8.0 CHILLER-HEATER AND HEAT RECOVERY SYSTEM ANALYSIS

The redesigned mechanical system also consists of a modified chiller and boiler plant. This redesign uses the same goals as the air system, integration of other building systems with the mechanical. The goal of the total mechanical redesign is also to lower operating and life cycle cost. Working in conjunction with the DOAS and WSHPs, the redesigned chiller plant must prove to save as much or more energy as compared to the base system to prove beneficial.

The existing system comprised of electric driven, water cooled centrifugal chillers. These chillers met the HVAC cooling load and, as shown in the DOAS schematic, also served a heat exchanger that cooled the walk-in freezer's condenser water loop. The existing system does not recover this rejected heat. Therefore, this 106 ton base load is met by the chilled water system 24 hours a day.

Taking advantage of the new natural gas service installed at the supply center, the redesigned mechanical system utilizes direct fired absorption chiller-heaters. The goal of the chiller-heater system is to simultaneously meet the cooling demand while producing hot water for domestic and HVAC heating.

From the load profiles shown in section 6.0, the base cooling load is formed from the condenser water loop system's heat rejection. Also shown is the high demand for hot water heating during a typical day. With the supply center having consistent heating and cooling demands year round, it becomes an excellent opportunity for simultaneous heating and cooling.

The DOAS configuration already incorporates a heat recovery system, but as figure 7-2 illustrates, the condenser water loop, at best, is only cooled to 78°F by the water source loop. This means there is a significant amount of energy still left in the condenser water loop. The redesign will recover more heat from this loop until it is cooled to its 65°F operating temperature by pre-heating the domestic hot water. This will create a lower heating load for the chiller-heater to handle, meaning that on hot design days, more cooling capacity is available. The chiller-heater's operating characteristics are described in more detail in the following subsections. Schematics of the redesigned chiller and boiler plants are also located in this section as well as an overall total mechanical system schematic.

8.1 DESIGN OF DIRECT FIRED ABSORPTION CHILLER-HEATER SYSTEM ANALYSIS

Chiller-heaters have three operating modes, cooling only, heating only, and simultaneous cooling and heating. Figure 8-1 illustrates the three modes of chiller-heaters.

Cooling mode sees the chiller-heater operating like a normal double effect LiBr absorption chiller. Since the chiller-heater is direct fired, the high temperature generator uses a gas-fired burner. The low temperature generator is activated in cooling mode and the evaporator produces chilled water. These chiller-heaters come in sizes from 100 to 1100 tons.

When the chiller-heater operates in heating only mode, the condenser section of the process is off, and the evaporator now produces hot water. The refrigerant vapor that is produced in the high temperature generator no longer passes through the low temperature generator and is used to directly create hot water in the evaporator. Hot water production temperatures can rise up to 210°F.

When simultaneous heating and cooling production occurs, the cycle operates as in the cooling only mode. However, hot water production takes place by means of an auxiliary heat exchanger. The heat exchanger condenses a portion of the refrigerant vapor that is produced in the high temperature heat generator. Therefore, the remaining refrigerant vapor is used to operate the cooling cycle. As this point forecasts, simultaneous hot water production reduces the

