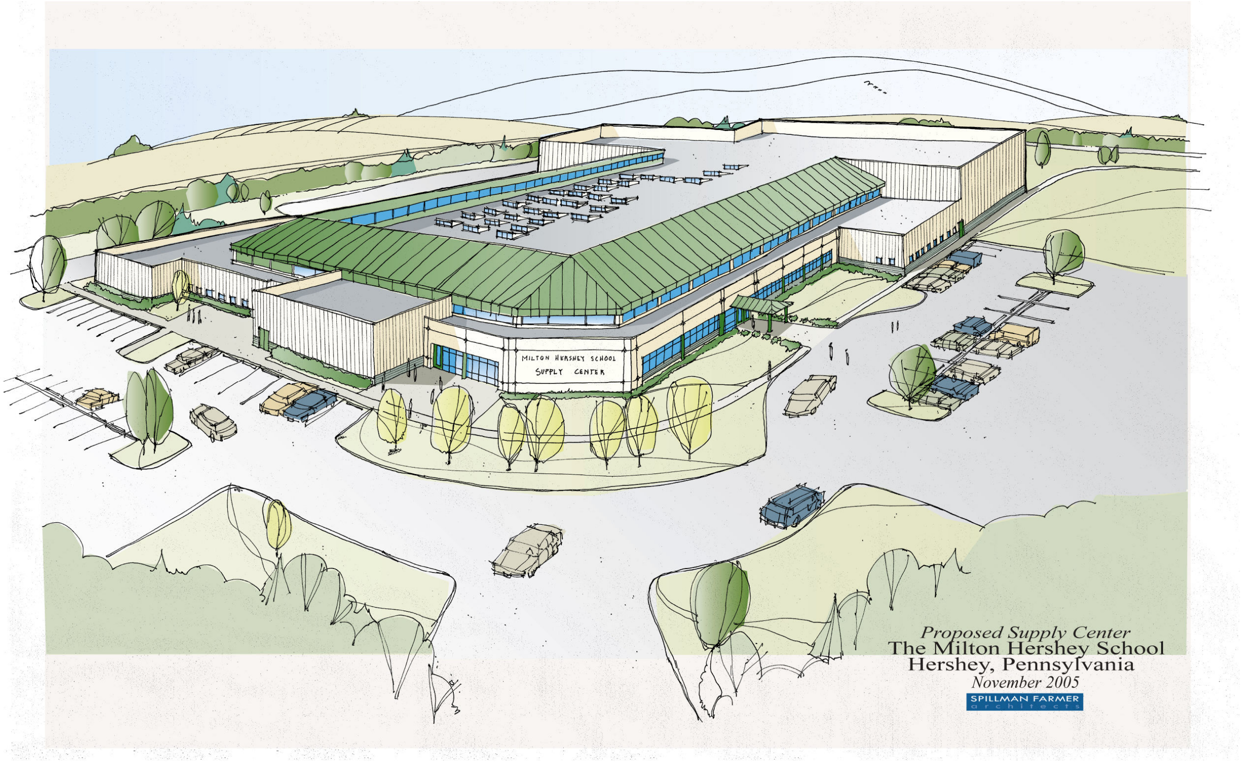
Building System Integration with Direct Fired Absorption Chiller-Heaters, Dedicated Outdoor Air Units, and Water Source Heat Pumps



The Milton Hershey School New Supply Center
Hershey, Pennsylvania

Prepared for:
William P. Bahnfleth, Ph.D., P.E., Professor
Department of Architectural Engineering
The Pennsylvania State University

Prepared by:
Justin Bem
Mechanical Option
April 12th, 2007

The Milton Hershey School New Supply Center
Hershey, PA

PROJECT DELIVERY TEAM
Building Owner/Operator: The Milton Hershey School
Architect: Spillman Farmer Architects
Structural Engineer: Barry Isett and Associates, Inc.
MEP Engineer: H. F. Lenz Company
Civil/Site Development: Pennoni Associates, Inc.
Food Service: Orlando Espinosa and Associates

ARCHITECTURE
Function: Central Food Distribution Center
Central Mail Distribution Center
Clothing Store With Alterations Area
Dry and Temperature Controlled Storage
Envelope: Metal Vertical Wall Panels
27 Clearstory Light Shafts

MECHANICAL SYSTEMS
14 Air Handling Units Ranging From 3,000 - 22,000 CFM
- *VAV System With Terminal Boxes and VFD*

Two 270 Ton Centrifugal Water Cooled Chillers
- *Water Side "Free" Cooling*

Two 35 Ton (20 Degree Water) Brine Chillers
- *For FCU's In Walk-In Coolers*

Two 200 BHP Gas Fired Fire Tube Boilers
One 125 BHP Gas Fired Fire Tube Boiler
- *40 psi Medium Pressure Steam For Process Loads*
- *Converts To Hot Water For Building Loads*

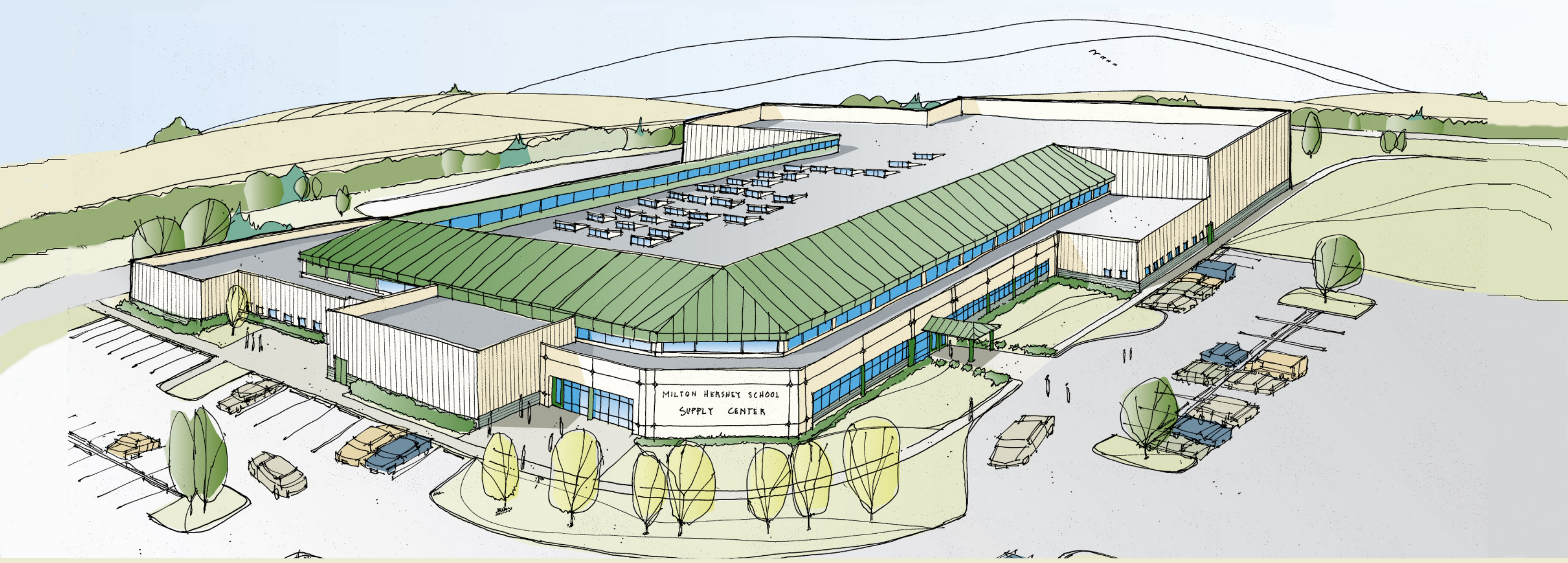
PROJECT INFORMATION
Overall Cost Estimate: $23,500,000
Project Size: 110,000 square feet
Project Delivery Method: Design-Bid-Build
Construction Dates: Start - July 2006
Finish - July 2007
Number of Stories: One above grade
Elevated Mechanical Mezzanine Rooms

STRUCTURAL SYSTEM
Skeleton: Steel Beams, Columns, and Girders
Interior Load Bearing CMU Walls
K-Series Joist Supporting Roof
5" Concrete Slab on Grade Flooring - 4000 psi
Continuous and Spread Foundation

LIGHTING/ELECTRICAL SYSTEMS
480/277V, 3Phase, 4 Wire Service
480 To 208/120V Transformers
Emergency 750kW Diesel Fueled Generator

Lighting: Generally 277V Fluorescent Fixtures
- T-8 Lamps
- 2x4 and 4x4 Recessed Troffers
- 1x4 Surface Mounted Fixtures With Cold Weather Ballast For Walk-in Freezers

Ground/Wall Mounted 39-70W Metal Halide Outdoor Fixtures



JUSTIN BEM **MECHANICAL OPTION**

http://www.arche.psu.edu/thesis/eportfolio/2007/portfolios/JSB284/

The Pennsylvania State University Department of Architectural Engineering

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Acknowledgements

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- Electrical Systems Redesign Help and Advise

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- Cost estimates for major HVAC equipment

Rick Browell of Baltimore Air Coil
- Cost estimates for major HVAC equipment

AE Students
Brian Barna
Cynthia Milinichik
Kevin Kaufman
Kyle Conrad
Katie Jenkins

1.0 EXECUTIVE SUMMARY

The Milton Hershey School New Supply Center is a very wide and long single story 110,000 square foot building. Analyzing the existing mechanical systems proves that the design is very practical and energy conscience for this application. However, there are specific features to the HVAC system that have the potential for improvements.

The goal of the mechanical system redesign is to increase energy efficiency, decrease life cycle cost, and to integrate multiple building systems with the mechanical system. The air side and water side mechanical systems are altered in the redesign. The HVAC systems are integrated with the buildings walk-in freezer's condenser water loop for energy recovery reasons. The redesign also finds potential to save more energy by using the freezer's rejected heat to per-heat the domestic hot water.

The building's cooling, heating, and domestic hot water load analysis indicates that the supply center is an excellent candidate for simultaneous heating and cooling through the use of a direct fired absorption chiller-heater. The chiller-heater also helps integrate multiple building systems, but drives up the initial cost. The mechanical redesign sees operating cost savings as well as energy consumption savings, which helps to pay itself back in less than 2 years.

The air side portion of the redesign sees the replacement of 10 VAV air handling units with 2 DOAS units. This saves in first cost and operating cost, and also paves the way for structural and construction work. Relocating the remaining 6 AHU's from the now half vacant mezzanine floor to the roof requires an upgrade of the structural system. However, initial cost savings are found since the supply center does not have to construct the 11,000 square foot concrete mezzanine floor.

The replacement of many electric driven pieces of mechanical equipment with direct fired units also has an impact on the electrical system. The power requirements change on each distribution panel, which means the respective feeders need resized. Cost savings are found from eliminating certain wires and decreasing the sizes of others.

The overall redesign and building systems integration process for the Milton Hershey School New Supply Center sees first cost savings, energy and operating cost savings, and has the lowest 20 year life cycle cost compared to the existing system. Therefore, even though the redesign's mechanical work is more expensive than the existing, the project as a whole is less expensive and beneficial for the Milton Hershey School.

2.0 BUILDING DESIGN BACKGROUND

The Milton Hershey School New Supply Center is a single story 110,000 square foot building with four elevated mechanical mezzanine rooms and contains a variety of spaces. The north and northwest sections of the building consists of general office spaces and conference rooms. Located in the center of the building is the food distribution center for the Milton Hershey School. This area contains large freezers, refrigerators, and temperature controlled storage areas, fifteen in all, totaling to 13,600 square feet to go along with its central food preparation spaces.

