Executive Summary

As the general contractor's Interim GMP was reaching numbers far exceeding Capital One's budget, a look at the buildings large mechanical system seemed beneficial. The current system is contained within two separate rooms of much different size. Two boilers located in a small mechanical room are creating space and access issues towards electrical equipment also located in the same room.

In order to alleviate these spatial problems, two additional mechanical considerations are analyzed to supplement the need for heating and hot water provided by the boilers. The supplied 67 gallons of water per minute was used to help estimate overall requirements for the alternate systems of an electric resistance heater or geothermal heat pumps.

After extended analyses, it was determined that the electric heat coils would save space and $48,000. The ground source heat pumps would also save on space, but cost Capital One an additional $400,000 and increase construction time by months. Despite the poor efficiency of electric heat coils and large energy costs, it was determined that this system is the best option of the three. The owner would be more content with dropping initial project costs than saving money 10 years down the road.

The mechanical breadth for this analysis is included within **Appendix F** and is primarily used to find a cumulative sensible cooling load. This load can then be used to help formulate an approximate size for the alternate mechanical systems. Further calculations divide the total load into smaller quantities used for each coil and its equivalent amount of kW power.

Background

With DAVIS' Interim GMP increasing as the 75% Construction Documents became more complete, it was imperative that the building systems be looked at in depth. Estimated project costs were amounting to much more than Capital One funded for. While the value engineering process began for the Lecture Hall project, DAVIS was requested by Capital One to create a preliminary list of VE items to be discussed.

As currently planned, there are two separate mechanical rooms. Besides the three air handling units, two boilers were designed in a congested area distant from the main mechanical space. With the sole purpose of supplying the AHU's with hot water, these two 4,100 lb pieces of equipment and their accompanying pumps do not seem like the most space efficient systems. In addition to the boilers, the Lecture Hall's two 800A main distribution panels are located within the second mechanical room.

Concerning chilled water for the Lecture Hall, all of the supply and return runs are connected to a chiller already existing inside the base building. Besides the supply and return of hot water, the air handling units exist as an independent system connected to an outside source. Lastly, localized heating on the variable air volume (VAV) boxes are located throughout the space and would be able to handle a large portion of the heating load during a warm winter.

In order to bring the boilers and air handling units into the building, pieces will be hoisted down to the basement through a shaft along the west wall. Once this is done, the individual sections will be assembled in place.

Proposal

In order to conserve space and possibly decrease the overall mechanical scope of work, removing the boilers and all associated piping would have numerous benefits. Alternative solutions such as electric heat coils and geothermal heat pumps are viable options. Within this analysis, these three schemes will be compared based on estimated costs, construction times, and other general system requirements. After further review, a smaller and less expensive source for hot water shall be obtained.

System Comparisons

The following mechanical systems will be investigated as only a few of multiple possibilities to provide a need for hot water in the building. These results have been obtained through research and conversations with a MEP engineer.

Boilers

Within the current mechanical system, two 4,100 pound boilers are provided for heating and hot water to three air handling units. In addition to the boilers, their accompanying 250 pound pumps are also contained in the small secondary mechanical room. Separate from the weight, respective dimensional sizes pose as a space concern. According to a Burnham Industrial cut sheet, the two boilers consume a space of approximately 5' in length, 8' in width, and 5' in height. Not to forget, there are also the Lecture Hall's main distribution panels located in the secondary mechanical room, causing possible inconveniences for access.

Getting back to the system in which further mechanical comparisons can be made to determine appropriate substitutions, the boilers are fueled by natural gas and are estimated to have an 80% efficiency. Over the past few years the cost of natural gas has skyrocketed. For this analysis an estimate of $0.40/ kWh[1] (kilo-watt hour) will be used. Considering its demand of 67 gallons per minute (gpm) with an entering water temperature of 140°F and a leaving water temperature of 180°F, an equivalent 1,336 MBtu/hour (1,000 Btu/hr) is provided. The conversion can be viewed within **Appendix F**. As quoted by W.E. Bowers, the installation and furnish price of the boilers alone should be around $85,000. Typical lead and construction time for the units, including installation and piping, are both 8-10 weeks.