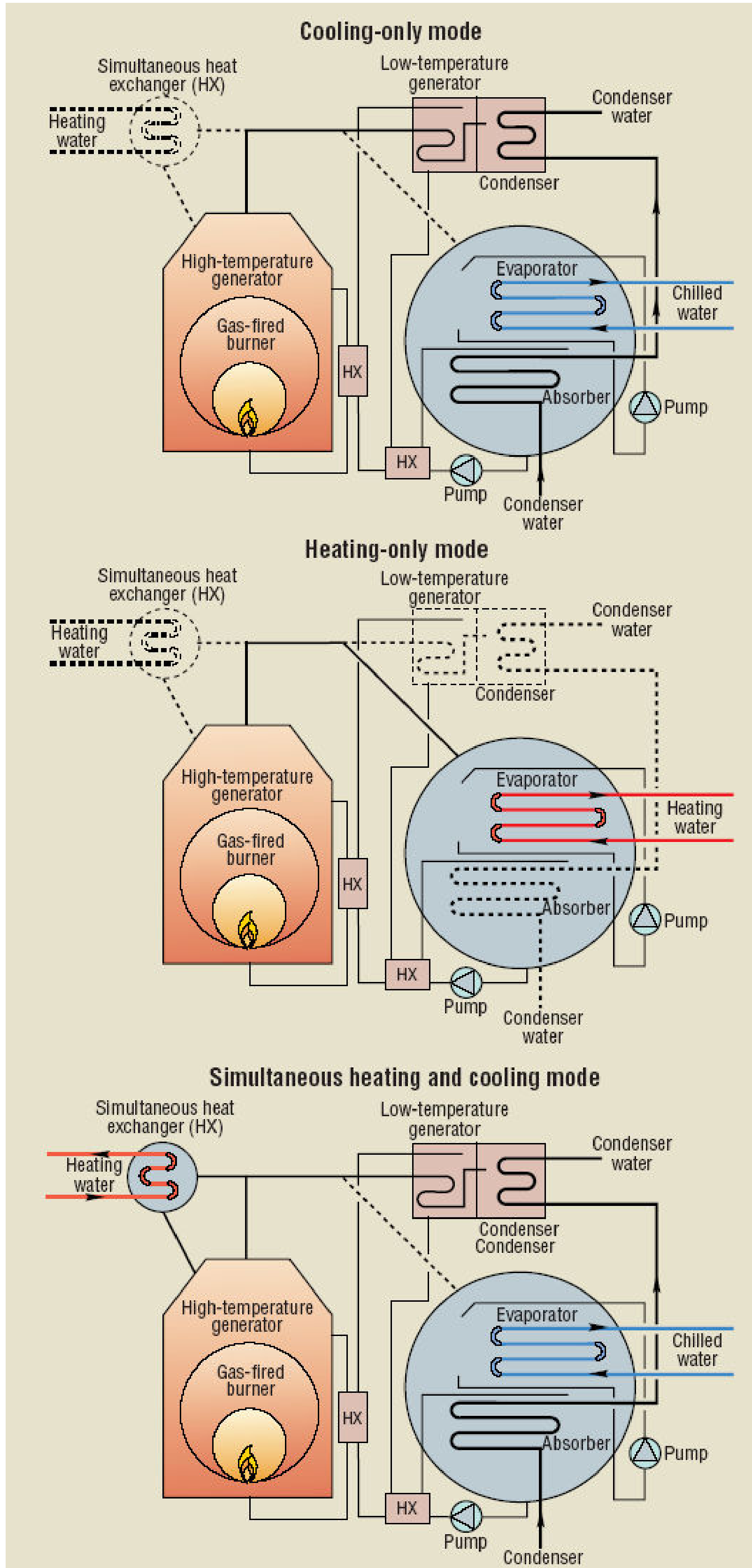

Figure 8-1 Double Effect Absorption Cycle

amount of cooling output.

The more cooling that is required directly affects the amount of hot water production. At full energy input, 100% of the cooling capacity is available. However, if hot water production is required and performed by the chiller-heater, the cooling capacity will decrease as low as to 30% of the rated value. Figure 8-2, taken from York's *Millennium* two-stage direct-fire absorption chiller-heater product literature illustrates this point.