Aside from the food production section of the building, the New Supply Center also includes a central mail distribution center for the school and a clothing store with an alterations work area. Complementing the four mechanical mezzanine rooms that house the air handling units, a boiler and chiller plant is located on the north side of the building. The east side is mostly loading docks for deliveries, and the south side accommodates a variety of storage space. There are also two data rooms located in the center of the floor plan. Figure one, shown below, gives a breakdown of the space's location in the building as well as the portion of area each occupancy type consumes.

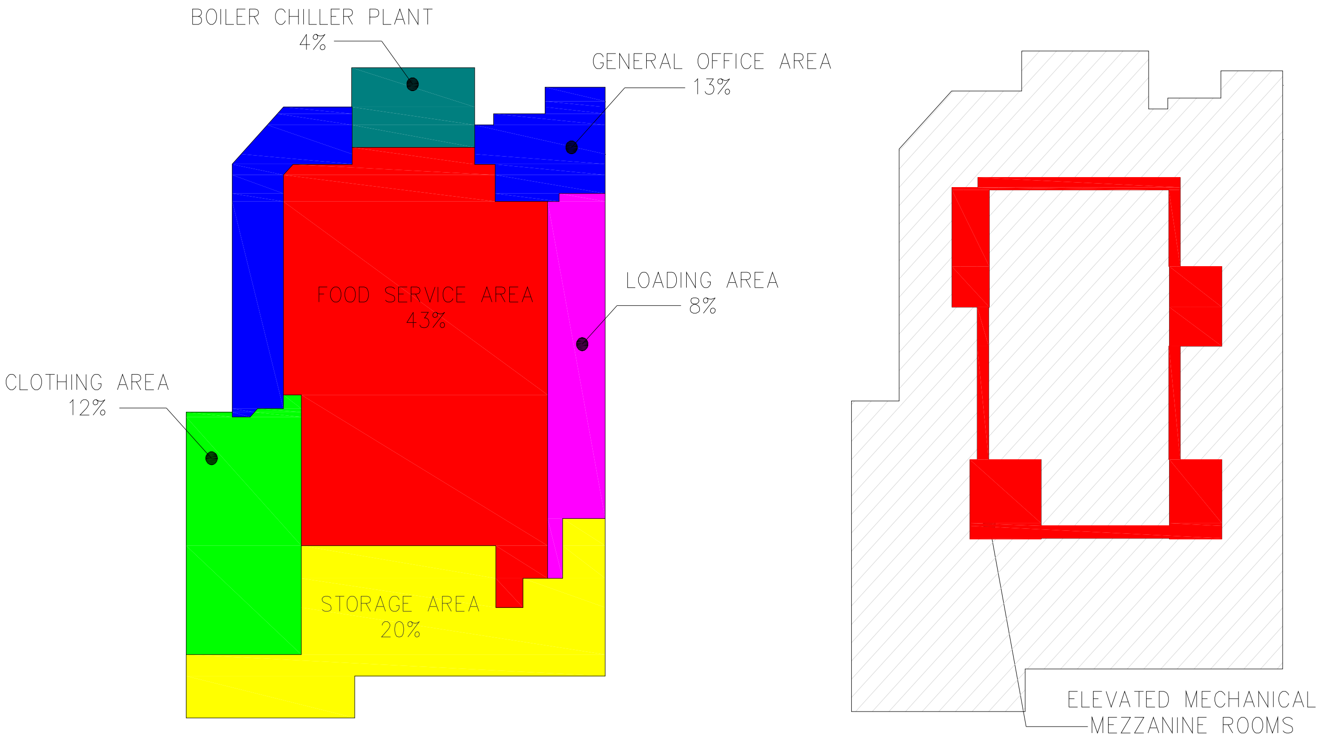

Figure 2-1 Space relationship and area breakdown

2.1 ELECTRICAL AND LIGHTING SYSTEM BACKGROUND

The Milton Hershey Supply Center electric service is distributed from a 480/277V three phase switchboard. The main distribution panel is rated at 2000 amps. The electrical service is installed in the main electrical room. Power is supplied from this room to five 480V panels located throughout the building, four of which are located in the elevated mechanical mezzanine rooms. The other 480V panel is the life safety distribution panel. Each distribution panel includes a 480 to 208/120V step-down transformer. 480/277V panels serve main mechanical equipment and 120V or 277V panels serve the building lighting and basic power loads.

For emergency power, a 750 kW diesel fueled emergency generator serves the emergency/life safety demand on the building. The generator serves equipment such as emergency egress lighting, fire alarm panels, and essential heating and cooling equipment.

A variety of lighting fixtures are used in the Supply Center. The offices, work areas, kitchen, mail room, and locker rooms use 277V fluorescent lighting fixtures with one to four 32 watt T-8 lamps. The lighting fixtures are 2x4 recessed troffers. The clothing section of the building uses 2x2 recessed troffers with two 31 watt T-8 U lamps.

In the freezers and refrigerators, fully gasketed, totally enclosed 1x4 surface mounted fixtures are used with 2 T-8 lamps. These lighting fixtures also require cold weather ballast.

The storage and receiving rooms in the Supply Center use pendent fixtures with two 32 watt T-8 lamps. The exterior lighting for the building consists of ground mounted or wall mounted fixtures with metal halide lamps of either 39 or 70 watts.

2.2 STRUCTURAL SYSTEM BACKGROUND

The structural system for the New Supply Center consists of steel columns, beams, and girders supporting the roofing system. Steel floor beams support the concrete floor of the elevated mechanical mezzanine rooms. There are interior load bearing masonry walls as well that help support portions of the mezzanine rooms. These beams carry the load to the girders which connect to the steel columns.

The Supply Center flooring is 5” concrete slab on grade. The floor slabs are 4000 psi concrete while other concrete used on the project are rated at 3000 psi.

The roofing system consists of K-series steel joist supporting the metal roof deck. These joist tie into steel roof beams and girders which transfer the roof load to the steel columns.

2.3 FIRE PROTECTION AND TELECOMMUNICATION SYSTEMS BACKGROUND

The Supply Center will be fully protected from fire with a sprinkler system. The freezer and refrigerator areas contain a dry pipe or double interlock pre-action sprinkler system to prevent freezing. The loading dock and trash disposal areas have a dry pipe sprinkler system. All other areas such as the mechanical and electrical areas, the kitchen, and the bakery have a wet pipe sprinkler system for fire protection. Areas of the building with ceilings use fully concealed pendant type sprinkler heads. Areas without ceilings use upright sprinkler heads with a protective cage guard.

Telecommunications systems for the Supply Center include an intercom system, an analog phone system connected to the rest of the Milton Hershey School, cable television for the employee break rooms and training rooms, and wireless internet.

The fiber optic cables handling the telecommunication services will branch from an existing telecom manhole and be fed to the building through new a new duct bank. The main cables will run above the ceilings in runways until finally terminating in the main data room located in approximately the center of the building.

3.0 MECHANICAL SYSTEMS EXISTING CONDITIONS

The design of the HVAC systems for the Milton Hershey School New Supply Center is based on cost and energy saving criteria. The MEP engineer for the project is H.F. Lenz Company. H.F. Lenz Company's most general goals of the HVAC system design are:

- The complete HVAC system shall meet the requirements of the 2003 International Building Code, ASHRAE 62.1-2004 Standard for Indoor Air Quality, and all applicable National Fire Protection Association Standards.
- The system will be made as energy efficient as practical in accordance with LEED design principles. Variable volume hydronic pumping and air systems are used where possible.
- The amount of rooftop HVAC equipment is minimized as much as possible to ensure good access for maintenance and to maximize equipment life.

Along with these goals, the system is designed to integrate other building systems. The central kitchen of the supply center, as explained above, consists of large walk-in freezers and coolers. The walk-in coolers are cooled by fan coil units that are supplied 20˚F water from brine chillers. The walk-in freezers are refrigerated by split system DX units using water cooled condensing units. These condensers reject heat to a condenser water loop that is picked up by the HVAC system.

Integration of other building systems does not just apply to the chilled water system. The HVAC design objectives also include integrating the process heating loads, dishwashers and steam kettles, with the buildings boiler plant. The buildings boiler plant also provides domestic hot water heating along with HVAC hot water.

Elaborate kitchen exhaust systems are also required in the project's goals. Incorporating energy saving techniques with the exhaust hoods such as variable speed fans help reduce energy cost. Due to an extensive amount of exhaust air in the food service and loading dock sections of the building, the air side mechanical systems include ventilation make-up air units.

The HVAC system, as a whole, generally consists of centrally ducted air handling unit systems. Chilled and hot water systems from the central plant are piped to cooling and heating coils in the AHUs and terminal equipment that both provide the means of conditioning the spaces.

3.1 DESIGN INDOOR AND OUTDOOR CONDITIONS

The design indoor conditions are developed by H.F. Lenz Company and the Milton Hershey School personnel. Collaboration between the two parties results in design heating dry bulb temperatures, cooling dry bulb temperatures, and maximum relative humidity levels for each space. Table 3-1 includes charts summarizing the design indoor conditions for all occupancy types found in the supply center.

The design outdoor conditions used in building simulation models, calculating thermal loads on spaces, and sizing HVAC equipment are found in the ASHRAE Handbook of Fundamentals 2005 (ASHRAE 2005). Since temperature data for Hershey Pennsylvania is not available in the handbook, the design temperatures are from Harrisburg Pennsylvania. Table 3-2 includes a summary of the design outdoor conditions used in the design of the supply center's HVAC systems.

Table 3-1 Design Indoor Conditions

	HEATING DBT (˚F)	COOLING DBT (˚F)	MAX % RELATIVE HUMIDITY
Main offices	70	74	None (3)
Lobby and Office Corridors	70	74	None (3)
Public Toilets	70	78	None (3)
Servery	70	74	None (3)
Dining / Conference	70	74	None (3)
Meal Van Loading Dock	60	82	65
Kitchen	70	80	60
Dishwashing	70	80	60
Kitchen Training	70	80	60
Chef's Office	70	74	None (1)
Bakery	70	80	60
Bakery Dry Storage	68	78	50 (4)
Food Service Offices	70	74	None (3)
Kitchen dry goods	68	78	50 (4)
Clothing Storage	68	78	None (3)
Clothing Shipping / Receiving	70	74	None (3)
Used Clothing	70	74	None (3)
Alterations	70	74	None (3)
Clothing Work Room	70	74	None (3)
Clothing Display and Waiting	70	74	None (3)
Dry Storage	68	78	50 (4)
Bulk Storage / Bulk Staging	68	78	None (3)
Staging and staging corridor	68	80	None (1)
Transportation Offices	70	74	None (3)
Washer / dryer	68	80	None (1)
Program Support Inventory	70 (5)	74 (5)	None (3)
Storage for "year round" experience	68	78	None (3)
Garbage / recycling	50	95	None
Receiving and General Building Storage	68	80	None (1)
Mail	70	74	None (3)
IT Rooms (2)	68	70	None (1)
Mechanical / Electrical Rooms	60	100	None
Custodial	70	80	60
Break Room	70	74	None (3)
Lockers	70	74	None (1)
Bread/Bakery Staging	68	80	None (1)
Catering Staging	68	80	None (1)

Footnotes:

(1) No direct, active humidity control is planned but should not rise above 60% RH under normal operating conditions

(2) Wintertime humidification may or may not be necessary.

(3) No direct humidity control is planned, but should not rise above 50% RH under normal operating conditions.

(4) Will require a separate de-humidification unit to control humidity.

(5) Assumes there will be staff working in this room consistently

Table 3-2 Design Conditions for Harrisburg, PA

LATITUDE	40.22°
Longitude	76.85°
Elevation	338 ft
Design Summer DBT	92.8°F
Design Summer WBT	73.7°F
Design Winter DBT	8.3°F

3.2 AIR SIDE EXISTING MECHANICAL SYSTEM

The air side mechanical system for the supply center uses fourteen air handling units. Four of the AHUs are part of multiple zone VAV systems. These air handling units serve offices, dining areas, clothing display and alterations areas, and staff spaces. The air is distributed to these spaces through VAV terminal units with hot water re-heat coils. The perimeter spaces also include fin-tube radiation systems for winter heating. The four VAV air handling units consists of a supply and return fans, 30% and 85% efficient filters, hot water pre-heat and re-heat coils, and a cooling coil.

