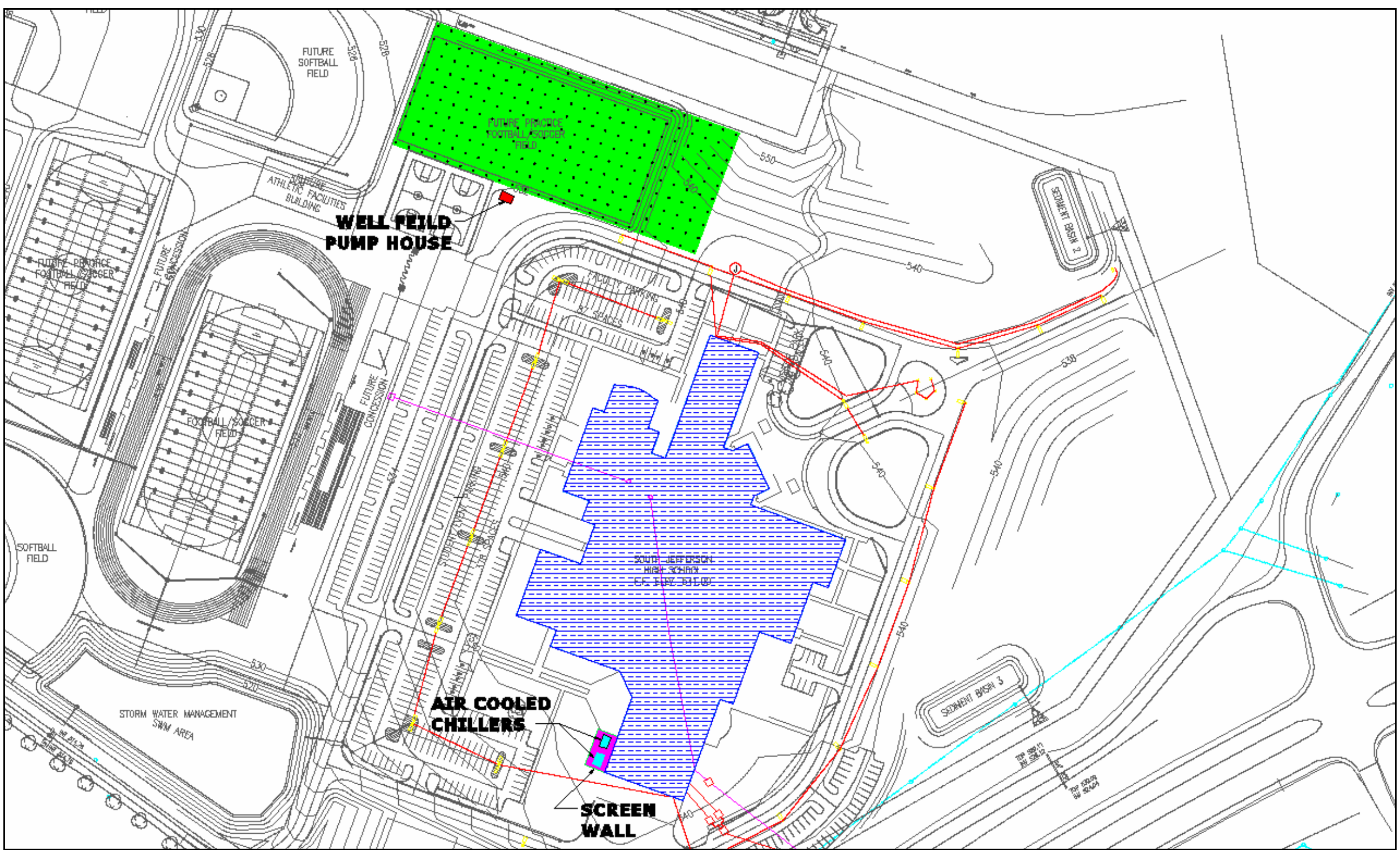
Utilizing a chiller water system or ground source heat pump system will directly affect the scheduling for the projects construction manager. Each alternative directly affected the construction of the buildings site. The chilled water plant would need to be constructed. While the ground source heat pump system requires the construction of a well field and pump house.

Construction Scheduling:

-VAV with Chilled Water Plant:

Adding a chilled water plant to a building affects usable space either inside or outside the building. In this case, an exterior site was selected because it has the least effect on the architecture of the building. The most practical location for the two 300 ton air-cooled chillers was by the loading docks outside the kitchen area. This location is hidden from view of a passersby driving on the main road, and is an easily accessible location for the maintenance staff. The addition of a screen wall also helps conceal the chillers and alleviate many of the screw chillers' noise concerns. The location of the air cooled chillers can be seen in Figure 5.

Figure 5 - Alternatives Site Impact



In comparison to a packaged roof top unit construction schedule, constructing an exterior chilled water plant does not effect duration and/or stop and start time of construction. All HVAC equipment construction would all be performed at the same times as the original system. The base construction schedule can be seen in Appendix H. The two air-cooled chillers would be installed replacing the 15 roof top condensing units. Also, four pipes need to be installed instead of two for the main heating and cooling hydronic distribution system. In each case, the construction would require more man power but no additional time is necessary to construct the system.

For chillers to operate efficiently, commissioning of the chilled water plant is necessary in the construction schedule. Sensors such as chilled water flow, chilled water supply and return temperatures, and chiller electric demand must all be properly calibrated. This will ensure that all data collected is correct and can be used to help the school save energy. The commissioning for a chilled water plant is more centralized but adds more complexity. Consequently, no additional time was either added or detracted from the base construction schedule for commissioning.

-Ground Source Heat Pump:

The site work construction is the component of construction scheduling intrinsically affected by the use of a ground source heat pump system in a building. This is because the construction of the geothermal well field is such a main constituent in the ground source heat pumps design. South Jefferson's well field requires 240 bore holes taking up an area of 96,000 square feet. The football and soccer practice fields were chosen as the best location for the geothermal well field. Here, the well field would avoid impacting any other construction on the site. The site locations can be seen on the previous page in Figure 2.

Since the well field does not impact any other construction, it can be constructed concurrently with the rest of the buildings site work. The South Jefferson High School ground source heat pump project would begin in the spring of 2007. The area of the future practice fields would be excavated and prepared for the installation of 240 boreholes. These wells will be drilled using two commercial drilling rigs, each drilling two holes a day, or 10 holes a week for 25 weeks. Each well hole will receive two 475 foot long pieces of polypropylene tubing attached by a "U-joint" at the bottom of the well. Each well will be connected in series, creating a large closed-loop geothermal space conditioning system. The well-field uses technology developed by the natural gas industry, including the ability to "field-splice" the polypropylene tubing as it is being assembled in the well-field. The well field manifold house will serve as a focal point for data generation and collection. From there, the loop is connected to the main pumps, also housed in the pump room. These variable speed 25 H.P. pumps control the speed of the water used to transport the water in the loop field.

During installation, all debris and small animals should have been kept out of the piping, but to ensure proper performance the geothermal well field should still be cleaned and tested. Each supply and return circuit will be flushed and purged with a water velocity of 2 ft/s. The lines will be left filled with clean water and then pressure tested. If connection to the manifold is not immediate, piping must be capped.

After the well field is deemed usable, the well field contractor must coordinate with the mechanical contractor on propylene glycol antifreeze installation. The mechanical contractor is responsible for the propylene glycol antifreeze. Once the propylene glycol is filled in the system to the proper percentage, the geothermal well field can be implemented into the rest of the ground source heat pump system.

Commissioning for the ground source heat pump system is done twice, once in the winter and once in the summer. This is to ensure that the system is operating properly and supplying proper water temperatures to condition the building. If the well field is not rejecting or receiving enough heat from the ground, expensive alterations to the system will occur.

11.0 References:

2003 ASHRAE Handbook – HVAC Applications. Inch-Pound Edition. ASHRAE, Inc. Atlanta, GA. 2001.

2005 ASHRAE Handbook – Fundamentals. Inch-Pound Edition. ASHRAE, Inc. Atlanta, GA. 2001.

ANSI/ASHRAE, Standard 62.1 – 2004, Ventilation for Acceptable Indoor Air Quality. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc., Atlanta, GA. 2004.

ANSI/ASHRAE/IESNA Standard 90.1-2004 – Energy Standard for Buildings Except Low-Rise Residential Buildings. American Society of Heating Refrigeration and Air Conditioning Engineers, Inc. Atlanta, GA. 2004.

Alpha Associates, Incorporated. 2004, Educational Specifications. Alpha Associates, Incorporated Morgantown, WV. 2004.

National Best Practices Manual for High Performance Schools. Department of Energy.

Environmental Protection Agency's Energy Star Target Finder tool. Environmental Protection Agency. 2006

H.F. Lenz Company. 2005, Mechanical Construction Documents. H.F. Lenz Company, Johnstown, PA. 2005.

Gridley, Jonathon. *Technical Assignment #1: ASHRAE Standard 62.1-2004 Ventilation Report.* October 5, 2006.

Gridley, Jonathon. *Technical Assignment #2: Building and Plant Energy Analysis Report*. October 27, 2006.

Gridley, Jonathon. *Technical Assignment #3: Mechanical Systems Existing Conditions Report*. November 21, 2006.

Trane TRACE 700 Comprehensive Building Analysis Software Version 4.1.11. Trane. 2005.

APPENDIX A: Energy Model Data:

Schedules:

- Regular school hours were assumed to be 7am to 5pm and between the months of August to June
- Administrative offices and classrooms follow regular school hours
- Cafeteria was assumed to be fully occupied between 11am and 1pm
- Gymnasium and Technology/Adult learning areas were assumed to have extended hours until 9pm and occupancy year round

Note: Utilization schedules were designed with the designer's best judgment, because no utilization data was provided.

Electricity Cost:

Demand Charge

First 3,000 kVA ……………………………………… $7.923 per kVA
Next 14,000 kVA …………………………………… $7.456 per kVA
Additional kVA ……………………………………… $7.104 per kVA

Energy Charge

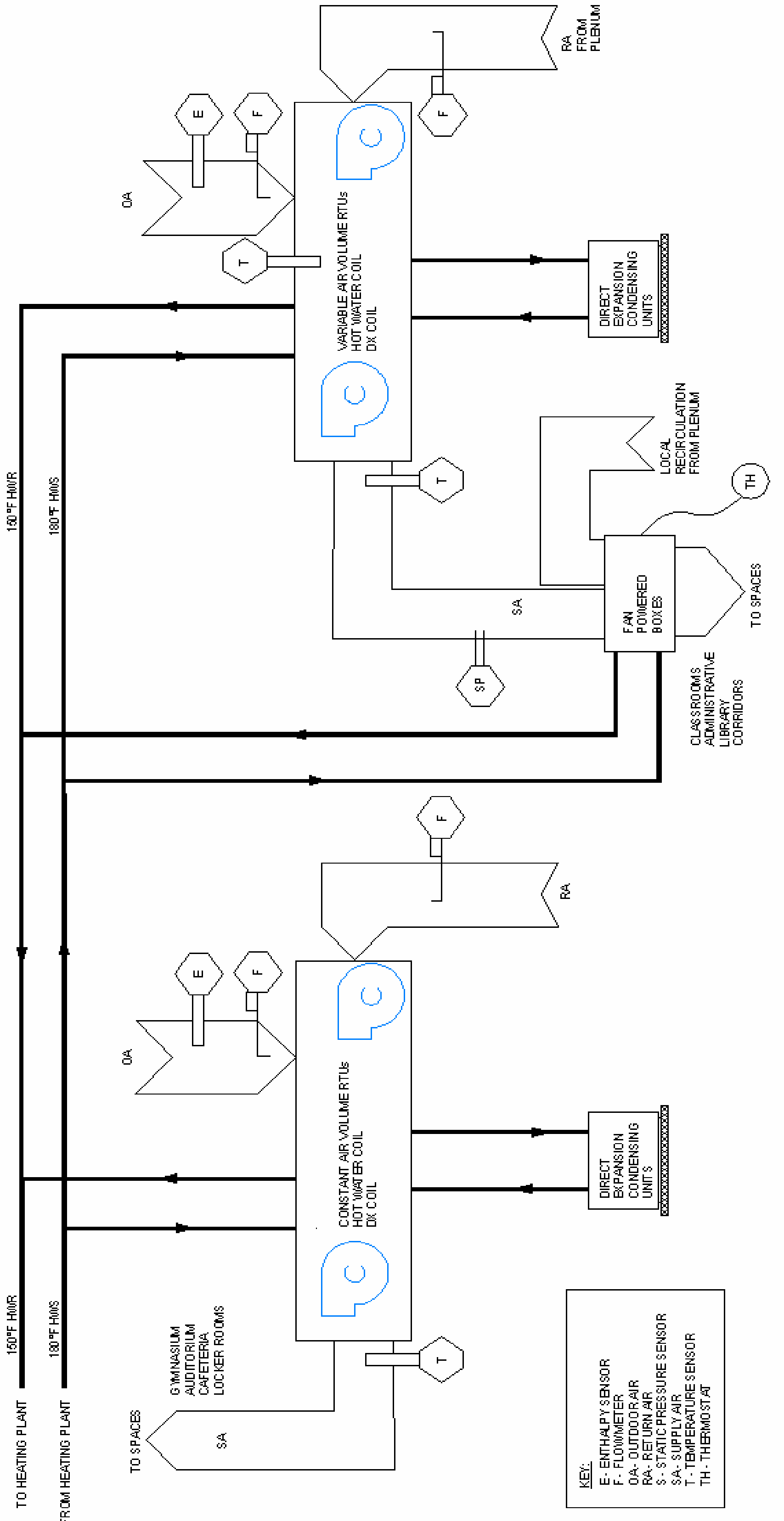
All kW ……………………………………………………… $0.02198 per kW

Loads:

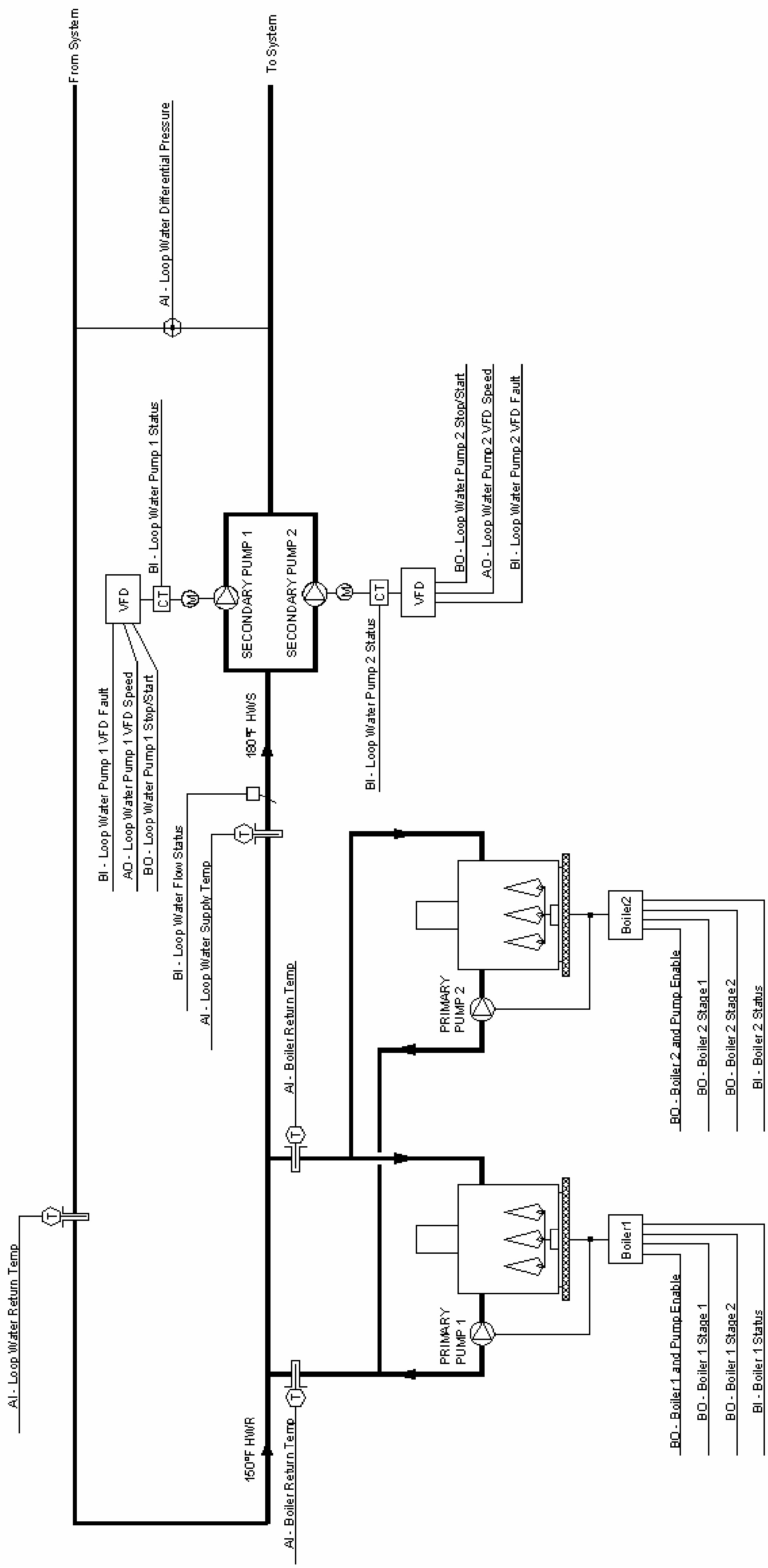
People: Varies depending on activity level
Computers
Kitchen Equipment
Receptacle
Lighting
Miscellaneous Loads
Domestic Hot Water
Base Utilities

APPENDIX B: Schematic Diagrams:

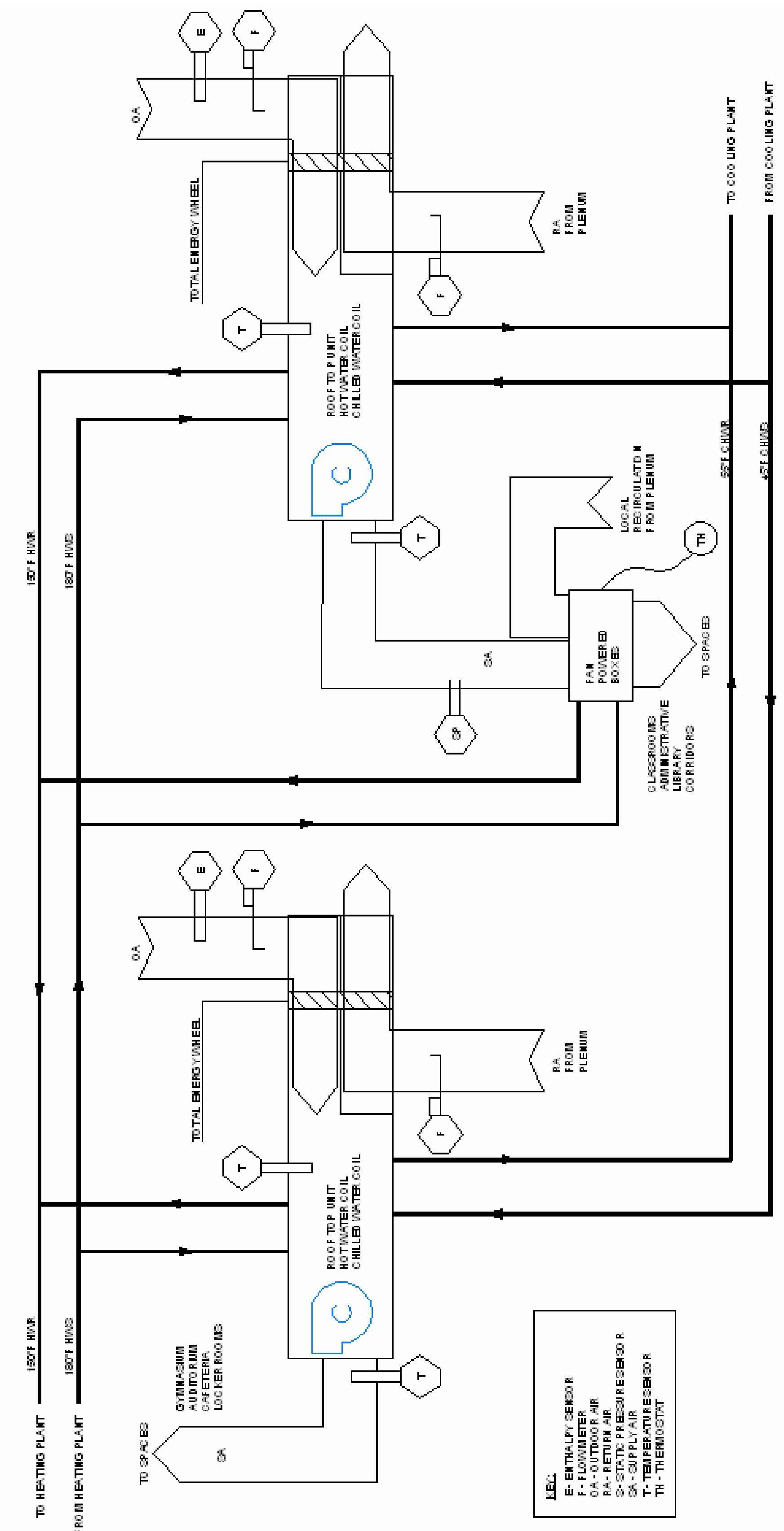
VAV with DX Roof Top Units Airside Schematic:



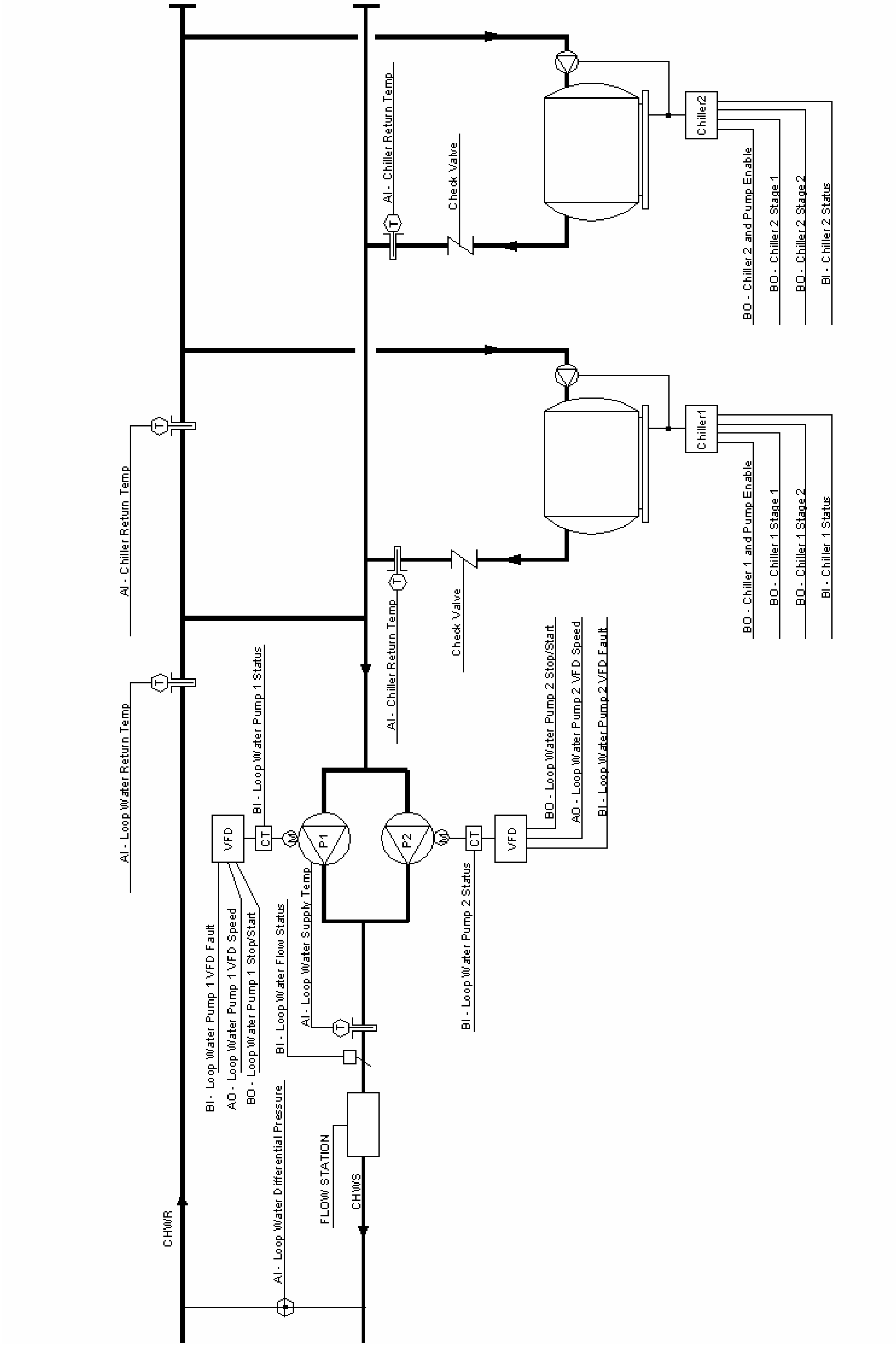
VAV Heating Plant Schematic:



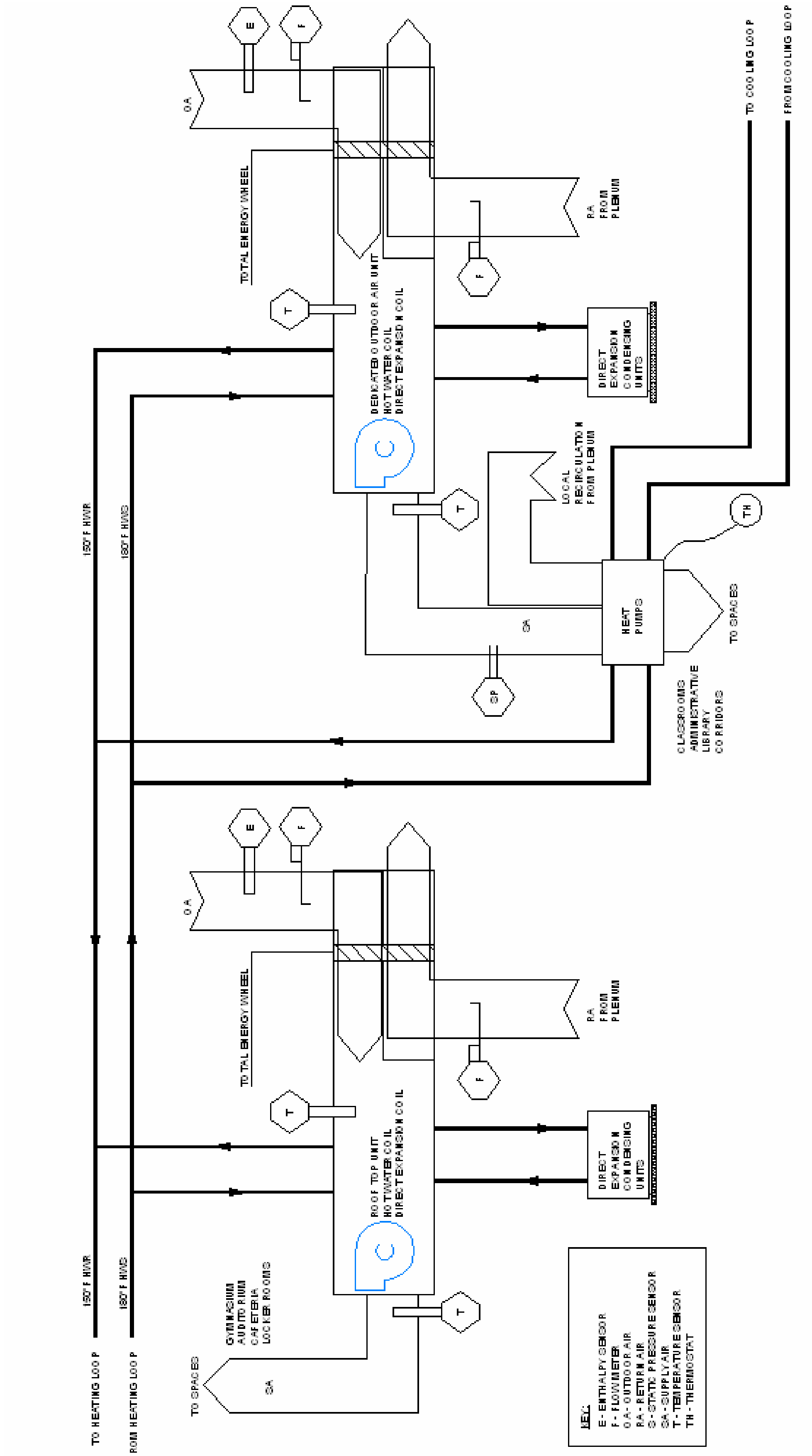
VAV with Chilled Water Plant Airside Schematic:



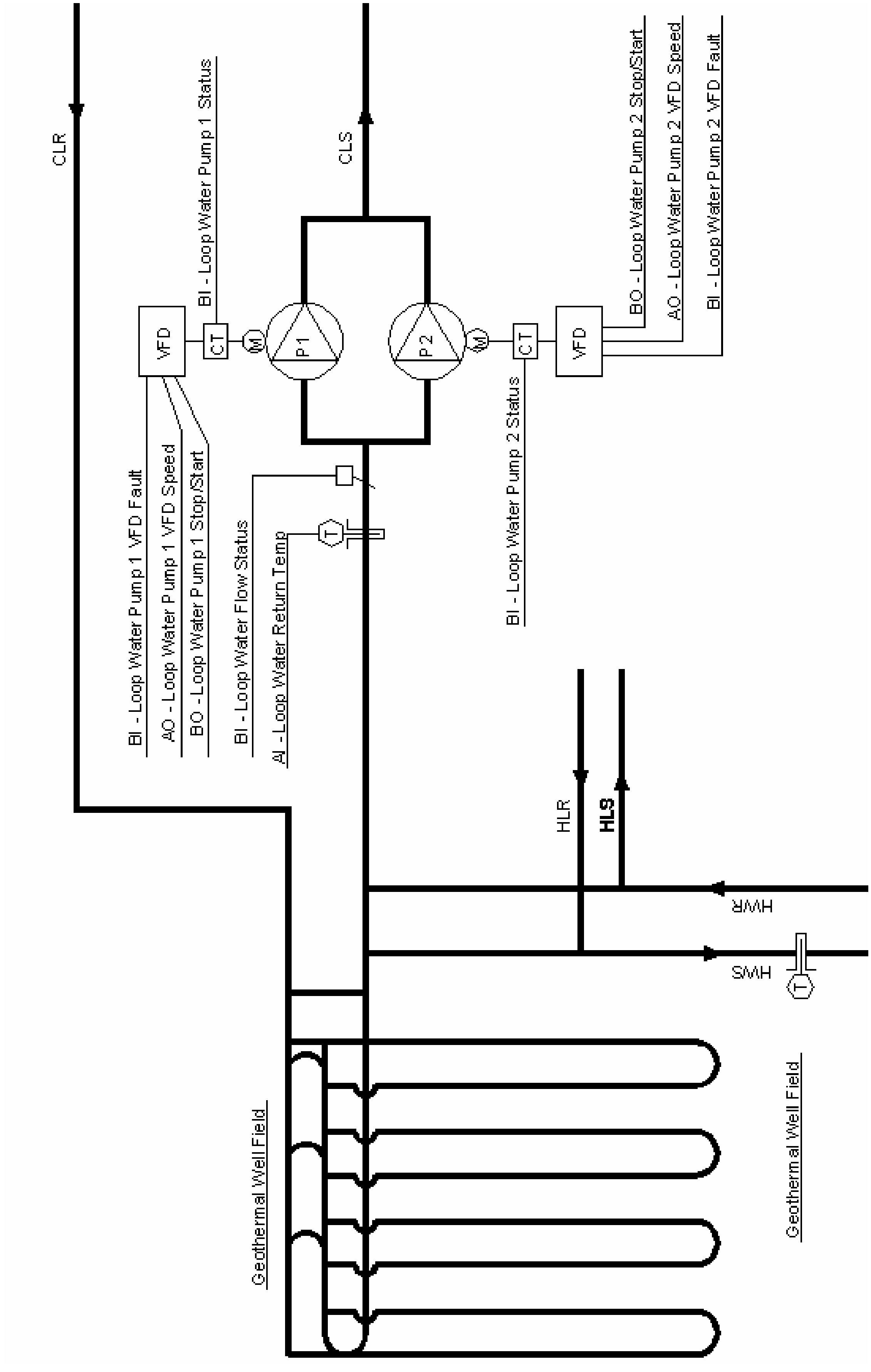
VAV with Chilled Water Plant Schematic:



Ground Source Heat Pump Airside Schematic:



Ground Source Heat Pump Schematic:



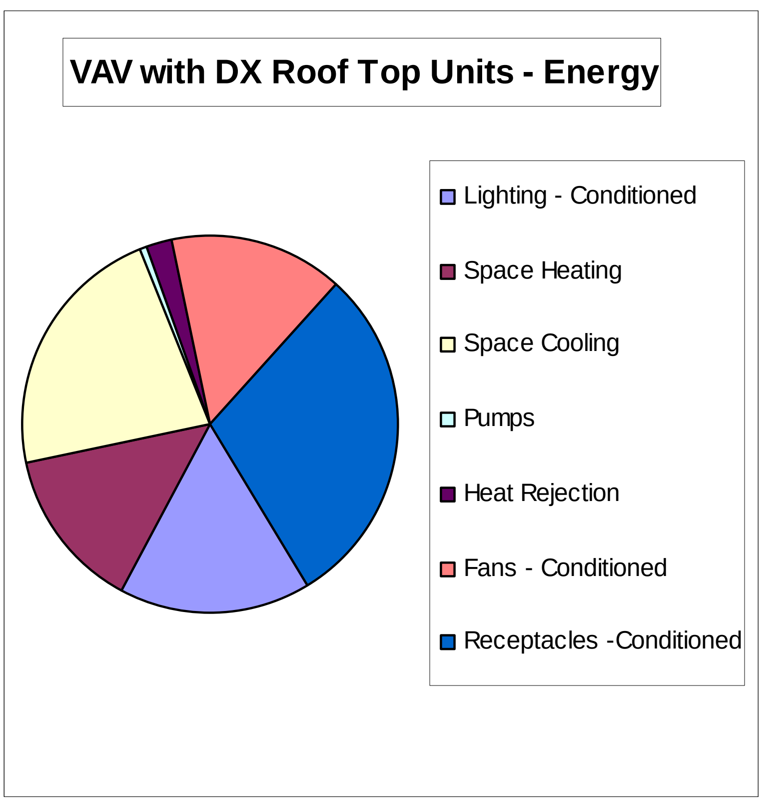
APPENDIX C: Energy Consumption:

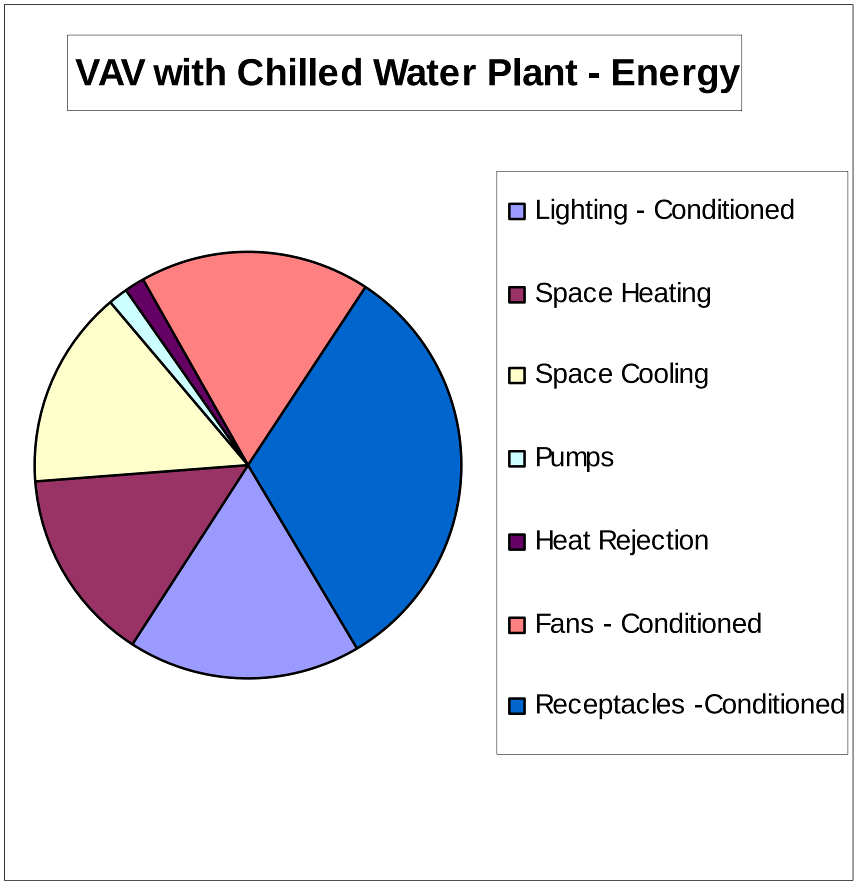
Energy Consumption and Costs - Alternatives Comparison

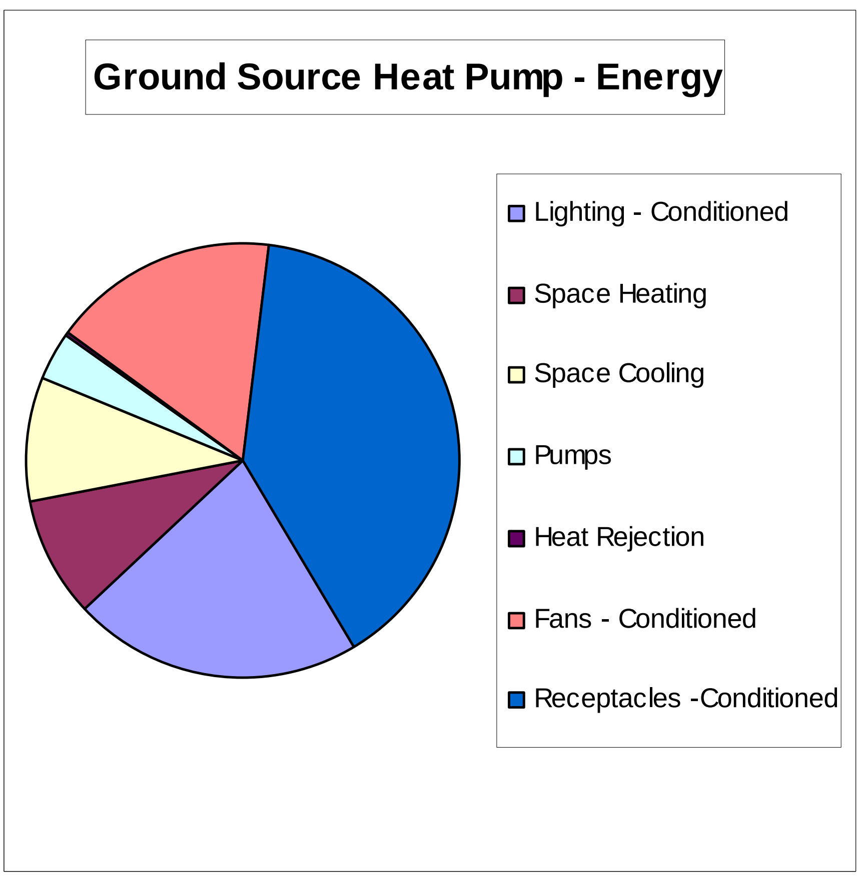
Project Name: South Jefferson High School	City: Charles Town, WV
Created by: Jonathon Gridley	Weather Data: Washington, D.C.

		VAV with DX Roof Top Units			VAV with Chilled Water Plant			Ground Source Heat Pump		
		Energy (10^6 Btu/yr)	Proposed / Base (%)	Peak (kBtuh)	Energy (10^6 Btu/yr)	Proposed / Base (%)	Peak (kBtuh)	Energy (10^6 Btu/yr)	Proposed / Base (%)	Peak (kBtuh)
Lighting - Conditioned	Elect.	1,915.7	16	781	1,940.2	101	791	1,914.4	100	781
Space Heating	Elect.	1,658.0	14	2,111	1,638.2	99	2,044	807.2	49	1,037
Space Cooling	Elect.	2,615.8	22	2,790	1,703.4	65	2,280	820.7	31	494
Pumps	Elect.	62.6	1	11	126.5	202	28	324.5	518	57
Heat Rejection	Elect.	243.7	2	258	206.1	85	226	15.3	6	145
Fans - Conditioned	Elect.	1,789.2	15	1002	1,943.0	109	1,158	1,522.4	85	528
Receptacles -Conditioned	Elect.	3,483.3	30	1,501	3,532.4	101	1,513	3,500.1	100	1,474
Total Building Consumption		11,768.3			11,089.8			8,904.6		

	VAV with DX Roof Top Units		VAV with Chilled Water Plant		Ground Source Heat Pump	
	Energy (10^6 Btu/yr)	Cost/ year ($/year)	Energy (10^6 Btu/yr)	Cost/ year ($/year)	Energy (10^6 Btu/yr)	Cost/ year ($/year)
Total	11,768	216,145	11,090	202,850	8,905	142,594



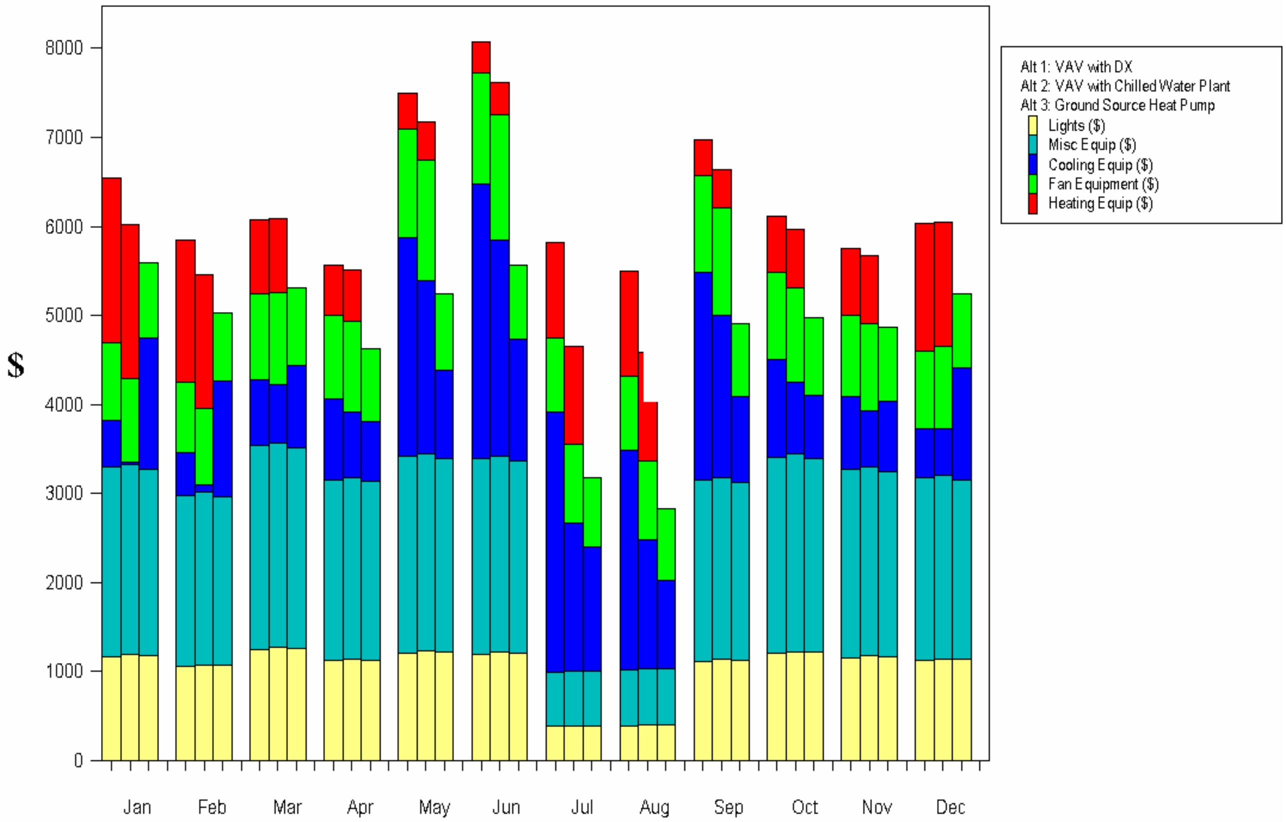

VAV with Chilled Water Plant - Energy
Lighting - Conditioned
Space Heating
Space Cooling
Pumps
Heat Rejection
Fans - Conditioned
Receptacles -Conditioned


Ground Source Heat Pump - Energy
Lighting - Conditioned
Space Heating
Space Cooling
Pumps
Heat Rejection
Fans - Conditioned
Receptacles -Conditioned

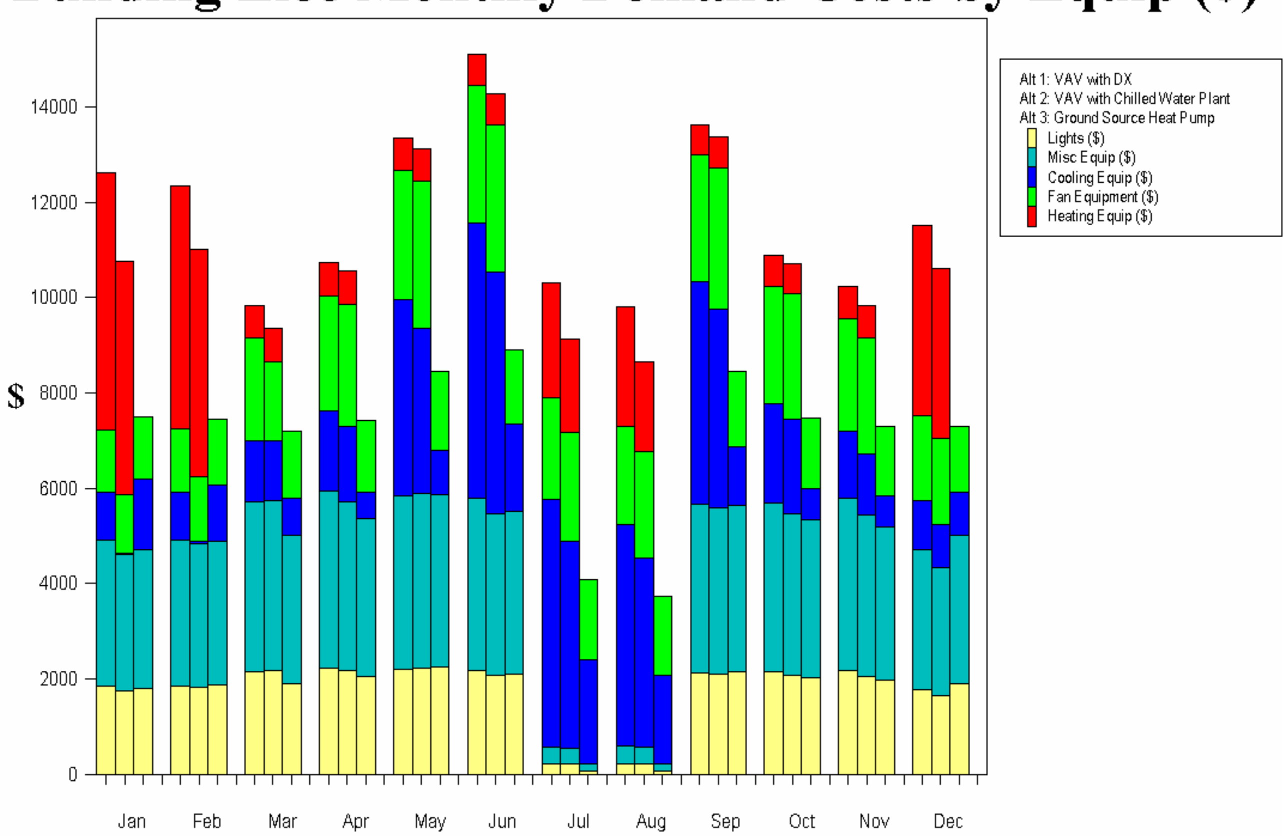
Equipment Energy Consumption by Alternative:

	Elect Cons. (kWh)	Percent of Total Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
Alternative: 1 - VAV with DX				
Primary heating	388,007	11.3%	1,324,266	3,973,196
Other Htg Accessories	97,781	2.8%	333,726	1,001,278
Cooling Compressor	765,642	22.2%	2,613,135	7,840,189
Tower/Cond Fans	71,403	2.1%	243,697	731,165
Other Clg Accessories	790	0.0%	2,697	8,092
Supply Fans	524,233	15.2%	1,789,206	5,368,154
Pumps	18,334	0.5%	62,574	187,739
Lighting	561,301	16.3%	1,915,721	5,747,738
Receptacles	1,020,594	29.6%	3,483,287	10,450,905
Totals**	**3,448,083**	**100.0%**	**11,768,308**	**35,308,452**
Alternative: 2 - VAV with Chilled Water Plant				
Primary heating	383,208	11.8%	1,307,888	3,924,058
Other Htg Accessories	96,774	3.0%	330,290	990,968
Cooling Compressor	493,140	15.2%	1,683,086	5,049,764
Tower/Cond Fans	60,394	1.9%	206,124	618,435
Other Clg Accessories	5,962	0.2%	20,350	61,055
Supply Fans	569,296	17.5%	1,943,008	5,829,606
Pumps	37,058	1.1%	126,478	379,472
Lighting	568,483	17.5%	1,940,233	5,821,281
Receptacles	1,034,986	31.9%	3,532,408	10,598,284
Totals**	**3,249,302**	**100.0%**	**11,089,866**	**33,272,924**
Alternative: 3 - Ground Source Heat Pump				
Primary heating	169,408	6.5%	578,188	1,734,738
Other Htg Accessories	67,099	2.6%	229,007	687,091
Cooling Compressor	240,338	9.2%	820,273	2,461,067
Tower/Cond Fans	4,479	0.2%	15,288	45,870
Other Clg Accessories	128	0.0%	438	1,315
Supply Fans	446,065	17.1%	1,522,420	4,567,716
Pumps	95,064	3.6%	324,454	973,458
Lighting	560,922	21.5%	1,914,426	5,743,852
Receptacles	1,025,512	39.3%	3,500,074	10,501,270
Totals**	**2,609,015**	**100.0%**	**8,904,568**	**26,716,376**

Building Elect Monthly Energy Cost by Equip ($)



Building Elec Monthly Demand Costs by Equip ($)



APPENDIX D: Cost Estimation:

VAV with Chilled Water Plant – Mechanical First Cost:

060 HVAC			
060-015 Air Side Equipment			
15730.000 Unitary Air Conditioning Equipment			
Ductless Split System @ Data Rooms	7 ea	3,335.74	23,350
15730.000 Unitary Air Conditioning Equipment			**23,350**
15830.000 Fans			
Exhaust Fans	1 alw	7,500.00	7,500
Allowancew for special exhaust at Science and Shops	1 alw	10,000.00	10,000
15830.000 Fans			**17,500**
060-015 Air Side Equipment			**40,850**
060-020 Cooling Equipment			
15620.000 Packaged Water Chillers			
Water chillers, recip, int air cooled cond, 100 ton cooling	1 ea	106,235.56	106,236
Water Chiller, recip, air cooled cond. 250 ton cooling	2 ea	116,032.41	232,065
15620.000 Packaged Water Chillers			**338,300**
15720.000 Air Handling Units			
Air-Handling Unit 1, 2, & 4, 30,000 CFM	3 ea	103,392.98	310,179
Air-Handling Unit 7, 28,000 CFM	1 ea	97,362.75	97,363
Air-Handling Unit 5, 25,000 CFM	1 ea	87,302.29	87,302
Air-handling Unit 12, 18,000 CFM	1 ea	63,272.06	63,272
Air-Handling Unit 3, 16,000 CFM	1 ea	56,181.38	56,181
Air-Handling Unit 6 & 10, 10,000 CFM	2 ea	35,151.14	70,302
Air-Handling Unit 9, 8000 CFM	1 ea	28,120.92	28,121
Air Handling Unit 11, 7500 CFM	1 ea	26,090.69	26,091
Air-Handling Unit 13, 14, 15, & 16 6000 CFM	4 ea	21,090.69	84,363
Air-Handling Unit 8, 4500 CFM	1 ea	15,060.46	15,060
15720.000 Air Handling Units			**838,235**
060-020 Cooling Equipment			**1,176,535**
060-025 Heating Equipment			
15130.000 Pumps			
Heating hot water supply/return pumps	2 ea	5,870.83	11,742
Chilled water supply/return pumps	5 ea	5,870.82	29,354

VAV with Chilled Water Plant – Mechanical First Cost: (Cont'd)