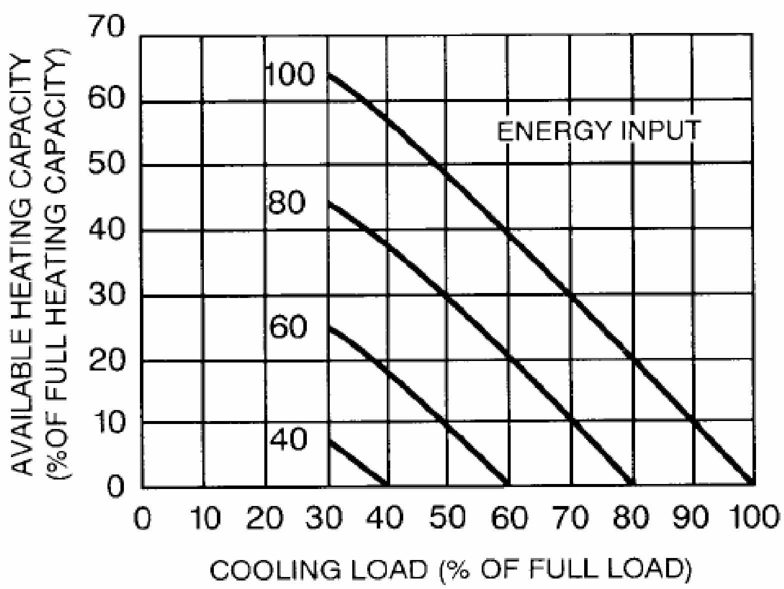

Figure 8-2 Cooling/Heating Capacities per Input Energy

The figure indicates that at maximum energy input, 100-30% of the available cooling capacity is available. At 30% cooling capacity and 100% energy input, approximately 65% of the total available heating capacity is possible for hot water production. When there is a demand for both cooling and heating, the chiller-heater must operate to meet the cooling demand and supplemental boilers will have to turn on to pick up the remaining heat load.

Now that the basics behind chiller-heaters are stated, understanding the applicability of using them in the supply center is important for analysis. Figure 8-3 shows the peak cooling loads per month. The figure shows that the redesigned system, including the DOAS and WSHPs and the heat recovery system, has a peak cooling load equal to about 390 tons. The chiller-heaters however are not sized to just meet this peak load.

The chiller-heaters are selected based on if there were no heat recovered from the condenser water loop, meaning the chilled water system must cool the CWL at all times. In addition to the cooling load, the chiller-heaters are also sized large enough so that they can meet the cooling demand and still have capacity for simultaneous hot water heating. In other words, referring back to figure 8-2, the chiller-heaters are selected so that the max cooling load, 390tons, is met operating at approximately 80% capacity. This allows for excess capacity for simultaneous hot water production. The chiller-heater will have more hours operating at full load than at part load in this case, which improves efficiency. Further analysis indicates that the chiller-heater operates at 80-100% capacity 1/3 of the year. Finally, both cooling and heating demands are satisfied using only one fuel source.