The remaining ten air handling units are single zone spaces that are either part of VAV or CAV systems. However, since they are single zone units, VAV boxes are not used for air distribution to the spaces. All ten AHUs consists of 30% and 85% efficient filters, hot water pre-heat and re-heat coils, cooling coils, and supply fans.

Six of the ten single zone AHUs are part of constant volume systems. These units provide make up air for spaces requiring excessive amounts of exhaust (kitchens spaces, loading docks, recycling room). Even though the units operate at 100% outdoor air when the spaces are in operation, the AHUs also have the ability to return air during unoccupied times. The final four single zone air handling units not mentioned are part of VAV systems. These units serve dry storage and clothing warehouse areas. The AHUs vary the volume of air supplied at the supply fan via variable frequency drives.

The two data rooms located in the center of the building incorporate two systems to provide cooling year round. The data rooms are served by VAV systems, however, when the central VAV air handling unit is operating at an unoccupied mode, ductless split system air conditioners are used to handle the cooling loads.

The following figure is a representation of the HVAC air side system zoning plan.

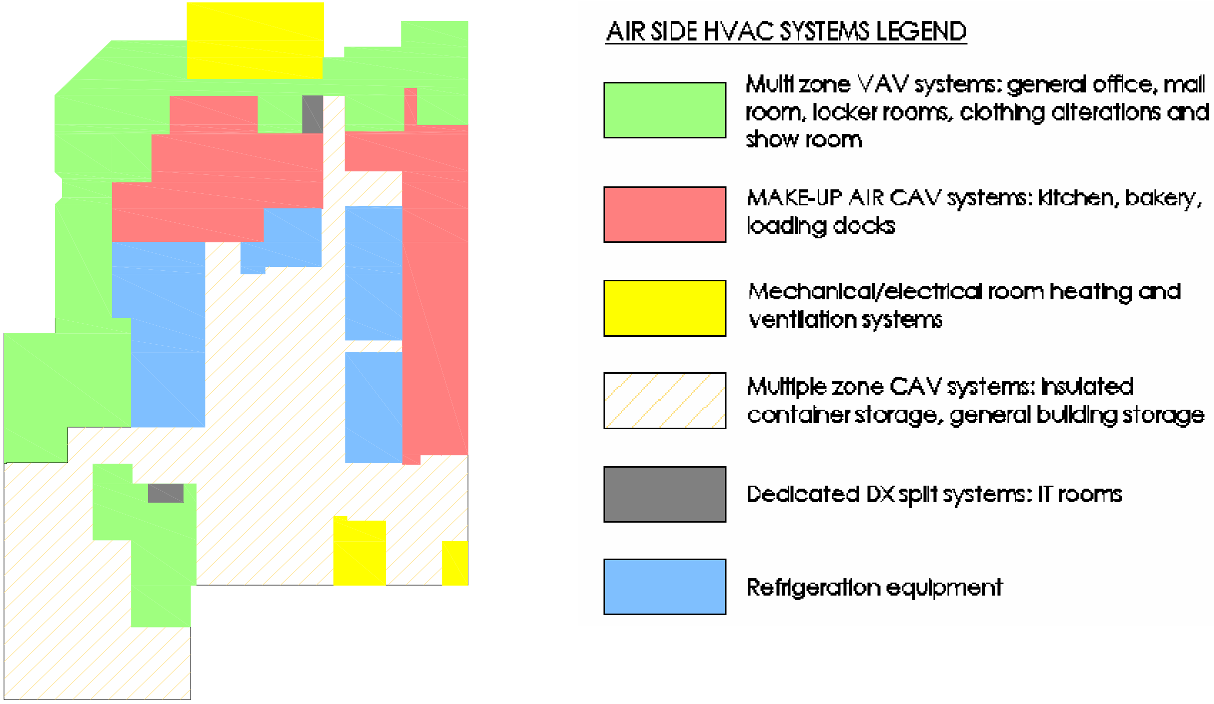

Figure 3-1 Air side mechanical systems zoning plan

3.3 CHILLED WATER EXISTING SYSTEM

The chiller plant of the supply center consists of two (one duty one standby) 270 ton electric driven centrifugal water cooled chillers that produce 45°F water. These chillers are used to meet the normal HVAC building loads. Also included in the chilled water system are two (one duty one standby) water cooled brine chillers that produce 20°F water. These chillers service fan coil units located in walk-in-coolers and refrigerated rooms year round. The two sets of chillers in the plant are interconnected in that they all have the capabilities to produce either 45°F or 20°F water for emergency purposes. All four of the chillers operate with R-134a refrigerant and the entire chilled water system (both the HVAC and brine loops) are provided with a 35% propylene glycol solution.

As mentioned above, the 45°F water loop also serves two plate frame heat exchangers to pick up the rejected heat from the walk-in freezers. The rejected heat from the freezers is distributed to a condenser water loop. This water loop is then cooled by the chilled water system before returning to the freezer's condensing units.

The HVAC chilled water loop incorporates a primary-secondary pumping system. Three primary pumps are located in the chilled water plant and are of a duty-duty-standby configuration. Two secondary pumps with VFDs distribute chilled water to the building loop. A similar pumping configuration is used for the brine loop, however, only four pumps are needed (2 primary, 2 secondary).

The chiller room includes a refrigerant leak detection and exhaust system that complies with ASHRAE Standard 15.

3.4 CONDENSER WATER EXISTING SYSTEM

The condenser water system for the chilled water plant includes two induced draft cooling towers for the heat rejection equipment. These service all four of the chiller's condensers. The walk-in freezer's condenser water loop also utilizes the chiller plant's condenser water system. As stated above, the freezer's rejected heat is handled by the HVAC chilled water loop. This operation occurs in the summer months, or when the ambient outdoor temperature is above 50°F. The freezer's condenser water loop bypasses the plate frame heat exchangers that are served by 45°F chilled water and enters a third plate frame heat exchanger served directly by 60°F condensing water from the cooling tower. This process is used for water side "free" cooling in seasons where the outdoor temperature is below 50°F.

The chilled water flow diagram, shown in Figure 3-2, show the three main water loops (condenser water, chilled water, and freezer condenser water). Design temperatures at which each water loop operates is also located on the flow diagram. The freezer's condenser water loop shows the 3-way valve that is used to bypass the chilled water heat exchangers when the system is operating in "free" cooling mode.

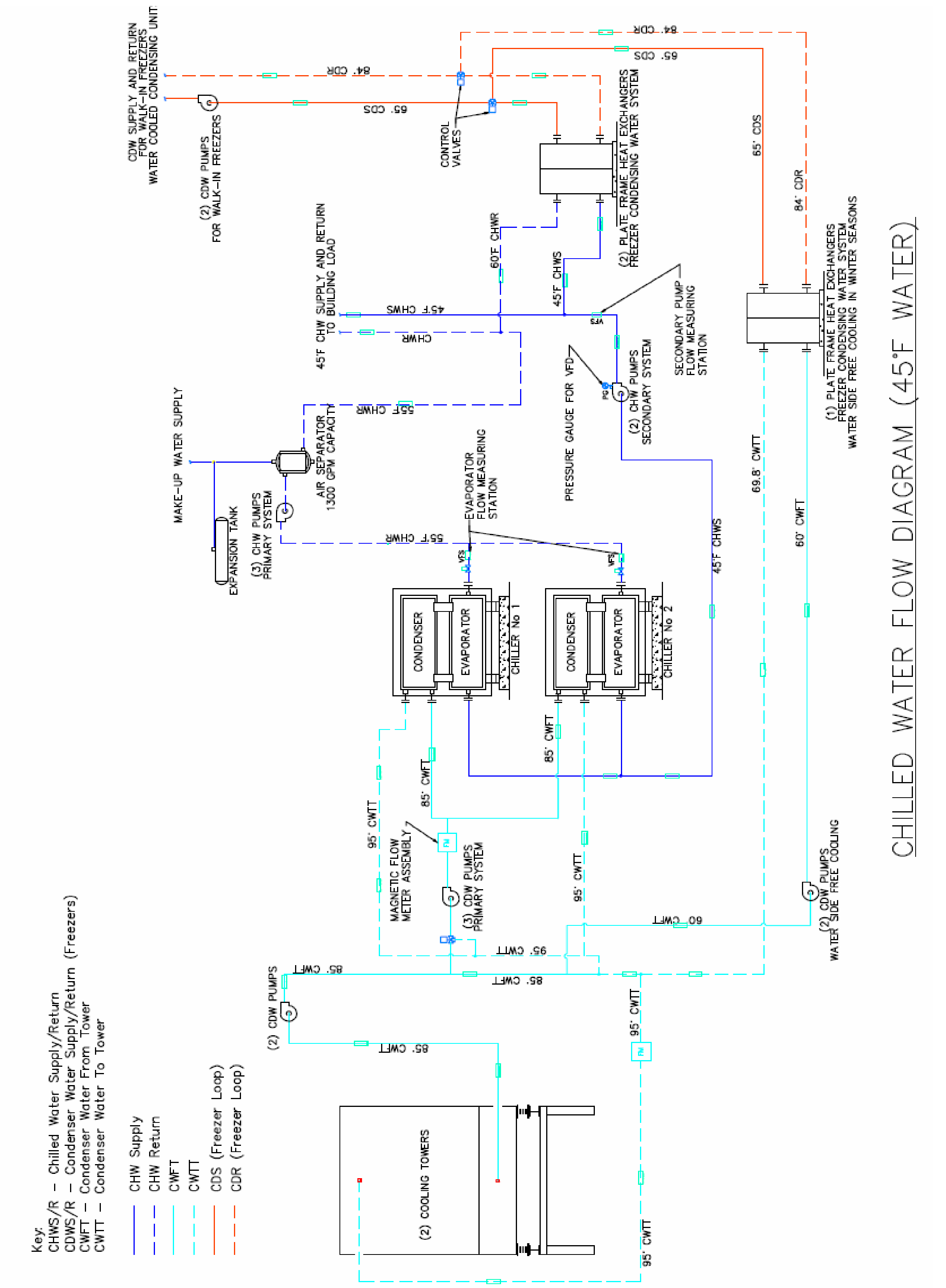

Figure 3-2 Chilled Water Flow Diagram

3.5 STEAM AND HOT WATER EXISTING SYSTEM

The boiler plant in the supply center consists of three natural gas-fired fire tube boilers. The two larger boilers, 200 BHP, service the building HVAC heating and domestic water heating loads. The third smaller boiler, 125 BHP, meets the kitchen equipment hot water demands. The boilers also incorporate flue gas recirculation to lower pollution levels. NO_X levels are held to 30 parts per million due to this configuration.

A combination deaerator and condensate storage tank is used to provide feed water to the boilers. Three active feed water pumps operate continuously with feed water valves located on the boilers. The feed water valves are controlled by level sensors so that minimum water levels are met to avoid potential hazards.

As stated above, the steam boilers produce 40 psig steam to service kitchen equipment loads, such as dishwashers. However, hot water for HVAC heating is also produced by these boilers. Hot water is needed to serve fin tube radiators, VAV box reheat coils, and cabinet and horizontal unit heaters. The hot water is produced by conversion of low pressure steam in two (one duty, one standby) shell and tube heat exchangers. Two hot water pumps with VFDs distribute the hot water to the HVAC equipment.

4.0 ASHRAE STANDARDS APPLICATIONS

This section includes summaries of compliance evaluations for the existing mechanical systems at the supply center for ASHRAE Standard 62.1-2004 and ASHRAE Standard 90.1-2004.

