Thesis Proposal

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This document outlines future study considerations for the Spring 2010 semester. Included are proposed simulation and calculation methodologies for quantifying benefits or detriments of system redesigns for Manassas Park Elementary School in Manassas Park, VA.

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Architectural Engineering: Mechanical
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Executive Summary:

The purpose of this report is to lay the foundation for next semester's thesis course, AE482. This report contains a design summary, an existing system analysis, mechanical system modification suggestions, two breadth topics, referenced schematics, and a draft work plan.

The mechanical system modification suggestions include the following:

- Connecting the existing Outdoor Air Units (OAUs) to the ground loop to remove the direct expansion coils and/or the direct fire reheat.
- Removing the sensible wheels from the OAUs to decrease associate pressure drop.
- Rerouting ductwork from the OAU's to the Ground Source Heat Pumps (GSHPs) such that the system goes from a series configuration to a parallel configuration, thus allowing the GSHP to be bypassed when applicable.
- Adding BACNET compatible people counters which manipulate added dampers on the Outdoor Air (OA) side of the GSHPs to ramp down the OAUs blowers when applicable.
- Decentralizing the water side of the GSHP system.
- Moving from a two-pipe GSHP system to a one-pipe GSHP system.
- Testing the rigor of a new type of ground loop system that integrates a dynamic dual containment thermal storage system.

The two breadth topics include the following:

- An envelope study which would analyze options related to changing and/or removing the "green light" natural ventilation system.
- An electrical study which would detail the impacts that a photovoltaic (PV) array would have on Manassas Park Elementary School (MPES), including implementation strategies, potential system accessories/auxiliaries, and design and construction considerations.

The most significant milestones of the included draft work plan are *research completion* and *substantial thesis completion*, slated for 4/2/2010 and 5/3/2010, respectively.

Building Design Summary:

Manassas Park Elementary School is a 123,000 square foot building located in Manassas Park, Virginia. The school is served by some relatively efficient heating and cooling systems that were chosen as the best combination of minimized first cost and an ability to provide a comfortable indoor environment to the buildings occupants. These systems were also chosen to help promote the school as an environmentally conscious building, minimizing the overall energy and associated resource consumption of the school.

Sustainability was a major consideration in the system selection, as the building was pre-determined to be an example of growing environmental consciousness in the construction of educational facilities in northern Virginia. The school was designed with the philosophy that a good school can be the catalyst for an evolving and maturing community; a philosophy that MPES ultimately proved robust[1].

Highlights of the building include a 75,000 gallon cistern used for grey water storage, light tubes that virtually eliminate artificial illumination requirements on a sunny day, floors made out of recycled airplane tires and a non-toxic adhesive, motion sensors with automatic light meters, and a non-automated natural ventilation system[2].

Existing Mechanical System:

Base mechanical heating and cooling is supplied to the building via a distributed two-pipe ground source heat pump system. These heat pumps utilize a 5 acre, 200-well variable primary geothermal system that is able to consistently supply water at 55 degrees Fahrenheit. System schematics can be viewed in Appendix A.

Table 1: Outdoor Air Unit Schedule[3]

Mark	Supply Air (CFM)	Supply Fan Power (HP)	Exhaust Fan Power (HP)	Enthalpy Wheel Power (HP)	Sensible Wheel Power (HP)	Cooling Coil Cap (MBH)	Gas Fired Cap (MBH)	Pre-Filter Efficiency
OAU-1,2,3	3360	5	3	0.25	0.25	128.5	123	30%
OAU-4	9330	15	7.5	0.5	0.25	365.3	341	30%
OAU-5	4650	7.5	3	0.25	0.25	188.3	170	30%

Before the supply air is supplied to the building occupants, it goes through one of 5 outside air units[4]. The specifications for the specific units can be seen in Table 1, above. In each one of thesis units, air goes through an enthalpy wheel, an air-cooled direct expansion coil[5], a sensible wheel, and an optional direct fire natural gas heater (in that order) to precondition the air to 72 degrees Fahrenheit and 50%