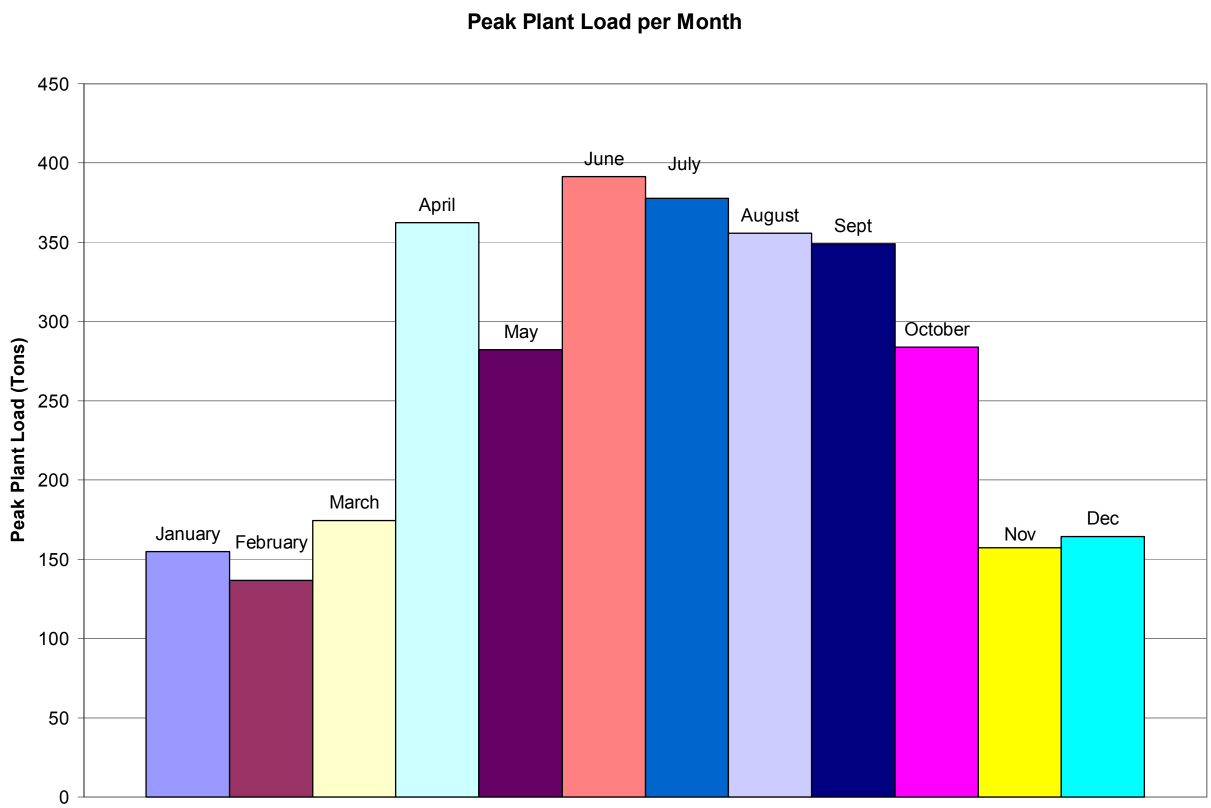

Figure 8-3 Monthly Peak Cooling Load

Figures 8-4 and 8-5 further illustrate how chiller-heaters simultaneously heat and cool. Broad Air Conditioning's direct fired chiller-heater product literature includes diagrams that clearly show how these units operate. Figure 8-4 shows the chilled water production side of the chiller-heater, while figure 8-5 illustrates the hot water portion of the machine. Other important areas of interest include the direct fired burner and natural gas line, shown in figure 8-4, as well as the basic refrigeration cycle parts (the condenser and evaporator).

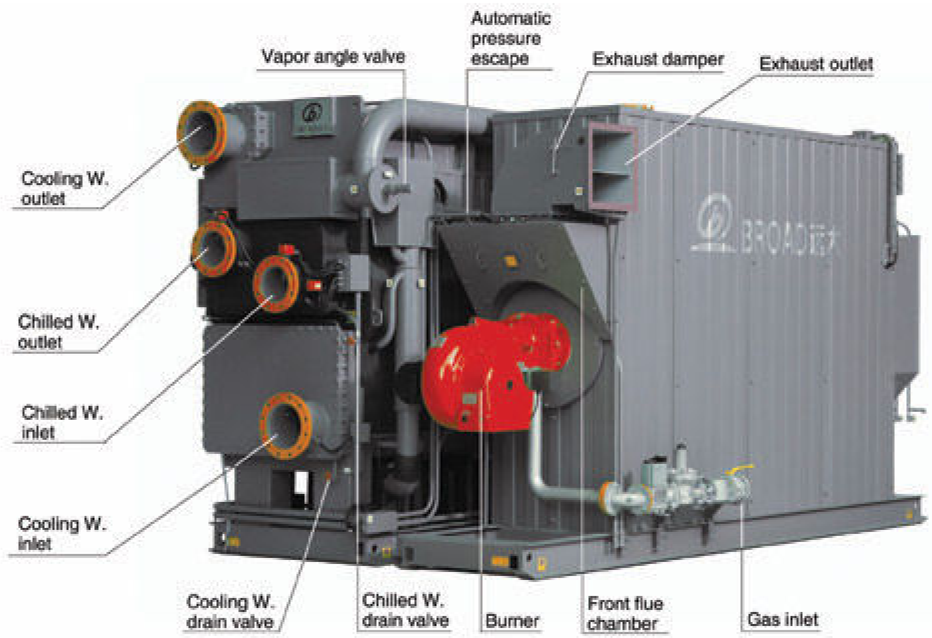

Figure 8-4 Broad Air Conditioning's Direct Fired Chiller-Heater Chilled Water Production Portion

