2.0 DEPTH WORK – ALTERNATIVE MECHANICAL DESIGN

2.1 OBJECTIVES OF ALTERNATIVE

The main goal of the design alternative system is to analyze potential energy savings compared to the current conventional water source heat pump system. While first cost was the primary concern for the existing design, this report will evaluate the possible savings over the life of the building. Factors such as installation, operation, and maintenance costs will be taken into consideration. It is important to note that the alternative presented in no way implies that there were any problems with the original design or that another design should have been pursued.

2.2 OVERVIEW OF GROUND SOURCE HEAT PUMP SYSTEMS

The concentration of this thesis depth is on the use of a geothermal system for the Try Street Terminal Building. With a ground source heat pump (GSHP) system design there are many factors to consider. Compared to the conventional system, the geothermal system can significantly reduce the energy consumed by a building. The operation and maintenance associated with the geothermal system is also considerably less when compared to the conventional. However, the installation cost can be more expensive.

The two types of ground source heat pumps that will be discussed in this section are the closed and open loop systems. There are two classifications of closed loop that include vertical and horizontal loops. With these two classifications, the ground-coupled system will be considered. As for the open loop system, the groundwater heat pump system will be presented. It should be noted that GSHP can be referred to as several different names. In this document they may be referenced to as: geothermal, earth-coupled, groundwater, ground-coupled, closed loop and open loop heat pump systems. Following this open and closed loop system discussion, the application chosen as the primary geothermal focus will be confirmed.

2.2.1 CLOSED LOOP SYSTEMS

With the closed loop ground-coupled heat pump (GCHP), a vertical or horizontal design may be chosen. In this system, heat is exchanged between the water circulating in the pipes and the relatively constant temperature of the soil. With the vertical arrangement, a series of vertical pipes that circulate water are buried deep within the ground. This arrangement requires approximately 250 to 300 ft^2 of surface area per ton of cooling. With the horizontal GCHP, a network of pipes is distributed horizontally at a more shallow depth. The horizontal system requires approximately 2500 ft^2 of surface area per ton of cooling. An advantage of this geothermal system is that the need for a cooling tower and boiler may be eliminated. This is possible because in the summer, heat from the building is rejected to the ground. While in the winter, the ground source heat pump would utilize the heat stored in the ground.

Figure 2.2-a Vertical (left) & Horizontal (right) Closed Loop

Assuming that there is adequate room on the site, the horizontal system provides several advantages over the vertical system. Some of these advantages include: known geology, lower excavation cost, and lower installation equipment cost. However, disadvantages exist such as pipe loops close to surface, removal of rocks and the likelihood of additional required excavation.

2.2.2 OPEN LOOP SYSTEMS

The concept of heating and cooling in an open loop is similar to the closed loop ground-coupled system except that groundwater is the source. With the open loop ground water heat pump (GWHP) system the fluid is not confined to a loop of pipes. Rather a pumping well is used to move the water through the heat pump. The open loop system can take on several configurations which include: direct use, indirect use, and standing column. With the direct arrangement, groundwater is used directly in the heat pump units and is typically limited to the smallest applications. The standing column system produces and returns water to the same well. Both the standing column and direct use are susceptible to water quality induced problems, such as scaling of the refrigerant-to-water heat exchangers. However, the indirect method utilizes a plate heat exchanger to isolate the building loop from the ground water which protects the building equipment from the scaling mentioned above. In addition, the separation allows the loops to operate at different flow rates which optimize the system performance. The following figure depicts the three different open loop configurations.