4.1 ASHRAE STANDARD 62.1 VENTILATION REQUIREMENTS

ASHRAE Standard 62.1-2004 Table 6-1 provides minimum ventilation rates for breathing zones and governs the design outdoor air requirements of the Supply Center. Table 6-1 includes a list of occupancy categories and the required minimum outdoor air rates per person and per square foot for those spaces.

The Ventilation Rate Procedure uses a series of equations in conjunction with tables found in Standard 62.1 which calculate the amount of ventilation air required for each space based on the it's use, occupancy, and floor area. This procedure then calculates the amount of outdoor air required for each AHU to intake in order to ensure that each space receives at least the minimum amount of outdoor air. Ventilation rates calculated for a compliance check are summarized in Table 4-1 shown below. The table illustrates the amount of outdoor air each AHU is to intake in order to comply with the standard and the amount of outdoor air each AHU is scheduled to intake according to the design documents provided by H.F. Lenz Company.

Table 4-1 Ventilation Compliance Summary

AHU	ΣVOZ	MAX ZP	MIN OA REQ. (VOT CFM)	OA SUPPLIED (CFM)	COMPLIES WITH STD. 62.1
1	1124	0.1	1124	1150	YES
2	795	0.14	795	1150	YES
3	1957	0.53	3215	3640	YES
4	1817	0.52	3008	5585	YES
5	833	0.26	1041	3000	YES
6	1133	0.30	1416	13500	YES
7	549	0.29	686	3000	YES
8	335	0.09	335	7400	YES
9	943	0.38	1348	1000	NO
10	849	0.51	1414	1125	NO
11	354	0.23	394	1045	YES
12	497	0.19	552	1250	YES
13	896	0.25	996	3000	YES
14	582	0.18	647	800	YES

Table 4-1 indicates that two of the fourteen air handlers do not comply with ASHRAE Standard 62.1 – 2004. The reason for the non-compliance is that the occupancy type assumed for certain areas, such as boys and girls fitting rooms, are assumed retail spaces which differ from the original design. Table 6-1 in Standard 62.1 requires 7.5 cfm per person and 0.06 cfm per square foot of ventilation air supplied to these spaces. The original design of the supply center did not use any values on a per person basis. This proves that the original design calculations produced smaller amounts of ventilation air than what Standard 62.1 recommends.

There are significant over ventilation results that Table 4-1 illustrates. These AHUs are 100% outdoor air units for make-up when the kitchen and loading dock areas are in operation. The units must provide enough air to meet the thermal loads and to maintain space pressurization. The resulting actual outdoor air flow rate proves to over ventilate the spaces when compared to the value calculated using Standard 62.1.

4.2 ASHRAE STANDARD 90.1 COMPLIANCE SUMMARY

ASHRAE Standard 90.1-2004 provides minimum requirements for the design of energy efficient buildings. Section 5 of Standard 90.1 specifies requirements for an energy efficient building envelope and is used as the basis for the calculations.

Standard 90.1 provides two methods for checking building envelope compliance, the Prescriptive Building Envelope Option and the Building Envelope Trade-Off Option. According to the standard, in order to use the Prescriptive Building Envelope Option the total vertical fenestration must not exceed 50% of the gross wall area. Also, the total skylight area can not surpass 5% of the total roof area. The supply center, however, contains vertical clear story windows not horizontal skylights. Therefore, the clearstory windows' areas are accounted for in the vertical fenestration calculation. Incase either of the two stipulations are not satisfied, the Building Envelope Trade-Off Option is used for determining envelope compliance.

Table 4-2 Percent Vertical Fenestration Breakdown

TOTAL GLASS AREA (FT^2)	TOTAL WALL AREA (FT^2)	% TOTAL VERTICAL FENESTRATION
2600	30,500	8.5%

Table 4-2 illustrates that the total glass area for the supply center is less than 50% of the total wall area verifying the use of the Prescriptive Building Envelope Option for the Standard 90.1 compliance check.

The Milton Hershey School New Supply Center, located in Hershey, Pennsylvania, falls under the climate zone 5A according to Table B-1 in Appendix B of the Standard. Table 5.5-5 in the Standard is used to determine building envelope compliance and breaks down into three sections; residential, nonresidential, and semi-heated. The supply center falls under the nonresidential section. The portions of Table 5.5-5 examined are as follows:

- Roofs, Walls, and Floors
  - Compliance based on the assembly maximum U-value or insulation minimum R-value.

- Vertical Glazing % of Wall
  - Compliance based on the assembly maximum U-value for both fixed and operable windows.
  - Compliance based on the assembly maximum solar heat gain coefficient (SHGC) for either case of the glass facing the north or all directions.

Construction documents provided by H.F. Lenz Company and the architectural specification provided by Spillman Farmer Architects indicate the R-values used for wall and roof insulation. The two design documents also provide the U-value for the windows as well as the solar heat gain coefficient which are both used in checking for fenestration compliance with Standard 90.1. Tables 4-3 and 4-4 compare the requirements for building envelope compliance dictated by Standard 90.1 to what is actually designed. As the tables indicate, the New Supply Center complies with ASHRAE Standard 90.1 for an energy efficient building envelope.

Table 4-3 Building Envelope Compliance Summary

	ROOF (INSULATION ENTIRELY ABOVE DECK) INSULATION MIN R-VALUE		**WALLS (METAL BUILDING) INSULATION MIN R-VALUE**		**FLOORS (SLAB ON GRADE) UNHEATED**
Required (ASHRAE 2004)	R-15 Continuous Insulation		R-13		N/A
Installed	3" Thick	R-18.5 Continuous Insulation	6" Thick	R-19	N/A
Compliance	**Complies**		**Complies**		**Complies**

Table 4-4 Fenestration Compliance Summary

% VERTICAL GLAZING 0-10%	**ASSEMBLY MAX U-VALUE (FIXED WINDOWS)**	**ASSEMBLY MAX SHGC (ALL ORIENTATIONS)**	**COMMENTS**
Required (ASHRAE 2004)	0.57	0.49	Windows are double pane (1/4" thick glass each) insulating float glass with Low-e coating
Installed	0.35	0.40	
Compliance	**Complies**	**Complies**	

The existing major mechanical equipment at the supply center all meet the minimum efficiency requirements outlined in Section 6 of Standard 90.1-2004. This includes the building's chillers, boilers, and cooling towers. Any new equipment analyzed in the mechanical systems redesign must comply with these same requirements.

5.0 MECHANICAL SYSTEM REDESIGN

The mechanical system redesign consists of two major parts, but the overall resulting system integrates as many building systems as possible for maximum energy usage optimization.

5.1 REDESIGN OBJECTIVES

The Milton Hershey School New Supply Center's mechanical systems are designed with careful attention towards energy conservation and thermal comfort. Overall, the combination of the HVAC system's ability to incorporate other building systems as well as its sophisticated control methods, used to minimize energy consumption while maintaining thermal comfort, classifies it as very good for this application. The design engineers at H.F. Lenz Company cut no corners in the design, however, there are still alternatives that need addressed. Adjustments to the current design or redesign of certain areas of the HVAC system can result in further optimization in first cost, construction cost, and operating cost.

The goal of this mechanical system redesign is to increase energy efficiency, decrease life cycle cost, and maintain or improve the level of thermal comfort that the existing systems set. The original design of the supply center achieves the status of LEED Certification. Any alterations to the mechanical system are not to lower this standard. The final goal of the redesign is to use unique or non-ordinary methods and systems for the study, and measure there performance in this situation. The results from the analyses will not only prove whether the redesign meets the project goals, but will serve as educational value to see how these different systems react with the given conditions.

The main goal of the ones listed above is to increase energy efficiency. Technical Assignment 2 looked at the supply center's annual energy usage. The results for the report indicate that the main source of energy to operate the refrigeration equipment and AHUs is electricity, and the heating equipment utilizes natural gas. Decreasing the amount of electricity consumed by the HVAC equipment will significantly lower the annual energy cost to operate the supply center. Lowering the annual energy cost will also create the potential for decreasing the life cycle cost of the HVAC systems.

Alterations to the HVAC system may result in significant differences in first cost compared to the existing system. The goal of this redesign is to recommend the most energy efficient, sustainable, and cost effective system. The recommended system must include a reasonable pay back period, about 3 years, when compared to the alternatives. Whether the existing system or the alternatives are selected as the best, pay back periods longer than 2 to 4 years will not justify their use in this application.

5.2 REDESIGN SUMMARY

Integration of as many building systems as possible for total building energy optimization is the goal of the mechanical systems redesign for the Milton Hershey School New Supply Center. The air side mechanical systems as well as the chiller and boiler plants are all altered in the redesign. The walk-in freezers condenser water loop is also used in an effort to integrate more building systems as well as recover the waste heat. The mechanical redesign directly affects other building systems that need attention as well. The structural system and electrical service all will change due to the mechanical changes which paves the way for a variety of cost analyses that will prove whether or not the redesign beneficial.

The redesign of the air side mechanical system will comprise of the replacement of ten VAV or CAV air handling units with dedicated outdoor air systems (DOAS). The remaining four air handling units that are direct fired make-up air units that serve the kitchen, bakery, and loading dock spaces will remain. Since the DOAS can not meet the cooling load of the spaces they serve, a water source heat pump system will act as the parallel cooling scheme.

The chilled water plant redesign will eliminate the electric driven centrifugal chillers and replace them with direct fired absorption chiller-heaters. The chiller-heaters will utilize their simultaneous heating and cooling ability and meet the cooling loads while handling most (if not all) of the HVAC and domestic hot water demands.

The waste heat rejected from the walk-in freezers will pass through heat exchangers and account for the water source loop heat addition as well as pre-heat the domestic water. As in the original design of the supply center, if recovering this waste heat is not sufficient to cool the condenser water loop back to operating temperatures (65°F), chilled water from the plant will meet the remaining load.

6.0 BUILDING LOAD ANALYSIS

The chilled water plant at the supply center sees various load profile changes throughout the year. However, since the chilled water system also handles the walk-in freezers heat rejection, it forms a base load that is near constant for the existing system. Figure 6-1 illustrates a typical cooling load profile during cooling season. Carrier's Hourly Analysis Program (HAP) is used to generate the data.