[1] See Technical Report 3
[2] Teachers are expected to open and close windows as a corridor mounted green light turns on and off, respectively.
[3] The building ventilation requirements do not exceed 24,060 cubic feet per minute.
[4] See Appendix B for the Outside Air Unit Schematic taken directly from the construction documents as drawn by 2rw Consulting Engineers.
[5] OAU-1,2,3 have individual remote 2-compressor air-cooled condensing units. OAU-4 has a packaged 4-compressor air-cooled condensing unit, and OAU-5 has a packaged 2-compressor air-cooled condensing.

relative humidity. From here, this 100% outside air is mixed with return air at the zone level, and is then delivered to the distributed ground source heat pumps. This mixed air is then conditioned to the supply temperature by the R-407c vapor compression cycle[6] within the heat pumps, rejecting heat to or absorbing heat from the ground loop water. Air is primarily exhausted[7] to the outside air units, where it provides supplemental conditioning to the intake air via the aforementioned sensible and enthalpy wheels.

The ventilation system also utilizes what is called a "green light" natural ventilation system. When the weather conditions fall into an acceptable range, a green light in the corridor turns on and teachers are expected to open all of the operable windows in their classrooms. Fan energy requirements are reduced as applicable OAUs are de-energized, and no mechanical ventilation is sent to the perimeter zones.

GSHP Perks:

The ground loop utilized by the heat pump system at Manassas Park Elementary School provides a relatively constant temperature water stream at 55 degrees Fahrenheit. This water stream is a relatively easy media to absorb heat from or to reject heat to compared to ambient air for a variety of reasons. First off, absorbing heat from winter ambient air and rejecting heat to summer ambient air is very difficult; at these conditions, there exists a very low temperature difference between what the system is trying to absorb or reject and the media that it is absorbing from or rejecting to (the surrounding air). The reason that the constant temperature water stream can provide highly efficient heating and cooling is because of the greatly increased relative temperature difference between what the system is trying to absorb or reject and the media that it is absorbing from or rejecting to (the ground loop).

Another perk of a GSHP system is that it uses water to transport heat as opposed to air. Water has a much higher thermal capacity than air, meaning that much less volume of water must be transported than air to have the same heat transportation effects. Because the transportation of heat is primarily accomplished via water pipes, the building area and volume allocations required to heat and/or cool each individual space are greatly decreased, saving energy, space, and money.

Possible System Changes:

OAU Changes:

As was previously noted, the condensers in the OAU's are currently air-cooled. An OAU study could detail the cost and energy implications if the OAU condensers rejected heat to the current (or a modified) ground loop instead of the air. Also, the ground loop could potentially be used for reheat to replace the current natural gas direct fire method of reheat. This study would detail required system modifications to have the OAU's utilize the current ground loop, and would include related energy, emission, and cost estimations. Further OAU study would include comparing both the benefit and

[6] Rooftop GSHP units utilize a 500W, 120V heater with a temperature stat set at 40 degrees Fahrenheit to precondition air. This is primarily used as freeze protection such that typical GSHP operation is possible.
[7] Areas including the mechanical rooms, penthouses, kitchens, data closets, and bathrooms are exhausted directly out of the building. A make-up air unit is used to balance the kitchen exhaust hood, and supplies a constant volume of air to the kitchen with optional direct fire heating.

detriment of utilizing a similar outside air unit that does not have a sensible wheel. Stanly Mumma, Professor Emeritus at The Pennsylvania State University, has suggested that the sensible wheels in the current system may consume more energy via increased air-side pressure drop (an estimated 0.75 to 1 inch of water column in each direction) than they save via decreased reheat requirements. This study would either validate or quash this hypothesis, and provide the associated details.

GSHP Changes:

There are many possible options to consider regarding adjustments to the ground source heat pumps. For instance, an applicable GSHP study could show the effects of moving the air-side arrangement of the current system from a series configuration to a parallel configuration[8]. This would synergize with the aforementioned change of removing the sensible wheel from the OAU's, as it would allow the GSHP to be bypassed for OAU only cooling. In this arrangement, I would suggest adding dampers on the OA side actuated by a BACNET compatible people counter. This proposed people counter would both indirectly actuate the dampers and ramp down the associated OAU's variable frequency drive, saving a significant amount of energy associated with both ventilation fan consumption and GSHP reheat. Figure 1 and Figure 2, below, show the proposed modifications to the air-side of the GSHP system.