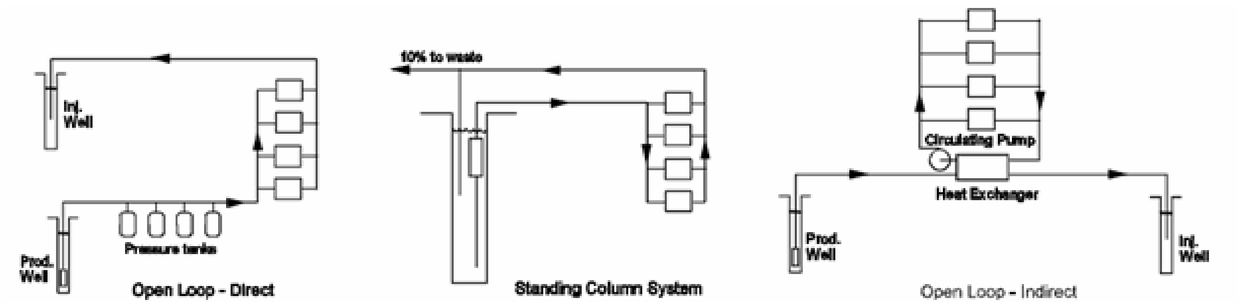

Figure 2.2-b Open Loop Configurations

2.2.3 PRIMARY FOCUS – OPEN LOOP-INDIRECT SYSTEM

Based on the information presented in the previous sections, it was determined that the open loop-indirect use system would best meet the design requirements of the Try Street Terminal Building. Due to site limitations and high installation cost, the closed loop systems were eliminated as possibilities. The scale of the project and water quality induced problems were some of the factors causing the dismissal of the open loop-direct and standing column systems.

For the indirect open loop, one and two well systems are possible. The one-well system that utilizes a surface disposal method was not chosen for several reasons. With the surface disposal, the return water is diverted to a surface body of water, such as a river. This was not considered a feasible option because of the building's location downtown. The closest body of water, the Monongahela River is approximately 600 feet away. Discharging this return water into the river may also require a National Pollutant Discharge Elimination System (NPDES) permit. Therefore, the more common commercial two-well approach was chosen to be analyzed. One well will be used for supply/production and the other for return/injection. It was also found that return wells for groundwater heat pumps are classified as Class V injection well by the U.S.

Environmental Protection Agency. These types of wells have been determined not to pose a significant threat to the environment. In Pennsylvania these wells are also known as return, recharge, or diffusion wells and do not require a permit.

2.3 UNDERGROUND RIVER

The water source to be used for this groundwater application is an aquifer. The proper name for this underground river is the Wisconsin Glacial Flow. This is because it was formed by the Wisconsin Ice Sheet that covered much of the Northern United States during the Ice age (70,000 year ago). Geologists also refer to this water source as an aquifer. An aquifer is described as having irregular, widespread flow and not following a channel. However, the underground river differs from these characteristics making it more like a true river.

The underground river water is said to be a fresh, fairly constant 55F source with no bacteriological count. It is actually a drinking source for much of downtown Pittsburgh. The fountain at Point State Park is also fed by this water.

The David L. Lawrence Convention Center, is a 1.5 million square foot convention, conference and exhibition building in downtown Pittsburgh, Pennsylvania. It sits along the Allegheny River and about a mile from the Try Street Terminal Building. It is also the first LEED certified "green" convention center in North America and one of the first in the world. The reason this is mentioned is because one of the proposed designs included the underground river to be used for 5000 tons of condenser cooling. With their intention to use this water source further investigation was needed to determine items such as the water table depth below the surface, quality of the soil, and flow rate of the water. As a result, a 12hr and 24hr drawdown test was performed and showed that the flow rate available was 1100 gpm.

2.4 PROCEDURE AND CALCUATIONS

The rating intended for the conventional WSHP systems is the ARI 320 rating, where stands for the Air Conditioning & Refrigeration Institute. The cooling performance (EER) is reported for an 85F entering water temperature and a 70F value for heating. Because this equipment is not intended for GSHP system, new heat pumps should be selected. The ARI rating for the GSHP system is reported as both the EER and COP having 70F and 50F entering water temperatures.

In most applications, the optimum system performance occurs when the groundwater flow rate is between 1 to 2.25 gpm/ton and the building loop flow rate is in the range of 2 to 3 gpm/ton. Therefore, knowing the heat of rejection and absorption of 4,200 MBH and 1053 MBH, respectively the plate and frame heat exchanger was sized using the Mueller Accu-Calc Heat Exchanger Calculator for the governing cooling conditions. The entering groundwater loop temperature of 55F was known along with a 59F leaving water loop temperature. Therefore, to size the heat exchanger various combinations of the building and ground loop in the ranges mentioned above were entered until the optimum combination shown in Figure 2.4-a were achieved. This calculation resulted in an 875 gpm building loop flow rate and a 788 gpm groundwater loop flow rate with a 3.4F approach. The program used to calculate this information is show below. Based on this calculation a Mueller 60MH model heat exchanger with 348 plates and 2,320 ft^2 heat transfer area was chosen.