15130.000 Pumps			**41,096**
15510.000 Heating Boilers and Accessories			
Boilers, Electric 1000 KW	3 ea	25,810.89	77,433
Expansion Tank	4 ea	2,102.64	8,411
Air Separator	1 ea	1,820.73	1,821
Chemical Feeder/Treatment	1 ls	10,000.00	10,000
Boilers, Control Panel	1 ea	6,888.17	6,888
Dom. H.W. Storage Heater (350 Gal.)	2 ea	2,077.51	4,155
15510.000 Heating Boilers and Accessories			**108,707**
15760.000 Terminal Heating and Cooling Units			
VAV Fan Powered Boxes	105 ea	1,406.05	147,635
15760.000 Terminal Heating and Cooling Units			**147,635**
15770.000 Floor-Heating and Snow-Melting Equipment			
Cabinet Unit Heaters, with fan, 120V, surf mtd, 2,250 W	5 ea	1,189.18	5,946
Horizontal Unit Heaters, with fan, 120V, ceiling mtd,	6 ea	1,189.18	7,135
15770.000 Floor-Heating and Snow-Melting Equipment			**13,081**
060-025 Heating Equipment			**310,519**
060-030 Ductwork			
15810.000 Ducts			
Duct, rect, incl ftg, supports	250,000 lb	5.09	1,273,606
Duct accessories, fire damper	10 ea	215.51	2,155
Duct accessories, volume damper	50 ea	275.08	13,754
Duct accessories, motorized damper	1 ea	515.51	516
Duct accessories, Specialties	1 ls	19,620.51	19,621
Floor Penetrations - cutting, patching and firestopping	1 ls	9,620.51	9,621
15810.000 Ducts			**1,319,271**
15850.000 Air Outlets and Inlets			
Diffusers, Grilles and Registers	1,150 ea	153.21	176,186
Louvers	1 ls	10,000.00	10,000
Roof Ventilator, base, damper&bird scr, sta mushroom, 42" orifice dia	16 ea	1,267.65	20,282

VAV with Chilled Water Plant – Mechanical First Cost: (Cont'd)

15850.000 Air Outlets and Inlets			**206,468**
060-030 Ductwork			**1,525,740**
060-035 HVAC Piping			
15105.000 Pipes and Tubes			
Pipe, HWS & HWR with fittings and supports	12,500 lf	38.00	475,000
Pipe, Refrigerant with fittings and supports	1,500 lf	38.00	57,000
Pipe, CWS & CWR with fittings and supports	9,875 lf	38.00	375,250
15105.000 Pipes and Tubes			**907,250**
060-035 HVAC Piping			**907,250**
060-040 HVAC Insulation			
15080.100 Duct Insulation			
Duct Insulation	1 ls	50,000.00	50,000
Piping Insulation	1 alw	15,000.00	15,000
Insulation Equipment	1 ls	5,000.00	5,000
15080.100 Duct Insulation			**70,000**
060-040 HVAC Insulation			**70,000**
060-045 Testing, Balancing & Commissioning			
15950.000 Testing, Adjusting, and Balancing			
Test & balance	180 hr	125.00	22,500
15950.000 Testing, Adjusting, and Balancing			**22,500**
060-045 Testing, Balancing & Commissioning			**22,500**
060-050 HVAC Controls			
15935.000 Building Systems Controls			
Building Systems Controls	1 ls	460,000.00	460,000
15935.000 Building Systems Controls			**460,000**
060-050 HVAC Controls			**460,000**
060-060 HVAC Miscellaneous			
15050.000 Basic Mechanical Materials and Methods			
Hvac mech equip, concrete pads	1 ls	5,000.00	5,000
Hvac mech equip, Comb. Starters & Disc. Switches	12 ea	1,200.00	14,400
15050.000 Basic Mechanical Materials and Methods			**19,400**
060-060 HVAC Miscellaneous			**19,400**
060 HVAC	**232,705 sf**	**19.48**	**4,532,793**

Estimating Mechanical Maintenance Costs:

The following method may be used for estimating or comparing the total office building HVAC maintenance costs. The premise of this method assumes that the base HVAC system in the building consists of fire-tube boilers for heating equipment, centrifugal chillers for cooling equipment, and VAV distribution systems. The total building HVAC maintenance cost for this system is 48.40 ¢/SF. Adjustment factors from the table are then applied to the base cost to account for building age and variations on the type of HVAC equipment as follows:

Total Building Area: 199,717 S.F.

C = Total building HVAC maintenance cost (¢/SF)
or C = 48.40 + 0.18n + h + c + d

= Base system maintenance cost (48.40 ¢/SF)
+ (age adjustment factor) x (age in years n)
+ Heating system adjustment factor h
+ Cooling system adjustment factor c
+ Distribution system adjustment factor d

Alternative 1		**Alternative 2**		**Alternative 3**	
Adjusted Cost (¢/SF)	**Total Cost**	**Adjusted Cost (¢/SF)**	**Total Cost**	**Adjusted Cost (¢/SF)**	**Total Cost**
27.54	$55,002	40.47	$80,825	16.82	$33,592

System Adjustment Factors:

	years		years		years
-3.87	h	-3.87	h	-14.05	h
-6.3	c	-5.8	c	-6.84	c
-10.69	d	1.74	d	-10.69	d

ASHRAE Adjustment Factors:

Heating Equipment h

Water tube boiler	1.12
Cast iron boiler	1.36
Electric boiler	-3.87
Heat pump	-14.05
Electric resistance	19.29

Cooling Equipment c

Reciprocating chiller	-5.8
Absorption chiller (single stage)	27.91
Water source heat pump	-6.84

Distribution System d

Single zone	12.02
Multizone	-6.67
Dual duct	-0.42
Constant volume	12.77
Two-pipe fan coil	-4.02
Four-pipe	8.41
Induction	9.89

Total Well Field Cost: (with drilling, piping, and grouting costs)

Output includes amount of materials, costs for grouting and total loop costs.

	INPUT:				
Bore Diameter (In.):	**6**				
U-Tube O.D. (In.):	**1.9**	3/4"= 1.05	1"=1.315	1-1/4"=1.66	1-1/2"=1.90
$ per 50# bentonite:	**14**				
$ per 50# sand	**4.5**				
$ per ft Drilling & Tube Insertion:	**10**				
$ per ft. Pipe:	**1**				
Labor $/hr - Grouter:	**30**				
:	**10**				

		Components per Batch					
***GshpCalc* Design Ft.**	**Bore Depth**	**50# Bags-Bent.**	**50# Silica Sand**	**Water (gal.)**	**Yield-Gal/Batch**	**Gal. Req'd**	**Batches**
Ft. Bore - k=0.4 Btu/hr*ft*F (20%):	**475**	1	0	23	36	557.76	15.49
Ft. Bore - k=0.90 Btu/hr*ft*F:	**400**	1	4	17.8	30.6	469.69	15.35
Ft. Bore - k=1.2 Btu/hr*ft*F:	**350**	1	8	22.4	44.6	410.98	9.21

	OUTPUT: Total per Borehole				
	Bags-Bent./Bore	**Bags-Sand/Bore**	**Gal. Wtr./Bore**	**Grouting $/Bore**	**Total $/Bore**
Net Cost for k=0.4 Btu/hr*ft*F:	15.49	0.00	356.34	$263.38	$5,963.38
Net Cost for k=0.90 Btu/hr*ft*F:	15.35	61.40	273.22	$721.42	$5,521.42
Net Cost for k=1.2 Btu/hr*ft*F:	9.21	73.72	206.41	$709.54	$4,909.54

		OUTPUT: Entire Well Field				
	# Bores	**Bags-Bent.**	**Bags-Sand**	**Gal. Wtr.**	**Grouting $**	**Total $**
Net Cost for k=0.4 Btu/hr*ft*F:	240	3,718.38	0.00	85,522.65	$63,212.39	$1,431,212.39
Net Cost for k=0.90 Btu/hr*ft*F:	240	3,683.84	14,735.36	65,572.35	$173,140.48	$1,325,140.48
Net Cost for k=1.2 Btu/hr*ft*F:	240	2,211.54	17,692.34	49,538.56	$170,288.81	$1,178,288.81

Ground Source Heat Pump Cost Estimation

Existing System Total Cost	$4,222,222	

	Subtracted Costs	
	Existing Cost	**Difference**
Boiler Elimination:	$104,500	$104,500
Duct Resizing:	$1,319,271	$461,745
AHU Resizing:	$838,235	$209,879
Heat Pump vs Fan Powered Box:		$19,680

Total Difference (Existing System to GSHP):	$795,803
Adjusted Cost:	$3,426,419

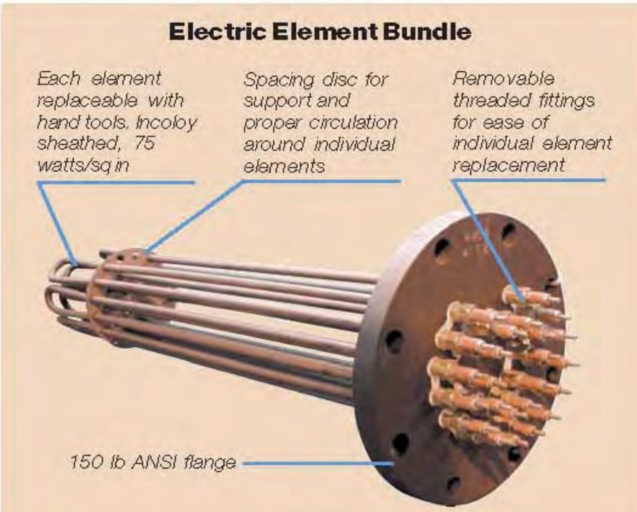
Added Costs	
GSHP Well Field Cost:	$1,807,847

Ground Source Heat Pump Total Cost:	$5,234,266

APPENDIX E: Equipment Cutsheets:

Bryan electric hot water or steam boilers...

For commercial, institutional and industrial applications



Bryan Series BH electric hot water** or steam boilers are compact, completely packaged and wired units with automatic controls featuring long life Incoloy sheathed elements. Applications include hot water heating, steam heating, process heating, and supplemental heat for heat pump type equipment.

All Bryan Boilers are built in accordance with the requirements of the ASME boiler and pressure vessel code and are UL listed. Water boilers are 150 psig MAWP and steam boilers either 15 psig or 150 psig. Higher pressures are available.

Efficiency

Bryan Electric Boilers are nearly 95% efficient at all load levels. Varying loads do not effect the efficiency since the resistive type heating elements are immersed and designed to heat the water directly. With a modulating step control only the elements that are required to heat the water to the desired temperature/ pressure will be energized in order to encourage a balanced load during operation.

Replaceable Hairpins

Each element hairpin is field replaceable with no welding, soldering, or brazing required. Each hairpin, as standard for all Bryan Electric Boilers, is Incoloy sheathed and industrial size 0.430" diameter. Elements are designed for 75 watts/sq. inch for long life (optional 50 W/D available). Elements are individually installed in a standard ANSI 150 lb. blind flange.

Steam Disengaging Area

Steam release area is near the middle of the horizontal vessel for maximum steam disengaging area for dry steam and stable water level.

Water Boiler Design

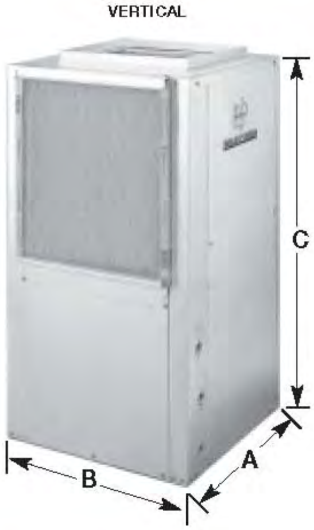
Vessel is designed for proper circulation around individual elements to maximize heat transfer. High velocities, i.e. heat pump applications, are handled with very little pressure drop when using a horizontal tank for the pressure vessel. Supply and return nozzle sizes can be made larger to accommodate the flow requirements. Pressure drop is minimal through the boiler and no dangers are involved with low flow conditions.

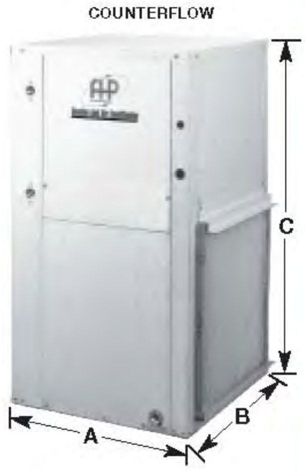
Bryan BH Series Boiler Specifications

Model	Nom. Output		Steam Output*	Approx. Shipping Weight		Model	Nom. Output		Steam Output*	Approx. Shipping Weight	
Input KW	MBH	BHP	lbs/hr (kg/hr)	Water lbs (kg)	Steam lbs (kg)	Input KW	MBH	BHP	lbs/hr (kg/hr)	Water lbs (kg)	Steam lbs (kg)
60BH	196	6	207 (93)	900 (408)	1,000 (454)	780BH	2,548	78	2,691 (1,221)	3,600 (1,633)	4,000 (1,814)
75BH	245	7.5	259 (117)	900 (408)	1,000 (454)	840BH	2,744	84	2,898 (1,315)	3,700 (1,678)	4,100 (1,860)
90BH	294	9	311 (141)	1,000 (454)	1,100 (499)	900BH	2,940	90	3,105 (1,408)	3,850 (1,746)	4,200 (1,905)
105BH	343	10.5	362 (164)	1,000 (454)	1,300 (590)	960BH	3,136	96	3,312 (1,502)	4,000 (1,814)	4,400 (1,996)
120BH	392	12	414 (187)	1,000 (454)	1,300 (590)	1020BH	3,332	102	3,519 (1,596)	4,500 (2,041)	5,000 (2,268)
135BH	441	13.5	466 (211)	1,200 (544)	1,400 (635)	1080BH	3,528	108	3,726 (1,690)	4,500 (2,041)	5,100 (2,313)
150BH	490	15	518 (234)	1,200 (544)	1,400 (635)	1140BH	3,724	114	3,933 (1,784)	5,000 (2,268)	5,500 (2,495)
165BH	539	16.5	569 (258)	1,300 (590)	1,500 (680)	1200BH	3,920	120	4,140 (1,878)	5,250 (2,381)	5,700 (2,586)
180BH	588	18	621 (281)	1,300 (590)	1,500 (680)	1260BH	4,116	126	4,347 (1,972)	5,500 (2,495)	6,000 (2,722)
195BH	637	19.5	673 (305)	1,400 (635)	1,700 (771)	1320BH	4,312	132	4,554 (2,066)	5,600 (2,540)	6,100 (2,767)
210BH	686	21	725 (328)	1,400 (635)	1,700 (771)	1380BH	4,508	138	4,761 (2,160)	5,700 (2,586)	6,300 (2,858)
225BH	735	22.5	776 (352)	1,500 (680)	1,800 (816)	1440BH	4,704	144	4,968 (2,253)	5,800 (2,361)	6,400 (2,903)
240BH	784	24	828 (375)	1,600 (726)	1,900 (862)	1530BH	4,999	153	5,279 (2,394)	6,000 (2,722)	6,600 (2,994)
270BH	882	27	932 (422)	1,600 (726)	2,000 (907)	1620BH	5,293	162	5,589 (2,535)	6,200 (2,812)	6,800 (3,084)
300BH	980	30	1,035 (469)	1,700 (771)	2,200 (998)	1710BH	5,587	171	5,900 (2,676)	6,400 (2,903)	7,000 (3,175)
330BH	1,078	33	1,139 (516)	1,800 (816)	2,300 (1,043)	1800BH	5,881	180	6,210 (2,817)	6,600 (2,994)	7,200 (3,266)
360BH	1,176	36	1,242 (563)	1,800 (816)	2,400 (1,089)	1920BH	6,273	192	6,624 (3,005)	6,800 (3,084)	7,400 (3,357)
390BH	1,274	39	1,346 (610)	2,000 (907)	2,500 (1,134)	2040BH	6,665	204	7,038 (3,192)	7,000 (3,175)	7,600 (3,447)
420BH	1,372	42	1,449 (657)	2,000 (907)	2,600 (1,179)	2160BH	7,057	216	7,452 (3,380)	7,200 (3,266)	7,800 (3,538)
450BH	1,470	45	1,553 (704)	2,100 (953)	2,700 (1,225)	2280BH	7,449	228	7,866 (3,568)	7,400 (3,357)	8,100 (3,764)
480BH	1,568	48	1,656 (751)	2,150 (975)	2,800 (1,270)	2400BH	7,841	240	8,280 (3,756)	7,600 (3,447)	8,300 (3,765)
510BH	1,666	51	1,760 (798)	2,500 (1,134)	2,900 (1,315)	2520BH	8,233	252	8,694 (3,944)	7,800 (3,538)	8,600 (3,901)
540BH	1,764	54	1,863 (845)	2,500 (1,134)	3,000 (1,361)	2640BH	8,625	264	9,108 (4,131)	8,000 (3,629)	8,800 (3,992)
600BH	1,960	60	2,070 (939)	3,000 (1,361)	3,500 (1,588)	2880BH	9,409	288	9,936 (4,507)	8,400 (3,810)	9,200 (4,173)
660BH	2,156	66	2,277 (1,033)	3,350 (1,520)	3,600 (1,633)	3000BH	9,801	300	10,350 (4,695)	8,600 (3,901)	9,400 (4,264)
720BH	2,352	72	2,484 (1,127)	3,500 (1,588)	3,800 (1,724)						

NOTES: * Lbs. steam per hour from and at 212°F. ** Not intended for use as a principal heating source for living space of any individual residence.