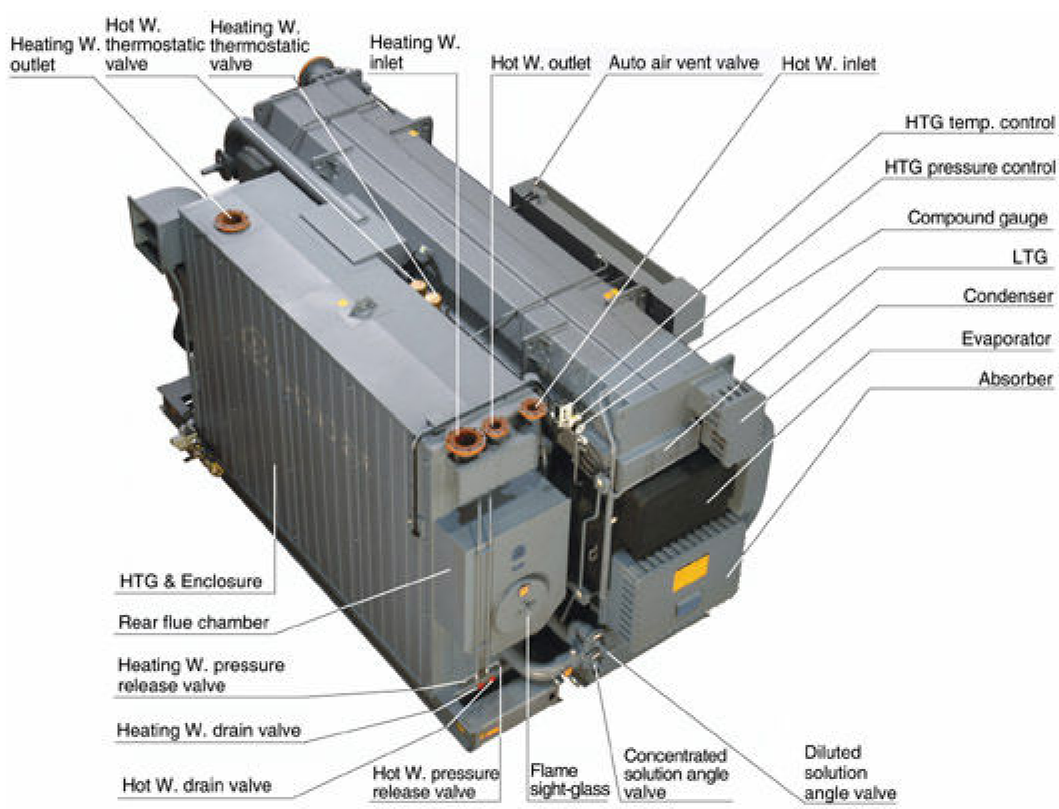

Figure 8-5 Broad Air Conditioning's Direct Fired Chiller-Heater Hot Water Production Portion

The redesigned chiller and boiler plant is designed for redundancy. Two 240 ton chiller-heaters are utilized in the supply center. This ensures that the total cooling load is met, and the extra capacity needed to produce enough hot water is also available. However, if one of the chiller-heaters must go off line for any reason (maintenance issues for example), the other chiller-heater is capable of handling the critical loads by itself. The supply center does not include any spaces that must have cooling year round such as hospital emergency rooms. Therefore, if a chiller-heater goes off line, the only system that requires chilled water production is the walk-in freezer's condenser water heat rejection. As previously stated, the condenser water loop requires 106 tons of cooling 24 hours a day. One chiller-heater can handle this load while the other is being serviced.

The systems that may suffer from only one chiller-heater being available are the 100% OA air handling units that serve the kitchen, bakery, and loading docks. The DOAS units also require chilled water. However, the remainder of the building still can meet the cooling demand via the water source heat pump system. The redundancy design for the supply center ensures all critical systems operate at design conditions and most of the building's cooling demands are satisfied.

The redesign considers the cooling demand redundancy; however, having a chiller-heater go offline creates hot water production issues. The remaining chiller-heater must meet the cooling load to operate the walk-in freezer's condensing units, but the remaining capacity of that unit is too small to meet the hot water production demand. As previously stated, the DOAS units do not serve any critical spaces, so for a down period there is no issues with not supplying chilled water to them. Hot water production is critical in the supply center, however.