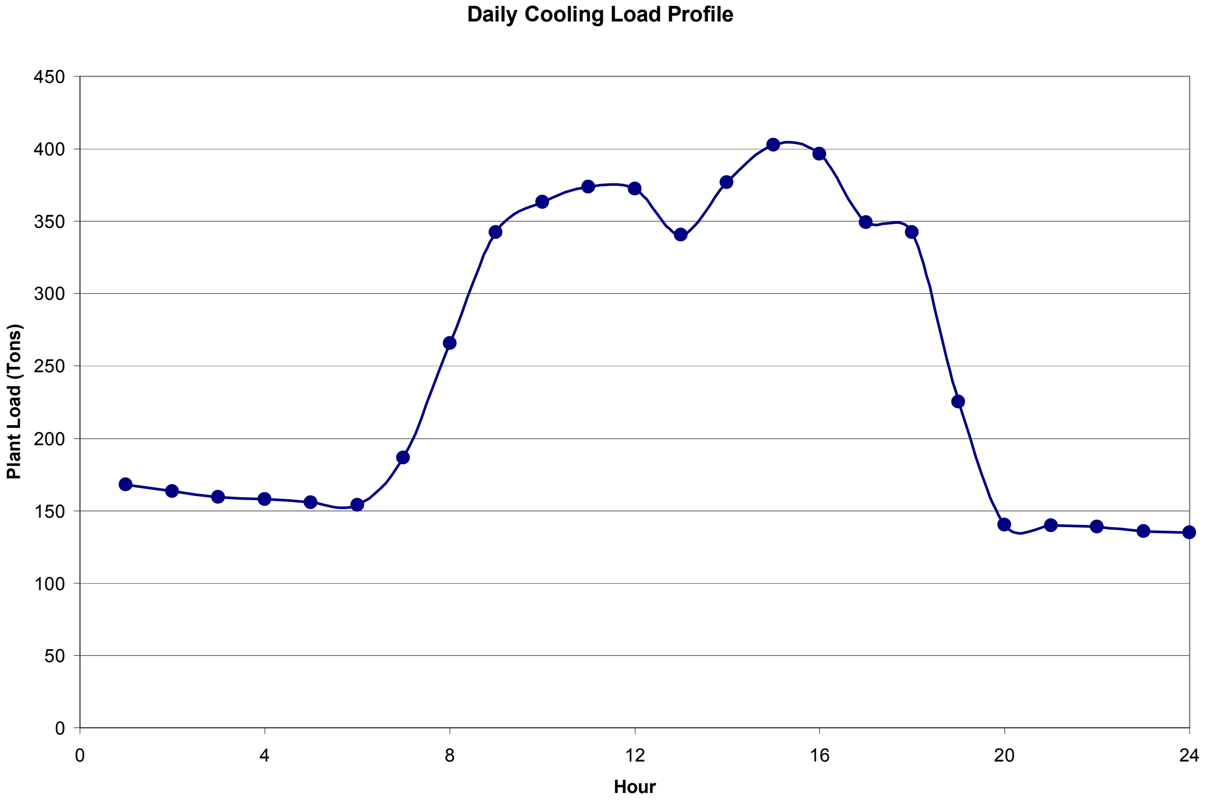

Figure 6-1 Existing Chiller Plant Daily Load Profile

As the figure illustrates, the supply center operates like most buildings, having peak cooling demand during the building's operational hours. The proposed redesign thermal load profile is much different in the fact that less cooling demand is required due to the use of a DOAS and a water source loop. Figure 6-2 shows the redesigned plant's load profile and is shown on the next page.

As the graph shows, the 106 ton base load produced from cooling the walk-in freezers' condenser loop forms the base load in this particular example. As the building becomes occupied the load increases, but not drastically. The domestic hot water demand increases when the building is occupied, and this water is pre-heated by the condenser water loop. For most cases during the year, this pre-heat process transfers enough heat out of the condenser loop so that it operates at the appropriate temperature (65°F). When this occurs, the chilled water plant no long has to meet this base load.

The following sections, 7.0 and 8.0, explain how the HVAC systems operate in more detail, and contain schematics that illustrate how the heat recovery scheme shifts the plant load profile downward.

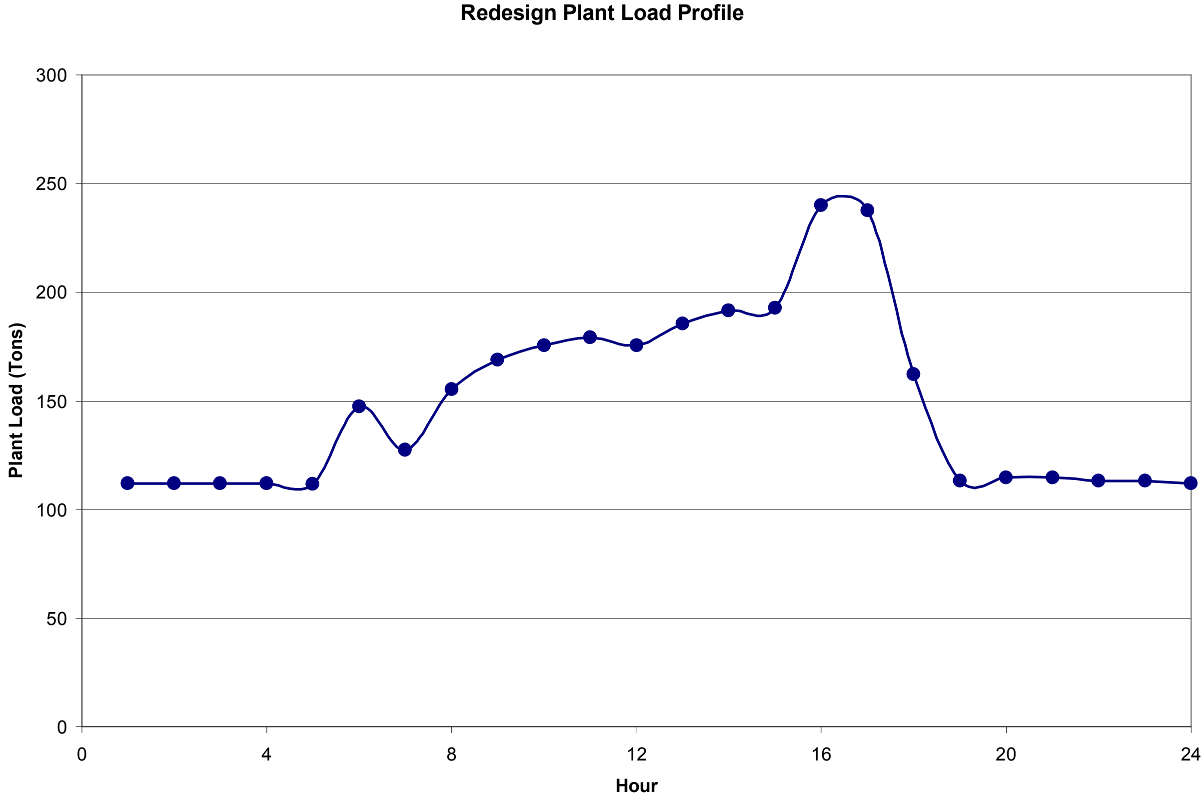

Figure 6-2 Redesigned Chiller Plant Daily Load Profile

Using Carrier's software, the heating loads also are easily obtainable. However, using a dedicated outdoor air system slightly raises the required amount of heating done by the boiler plant. Figure 6-3 shows the existing systems daily heating plant load profile (with the load in MBH). This data is from a winter day, therefore, shows a high HVAC heating demand.

Figure 6-4 illustrates the boiler plant's heating load profile with the redesigned system. The profile is slightly shifted upward, unlike in the cooling scenario, and the peak heating load is close to 200 MBH higher. The space loads are the same in both situations, however, the majority of the heating is now performed by the parallel water source heat pump system, and this is not directly seen by the boiler plant. The boiler plant is needed occasionally to add heat in the water source loop to maintain the winter temperature of 68°F, but this is a much smaller demand than continuous hot water production required for terminal re-heat coils and AHU per-heat coils that existing system utilizes. The main reason for the increase in heating demand in the new system is because the dedicated outdoor air units need cold outside air heated to 55°F without any type of recirculation that would pre-heat the air in VAV systems.

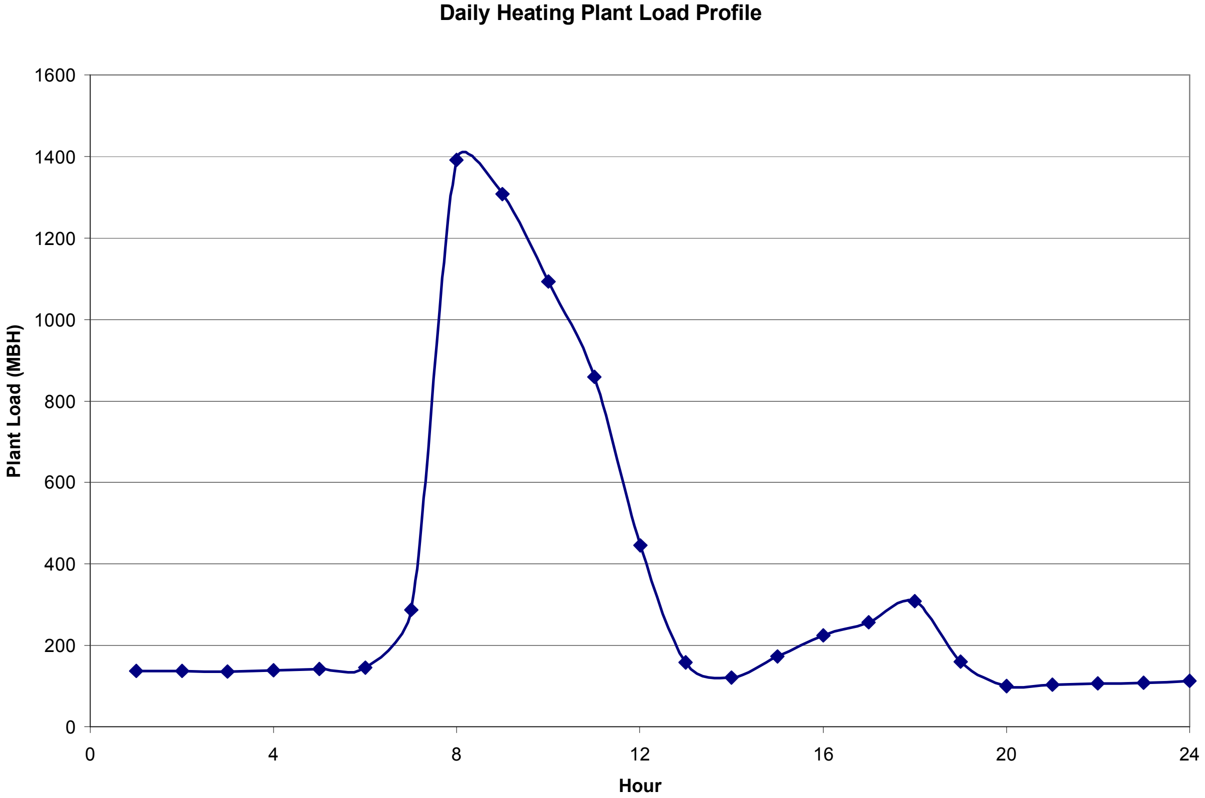

Figure 6-3 Existing Boiler Plant Daily Load Profile

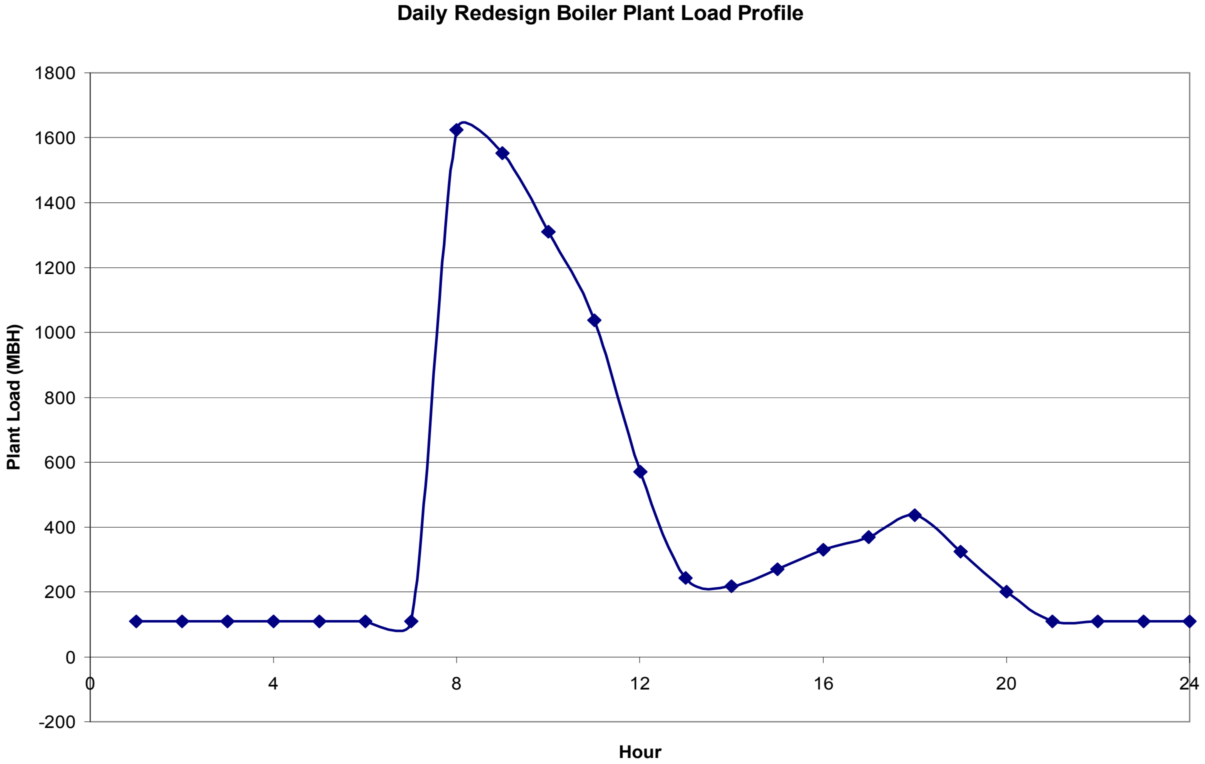

Figure 6-4 Redesigned Boiler Plant Daily Load Profile

The typical domestic hot water production demand is also important in this redesign. Originally, a separate hot water boiler is used to meet this load. The redesign system recovers heat from the walk-in freezers to pre-heat this water. The remaining load is met with the chiller-heater system as explained in section 8.0. Figure 6-5 shows the estimated typical, in-operation daily domestic hot water demand load profile. Although it is difficult to accurately predict the hot water usage for a building, this hot water demand estimate follows the occupancy schedule for the spaces requiring the hot water.