GS SERIES PERFORMANCE DATA





DIMENSIONS						
MODEL	VERTICAL/C.FLOW			HORIZONTAL		
	A	B	C	D	E	F
GS018	21 1/2	21 1/2	40 1/4	25 1/2	45	21 3/4
GS024	21 1/2	21 1/2	40 1/4	25 1/2	43	21 3/4
GS030,036	21 1/2	26	47 1/4	26	54 1/2	21 3/4
GS042,048	24	32 3/4	47 1/4	30	68	21 3/4
GS054,062	26	33 1/4	51 1/4	30	68	21 3/4
GS070	26	33 1/4	58 1/4	30	78	21 3/4

All ratings and specifications are subject to change without notice.

MODEL	CFM	ARI / ISO 13256-1 PERFORMANCE DATA											
		ENTERING WATER TEMPERATURES											
		Water Loop				Ground Water				Ground Loop			
		86° F		68° F		59° F		50° F		77° F		32° F	
		CAPACITY AND EFFICIENCY DATA											
		COOLING CAPACITY (WLHP)	EER (WLHP)	HEATING CAPACITY (WLHP)	COP (WLHP)	COOLING CAPACITY (GWHP)	EER (GWHP)	HEATING CAPACITY (GWHP)	COP (GWHP)	COOLING CAPACITY (GLHP)	EER (GLHP)	HEATING CAPACITY (GLHP)	COP (GLHP)
GS018	600	15,500	16.8	16,300	5.2	17,200	25.9	13,200	4.5	16,000	19.4	10,600	3.8
GS024	800	23,500	14.9	28,500	4.8	26,400	22.6	23,200	4.2	24,500	16.7	18,200	3.6
GS030	1000	28,000	17.6	33,200	5.9	30,000	25.9	26,000	4.9	29,000	20.7	19,000	4.1
GS036	1200	34,000	15.5	40,500	5.3	37,800	22.8	32,400	4.6	35,000	18.7	24,500	3.6
GS042	1400	39,600	15.7	48,500	5.5	44,000	22.8	39,000	4.6	41,000	17.9	30,000	3.8
GS048	1600	47,000	14.5	58,000	5.1	52,000	21.1	47,000	4.3	49,000	16.6	36,500	3.6
GS054	1800	51,000	14	62,000	4.5	57,000	19.8	52,000	4.1	52,000	15.4	41,000	3.5
GS062	2000	60,000	13.2	77,000	4.6	65,000	18.3	60,000	4.1	60,500	14.6	48,000	3.3
GS070	2200	68,000	13	82,000	4.7	76,000	19.2	66,000	3.9	69,000	14.3	53,000	3.5

Tabulated performance data is at noted entering water temperatures and entering air conditions of 80.6° F DB/66.2°F WB at ARI/ISO 13256-1 rated CFM and copper heat exchangers.

ARI PERFORMANCE CERTIFIED ANSI/ARI/ASHRAE/ISO Standard 13256-1

c UL us

GEOEXCHANGE

IGSHPA

energy

FHP MANUFACTURING COMPANY
601 N.W. 65TH COURT • FT. LAUDERDALE, FL 33309 • PHONE: (954) 776-5471 • FAX: (800) 776-5529
http://www.fhp-mfg.com

HEAT PUMPS

GSGW Rev. 4/06

High Efficiency Ratings – English - R134a

MODEL: YCAV0247E/V E_ IPLV= 12.8 V_ IPLV= 14.9

AIR TEMPERATURE ON - CONDENSER (°F)

LCWT (°F)	75.0			80.0			85.0			90.0			95.0			100.0		
	TONS	KW	EER	TONS	KW	EER	TONS	KW	EER	TONS	KW	EER	TONS	KW	EER	TONS	KW	EER
40.0	232.7	192.6	13.1	230.8	206.9	12.2	228.7	222.3	11.3	226.4	238.6	10.5	223.9	255.8	9.7	221.1	275.2	9.0
42.0	240.0	194.4	13.4	238.0	208.6	12.5	235.8	223.9	11.6	233.4	240.2	10.8	230.8	257.3	10.0	227.9	276.8	9.2
44.0	247.4	196.3	13.7	245.4	210.4	12.8	243.1	225.6	11.9	240.6	241.8	11.0	237.9	259.0	10.2	234.7	278.3	9.4
45.0	251.2	197.4	13.9	249.1	211.4	12.9	246.8	226.5	12.0	244.2	242.7	11.1	241.4	259.9	10.3	238.1	278.9	9.6
46.0	255.1	198.5	14.0	252.9	212.3	13.1	250.5	227.4	12.1	247.9	243.6	11.3	245.1	260.7	10.5	241.5	279.6	9.7
48.0	262.8	200.8	14.3	260.6	214.5	13.3	258.1	229.4	12.4	255.4	245.4	11.5	252.4	262.6	10.7	248.4	280.9	9.9
50.0	270.8	203.3	14.5	268.5	216.8	13.6	265.9	231.5	12.7	263.1	247.5	11.8	260.0	264.5	11.0	255.5	282.2	10.1
52.0	278.9	205.9	14.8	276.5	219.2	13.9	273.8	233.8	12.9	270.9	249.6	12.0	267.7	266.6	11.2	262.8	283.6	10.4
55.0	291.2	209.7	15.2	288.7	223.1	14.2	285.9	237.5	13.3	282.8	253.1	12.4	279.5	269.8	11.6	273.9	286.0	10.7

MODEL: YCAV0267E/V E_IPLV= 13.3 V_IPLV= 14.9

AIR TEMPERATURE ON - CONDENSER (°F)

LCWT (°F)	75.0			80.0			85.0			90.0			95.0			100.0		
	TONS	KW	EER	TONS	KW	EER	TONS	KW	EER	TONS	KW	EER	TONS	KW	EER	TONS	KW	EER
40.0	264.2	211.7	13.5	261.9	228.6	12.5	259.3	246.9	11.5	256.4	266.4	10.6	253.3	286.8	9.8	249.7	309.7	9.0
42.0	272.6	213.3	13.8	270.3	229.9	12.8	267.6	248.0	11.8	264.6	267.4	10.9	261.3	287.9	10.1	257.6	310.9	9.2
44.0	281.2	215.2	14.1	278.8	231.4	13.1	276.0	249.2	12.1	272.9	268.5	11.2	269.5	288.9	10.4	265.6	312.2	9.5
45.0	285.5	216.3	14.3	283.1	232.3	13.3	280.3	249.9	12.3	277.2	269.1	11.4	273.7	289.5	10.5	269.7	312.7	9.6
46.0	289.9	217.4	14.4	287.4	233.2	13.4	284.6	250.7	12.5	281.4	269.8	11.5	277.9	290.1	10.6	273.8	313.4	9.8
48.0	298.8	219.9	14.7	296.3	235.3	13.7	293.4	252.4	12.8	290.1	271.2	11.8	286.5	291.4	10.9	282.2	314.7	10.0
50.0	307.8	222.7	15.0	305.3	237.6	14.0	302.3	254.4	13.1	299.0	273.0	12.1	295.2	293.0	11.2	290.8	316.1	10.3
52.0	317.0	225.8	15.3	314.5	240.3	14.3	311.5	256.6	13.3	308.0	274.9	12.4	304.2	294.7	11.5	299.6	317.8	10.5
55.0	331.1	231.1	15.6	328.5	244.8	14.7	325.4	260.5	13.8	321.9	278.2	12.8	317.9	297.6	11.9	312.4	319.0	10.9

MODEL: YCAV0287E/V E_IPLV= 12.9 V_IPLV= 14.8

AIR TEMPERATURE ON - CONDENSER (°F)

LCWT (°F)	75.0			80.0			85.0			90.0			95.0			100.0		
	TONS	KW	EER	TONS	KW	EER	TONS	KW	EER	TONS	KW	EER	TONS	KW	EER	TONS	KW	EER
40.0	281.2	222.4	13.6	278.8	240.6	12.6	276.1	260.6	11.6	273.1	282.2	10.7	270.0	304.7	9.8	266.3	330.2	9.0
42.0	290.1	224.2	14.0	287.6	241.7	12.9	284.8	261.4	11.9	281.7	282.7	11.0	278.4	305.4	10.1	274.6	331.0	9.3
44.0	299.3	226.2	14.3	296.7	243.2	13.3	293.8	262.4	12.3	290.5	283.5	11.3	287.1	306.0	10.4	283.1	331.8	9.5
45.0	303.9	227.4	14.4	301.3	244.2	13.4	298.3	263.1	12.4	295.0	284.0	11.5	291.5	306.4	10.5	287.4	332.2	9.6
46.0	308.6	228.7	14.6	305.9	245.2	13.6	302.9	263.9	12.6	299.6	284.5	11.6	296.0	306.8	10.7	291.8	332.6	9.8
48.0	318.1	231.7	14.9	315.4	247.4	13.9	312.2	265.5	12.9	308.8	285.7	11.9	305.0	307.8	11.0	300.7	333.6	10.1
50.0	327.8	235.1	15.1	325.0	250.0	14.2	321.8	267.5	13.2	318.2	287.4	12.2	314.3	309.2	11.3	309.8	334.6	10.3
52.0	337.8	239.0	15.3	334.8	253.2	14.4	331.5	269.9	13.5	327.8	289.4	12.5	323.8	310.7	11.6	319.1	335.8	10.6
55.0	353.0	245.8	15.6	349.9	258.6	14.8	346.5	274.4	13.9	342.7	292.8	12.9	338.4	313.4	12.0	333.2	337.9	11.0

NOTES:

1. kW = Compressor Input Power
2. EER = Chiller EER (includes power from compressors, fans, and control panels 0.8 KW)
3. LCWT = Leaving Chilled Water Temperature
4. Ratings based on 2.4 GPM cooler water per ton
5. Rated in accordance with ARI Standard 550/590-98 and are accordingly certified

34 YORK INTERNATIONAL

Selection List Report - 60Hz Centrifugal Demo Catalog

Company: South Jefferson High School
Name: Jonathon A. Gridley
Date: 4/9/2007
Selection: pump 1

Powered By PUMP-FLO

Search Criteria:

Flow: 792 US gpm Head: 92.3 ft

Motor:

Standard: NEMA
Enclosure: TEFC

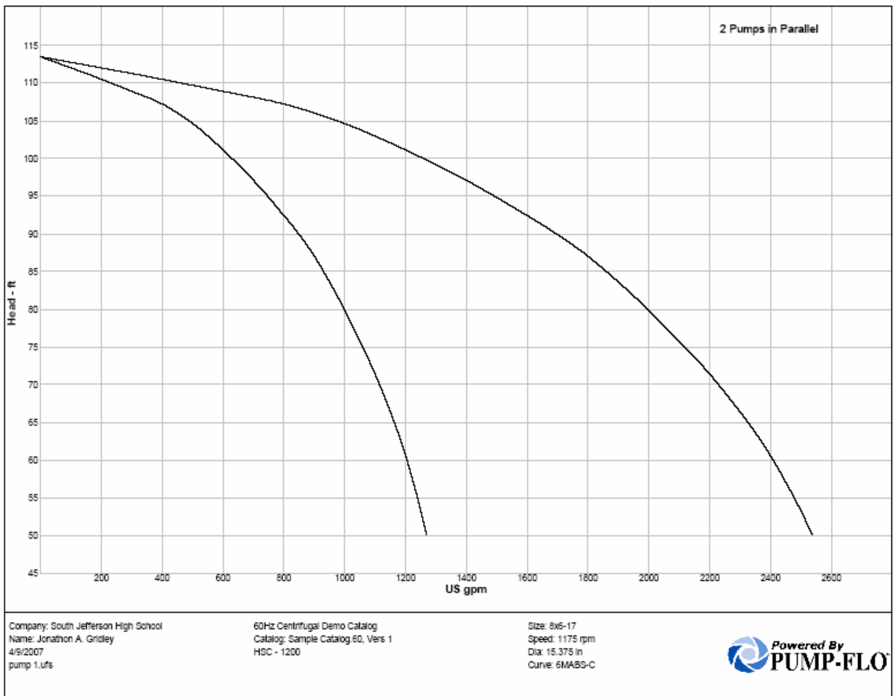
Sizing criteria: Max Power on Design Curve

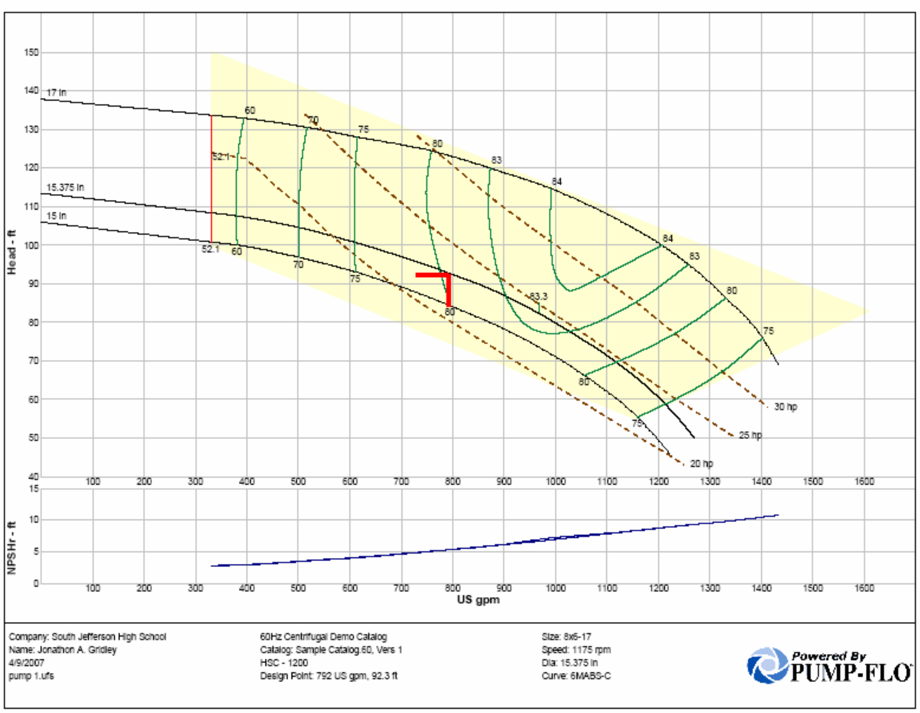
Fluid:

Water
Density: 62.25 lb/ft³
Viscosity: 1.105 cP
NPSHa: ---

Temperature: 60 °F
Vapor pressure: 0.2563 psi a
Atm pressure: 14.7 psi a

Flags	Type	Size	Curve	Speed rpm	Dia	Head ft	Eff %	BEP %	NPSHr ft	Pwr hp	NOL Pwr hp	Motor hp	Frame	Energy	Min Flow US gpm	Sphere in	Ns	Nss
---	HSC	10x8-17.125	8M-D	1175	14.25	93.1	73	84.8	3.67	25.4	42.6	50	365T	---	359	1.63	1435	---
---	VSS	6x4-17	ABC1039-2	1180	14.875	93.7	72	74.3	4.28	26	32.2	40	364T	---	477	0.157	1100	10320
---	ESP	6x4-17	ABC1039-2	1180	14.875	93.7	72	74.3	4.27	26	32.2	40	364T	---	351	0.157	1100	10320
---	VSS	8x6-15	ABC1041-2	1180	14.375	92.8	66.2	84.4	5.46	27.9	37.7	40	364T	---	600	0.157	1670	9560
---	ESP	8x6-15	ABC1041-2	1180	14.375	92.8	66.2	84.4	5.46	27.9	37.7	40	364T	---	462	0.157	1670	9560
---	ESP	8x6-17	ABC1042-2	1180	14.25	93.9	57.1	77.6	5	32.9	47.9	50	365T	---	700	0.157	1480	11140
---	HSC	8x6-17	6MABS-C	1175	15.375	92.7	80.4	83.3	5.32	23	24.6	25	324T	---	330	0.75	1193	---





APPENDIX F: Well Field Sizing Calculations:

Printed from GLHEPRO -- Output file

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Active borehole length, ft                              =450.0
Borehole Radius, in                                     =4.000
Borehole spacing, ft                                    =239.9
Borehole Geometry                                       : RECTANGULAR CONFIGURATION
                                                        : 120 : 10 x 12, rectangle
Soil Type currently used                                :
Thermal conductivity of the ground, Btu/(hr*ft*°F)      =3.634
Volumetric heat capacity of Ground, Btu/(°F*ft^3)       =36.90
Volumetric heat capacity of fluid, Btu/(°F*ft^3)        =62.00
Undisturbed ground temperature, °F                      =53.00
Borehole thermal resistance, °F/(Btu/(hr*ft))           =0.4300
Fluid type currently entered                            : 12.90% Propylene Glycol / Water
Mass flow rate of the fluid, gal/min                    =1000
Density of the fluid, lb/ft^3                           =63.21
Heat Pump Selected                                      : Florida Heat Pump GT026
```

GLHE Monthly Loads

Month	Total Heating 1000 Btu	Total Cooling 1000 Btu	Peak Heating 1000 Btu/Hr	Peak Cooling 1000 Btu/Hr
January	000000.00	000000.00	000000.00	000000.00
February	000000.00	000000.00	000000.00	000000.00
March	000000.00	000000.00	000000.00	000000.00
April	000000.00	000000.00	000000.00	000000.00
May	000000.00	000000.00	000000.00	000000.00
June	000000.00	000000.00	000000.00	000000.00
July	000000.00	000000.00	000000.00	000000.00
August	000000.00	000000.00	000000.00	000000.00
September	000000.00	000000.00	000000.00	000000.00
October	000000.00	000000.00	000000.00	000000.00
November	000000.00	000000.00	000000.00	000000.00
December	000000.00	000000.00	000000.00	000000.00

Heat Pump Monthly Loads

Month	Total Heating 1000 Btu	Total Cooling 1000 Btu	Peak Heating 1000 Btu/Hr	Peak Cooling 1000 Btu/Hr
January	154101.00	751497.00	000870.82	001851.89
February	140297.00	660634.50	000887.84	001769.62
March	211702.50	447745.50	001403.15	001391.42
April	239495.00	269688.50	001960.18	001088.68
May	500991.00	050547.00	002880.96	000510.16
June	384676.50	057588.50	002485.57	000576.30
July	486722.00	061338.50	002824.62	000650.75
August	341178.00	057154.50	001870.27	000475.94
September	487157.50	039927.50	003203.37	000581.90
October	281252.50	280103.00	001921.81	001105.49
November	220477.50	394591.50	001570.08	001246.04
December	158987.50	677034.00	000956.27	001515.44