Serving as a back-up when the chiller-heater system can not meet the HVAC and domestic hot water demands is a 9000 MBH natural gas fired boiler. The boiler is sized to completely meet all HVAC and domestic hot water needs. The hot water system of the supply center's redesigned mechanical system is integrated with the chilled water system though the chiller-heater. However, incase there is a problem with one of the machines for any reason; the hot water system has the ability to be totally independent.

The following subsection describes the entire heat recovery system using the condenser water loop in detail and includes an overall system schematic of the redesigned chiller and boiler plants. The schematic also shows the integration with the DOAS and heat pump system.

8.2 CONDENSER WATER LOOP HEAT RECOVERY SYSTEM ANALYSIS

The DOAS and heat pump system analysis explained how that portion of the redesign incorporated the condenser water loop from the walk-in freezers for heat recovery. Figure 7-2 in section 7 of this report indicates that the condenser water loop only gets cooled from 84°F to 78°F at peak design by the water source loop. This leaves a good portion of energy to recover that is otherwise wasted in the chilled water system as explained in the previous subsection.

The next phase of heat recovery from the condenser water loop includes domestic hot water preheating. The design conditions for domestic hot water production is 50°F entering water temperature and 180°F leaving water temperature at a maximum flow rate of 100gpm. The condenser water loop's maximum temperature is only 84°F. Therefore, the maximum possible domestic water preheated temperature is roughly 79-81°F (dependant upon thermodynamic fluid flow properties). The preheat process occurs though a plate-frame heat exchanger, similar to the water source loop configuration, and is shown in figure 8-6.

The next phase of hot water production is to raise the preheated domestic water to design temperature. Since the chiller-heater can only produce one hot water loop, the domestic water is heated though another plate-frame heat exchanger. The chiller-heater plant will produce enough hot water to meet the air handling unit's heating demands and have a branch that services the domestic water heat exchanger. Therefore, there is only one closed hot water loop running into the chiller-heater which helps keep the system running clean. Running domestic water directly into the chiller-heater creates more maintenance issues which is why the redesigned closed loop configuration is used.

The hot water system does have redundancy as explained in the previous subsection. If the chiller-heaters are not sufficient to meet the required hot water demands, or if one unit goes off line, the back up boiler is sized large enough to meet all HVAC and hot water needs. Hot water preheat is still available when the chiller-heater system is not working since it is independent.

Figure 8-6 illustrates the entire redesign schematic. The schematic illustrates the DOAS and water source heat pump system, the redesigned chiller and boiler plant, and all of the heat recovery mechanisms. For comparison, the existing HVAC system schematic is also shown in figure 8-7. One point of reference in the comparison is that the redesigned system requires less equipment than the existing system.