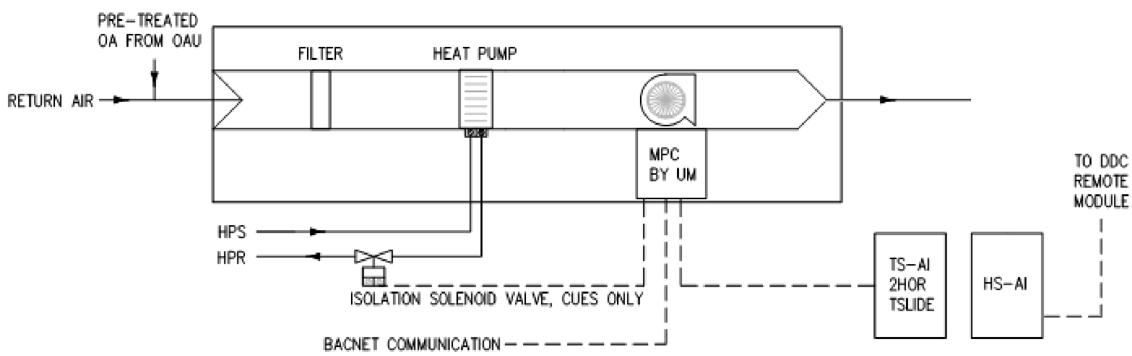


Figure 1: Current GSHP Schematic

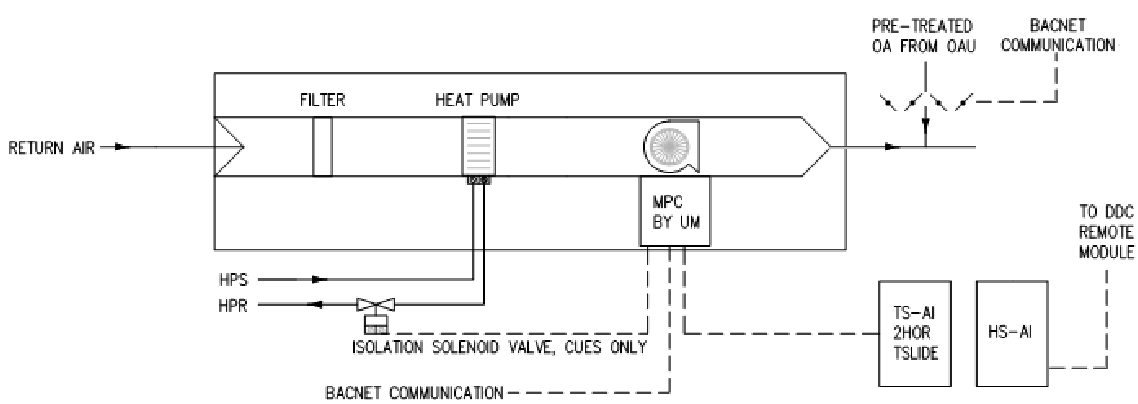


Figure 2: Proposed GSHP Schematic

[8] This would involve moving the OA/RA mixing point from the individual heat pumps intake side to their supply side.

Another option of study could include the effects of decentralizing the water side of the GSHP system, moving from one large variable primary arrangement to many smaller subsystems with individual pumps. The study could potentially also detail the effects of moving from a two-pipe system to a one-pipe system. Articles in recent ASHRAE Journals inspired these rational, showing many benefits of decentralized ground loops and one-pipe loops. It would be interesting to see the results of similar tests for a small building with a high percentage of perimeter space, such as MPES.

A third GSHP option is to test the rigor of a new type of ground loop system, where the summer and winter operation of the ground loop are coupled with a dynamic dual containment thermal storage system to provide an innovative method of heating and cooling. This method may only prove to be affective on a building with a more definitive difference between the perimeter zones and the interior zones; however, a short study may still be of interest.