```
**********************************************************************

                         Results

**********************************************************************

Borehole Information
---------------------

Each Borehole Depth, ft =   474.41
Total Borehole Depth, ft =   56929.08
Distance between borhole centers, ft =   020.00

Average Temperature
--------------------
```

```
Maximum Average Temperature, °F =   072.38 at month 231
Minimum Average Temperature, °F =   048.87 at month 10

Peak temperature
-----------------

Maximum Peak Temperature, °F    =   082.51 at month 231
Minimum Peak Temperature, °F    =   036.04 at month 10
```

Monthly loads

Month	Heating(Btu)	Cooling(Btu)	Peak Heating(Btu/hr)	Peak Cooling
January	154101000.000	751497000.000	870817.500	1851894.000
February	140297000.000	660634500.000	887844.000	1769622.000
March	211702500.000	447745500.000	1403146.000	1391425.000
April	239495000.000	269688500.000	1960182.000	1088683.000
May	500991000.000	50547000.000	2880957.000	510158.500
June	384676500.000	57588500.000	2485566.000	576301.000
July	486722000.000	61338500.000	2824622.000	650754.000
August	341178000.000	57154500.000	1870274.000	475943.000
September	487157500.000	39927500.000	3203366.000	581903.500
October	281252500.000	280103000.000	1921809.000	1105492.000
November	220477500.000	394591500.000	1570083.000	1246035.000
December	158987500.000	677034000.000	956267.000	1515437.000

Note : EWT = Entering water temperature to heat pump(s)
ExWT = Exiting water temperature from heat pump(s)

Time (months)	Q (Btu/hr*ft)	Power (kW-hr)	Tf (F)	Average ExWT (F)	Average EWT (F)	Minimum EWT (F)	Maximum EWT (F)
1	-17.71	44693.64	53.00	54.01	51.99	38.33	61.66
2	-17.50	43691.86	63.78	64.78	62.78	48.98	72.18
3	-8.62	37879.43	64.57	65.06	64.07	51.23	73.96
4	-3.23	29906.71	60.09	60.28	59.91	46.26	69.17
5	7.62	37455.89	57.04	56.61	57.48	43.38	66.10
6	5.44	30516.72	50.47	50.16	50.79	38.28	58.94
7	6.99	37950.03	51.24	50.84	51.64	37.82	61.27
8	4.50	27410.61	49.90	49.64	50.16	40.86	56.88
9	7.83	37018.45	51.24	50.80	51.69	36.07	61.06
10	-2.61	32751.23	49.02	49.17	48.87	36.04	58.34
11	-7.07	33896.68	54.99	55.39	54.59	41.64	63.43
12	-15.73	43367.53	57.72	58.62	56.82	43.52	64.24
13	-18.06	49058.82	63.27	64.31	62.24	48.30	72.21
14	-17.56	44398.27	65.34	66.34	64.33	50.49	73.78
15	-8.66	38278.00	66.00	66.49	65.50	52.62	75.43
16	-3.24	30041.44	61.42	61.60	61.23	47.55	70.53
17	7.64	37232.02	58.42	57.98	58.85	44.71	67.50
18	5.46	30333.35	51.80	51.49	52.11	39.56	60.29
19	7.01	37708.46	52.59	52.19	52.99	39.12	62.65
20	4.51	27246.45	51.25	50.99	51.51	42.19	58.25
21	7.85	36792.52	52.44	51.99	52.89	37.21	62.27
22	-2.61	32768.74	50.15	50.30	50.00	37.14	59.49
23	-7.08	34058.62	56.07	56.47	55.66	42.68	64.53
24	-15.76	43767.95	58.78	59.68	57.88	44.54	65.32
25	-18.10	49603.16	64.35	65.39	63.31	49.34	73.31
26	-17.61	44927.07	66.46	67.47	65.45	51.58	74.94
27	-8.68	38591.29	67.08	67.58	66.58	53.67	76.54
28	-3.25	30152.87	62.44	62.62	62.25	48.54	71.58
29	7.65	37074.29	59.42	58.98	59.86	45.68	68.52
30	5.47	30205.13	52.76	52.45	53.07	40.49	61.27
31	7.02	37546.58	53.54	53.14	53.94	40.05	63.63
32	4.52	27135.54	52.20	51.94	52.46	43.11	59.21
33	7.86	36616.29	53.39	52.94	53.84	38.13	63.24
34	-2.61	32788.89	51.05	51.20	50.90	38.01	60.41
35	-7.09	34193.90	56.92	57.32	56.51	43.51	65.40
36	-15.78	44083.13	59.59	60.49	58.68	45.32	66.14
37	-18.13	50009.54	65.13	66.17	64.09	50.10	74.12
38	-17.64	45303.56	67.24	68.25	66.23	52.34	75.74
39	-8.70	38830.80	67.88	68.38	67.38	54.45	77.36
40	-3.25	30244.31	63.23	63.42	63.05	49.31	72.39
41	7.66	36954.74	60.20	59.76	60.64	46.44	69.31
42	5.47	30102.56	53.55	53.23	53.86	41.25	62.07
43	7.03	37412.85	54.34	53.94	54.74	40.82	64.44

44	4.53	27045.30	52.99	52.73	53.24	43.88	60.01
45	7.88	36476.72	54.16	53.71	54.61	38.87	64.03
46	-2.62	32809.55	51.78	51.93	51.63	38.72	61.15
47	-7.10	34311.14	57.62	58.03	57.22	44.20	66.12
48	-15.80	44356.48	60.27	61.17	59.36	45.99	66.83
49	-18.16	50360.08	65.79	66.83	64.75	50.74	74.80
50	-17.67	45618.73	67.89	68.90	66.87	52.96	76.40
51	-8.72	39026.18	68.52	69.02	68.02	55.07	78.02
52	-3.26	30321.13	63.87	64.06	63.69	49.93	73.05
53	7.67	36857.52	60.84	60.41	61.28	47.06	69.97
54	5.48	30022.17	54.17	53.86	54.49	41.87	62.71
55	7.04	37307.38	54.98	54.58	55.38	41.44	65.10
56	4.53	26972.65	53.64	53.38	53.89	44.52	60.67
57	7.89	36360.95	54.81	54.36	55.26	39.49	64.69
58	-2.62	32830.56	52.42	52.57	52.27	39.34	61.80
59	-7.11	34417.41	58.25	58.65	57.84	44.80	66.76
60	-15.82	44604.10	60.87	61.78	59.97	46.57	67.45
61	-18.19	50678.97	66.39	67.43	65.35	51.31	75.41
62	-17.70	45907.48	68.47	69.48	67.45	53.52	77.00
63	-8.73	39201.18	69.08	69.58	68.58	55.61	78.60
64	-3.27	30389.30	64.43	64.61	64.24	50.47	73.61
65	7.67	36776.46	61.39	60.95	61.83	47.60	70.53
66	5.49	29952.83	54.73	54.41	55.04	42.40	63.27
67	7.05	37219.45	55.52	55.12	55.93	41.96	65.65
68	4.54	26914.06	54.17	53.91	54.43	45.04	61.21
69	7.89	36268.39	55.33	54.88	55.79	40.00	65.23
70	-2.62	32849.68	52.93	53.08	52.78	39.84	62.33
71	-7.12	34507.80	58.76	59.17	58.35	45.30	67.28
72	-15.84	44815.98	61.38	62.29	60.48	47.07	67.97
73	-18.21	50956.17	66.89	67.94	65.85	51.80	75.93
74	-17.72	46162.11	68.97	69.98	67.96	54.00	77.51
75	-8.74	39353.12	69.58	70.08	69.08	56.10	79.11
76	-3.27	30451.05	64.91	65.10	64.72	50.94	74.11
77	7.68	36707.37	61.87	61.43	62.31	48.06	71.02
78	5.49	29895.62	55.19	54.88	55.50	42.85	63.74
79	7.05	37146.64	55.98	55.58	56.38	42.41	66.12
80	4.54	26865.49	54.62	54.36	54.88	45.48	61.66
81	7.90	36191.15	55.78	55.33	56.23	40.42	65.68
82	-2.62	32867.32	53.37	53.52	53.22	40.26	62.78
83	-7.13	34586.26	59.19	59.60	58.79	45.72	67.73
84	-15.86	44998.85	61.82	62.72	60.91	47.49	68.41
85	-18.23	51195.36	67.33	68.37	66.28	52.22	76.38
86	-17.74	46382.19	69.40	70.42	68.38	54.42	77.96
87	-8.75	39489.71	70.01	70.51	69.50	56.51	79.55
88	-3.28	30505.29	65.33	65.52	65.14	51.34	74.54
89	7.68	36648.80	62.28	61.84	62.72	48.45	71.44
90	5.50	29846.99	55.59	55.27	55.90	43.24	64.15
91	7.06	37084.59	56.37	55.97	56.78	42.79	66.52
92	4.55	26824.07	55.01	54.75	55.27	45.86	62.06
93	7.90	36124.95	56.16	55.71	56.62	40.79	66.08
94	-2.62	32883.70	53.75	53.90	53.60	40.63	63.17
95	-7.13	34655.77	59.57	59.98	59.16	46.09	68.11
96	-15.87	45160.07	62.19	63.10	61.28	47.85	68.79
97	-18.25	51406.17	67.70	68.75	66.66	52.58	76.76
98	-17.76	46576.36	69.78	70.79	68.76	54.78	78.34
99	-8.76	39610.64	70.38	70.88	69.88	56.87	79.93
100	-3.28	30553.75	65.70	65.88	65.51	51.70	74.91
101	7.69	36598.03	62.64	62.20	63.08	48.80	71.80
102	5.50	29804.76	55.94	55.62	56.25	43.58	64.50
103	7.06	37030.58	56.72	56.32	57.12	43.12	66.88
104	4.55	26788.00	55.35	55.09	55.61	46.20	62.40
105	7.91	36067.05	56.50	56.05	56.96	41.12	66.42
106	-2.62	32899.00	54.08	54.23	53.93	40.96	63.51
107	-7.14	34718.41	59.91	60.32	59.50	46.42	68.46
108	-15.88	45305.65	62.53	63.44	61.62	48.18	69.14
109	-18.26	51597.47	68.04	69.09	67.00	52.91	77.11
110	-17.77	46753.19	70.12	71.13	69.10	55.11	78.69
111	-8.77	39721.08	70.72	71.22	70.21	57.20	80.28
112	-3.28	30598.23	66.03	66.21	65.84	52.02	75.25
113	7.69	36552.74	62.96	62.52	63.40	49.12	72.13
114	5.50	29767.13	56.25	55.94	56.57	43.88	64.82
115	7.07	36982.46	57.03	56.63	57.44	43.42	67.20
116	4.55	26755.92	55.66	55.40	55.92	46.50	62.72
117	7.91	36015.29	56.81	56.36	57.26	41.42	66.74
118	-2.62	32913.55	54.39	54.54	54.24	41.25	63.82
119	-7.14	34776.20	60.21	60.62	59.80	46.71	68.77

120	-15.89	45438.58	62.83	63.74	61.92	48.47	69.45
121	-18.28	51771.12	68.35	69.39	67.30	53.20	77.43
122	-17.79	46913.39	70.42	71.44	69.40	55.41	79.01
123	-8.78	39821.36	71.02	71.52	70.52	57.50	80.59
124	-3.29	30639.01	66.32	66.51	66.14	52.31	75.55
125	7.69	36512.15	63.25	62.81	63.69	49.40	72.43
126	5.51	29733.27	56.54	56.23	56.86	44.16	65.12
127	7.07	36939.01	57.32	56.91	57.72	43.70	67.49
128	4.55	26726.91	55.94	55.68	56.20	46.78	63.00
129	7.92	35968.37	57.09	56.64	57.54	41.69	67.02
130	-2.63	32927.35	54.66	54.81	54.51	41.52	64.10
131	-7.15	34829.30	60.49	60.90	60.08	46.98	69.05
132	-15.90	45560.32	63.11	64.02	62.20	48.74	69.73
133	-18.29	51930.07	68.63	69.67	67.58	53.47	77.71
134	-17.80	47060.09	70.70	71.72	69.68	55.67	79.29
135	-8.79	39913.38	71.30	71.80	70.79	57.77	80.88
136	-3.29	30676.64	66.60	66.78	66.41	52.57	75.83
137	7.70	36475.49	63.52	63.08	63.96	49.66	72.70
138	5.51	29702.66	56.80	56.49	57.12	44.42	65.38
139	7.07	36899.68	57.58	57.17	57.98	43.95	67.75
140	4.56	26700.65	56.20	55.94	56.46	47.03	63.26
141	7.92	35925.79	57.34	56.89	57.80	41.93	67.28
142	-2.63	32940.43	54.92	55.07	54.76	41.76	64.36
143	-7.15	34878.48	60.74	61.15	60.33	47.23	69.31
144	-15.91	45672.69	63.36	64.27	62.45	48.99	69.99
145	-18.30	52076.72	68.88	69.93	67.83	53.72	77.98
146	-17.81	47195.48	70.95	71.97	69.93	55.92	79.55
147	-8.80	39998.45	71.55	72.05	71.05	58.01	81.14
148	-3.29	30711.62	66.84	67.03	66.66	52.81	76.09
149	7.70	36442.10	63.77	63.33	64.21	49.90	72.95
150	5.51	29674.75	57.04	56.73	57.36	44.65	65.63
151	7.07	36863.77	57.82	57.41	58.22	44.18	68.00
152	4.56	26676.68	56.43	56.17	56.69	47.26	63.50
153	7.92	35886.81	57.58	57.13	58.03	42.16	67.52
154	-2.63	32952.89	55.15	55.30	55.00	41.99	64.60
155	-7.16	34924.31	60.98	61.39	60.57	47.45	69.55
156	-15.92	45777.11	63.60	64.51	62.69	49.21	70.22
157	-18.31	52212.93	69.12	70.16	68.07	53.94	78.22
158	-17.82	47321.27	71.19	72.21	70.17	56.15	79.80
159	-8.80	40077.62	71.78	72.29	71.28	58.24	81.38
160	-3.30	30744.32	67.07	67.26	66.89	53.04	76.32
161	7.70	36411.44	63.99	63.55	64.43	50.12	73.18
162	5.51	29649.12	57.27	56.95	57.58	44.87	65.85
163	7.08	36830.77	58.04	57.63	58.44	44.40	68.22
164	4.56	26654.65	56.65	56.39	56.91	47.47	63.73
165	7.93	35850.89	57.80	57.34	58.25	42.37	67.75
166	-2.63	32964.78	55.36	55.51	55.21	42.20	64.82
167	-7.16	34967.26	61.19	61.60	60.78	47.66	69.77
168	-15.93	45874.68	63.81	64.73	62.90	49.42	70.45
169	-18.32	52340.12	69.33	70.38	68.28	54.15	78.44
170	-17.83	47438.80	71.41	72.43	70.39	56.36	80.02
171	-8.81	40151.69	72.00	72.51	71.50	58.45	81.61
172	-3.30	30775.05	67.29	67.48	67.10	53.25	76.54
173	7.71	36383.13	64.21	63.76	64.65	50.32	73.40
174	5.51	29625.43	57.47	57.16	57.79	45.07	66.07
175	7.08	36800.22	58.24	57.84	58.65	44.59	68.43
176	4.56	26634.28	56.86	56.59	57.12	47.67	63.93
177	7.93	35817.59	58.00	57.55	58.46	42.56	67.95
178	-2.63	32976.16	55.57	55.72	55.41	42.39	65.02
179	-7.16	35007.68	61.40	61.81	60.99	47.86	69.98
180	-15.93	45958.09	64.02	64.93	63.10	49.62	70.65
181	-18.33	52459.29	69.54	70.59	68.49	54.35	78.65
182	-17.84	47549.09	71.61	72.63	70.59	56.55	80.23
183	-8.81	40221.29	72.21	72.71	71.70	58.65	81.81
184	-3.30	30804.04	67.49	67.68	67.30	53.44	76.75
185	7.71	36356.84	64.40	63.96	64.84	50.51	73.60
186	5.52	29603.42	57.67	57.35	57.98	45.26	66.26
187	7.08	36771.82	58.43	58.03	58.84	44.78	68.63
188	4.56	26615.34	57.05	56.79	57.31	47.86	64.13
189	7.93	35786.57	58.19	57.74	58.65	42.75	68.15
190	-2.63	32987.07	55.75	55.90	55.60	42.58	65.22
191	-7.17	35045.88	61.58	61.99	61.17	48.04	70.17
192	-15.94	46044.24	64.21	65.12	63.29	49.80	70.85
193	-18.34	52571.78	69.73	70.78	68.68	54.53	78.85
194	-17.85	47653.07	71.80	72.83	70.78	56.74	80.43
195	-8.82	40286.98	72.40	72.90	71.89	58.83	82.01

196	-3.30	30831.50	67.68	67.87	67.49	53.62	76.94
197	7.71	36332.32	64.59	64.15	65.03	50.69	73.79
198	5.52	29582.86	57.85	57.53	58.16	45.43	66.45