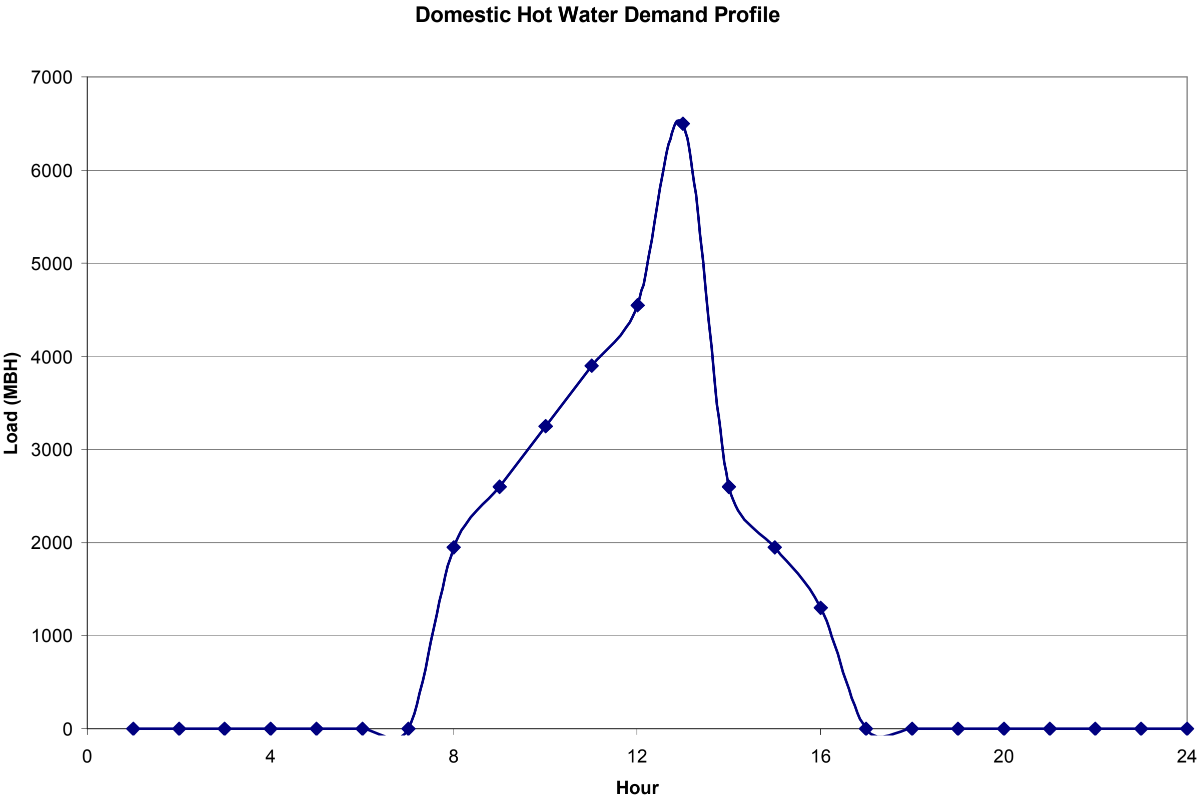

Figure 6-5 Domestic Hot Water Demand Profile

The peak load is designed for a 100gpm flow rate, with an entering water design temperature of 50°F and leaving design temperature of 180°F. This load profile, although is an estimate, is used for every analysis for consistency and comparison reasons.

7.0 DOAS WITH WATER SOURCE HEAT PUMPS ANALYSIS

The air side portion of the mechanical system redesign for the supply center consists of replacing ten of the fourteen VAV and CAV air handling units with dedicated outdoor air units. The AHUs serve offices, conference rooms, the clothing shops and alteration areas, the mail room, and a variety of storage spaces. The remaining AHUs are constant volume make-up air units. Due to the large amount of exhaust in the kitchen and bakery areas, these units are still required for space pressurization reasons. Also, since the 100% outdoor air mode is only needed when the building is in operation, these units have the ability to back the outdoor air intake down to 5% and re-circulate the space air for conditioning purposes. Since it makes sense to keep these area's separated from the rest of the HVAC system, their existing AHUs will remain.

The parallel system working in conjunction with the DOAS is a water source heat pump (WSHP) system. The WSHP system handles the sensible loads in the spaces served by the dedicated units. The latent loads are met by the ventilation air.

7.1 DESIGN OF THE DEDICATED OUTDOOR AIR SYSTEM

Using ASHRAE Standard 62.1-2004, the required amounts of ventilation air that each space in the supply center required per person and per square foot is easily calculated. Dedicated outdoor air systems supply this correct amount of ventilation air to each space with out return air. Therefore there is no need to intake more outdoor air than the minimum amount.

In VAV systems, the ventilation air is part of a large mixture of outdoor air and return air. To ensure that each space receives the proper amount of ventilation air, correction factors are used increasing the total amount of outdoor air brought in by the AHU. This means more outdoor air to condition, and larger ductwork.

Dedicated outdoor air systems require much smaller ductwork sizes since only a small volume of air is required for ventilation as compared to heating and cooling needs. However, the DOAS must also handle the latent loads in the spaces it serves. The DOAS will dehumidify each space, and by doing so will require more outdoor air than the minimum. The DOAS receives chilled water to dehumidify the outdoor air and supplies it at 55°F. Supplying the ventilation air at a low temperature means that it also handles a small portion of the space sensible load, which creates less demand for the parallel system.

The total amount of ventilation air required for dehumidifying and meeting the requirements in ASHRAE Standard 62.1-2004 is 9,791cfm. Table 7-1 compares the amount of outdoor air required in the VAV systems to the DOAS.

Table 7-1 Outdoor Air Supply Comparison

AHU	Outdoor Air Supplied
3	3640
4	5585
5	3000
7	3000
9	1000
10	1125
11	1045
12	1250
13	3000
14	800
Total	**23,445**
DOAS 1	6176
DOAS 2	3615
Total	**9,791**
Difference	**13,654**

7.2 DESIGN OF THE WATER SOURCE HEAT PUMP SYSTEM

The parallel system, as stated above, that handles the sensible load in each space that the dedicated units serve is water source heat pumps. Since the DOAS handles the dehumidifying duties, the water source heat pumps provide heating or cooling to maintain space temperatures.

With many options available for parallel systems, water source heat pumps are used in the redesign for a variety of reasons. First, the application of the water source loop helps in the integration process of other building systems. Second, the system operates with a heat source and heat sink. No refrigeration equipment is required for operation.

ASHRAE Standard 90.1-2004 states that its minimum efficiency requirements for water source heat pumps are tested with the loop temperature maintained at 86°F for summer operation and 68°F for winter. The redesign heat pump system follows this design guideline. A heat source, such as a boiler or recovered heat, adds heat to the water loop in the winter to maintain the 68°F temperature when needed. Since there are many spaces that require cooling year round, heat addition is rare in this situation. When the water loop temperature is above the 86°F in the cooling seasons, a cooling tower is used for heat rejection. The cooling tower duty is shared with what ever other refrigeration equipment is in the building.

Water source heat pumps reduce the amount of energy used for heating and cooling, but do use a significant amount of electricity. The WSHPs used in the redesign are horizontal concealed units located above the drop ceilings in each space or the corridors. Ductwork and overhead diffusers supply the conditioned air to each space. This means that each WSHP requires fan energy for operation, which is a drawback to using this system for the parallel cooling method.

Each WSHP includes it own compressor to perform the thermodynamic functions for space conditioning. This creates another disadvantage in using this system because of maintenance issues. Since there is no noise criteria established for any spaces, using WSHPs is not an issue in regard to noise. The compressors make WSHPs nosier than using fan coils or VAV systems, but this is a non-issue for the situation.

Figure 7-1 Water Source Heat Pump from McQuay Product Literature

Integration of other building systems is a main goal of the redesign. Using water source heat pumps helps with this process. The walk-in freezers located in the kitchen, as previously explained, uses a condenser water loop for rejecting the produced heat in the refrigeration process. This technique eliminates excess cooling loads in the kitchen spaces, but is the condenser water is cooled back to operating conditions, 65°F, by the chilled water system. The load profiles shown in section 6.0 illustrated that this creates a 106 ton base load for the chilled water plant.

Recovering this waste heat helps integrate other building systems with the HVAC system as well as lowers the load on the chilled water system. The water source loop requires heat addition in the winter time to maintain the required temperatures for operation. Using temperature control valves and a plate frame heat exchanger, the redesigned system recovers the waste heat from the walk-in freezer’s condensing units by using it as the water source loop’s heat source.

Figure 7-2 illustrates the DOAS configuration with WSHPs and the heat recovery scheme.