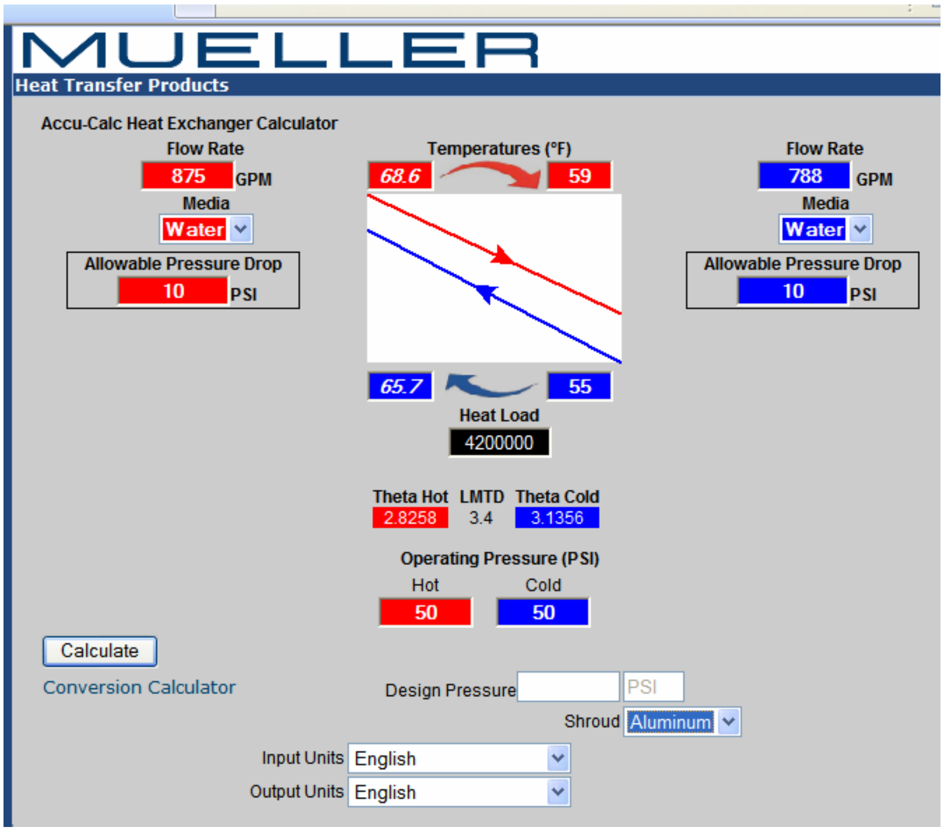

Figure 2.4-a Heat Exchanger Calculator

2.4.1 HAP ENERGY ANALAYSIS

Using the existing building model as a base case, Carrier's Hourly Analysis Program (HAP) was used to perform an energy analysis of the new groundwater open loop system. It should be noted that an indirect model was not able to be performed with this software. Therefore, an open loop direct use system was modeled. For the purpose of this evaluation the model was considered to be an accurate representation of the indirect use system. When viewing the results below, one may notice a building area lower than that of the Try Street Terminal Building. Since the apartments are the primary focus of this project, this area represents the total percent of apartment and

other spaces with heat pump units. Comparing these results to the existing building results it is noticed that there is a reduction of about 30% in cooling component cost.