Breadth – Ventilation & Envelope Changes:

A ventilation study would analyze the options of changing and/or removing the "green light" natural ventilation system. This study would detail many different system scenarios, such as removing the currently required human/system interaction and installing automatic window actuators, minimizing human/system interaction by increasing the number of green lights or changing the current ventilation system controls, and switching out operable windows for a more tightly configured façade (thus eliminating the option of natural ventilation altogether). A more tightly configured envelope would affect the performance of the current mechanical system, as it would significantly minimize infiltration and exfiltration. This would provide substantial energy savings to the system during periods that are typically unsuitable for natural ventilation. Being said, this system would consume *considerably* higher amounts of energy during periods that are typically acceptable for natural ventilation.

Breadth – Electrical/PV study:

An electrical study would detail the financial and energy impacts that a photovoltaic (PV) array would have on Manassas Park Elementary School. The study would also look into the best implementation strategies of a PV array, as well as potential options including battery backup, solar tracking, etcetera. This study would also feature the design and construction considerations of the specific PV system chosen for MPES. Structural impacts would be discussed; however no detailed structural calculations would supplement this study.

The main reason that I plan to study the option of photovoltaic solar collection is that I have been impartial to solar thermal collectors for much of my college career. I had used them often on studio projects, ASHRAE design submissions, and personal designs; all the while barely giving PV any consideration. This study should help educate me on different solar collection options, and should ultimately make me a more well-rounded engineer.

Tools and Methods:

I plan to conduct research on the aforementioned material using computer programs such as Engineering Equation Solver, Trane Trace, and Microsoft Excel. These programs can be used to show if a particular methodology is technically and/or financially robust. Conclusions drawn during the testing period will be detailed in the coming reports, and will include references to related material including the LEED® rating system.

Engineering Equation Solver (EES) has a wide variety of functions that could potentially be useful for these analyses. It allows the user to write a large series of equations, and have those equations simultaneously solved with minimal effort. There are, however, some drawbacks to using Engineering Equation Solver for these analyses. Many of the useful functions of the program are new to the user, and may require a bit of a “learning curve”. Also, the program has been known to give the user a “block error”, which can sometimes lead the user to abandon a total equation set in favor of starting over; a time consuming prospect.

Trane Trace can be used to create single zone models that can emulate conditions that are expected within the space. A myriad of different systems can be specified to condition these zones; each independent simulation of these individual arrangements would show the pros and cons of the conditioning method specified.

Microsoft Excel, like EES, would be used to solve systems of equations and produce study related tables and images. This program is significantly more familiar to the user, and should prove to add substantially to the quality of the following semesters reports.

Resources:

Gao, X., S.A. McInerny, S.P. Kavanaugh. 2001. "Effciencies of 11 kW variable speed motor and drive." ASHRAE Transactions 107(2):259-265.

Hubbard, R. 2009. "Water-to-Water Heat Pumps." ASHRAE Journal 51(1):28-35

Kavanaugh, S., K. Rafferty. 1997. Ground-Source Heat Pumps. Atlanta: ASHRAE.

Kavanaugh, S.P., S.A. McInerny. 2001. "Energy use of pumping options for ground-source heat pump systems." ASHRAE Transactions 107(1):589-599.

Mescher, K. 2009. "One-pipe geothermal design: simplified GSHP system." ASHRAE Journal 51(10):24-30.