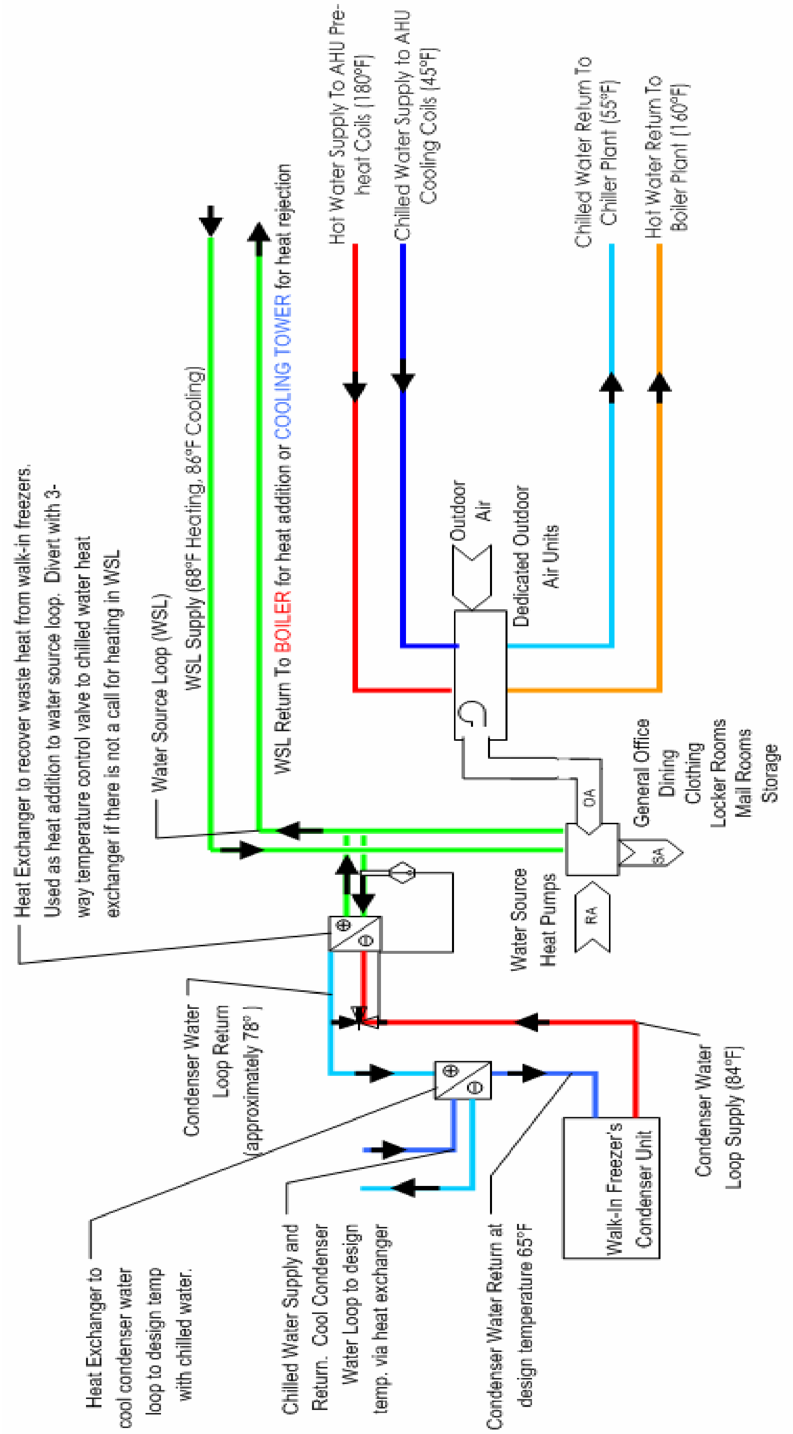

Figure 7-2 DOAS and WSHP Schematic

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

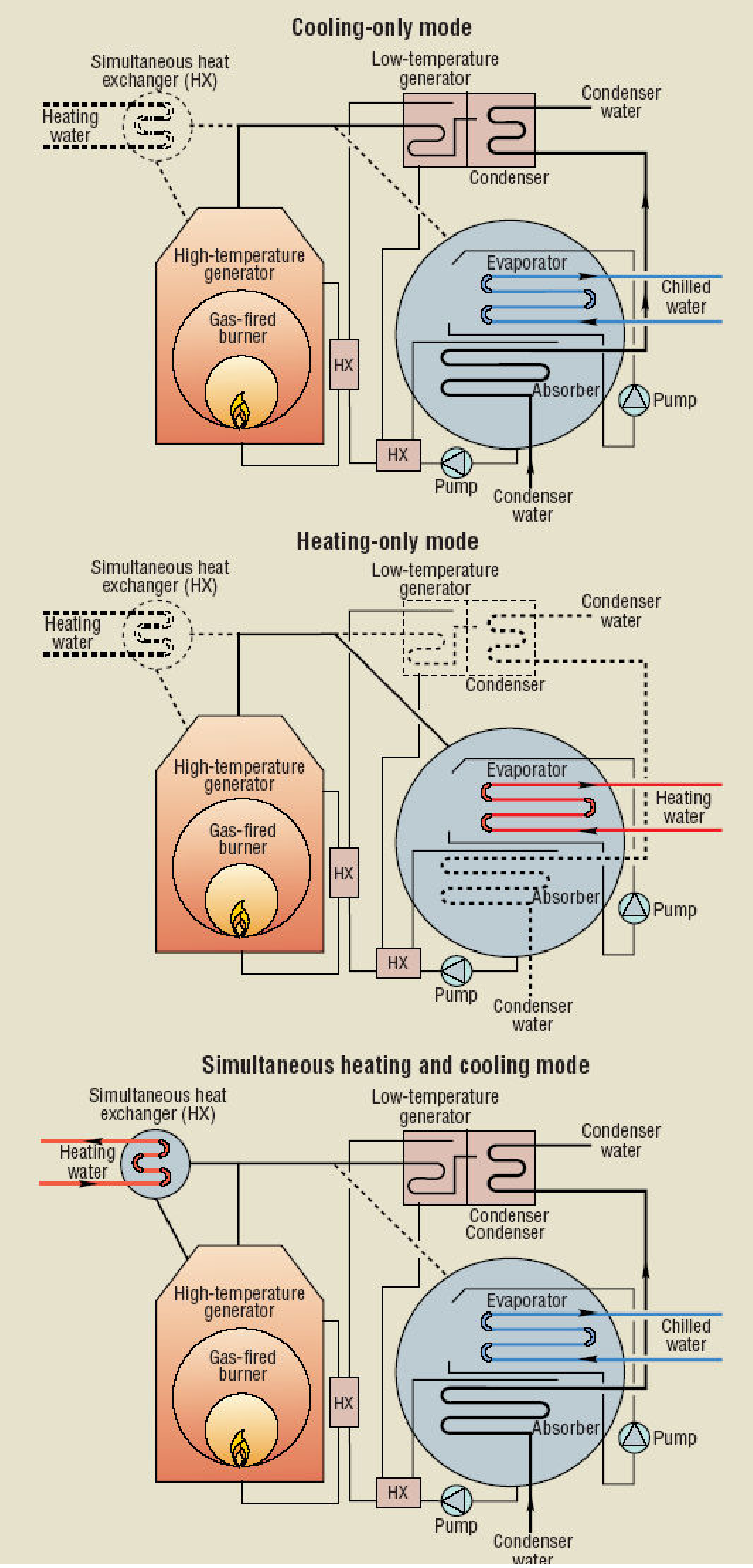

Figure 8-1 Double Effect Absorption Cycle

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.

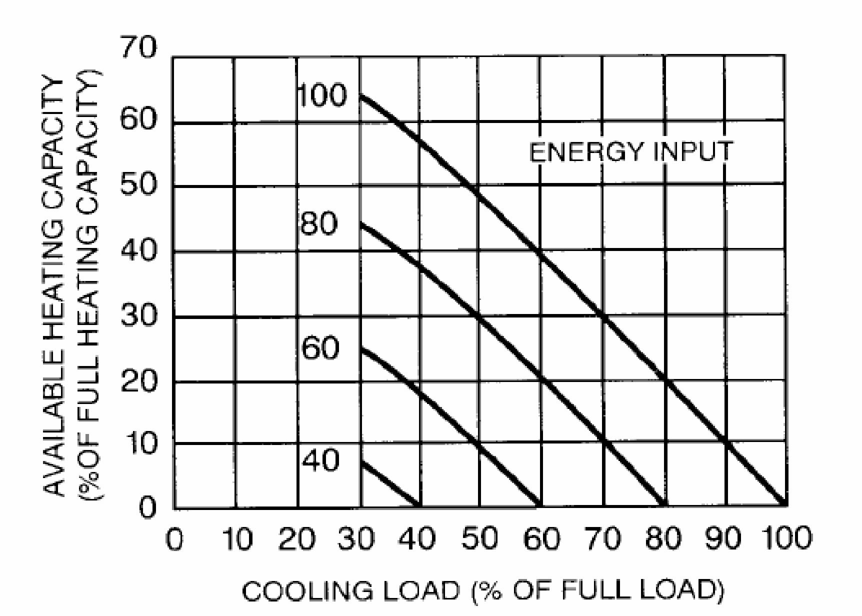

Figure 8-2 Cooling/Heating Capacities per Input Energy

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.

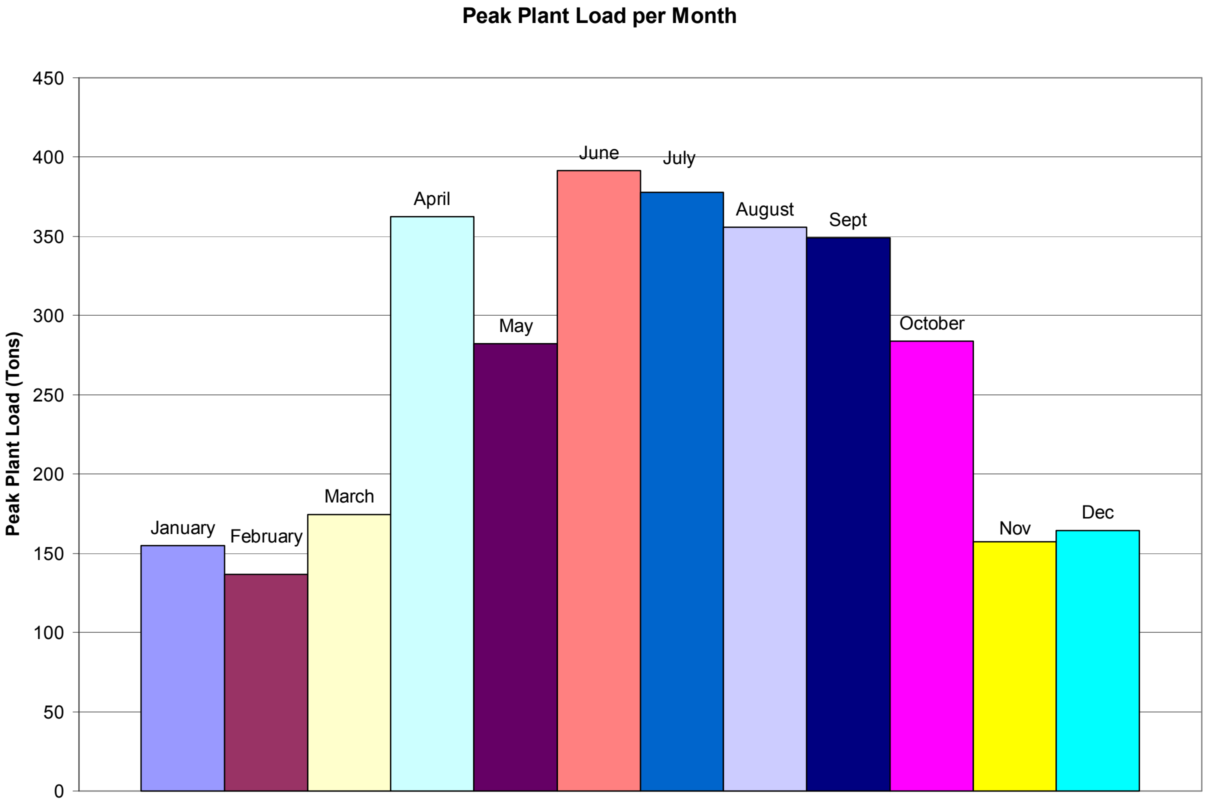

Figure 8-3 Monthly Peak Cooling Load

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).