199	7.08	36745.29	58.62	58.21	59.02	44.96	68.81
200	4.56	26597.65	57.23	56.97	57.49	48.04	64.31
201	7.94	35757.54	58.37	57.92	58.83	42.92	68.33
202	-2.63	32997.57	55.93	56.08	55.78	42.75	65.40
203	-7.17	35082.11	61.76	62.17	61.35	48.22	70.35
204	-15.95	46125.77	64.38	65.30	63.47	49.98	71.03
205	-18.35	52678.21	69.91	70.96	68.86	54.71	79.03
206	-17.86	47751.44	71.98	73.01	70.96	56.91	80.61
207	-8.82	40349.21	72.58	73.08	72.07	59.01	82.20
208	-3.31	30857.60	67.86	68.04	67.67	53.80	77.12
209	7.71	36309.33	64.76	64.32	65.20	50.86	73.97
210	5.52	29563.59	58.02	57.70	58.34	45.60	66.62
211	7.09	36720.39	58.79	58.38	59.19	45.12	68.99
212	4.57	26581.06	57.40	57.14	57.66	48.20	64.48
213	7.94	35730.71	58.54	58.08	58.99	43.08	68.50
214	-2.63	33007.09	56.09	56.24	55.94	42.90	65.56
215	-7.17	35113.44	61.92	62.33	61.51	48.37	70.51
216	-15.95	46194.92	64.54	65.45	63.62	50.12	71.18
217	-18.36	52768.63	70.06	71.11	69.01	54.86	79.19
218	-17.87	47836.52	72.14	73.16	71.12	57.06	80.77
219	-8.83	40403.92	72.74	73.24	72.23	59.16	82.36
220	-3.31	30880.98	68.01	68.20	67.82	53.95	77.29
221	7.71	36288.69	64.92	64.48	65.36	51.02	74.13
222	5.52	29546.12	58.18	57.86	58.49	45.75	66.78
223	7.09	36698.04	58.94	58.54	59.35	45.27	69.15
224	4.57	26566.57	57.55	57.28	57.81	48.35	64.63
225	7.94	35707.46	58.68	58.23	59.14	43.22	68.65
226	-2.63	33015.89	56.23	56.38	56.08	43.04	65.71
227	-7.17	35143.11	62.06	62.47	61.65	48.50	70.66
228	-15.96	46261.41	64.68	65.59	63.77	50.26	71.33
229	-18.36	52855.34	70.21	71.26	69.15	55.00	79.34
230	-17.88	47916.68	72.29	73.31	71.26	57.20	80.92
231	-8.83	40454.72	72.88	73.39	72.38	59.30	82.51
232	-3.31	30902.41	68.16	68.35	67.97	54.09	77.43
233	7.71	36270.27	65.06	64.62	65.50	51.15	74.27
234	5.52	29530.66	58.32	58.00	58.63	45.89	66.92
235	7.09	36678.05	59.08	58.67	59.49	45.41	69.29
236	4.57	26553.26	57.68	57.42	57.94	48.48	64.77
237	7.94	35685.49	58.82	58.36	59.27	43.35	68.79
238	-2.63	33024.37	56.37	56.52	56.22	43.17	65.84
239	-7.18	35171.43	62.20	62.61	61.79	48.64	70.80
240	-15.96	46324.81	64.82	65.73	63.90	50.39	71.47

Compliments of:

Bore Depth

475 Ft

GLHX Size

216 Ft/Ton

Designed by:

GLHX Flow Rate

3.00 gpm/Ton

Circulating Fluid

12.8% Propylene Glycol (25 F Freeze Point)

Loop Operating Conditions @ 6.6 gpm/loop & 1584 gpm total

Pipe	Velocity	Reynolds #	Pressure Drop		Select
			Loop	per 100	
3/4	3.64	12,973	89.2	9.4	○
1	2.31	10,330	30.3	3.2	○
1 1/4	1.42	8,085	9.5	1.0	○
1 1/2	1.04	6,930	4.6	0.5	◉
2	0.63	5,390	1.4	0.1	○
3	0.29	3,660	0.2	0.0	○
4	0.18	2,846	0.1	0.0	○

#.# - Good Pressure Drop (>6 & <20)
#,### - Reynolds Number < 2,500

Header Calculations

# of Loops	240	
# of Hdr Pairs	40	
loops/hdr	6	
Min Op Vel.	1.5	
Total Flow	39.6	
Length between circuits	100	
Single Header PD	7.56	Ft
Total PD for Both	15.12	Ft

Supply & Return Piping

Length (one way)	240	Ft
Pipe Diameter	2	in.
Supply & Return PD	12.57	Ft
1 1/2" loop PD	4.58	Ft
TOTAL PD	**32.27**	Ft

Header Design/Details

Section	Flow	Max Size	Act Size	PD
Ent			1.25	
1	33	2	2	2.62
2	26.4	2	2	1.75
3	19.8	2	2	1.04
4	13.2	1.5	1.5	1.66
5	6.6	1	1.5	0.48

APPENDIX G: Lighting Power Data:

Please enter the following:

								AREA of Wall for:	Actaul Area
Ceiling Cavity ht:	0							0.00	
Room Cavity ht:	6.5							730.30	572.30
Floor Cavity ht:	2.5							280.89	
Rm Length:	25.5								
RM width:	30.677								
Ceiling Reflectance:	0.8								
Wall Reflectance:	0.6								
Floor Reflectance:	0.3							AREA	AREA*REFL
Window Reflectance:	0.05	Window Length	4	Window ht	8	Window ht off FLR	3	32	1.6
Other Reflectance:	0.05	Length	4	ht	4	ht off FLR	3	16	0.8
Other Reflectance:	0.05	Length	12	ht	4	ht off FLR	3	48	2.4
Other Reflectance:	0.05	Length	4	ht	4	ht off FLR	3	16	0.8
Other Reflectance:	0.05	Length	5	ht	5	ht off FLR	3	25	1.25
Other Reflectance:	0.05	Length	3	ht	7	ht off FLR	0	21	1.05

GENERAL INFORMATION

Project Identification: South Jefferson High School - High Efficiency Lighting - Typical Classroom
(give name of area and/or building and room number)

Average maintained Illuminance for design: 500 lux
50 fc

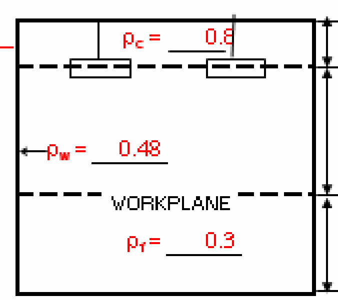
Luminaire Data:
Manufacturer: Ledalite (Vectra)
Catalog number: 9724-A1-SMS-T232-C-7-2-T

Lamp Data:
Type and Color: Philips Fl. Alto T832 4100K
Number per luminaire: 2
Total lumens per luminaire: 3100

SELECTION OF COEFFICIENT OF UTILIZATION

Step 1: Fill in sketch at right

pw(cc) = ______



h_{cc} = 0
h_{rc} = 6.5
h_{fc} = 2.5
pw(fc) = ______
L = 25.50
W = 30.677

Step 2: Determine Cavity Ratios

Ceiling Cavity Ratio, CCR = 0.00

Room Cavity Ratio, RCR = 2.33

Floor Cavity Ratio, FCR = 0.90

Step 3: Obtain Effective Ceiling Cavity Reflectance (ρ_{cc}) ρ_{cc} = 57.36

Step 4: Obtain Effective Floor Cavity Reflectance (ρ_{fc}) ρ_{fc} = 70.25

Step 5: Obtain Co-efficient of Utilization (CU) from Manufacturer's Data CU (57 / 70 /20) = 65.303

Correction for ρ_{fc} = CU (57 / 70 /30) = 65.303 X 1.043 = 68.111

SELECTION OF LIGHT LOSS FACTORS

Nonrecoverable		Recoverable	
Luminaire ambient temperature	75	Room surface dirt depreciation (RSDD)	0.98
Heat extraction thermal factor	1	Lamp lumen depreciation (LLD)	0.9516
Voltage to luminaire	277	Lamp burnouts factor (LBO)	1
Ballast factor	1	Luminaire dirt depreciation (LDD)	0.9
Ballast-lamp photometric factor	1		
Equipment operating factor	1		
Luminaire surface depreciation	1		

LLF = 0.84

CALCULATIONS

(average maintained Illuminance)

$$\text{Number of Luminaires} = \frac{(\text{Illuminance}) \times (\text{Area})}{(\text{Lamps per Luminaire}) \times (\text{Lumens per lamp}) \times (\text{CU}) \times (\text{LLF})}$$

$$= \frac{50 \times (25.5 \times 30.67)}{2 \times 3100 \times .68 \times .84} = 11$$

$$\text{Illuminance} = \frac{(\#\ \text{luminaires}) \times (\text{Lamps per Luminaire}) \times (\text{Lumens per lamp}) \times (\text{CU}) \times (\text{LLF})}{\text{Area}}$$

$$= \frac{12 \times 2 \times 3100 \times .68 \times .84}{25.5 \times 30.67} = 54.4$$

VECTRA™ with MesoOptics®

mesoOptics® by Ledalite

Recessed 2′ x 4′
2 T8
9724

- MesoOptics® technology provides exceptional lighting control and uniformity
- Highly efficient optical system allows for reduced energy consumption
- Available in 2′x2′, 2′x4′, 1′x4′ and 6″x4′ sizes
- Multiple lamp configurations available with TT5, T8, T5 or T5HO lamps
- Lift and shift frame requires no tools for quick and easy maintenance

RESPONSE READY

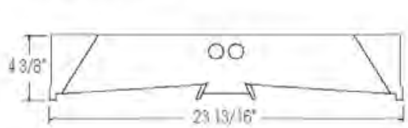
Order Number Guide

Example: 9724 D1ST T232 S11E

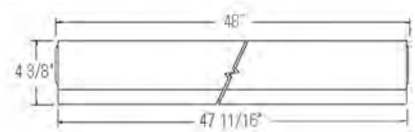
97	24	__	__	T	2	32	_	_	_	_
Series	**Size**	**Version**	**Configuration**	**Lamp Type**	**Lamp**	**Wattage**	**Housing**	**Wiring**	**Voltage**	**Ballast**
Vectra	2′x4′	**D1** - Standard T-Grid (9/16" or 15/16") **D2** - Slot T-Grid (sits flush with bottom of T-bar) **A1** - Air Return on Standard T-Grid* **A2** - Air Return on Slot T-Grid* *NOTE: not available with continuous row mounting (configuration types 'CR' or 'CMS').*	**ST** - Standalone **SMS** - Standalone Master/Satellite* **CR** - Continuous Row **CMS** - Continuous Row Master/Satellite* *NOTE: two fixtures with a shared ballast.*	**T** - T8	2 Lamp	**32** - 32W	**S** - Standard (22ga.) **N** - New York (20ga.) **C** - Chicago Plenum **T** - Standard w/ frame restraint	**1** - 1cct **5** - 1cct w/ Battery Pack **7** - 1cct w/ Dimming **8** - 1cct w/ Thru Wire	**1** - 120V **2** - 277V **3** - 347V* *NOTE: consult factory.*	**E** - Electronic **S** - Step-dimming 50/100 **T** - Step-dimming 30/60/100

NOTE: Some options may not be available for each configuration. Consult factory for details.

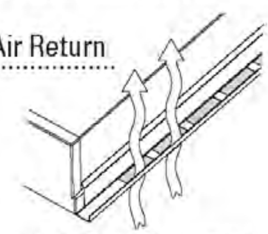
Cross Section



Side View



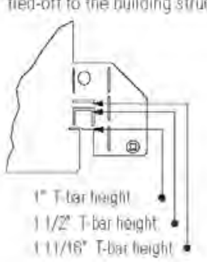
Air Return



A1 - Air Return on Standard T-Grid
A2 - Air Return on Slot T-Grid

Ceiling Types

Integrated mounting tabs can be field-adjusted to various T-bar ceiling heights for fastening directly to the T-bar grid and/or tied-off to the building structure.



Mounting

Integrates with most common T bar ceiling types.

D1 - Standard T-Grid 15/16" **D1** - Standard T-Grid 9/16" **D2** - Slot T-Grid 9/16"

NOTE: Option D1 can be used with Slot T-Grid ceilings, but it will not sit flush with the bottom of the T-Bar. Option D2 is designed to sit flush with Slot T-Grid ceilings and some regular tile ceiling types. Consult factory for more information on ceiling integration. Consult factory for air return mounting details.

Drywall Kit

Available for non-accessible ceilings.

DK24ST - Standalone Kit
DK24CR - Continuous Row Kit

LD197 rev 2

 Phone: 604-888-6811 Toll Free/Fax: 1-800-665-LEDA (5332) Fax: 604-888-2003 Email: info@ledalite.com www.ledalite.com

Ledalite

VECTRA with MesoOptics®

9724	2 Lamp	T8

Specifications

Housing Construction
Die formed, post painted, 22 gauge cold-rolled steel (New York City version is 20 gauge). Wire entrances are positioned on the side of the housing to allow easy wiring access for the installer. Multiple wire entrances are available (top or side) to allow continuous row mounting of fixtures. Optional frame restraint is available to provide additional support to the optical frame.

Optical System
Optical assembly consists of flat non-glaze acrylic panels and flat acrylic lens. A protected MesoOptics® film layer creates optimal light distribution and high efficiency. The optical frame ends are constructed from die-formed cold-rolled steel assembled together with extruded aluminum profiles in a sturdy frame. The frame is hinged to allow easy access to the inside of the fixture. Maintenance can be performed from below the ceiling without the need of tools. No hardware is visible.

Finish
Housing and frame are post-painted, high quality powder coat. Available in white only.

Ballast
Ballasts are electronic and available in 120V, 277V or 347V. Optional 50/100 or 30/60/100 step-dimming ballasts can be used to provide mult-level switching.

Mounting
Fixture is compatible with most ceiling types. Integrated bend-out tabs are provided for different T-grid heights. Optional drywall kit is available for non-accessible ceilings. Use screws or hanger wire (supplied by others) to secure fixture.

Air Return
Air return option available. Side rails are finished in black.

Wiring
Flexible cable whips supplied in 9' or 12' lengths for standard master/satellite configurations.

Weight
2x4 - maximum 40 lbs.

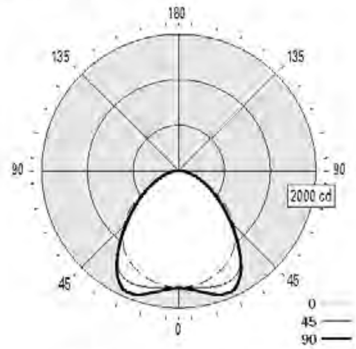
Approvals
Certified to UL & CSA Standards.
City of Chicago Approved CCEA (Housing Option - **C**).
Designed to comply with NYC code requirements (Housing Option - **N**).

RESPONSE READY Available with Response Integrated Controls. See www.ledalite.com for details.

Due to continuing product improvements, Ledalite reserves the right to change specifications without notice.

Photometry

2 T8 32W



Report # 2101751
Efficiency 76.4%
Spacing Criteria 1.3 @ 0° along
1.4 @ 90° across

CANDELA DISTRIBUTION

Vert. Angle	Horizontal Angle 0	22.5	45	67.5	90	Zonal Lumens
0	1761	1761	1761	1761	1761	
5	1752	1757	1771	1786	1790	173
15	1693	1730	1815	1893	1920	513
25	1587	1663	1820	1906	1943	819
35	1421	1488	1577	1534	1552	944
45	1146	1124	1104	1022	1049	839
55	760	703	689	646	669	617
65	392	380	387	374	391	382
75	136	146	180	182	194	182
85	19	25	45	39	45	43
90	0	0	0	0	0	

AVERAGE LUMINANCE (cd/m^2)