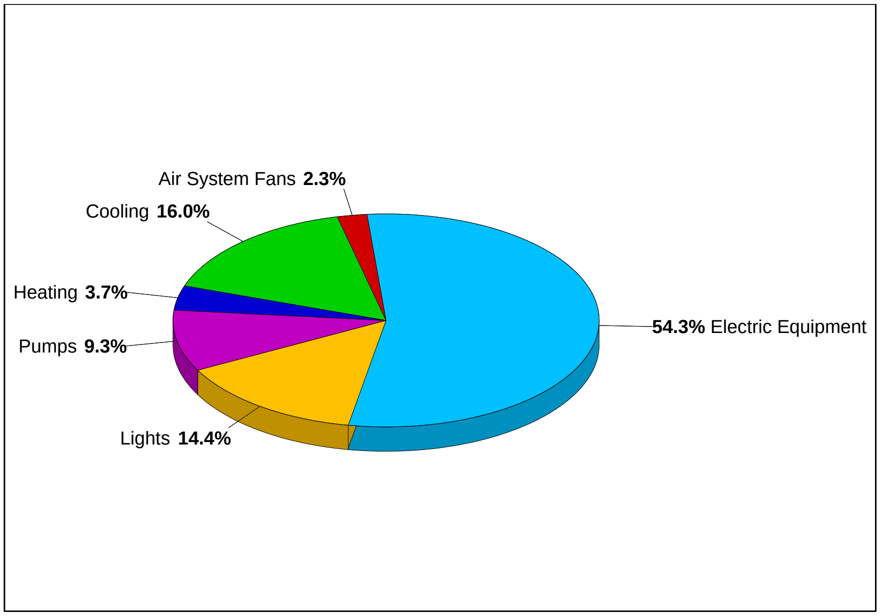

Figure 2.4-b Annual Component Cost - GWHP design

Component	Annual Cost ($)	($/ft²)	Percent of Total (%)
Air System Fans	18,554	0.131	2.3
Cooling	129,843	0.919	16
Heating	30,234	0.214	3.7
Pumps	75,128	0.532	9.3
Cooling Tower Fans	0	0	0
HVAC Sub-Total	**253,758**	**1.796**	**31.4**
Lights	116,317	0.823	14.4
Electric Equipment	439,187	3.108	54.3
Non-HVAC Sub-Total	**555,505**	**3.931**	**68.6**
Grand Total	**809,263**	**5.727**	**100**

Note: Cost per unit floor area is based on the gross building floor area.
Gross Floor Area **167920.4** ft²
Conditioned Floor Area **167920.4** ft²

Table 2.4-a Annual Component Costs - GWHP design

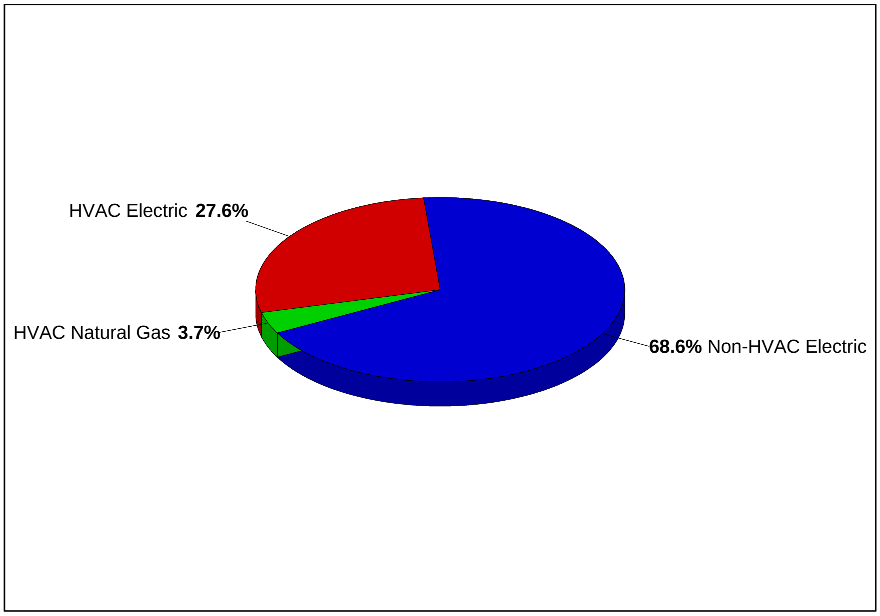

Figure 2.4-c Annual Energy Costs - GWHP design

Component	Annual Cost ($/yr)	($/ft²)	Percent of Total (%)
HVAC Components			
Electric	223,635	1.583	27.6
Natural Gas	30,126	0.213	3.7
HVAC Sub-Total	**253,762**	**1.796**	**31.4**
Non-HVAC Components			
Electric	555,486	3.931	68.6
Natural Gas	0	0	0
Non-HVAC Sub-Total	**555,486**	**3.931**	**68.6**
Grand Total	**809,248**	**5.727**	**100**

Note: Cost per unit floor area is based on the gross building floor area.

Gross Floor Area **167920.4** ft²

Conditioned Floor Area **167920.4** ft²

Table 2.4-b Annual Energy Costs - GWHP design

2.4.2 RETScreen PROJECT MODEL

RETScreen software was used to create a ground source heat pump project model. With this program a project was created that evaluated the heating and cooling loads, performed an energy model, completed a cost analysis, analyzed the reduction of greenhouse gas emissions, and included a financial summary. A sensitivity and risk analysis was chosen not to be competed.

Overall, compared to the HAP analysis the RETScreen model provided comparable results in corresponding HAP categories such as heating and cooling loads and building/groundwater loop calculations. Therefore, the year-to-positive cash flow of 12 years was considered reasonable estimate.

2.5 FINAL RECOMMENDATION

Based on the information available and the calculation performed it would be recommended for an indirect-open loop heat pump system to be installed. Although the simple payback exceeds the typical 3-5 year payback period, the energy savings remains appealing. Also, the Art Institute has made a 20 year commitment to the property. Therefore, the Art Institute would be able to benefit from the energy savings associated with this geothermal system.