Since the alternate mechanical system to follow has an effect on the air handling unites, it is important to also take a look at their characteristics. AHU-1, -2, and -3 have total cfm of 4,800, 19,200, and 10,725 respectively. Like any typical AHU, its main components include a supply fan, cooling coil, heating coil, and return fan. Without piping and additional duct work, AHU's of this size run about $150,000 combined. Lastly, its lead time is also around 8-10 weeks, but installation can take up to 20 weeks to complete. Installation of these pieces of equipment may occur simultaneously if space and labor permit, not creating a combined time of 28-30 weeks.

Electric Heat Coil

Within this analysis, our previously design boilers will be eliminated. The inclusion of electric heat coils within Capital One's existing AHU's could possibly be an adequate substitute. Instead of having boilers present to supply the units with hot water, these heat coil sections could produce the appropriate heat themselves.

A benefit of this electrical resistance heating is that it converts nearly 100% of the energy in the electricity to heat. However, most electricity is produced from oil, gas, or coal generators that convert only about 30% of the fuel's energy into electricity. Because of electricity's generation and transmission losses, electric heat is often more expensive than heat produced with combustion. The lower $0.06/kWh for electric is deceptive. As stated before, since electric resistance is so much more inefficient than the boilers, having to fulfill the same load requirements often results in higher fuel costs for electricity.

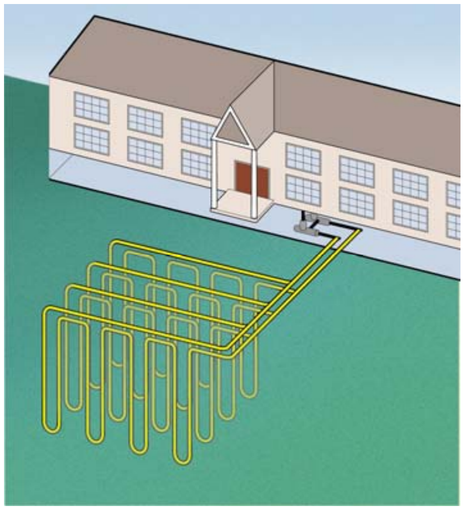
In terms of the air handling unit, the addition of an electric heat coil shall include another 3' of length to each. Dealing with this extra volume of occupied space is not a concern in the main mechanical room as it is with the secondary. Lead times for the modified AHU's are still between 8-10 weeks. Considering installation times, inserting an additional heat coil section would not be that difficult for the mechanical subcontractor. Around 20 weeks for installation is expected and can cost up to $158,000.

Although there are a few electrical considerations for removing boilers and adding electrical heat coils, these calculations were not assessed as part of the analysis. Despite the specific fused switch and feeder alterations, a $29,000 electrical scope increase can be expected.

Geothermal Heat Pump

Although this next mechanical system has been well established in residential construction, geothermal heat pumps (aka ground-source heat pumps or GSHP's) have been increasing in popularity in the commercial and Federal sector. While there may a significant difference between air and ground temperatures, temperatures of the earth and its waters are very stable. In order to tap this energy source, heat pumps have external piping buried in the earth or submerged in a body of water. In our case, a GSHP would use the ground as a heat source during the winter months and as a heat sink during the summer cooling month. These ground coupled types can be placed either vertically or horizontally near the surface. According to John Lund, as a rule of thumb, 150-200 feet/ton is associated with vertical loops and approximately 30-50% longer for horizontal loops under the same condition.

Figure 11. Commercial Vertical Loop



*http://www.geoexchange.org

Being on a site where future high rise buildings will be constructed, adjacent to the I-495 Capital Beltway, open land is at a minimum. This will automatically eliminate any horizontal GSHP configuration. To better understand the cost of the geothermal system, vertical earth coils will be evaluated.