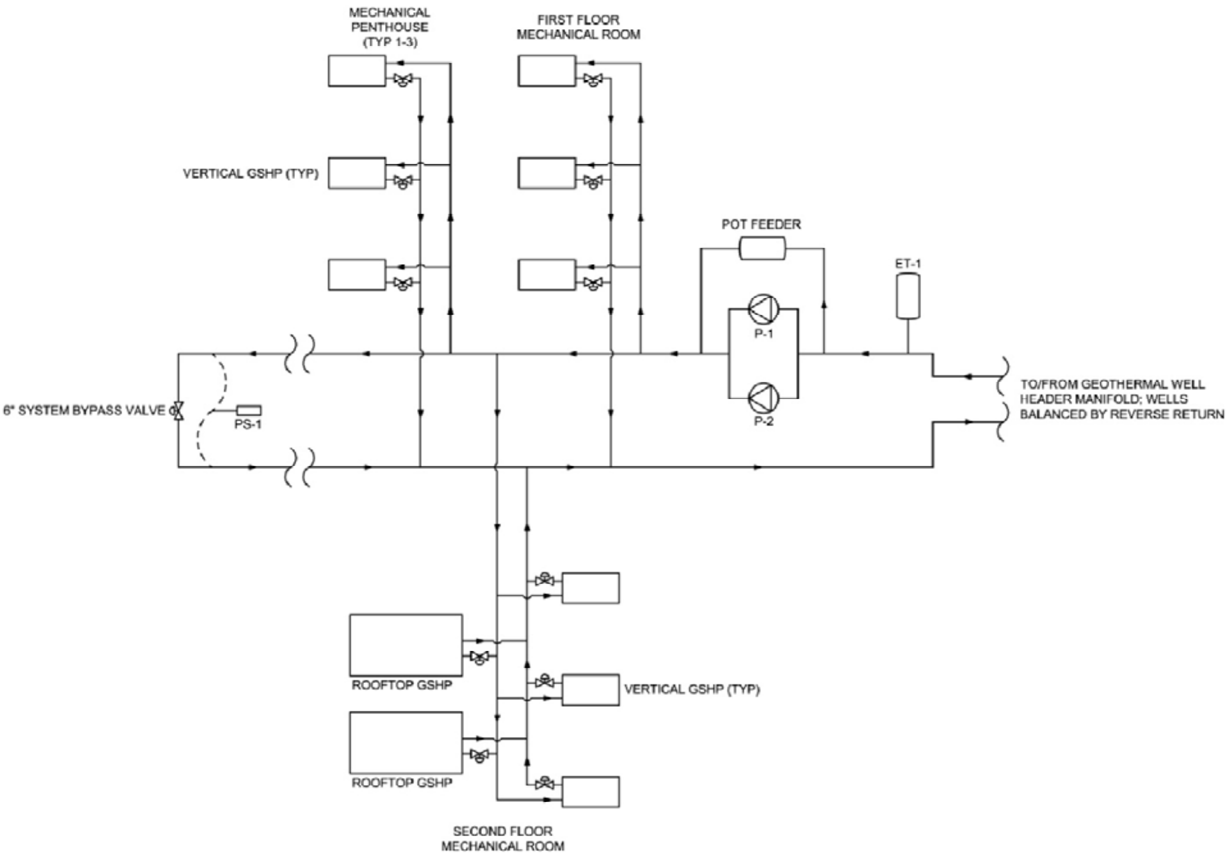
Mumma, S. 2009. Personal Interview.

Rishel, J. 2003. "How to calculate motor effciency for variable-speed centrifugal pumps." Engineered Systems (7).

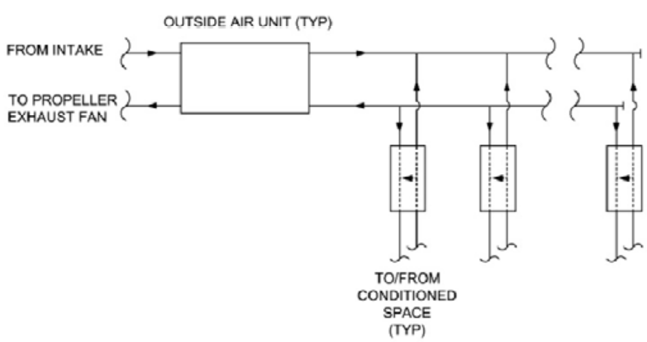
U.S. Environmental Protecton Agency. 2009. "ENERGY STAR Labeled Buildings and Plants." www.energystar.gov/index.cfm?fuseacton=labeled_buildings.locator.