Vert. angle	Horizontal angle 0	45	90
55	1894	1717	1687
65	1326	1309	1323
75	751	994	1072
85	312	738	738

COEFFICIENTS OF UTILIZATION (%)

Ceiling	80				70			50			0
Wall	70	50	30	10	70	50	30	50	30	10	0
RCR											
0	91	91	91	91	89	89	89	85	85	85	76
1	84	81	78	75	82	79	76	76	74	72	66
2	77	71	67	63	75	70	66	67	64	61	56
3	71	64	58	53	69	62	57	60	56	52	49
4	65	57	51	46	64	56	50	54	49	45	42
5	60	51	45	40	59	50	44	49	43	39	37
6	56	46	40	35	54	46	39	44	39	35	33
7	52	42	36	31	51	41	35	40	35	31	29
8	48	39	32	28	47	38	32	37	32	28	26
9	45	35	29	25	44	35	29	34	29	25	24
10	42	33	27	23	41	32	27	32	28	23	21

Based on a floor reflectance of 0.2

Philips Advantage T8 Lamps
featuring ALTO® Lamp Technology

High Performance: 3100 approximate initial lumens is 10% more than standard T8 lamps

Long Life: 36,000 hours rated average life at 12 hours per start (see footnote 241); 50% more life than standard F32T8 lamps means reduced maintenance and disposal costs

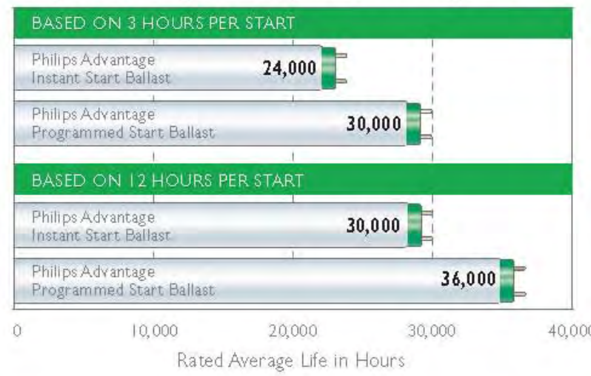
Ultimate System Solution: Higher lumens enables multiple system options to maximize energy saving and reduce lighting costs; fully dimmable without burn-in; ideal for light harvesting

Outstanding Lumen Maintenance: HI-VISION® Phosphor combined with Philips exclusive cathode guard delivers 95% lumen maintenance and reduced lamp-end blackening

Enhanced CRI: 85 CRI

Ideal for: T8 applications requiring maximum quality of light and maintained light output

Philips Advantage T8 Lamp Rated Average Life



Philips Advantage T8 Warranty Period: 36 months

Nom. Lamp Watts	Product Number	Symbols, Footnotes	Ordering Code	Pkg. Qty.●	Description	Nom. Length (In.)	Rated Avg. Life, Hrs. 3-Hr. Start (202)	Rated Avg. Life, Hrs. 12-Hr. Start (241)	Approx. Initial Lumens (203, 204)	Design Lumens (208, 239)	CRI
Advantage T8 Fluorescent Lamps T8 Medium Bipin Featuring HI-VISION® Phosphor											
32	13987-3	E □ $	**F32T8/ADV830/ALTO**	25	Advantage 830, 3000K	48	30,000	36,000	3100	2950	85
	13988-1	E □ $	**F32T8/ADV835/ALTO**	25	Advantage 835, 3500K	48	30,000	36,000	3100	2950	85
	13989-9	E □ $	**F32T8/ADV841/ALTO**	25	Advantage 841, 4100K	48	30,000	36,000	3100	2950	85
	13990-7	E □ $	**F32T8/ADV850/ALTO**	25	Advantage 850, 5000K	48	30,000	36,000	3025	2875	85

Advantage T8 Systems vs. Standard T8 Systems

Energy Savings: 2 Lamp vs. 2 Lamp System

Electronic Ballast	Ballast Factor	No. of Lamps	Lamp Watts	Standard T8 Lumens	Advantage T8 Lumens	System Watts	Savings
Standard T8	0.87	2	32	2850		58	
Reduced Light Output T8	0.75	2	32		3100	51	$2.80/yr

Combine Advantage T8 lamps with Reduced Light Output Electronic Ballasts, with these Results:

- Produce comparable light output
- Save 7 system watts vs. standard T8 system
- Save $2.80 per fixture per year
- Energy savings based on 4000 hrs/yr @ $.10 kw/hr

Energy Savings: 2 Lamp vs. 3 Lamp System

Electronic Ballast	Ballast Factor	No. of Lamps	Lamp Watts	Standard T8 Lumens	Advantage T8 Lumens	System Watts	Savings
Standard T8	0.87	3	32	2850		88	
Increased Light Output T8	1.20	2	32		3100	78	$4.00/yr

Combine Advantage T8 Lamps with Increased Light Output Ballasts. A 2 Lamp Advantage T8 System vs. a 3 Lamp Standard T8 System will:

- Produce comparable light output
- Save 10 system watts
- Save $4.00 per fixture per year
- Energy savings based on 4000 hrs/yr @ $.10 kw/hr
- Reduce lighting installation costs (lamps, ballasts, fixtures and labor)
- Philips Advantage T8 lamps operate on ballast with ballast factors up to 1.32 with warranty intact

For the most current product information, go to the e-catalog on www.philips.com
Fluorescent symbols and footnotes located on page 87
□ This product utilizes ALTO® Lamp Technology
* *The TCLP is the US EPA's Toxicity Characteristic Leaching Procedure.*

T8

HIGH FREQUENCY ELECTRONIC BALLASTS
For 17 - 32W Lamps

HIGH POWER FACTOR SOUND RATED A

Mark 10 Powerline Electronic Dimming Ballast

CONTROLLABLE

MARK 10 *POWERLINE*

No. of Lamps	Input Volts	Lamp Starting Method	Ballast Family	Catalog Number	Max/Min Input Power ANSI (Watts)	Max/Min Ballast Factor	Full Light Output THD %	Full Light Output Line Current (Amps)	Min. Starting Temp. (°F/°C)	Dim.	Wiring Dia.
F17T8, FBO16T8 (17W)											
1	120	PS	Mark 10 *Powerline*	REZ-132-SC	24/7	1.05/0.05	10	0.20	50/10	B	152
	277			VEZ-132-SC				0.09			
2	120			REZ-2S32-SC	38/13			0.32			153
	277			VEZ-2S32-SC				0.14			
3	120			REZ-3S32-SC	56/18			0.47			155
	277			VEZ-3S32-SC				0.21			
F25T8, FBO24T8 (25W)											
1	120	PS	Mark 10 *Powerline*	REZ-132-SC	30/7	1.05/0.05	10	0.26	50/10	B	152
	277			VEZ-132-SC				0.11			
2	120			REZ-2S32-SC	55/13			0.46			153
	277			VEZ-2S32-SC				0.20			
3	120			REZ-3S32-SC	79/19			0.66			155
	277			VEZ-3S32-SC				0.29			
F32T8, FBO31T8, F32T8/U6 (32W)											
1	120	PS	Mark 10 *Powerline*	REZ-132-SC	35/9	1.00/0.05	10	0.29	50/10	B	152
	277			VEZ-132-SC				0.13			
2	120			REZ-2S32-SC	68/15			0.57			153
	277			VEZ-2S32-SC				0.25			
3	120			REZ-3S32-SC	102/20			0.86			155
	277			VEZ-3S32-SC				0.37			

ONLY USE RAPID-START SOCKETS

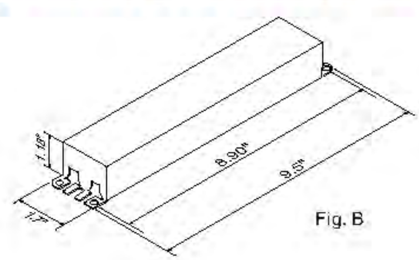
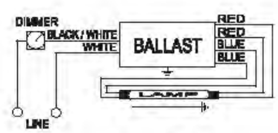
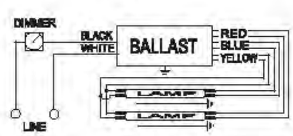


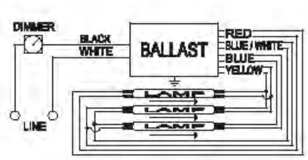
Fig. B



Diag. 152



Diag. 153



Diag. 155

Refer to page 1-15 for information on remote/tandem wiring and lead length extension

Use compatible Mark 10 Powerline controls only as referenced on page 2-22 & 2-23

Refer to pages 8-17 to 8-19 for lead lengths and shipping data

 ADVANCE, 10275 WEST HIGGINS ROAD, ROSEMONT, IL 60018. TEL: (847) 390-5000, FAX: (847) 390-5109

Existing Lighting Power Calculation:

Allowed Lighting Power Calculation

	Floor Area:	Allowed Watts/ ft^2:	Total Allowed Watts:
School/University:	199717	1.2	239660

A Fixture ID : Description / Lamp / Wattage Per Lamp / Ballast	B Lamps/ Fixture	C # of Fixtures	D Fixture Watt.	E (C X D)
Linear Fluorescent 1: RF-1: 3 - 32W T8 / Other / Electronic	3	500	96	48000
Linear Fluorescent 2: RF-2: 2 - 32W T8 / Other / Electronic	2	317	64	20288
Linear Fluorescent 3: RF-3: 3 - 32W T8 / Other / Electronic	3	160	96	15360
Linear Fluorescent 4: RF-4: 2 - 26W TRT / Other / Electronic	2	35	52	1820
Linear Fluorescent 5: RF-5: 3 - 32W T8 / Other / Electronic	3	118	96	11328
Linear Fluorescent 6: RF-6: 3 - 32W T8 / Other / Electronic	3	41	96	3936
Linear Fluorescent 7: RF-7: 2 - 26W TRT / Other / Electronic	2	90	52	4680
Linear Fluorescent 8: RF-8: 2 - 26W TRT / Other / Electronic	2	43	52	2236
Linear Fluorescent 9: RF-9: 2 - 26W TRT / Other / Electronic	2	53	52	2756
Linear Fluorescent 10: RF-10: 3 - 26W TRT / Other / Electronic	3	12	78	936
Linear Fluorescent 11: RF-11: 2 - 32W T8 / Other / Electronic	2	14	64	896
Linear Fluorescent 12: RF-12: 3 - 32W T8 / Other / Electronic	3	37	96	3552
Linear Fluorescent 13: RF-13: 4 - 32W T8 / Other / Electronic	4	7	128	896
Linear Fluorescent 14: RF-14: 6 - 32W T8 / Other / Electronic	6	53	192	10176
Linear Fluorescent 15: SF-1: 2 - 32W T8 / Other / Electronic	2	1	64	64
Linear Fluorescent 16: SF-2: 3 - 32W T8 / Other / Electronic	3	8	96	768
Linear Fluorescent 17: SF-3: 1 - 26W TRT / Other / Electronic	1	1	26	26
Linear Fluorescent 18: WSF-1: 1 - 26W TRT / Other / Electronic	1	3	26	78
Incandescent 1: WSI-1: 100W INCAND / Incandescent 100W	1	1	100	100
Linear Fluorescent 19: DF-1: 2 - 32W T8 / Other / Electronic	2	122	64	7808
Linear Fluorescent 20: DF-2: 3 - 32W T8 / Other / Electronic	3	17	96	1632
Linear Fluorescent 21: DF-3: 2 - 32W T8 / Other / Electronic	2	68	64	4352
Linear Fluorescent 22: DF-4: 3 - 32W T8 / Other / Electronic	3	12	96	1152
Linear Fluorescent 23: DF-5: 5 - 54W T5 / Other / Electronic	5	34	270	9180
Linear Fluorescent 24: DF-6: 1 - 32W TT / Other / Electronic	1	12	32	384
HID 1: DI-1: 500W QUARTZ / Other / Magnetic	1	32	500	16000
HID 2: DI-2: 250W QUARTZ / Other / Magnetic	1	22	250	5500
HID 3: RMH-1: 100W MH/100W QUARTZ / Metal Halide 100W / Magnetic	1	14	200	2800
HID 4: RMH-2: 100W MH / Metal Halide 100W / Electronic	1	15	100	1500
HID 5: RMH-3: 100W MH / Metal Halide 100W / Electronic	1	33	100	3300
HID 6: WMH-1: 175W MH/100W QUARTZ / Metal Halide 175W / Electronic	1	15	275	4125
HID 7: WMH-2: 175W MH / Metal Halide 175W / Electronic	1	26	175	4550
HID 8: SL-1: 400W MH / Metal Halide 400W / Magnetic	1	1	400	400
HID 9: SL-2: 100W MH / Metal Halide 100W / Electronic	1	1	100	100
Linear Fluorescent 1 copy 1: RF-1: 3 - 32W T8 / Other / Electronic	3	237	96	22752

		Watts/ft^2:	Total Allowed Watts:
Lighting PASSES: Design by:	10.94%	1.07	213431

Note: Calculated using the COMcheck Software Version 3.3.1 Lighting Application Worksheet.

Alternative Lighting Power Calculation:

Allowed Lighting Power Calculation

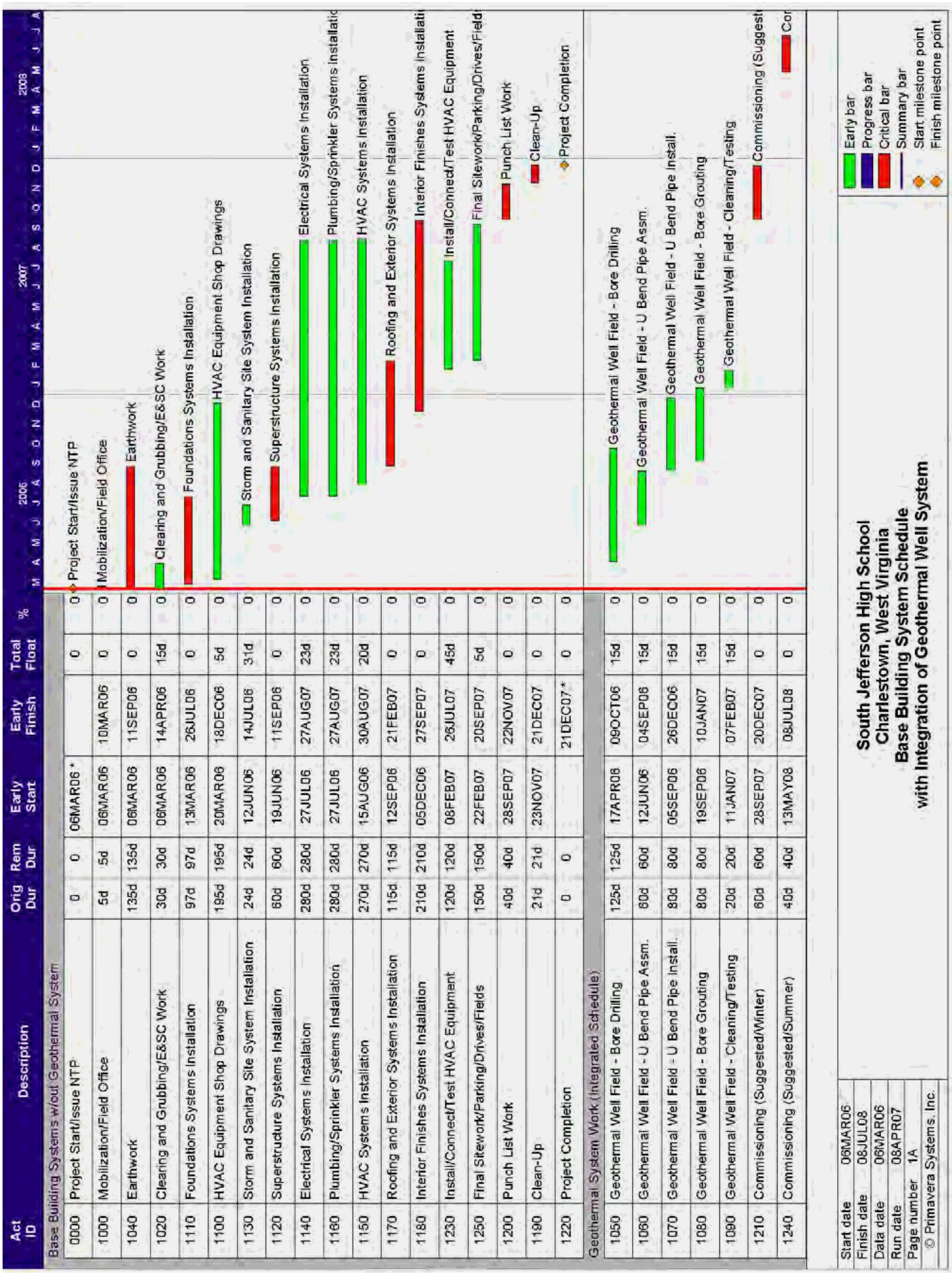
Floor Area:		Allowed Watts/ft2:	Total Allowed Watts:
School/University:	199717	1.2	239660

A Fixture ID : Description / Lamp / Wattage Per Lamp / Ballast	B Lamps/ Fixture	C # of Fixtures	D Fixture Watt.	E (C X D)
Linear Fluorescent 1: RF-2: 2 - 32W T8 / Other / Electronic	2	1300	64	83200
Linear Fluorescent 4: RF-4: 2 - 26W TRT / Other / Electronic	2	35	52	1820
Linear Fluorescent 7: RF-7: 2 - 26W TRT / Other / Electronic	2	90	52	4680
Linear Fluorescent 8: RF-8: 2 - 26W TRT / Other / Electronic	2	43	52	2236
Linear Fluorescent 9: RF-9: 2 - 26W TRT / Other / Electronic	2	53	52	2756
Linear Fluorescent 10: RF-10: 3 - 26W TRT / Other / Electronic	3	12	78	936
Linear Fluorescent 13: RF-13: 4 - 32W T8 / Other / Electronic	4	7	128	896
Linear Fluorescent 14: RF-14: 6 - 32W T8 / Other / Electronic	6	53	192	10176
Linear Fluorescent 15: SF-1: 2 - 32W T8 / Other / Electronic	2	1	64	64
Linear Fluorescent 16: SF-2: 3 - 32W T8 / Other / Electronic	3	8	96	768
Linear Fluorescent 17: SF-3: 1 - 26W TRT / Other / Electronic	1	1	26	26
Linear Fluorescent 18: WSF-1: 1 - 26W TRT / Other / Electronic	1	3	26	78
Incandescent 1: WSI-1: 100W INCAND / Incandescent 100W	1	1	100	100
Linear Fluorescent 19: DF-1: 2 - 32W T8 / Other / Electronic	2	122	64	7808
Linear Fluorescent 20: DF-2: 3 - 32W T8 / Other / Electronic	3	17	96	1632
Linear Fluorescent 21: DF-3: 2 - 32W T8 / Other / Electronic	2	68	64	4352
Linear Fluorescent 22: DF-4: 3 - 32W T8 / Other / Electronic	3	12	96	1152
Linear Fluorescent 23: DF-5: 5 - 54W T5 / Other / Electronic	5	34	270	9180
Linear Fluorescent 24: DF-6: 1 - 32W TT / Other / Electronic	1	12	32	384
HID 1: DI-1: 500W QUARTZ / Other / Magnetic	1	32	500	16000
HID 2: DI-2: 250W QUARTZ / Other / Magnetic	1	22	250	5500
HID 3: RMH-1: 100W MH/100W QUARTZ / Metal Halide 100W / Magnetic	1	14	200	2800
HID 4: RMH-2: 100W MH / Metal Halide 100W / Electronic	1	15	100	1500
HID 5: RMH-3: 100W MH / Metal Halide 100W / Electronic	1	33	100	3300
HID 6: WMH-1: 175W MH/100W QUARTZ / Metal Halide 175W / Electronic	1	15	275	4125
HID 7: WMH-2: 175W MH / Metal Halide 175W / Electronic	1	26	175	4550
HID 8: SL-1: 400W MH / Metal Halide 400W / Magnetic	1	1	400	400
HID 9: SL-2: 100W MH / Metal Halide 100W / Electronic	1	1	100	100
Linear Fluorescent 1 copy 1: RF-1: 3 - 32W T8 / Other / Electronic	3	237	96	22752

		Watts/ ft2:	Total Watts:
Lighting PASSES: Design by:	19.36%	0.97	193271

APPENDIX H: Construction Data:

Construction Schedule – Base and with Geothermal Well Field:



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