As calculated in **Appendix F**, the total load required for our space is 1,336 MBtu/hr. Looking further into *RS Means 2006* to estimate the cumulative amount of heat pumps necessary to fulfill this need, (16) 20 ton heat pumps would be used. With an 85 MBtu/hr heat capacity at 0°F, these 20 ton pieces of equipment would cost $20,400 each. Being able to install one heat pump every 5 working days would result in a 16 week installation time. Assisted by a fellow student, an estimated $4.40/ft for drilling was obtained from the Royal Electric Company. Accumulating a 320 ton system and a 160 ft deep hole per ton, will result in soil work around $225,280.

Recommendation

In order to come up with a final proposal, many things need to be taken into consideration. Especially within this scenario, although an overall price is appealing; outside factors need to be examined. The summary table below will help guide our decision making process.

Table 8. Mechanical Summary Table

System	Lead Time	Installation Time	Energy Cost	Cost	Other
Current					
+Boilers (2)	8-10 wks	8-10 wks	gas - $0.40/kWh	$85,000	tight mechanical space
+AHU-1,-2,-3	8-10 wks	20 wks	*elec - $0.06/kWh	$150,000	
			Total	$235,000	
Alt. #1 - Electric Heat					
+AHU-1,-2,-3	8-10 wks	20 wks	*elec - $0.06/kWh	$158,000	+$29,000 for electrical work
+Electric Heat Coil	incl.	incl.	incl.	incl.	
			Total	$187,000	
Alt. #2 - GSHP					
+Heat Pumps (16)	-	16 wks	N/A	$408,000	land area not available
+Earth Coil System	-	64 wks	N/A	$225,280	
			Total	$633,280	

The biggest concern with the Lecture Hall's current mechanical system is the overall size, consuming two separate rooms. Lead and installation times of 8-10 and 20 weeks are typical and won't have a large impact on its outcome. Comparatively, the $235,000 cumulative cost of the two boilers and three air handling units is fairly larger than alternative #1.

When looking at the geothermal heat pump option, numerous figures stand out. Although there are a lot of benefits with an environmentally friendly mechanical system and a cheap source of energy, its installation time and costs are expensive. Thinking back to Capital One and their influence as an owner, setting aside fixed sums of money for projects, adding $400,000+ dollars to an already tight budget is in the best interest of no party on this project. Not to mention, the large amount of land required for pursuit of a geothermal heat pump system does not exist. Their property is filled with recently completed soccer fields, baseball fields, basketball courts, security booths, a 14 story high rise building, and is the future site of an additional multi-story structure. Digging up these fields and possibly rupturing the geothermal piping when excavations occur during future expansion would not please Capital One. Lastly, the current cooling system is already supported by the base building chiller. If GSHP's are put in place, they will only be used for heating purposes only. Utilizing only half of their intended purpose would be absurd considering the large additional cost.

That brings us to our final electric resistance heat coil option. First, the additional 8-10 weeks of installation time for the boilers will be cut and allow for other mechanical work to take place. Despite the additional electrical work needed to support this alternate system, there can still be a savings of $48,000. Bringing ourselves back to our initial goal of saving space, the addition of these coil units will have little effect on the available space within the main mechanical room. Alternatively, an estimated 300ft^3 of space will become available for access to the main distribution panels and similar equipment.

An argument over the poor efficiency and overall cost of its energy is a viable point. In time, this mechanical system will eventually cost the owner more money than its current system. But looking at the owner and their objectives, we aren't dealing with an environmental engineering firm or government body that wants their new building looking as energy efficient as possible. Capital One only wants to know "what's in your wallet?" and theirs, not "what's in our mechanical room?" At the end of the day, as a general contractor, final value engineering ideas are decided by the owner. If they are happy with the older and reliable mechanical systems that don't cost a fortune, that is their decision.