Appendix F – Mechanical Calculations

Geothermal Heat Pump:

In order to estimate the size of units needed for this system, the boiler MBtu/hr (1,000 British thermal units per hour) must be calculated. As an aside, Btu's are a unit of energy used in the United States and is defined as the amount of heat required to raise the temperature of one of water by one degree Fahrenheit.

Provided in the mechanical schedule, the two boilers have an entering water temperature of 140°F and a leaving water temperature of 180°F. Moreover, they are designed to provide the Lecture hall space with 67 gallons of water per minute (gpm). The sensible cooling load equation to follow can be utilized to help convert the 40°F change and 67 gpm into MBtu/hr.

$Q = C_p \times \cdot m \times \Delta T$, where

Q = total heat

C_p = specific heat of water at 80°F and 1atm

$\cdot m$ = mass flow rate of water

ΔT = change in temperature

This equation will change to $Q = C_p \times \cdot V \times \rho \times \Delta T$ since we have a volumetric flow per minute,

where: $\cdot V$ = volume flow rate

ρ = density of water at 80°F and 1 atm

a = conversion from gpm to cfm

$\cdot V = a \times \text{gpm} = (0.133681\ \text{ft2/min / gal/min}) \times 67\ \text{gpm} = 8.957\ \text{cfm}$

$C_p = 0.9991$ Btu/lbm-R

$\Delta T = 40°F$

$\rho = 62.22\ lb_m/ft^3$

Substituting these numbers gives us Q = 22271Btu/min. Multiplying this by 60 min/hr and dividing by 1,000 Btu/MBtu = 1,336 MBtu/hr. In order to satisfy the existing boiler system, heat pumps will have to supply the Lecture Hall with around 1,336 MBtu/hr.

Electric Heating Coils:

As calculated above, the estimated heating load at the air handling units is 1,336 MBtu/hr. Looking at the three different air handling units and the spaces they serve, it is important to get an idea of mixed air temperatures within each system and calculate their sensible heating capacity. Depending on the amount of MBtu/hr, one can get an idea of the required heat coil demands for sizing. Speaking with Capital One's MEP engineer, supply and mixed air temperatures were obtained. The following numbers are at full load, design conditions in the worst case scenario.

- AHU-1 services the offices with 4,800 cfm, needing 77.5°F supply air from 48.9°F mixed air
- AHU-2 services the atrium with 19,200 cfm, needing 75.8°F supply air from 43.9°F mixed air
- AHU-3 services the auditorium with 10,725 cfm, needing 72.4°F supply air from 33°F mixed air

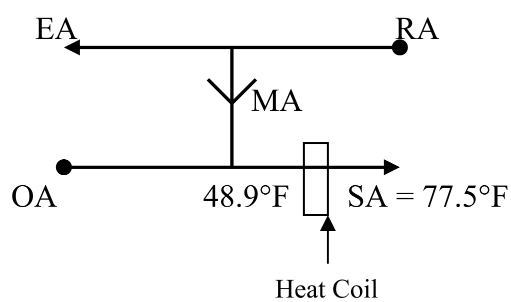
Using the same $Q = C_p \times \cdot m \times \Delta T$ equation as before, but adjusting it for air because the heating no longer deals with water, gives us $Q = 1.08 \times cfm \times \Delta T$. The 1.08 includes the density of air, C_p and conversion factors for air only. The sum of all these quantities should be approximately the same value as the 1,336 MBtu/hr calculated before for the geothermal heat pump system.

For AHU-1: $Q_1 = 1.08 \times cfm \times \Delta T$

$Q_1 = 1.08 \times 4800cfm \times (77.5°F - 48.9°F)$

$Q_1 = 148.1$ MBtu/hr

Figure 14. Heat Coil Schematic for AHU-1



For AHU-2: $Q_2 = 1.08 \times cfm \times \Delta T$

$Q_2 = 1.08 \times 19{,}200cfm \times (75.8°F – 43.9°F)$

$Q_2 = 456.3$ MBtu/hr

For AHU-2: $Q_3 = 1.08 \times cfm \times \Delta T$

$Q_3 = 1.08 \times 19{,}200cfm \times (72.4°F - 33°F)$

$Q_3 = 659.7$ MBtu/hr

Lastly, in order to calculate the required amount of energy for the electric heat coils, divide each coil's MBtu/hr by 3.412 to obtain kilowatts (kW). This will give us 44 kW for coil #1, 194 kW for #2, and 134 kW for #3.