Appendix A: System Schematics

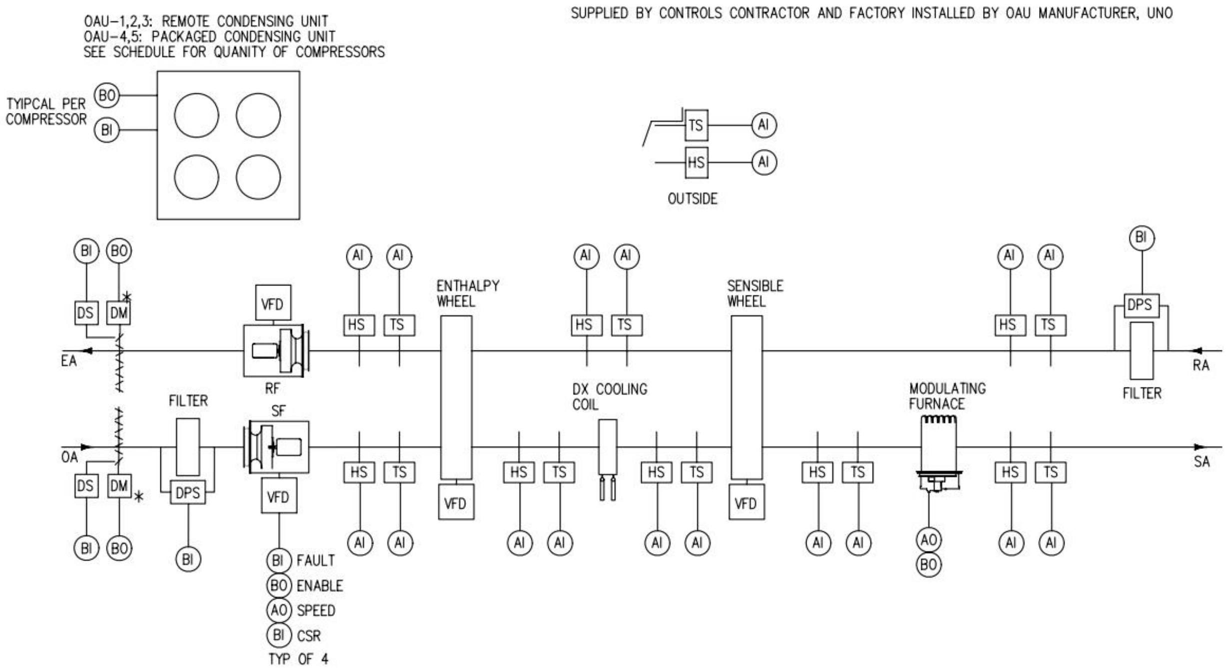
Water Side System Schematic



Air Side System Schematic



Appendix B: Outside Air Unit Schematic



Appendix C: Draft Work Plan

ID	Task Name	Start	Finish
1	Return from Winter Break	Mon 1/11/10	Mon 1/11/10
2	Depths: OAU/GSHP Considerations	Tue 1/12/10	Fri 2/5/10
3	Powerpoint: Depths	Tue 1/19/10	Fri 2/5/10
4	Depth Integration	Mon 2/8/10	Fri 2/12/10
5	Breadth: Vent & Envelope	Mon 2/15/10	Fri 2/26/10
6	Powerpoint: Vent & Envelope	Mon 2/15/10	Fri 2/26/10
7	Breadth: Electrical/PV	Mon 3/1/10	Fri 3/5/10
8	Powerpoint: Electrical/PV	Mon 3/1/10	Fri 3/5/10
9	Spring Break	Mon 3/8/10	Fri 3/12/10
10	Breadth: Electrical/PV	Mon 3/15/10	Fri 3/19/10
11	Powerpoint: Electrical/PV	Mon 3/15/10	Fri 3/19/10
12	Breadth Integration	Mon 3/22/10	Fri 3/26/10
13	Research Completion	Mon 3/29/10	Fri 4/2/10
14	Powerpoint/Report Work	Mon 4/5/10	Fri 4/30/10
15	Substancial Completion	Mon 5/3/10	Mon 5/3/10