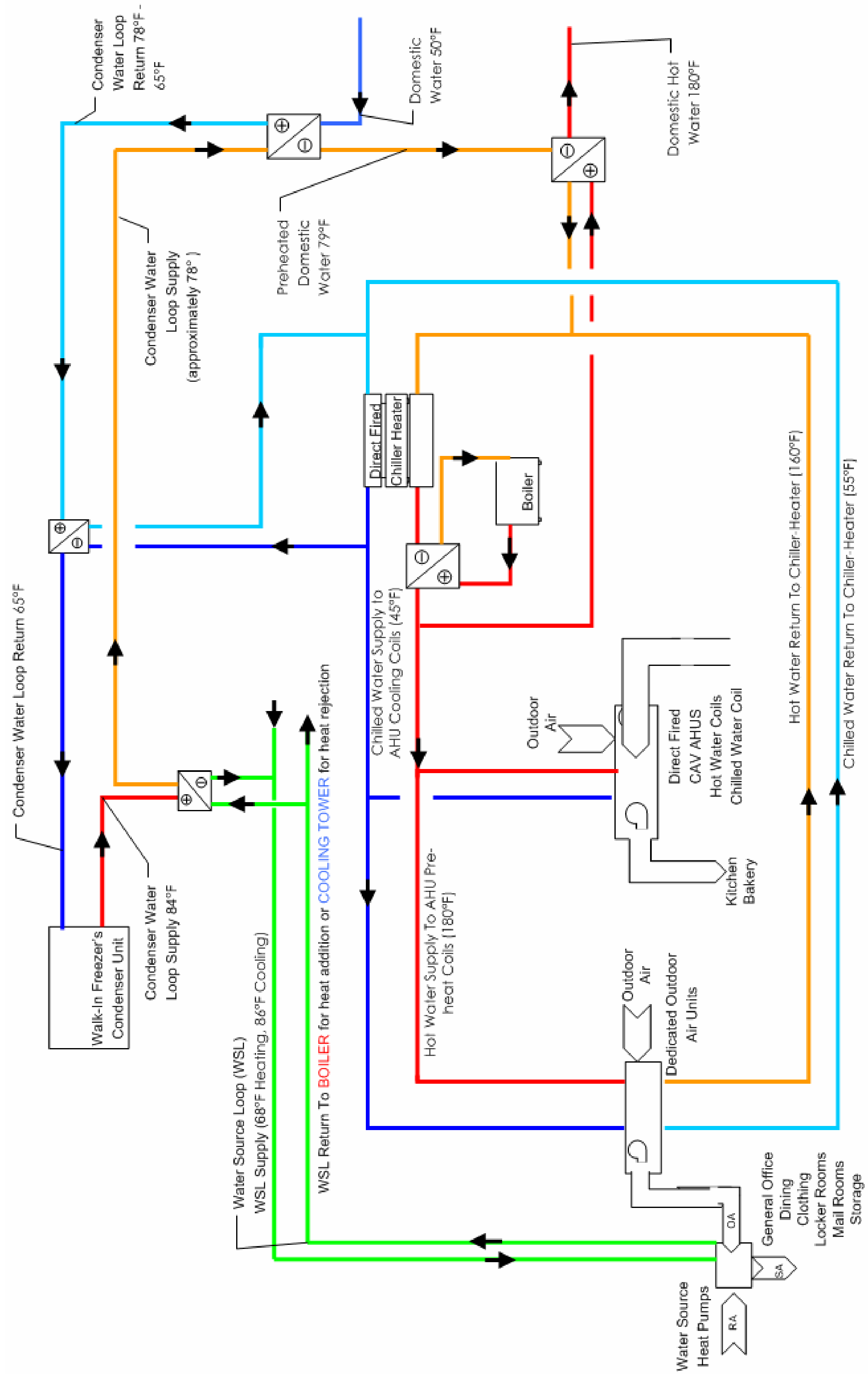

Figure 8-6 Redesigned HVAC System Overall Schematic

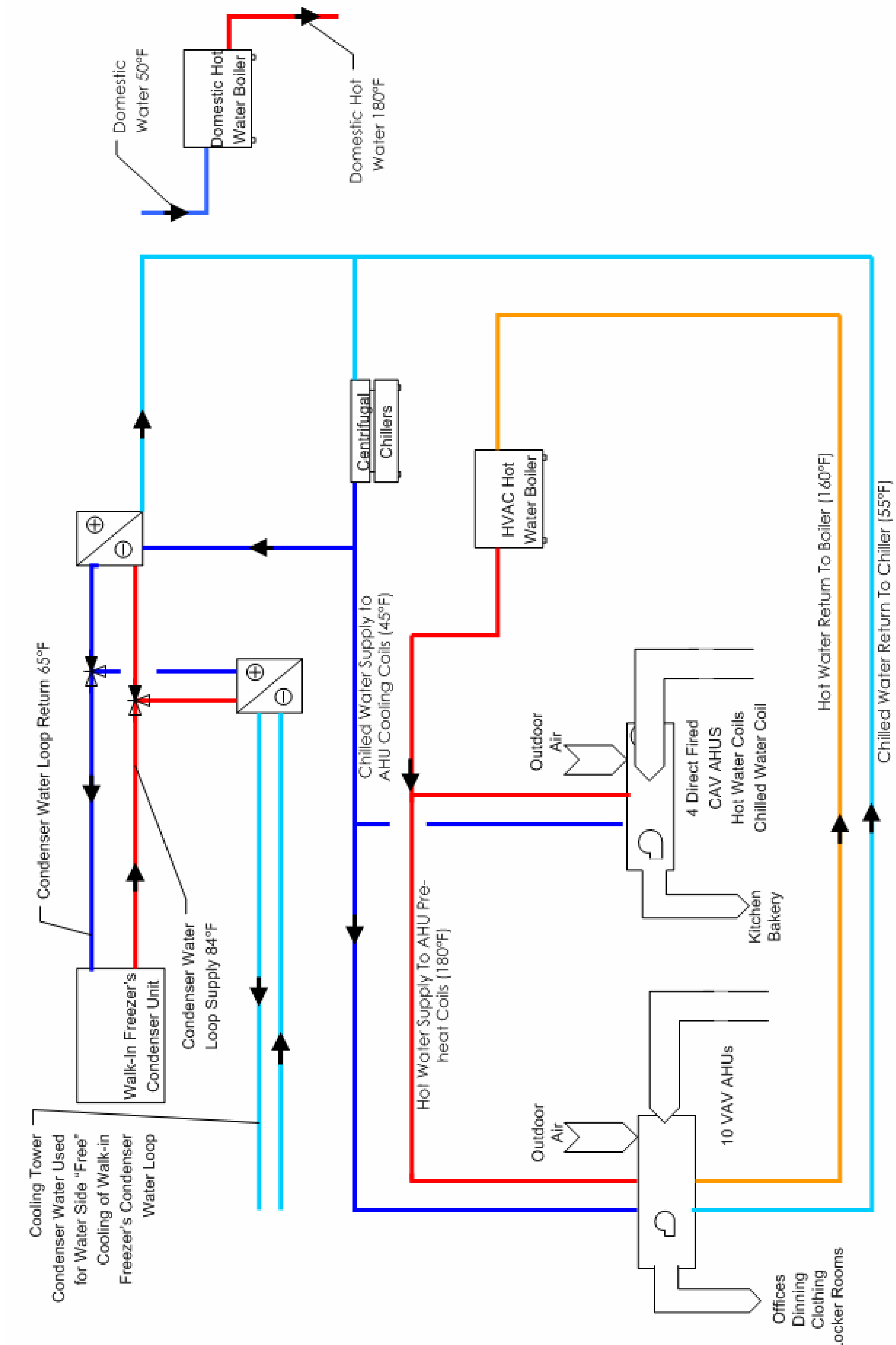

Figure 8-7 Existing HVAC System Overall Schematic

The figures above seem to prove that the existing system is simpler at first glance. However, the existing system is comprised of four totally independent systems. The redesigned system integrates all sections of the HVAC requirements as well as other building systems. The only independent system in the redesign is the back-up supplemental boiler which is still in series with the chiller-heater system. So while the existing system's concept is simpler, the redesign's complexity is used to save as much energy as possible compared to the original.

9.0 MECHANICAL SYSTEM REDESIGN CONCLUSIONS

The proposed mechanical system redesign for the Milton Hershey School New Supply Center focused on building system integration and energy savings. Integrating different building systems with the HVAC system is essential in the redesign to save as much energy as possible. The redesign system utilizes more expensive equipment than in the existing system, therefore, this integration process is even more important in an effort to receive reasonable pay back periods (about 2-4 years).

The initial cost of each system is required for the economic calculations as well as the results from a yearly energy simulation. Carrier's Hourly Analysis Program (HAP) is used to perform load calculations as well as energy simulations for both the redesigned system and the existing system. The HAP's load results for the DOAS and water source heat pumps are imported in a chiller-heater model performed in Microsoft Excel. An extensive yearly energy simulation model of the supply center using a chiller-heater and the energy recovery system is also created using Excel. The model calculates the total energy consumed by the chiller-heater and the energy savings created by using the heat recovery system. HAP is used to calculate the energy consumed by AHU fans, terminal unit fans, cooling towers, and pumps.

9.1 ECONOMIC ANALYSIS

The yearly energy simulations prove that the supply center's existing and redesigned mechanical systems have much different results. Table 9-1 indicates the natural gas rates that are provided by H.F. Lenz Company and are used for each simulation. The electric rate for the supply center used in the analysis is $0.06/kwh

Table 9-1 Natural Gas Monthly Rates

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
$/Therm	1.13	1.13	.85	.85	.85	.50	.50	.50	.50	.85	1.13	1.13