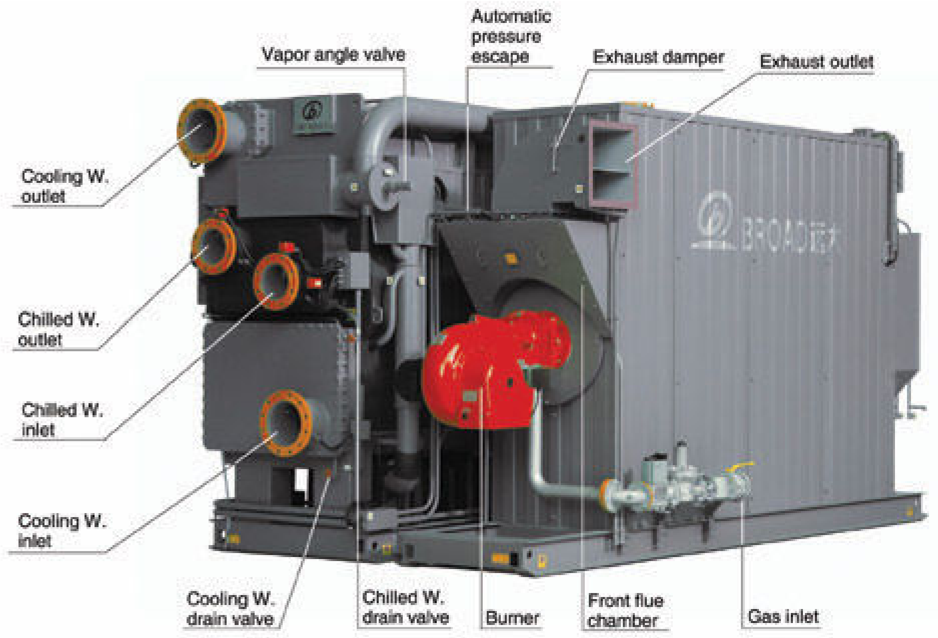

Figure 8-4 Broad Air Conditioning's Direct Fired Chiller-Heater Chilled Water Production Portion

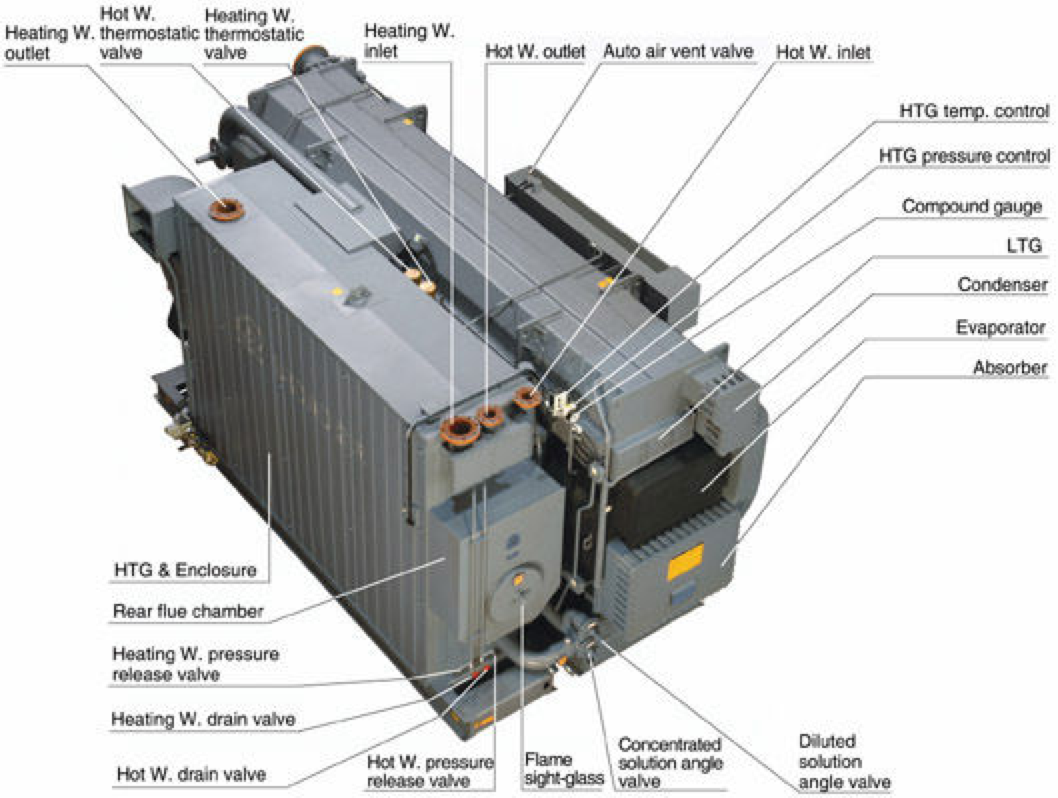

Figure 8-5 Broad Air Conditioning's Direct Fired Chiller-Heater Hot Water Production Portion

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.

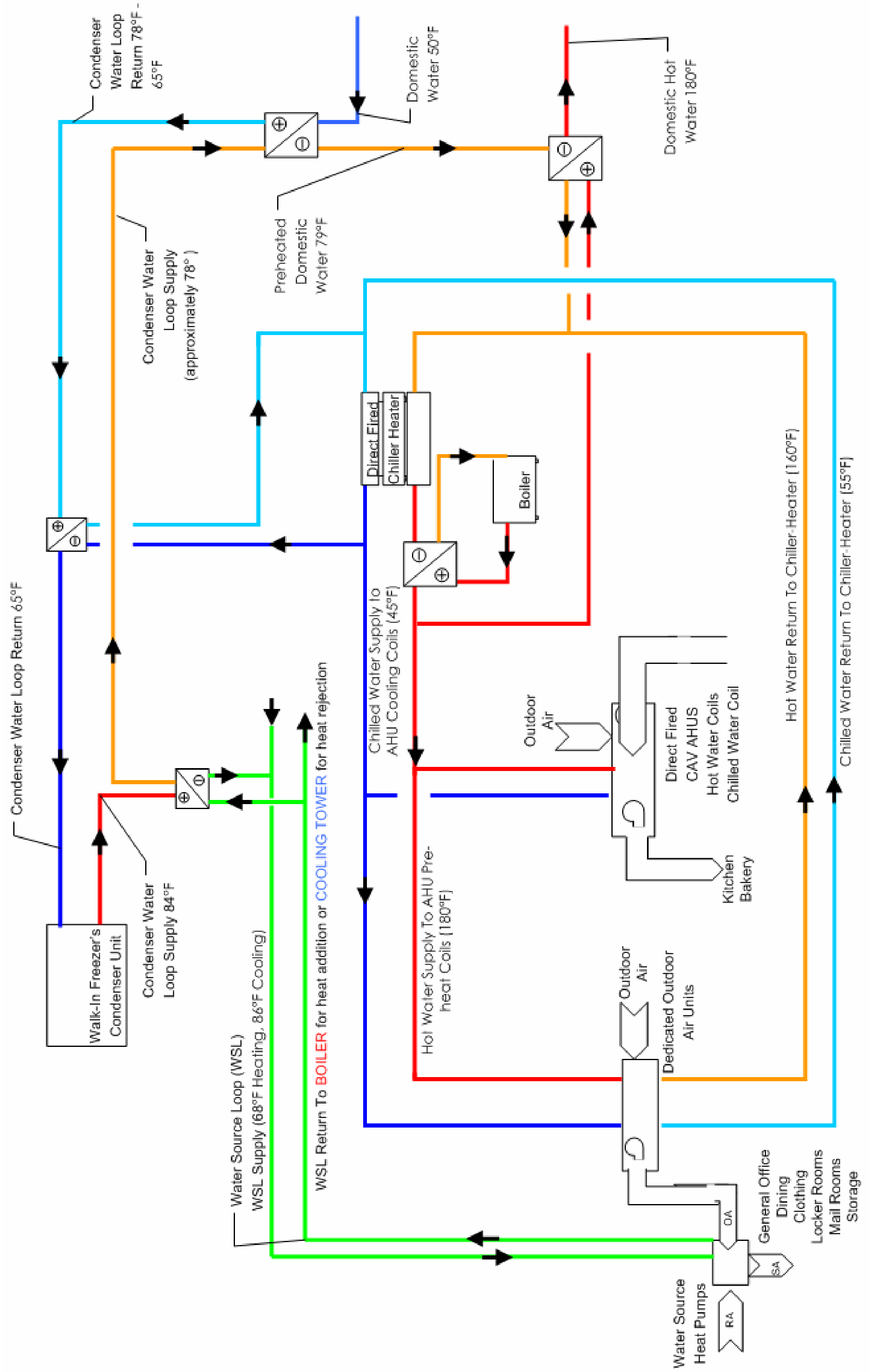

Figure 8-6 Redesigned HVAC System Overall Schematic

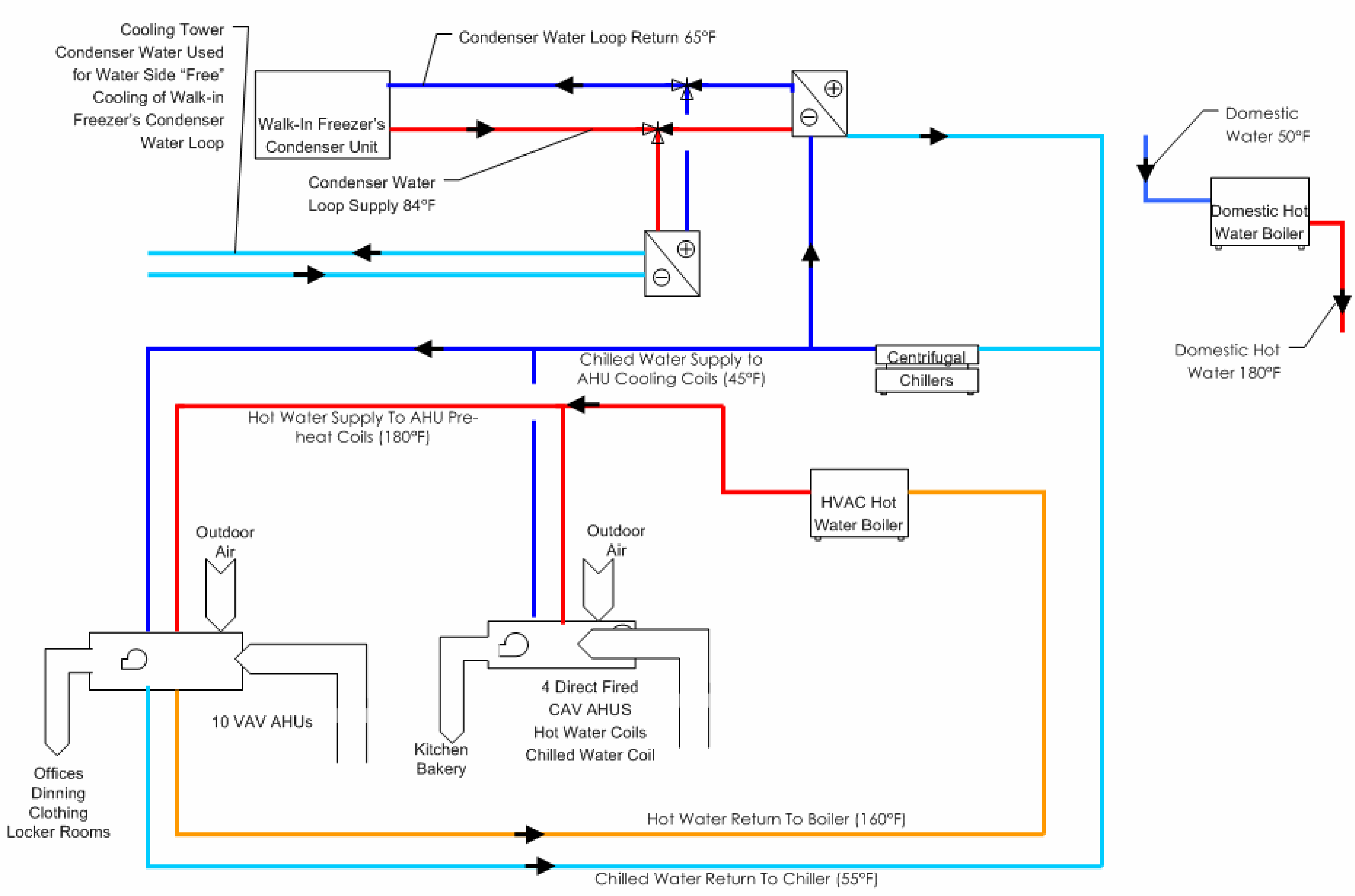

Figure 8-7 Existing HVAC System Overall Schematic

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

Table 9-2 illustrates the comparison of results between the existing and redesigned mechanical system.

Table 9-2 Annual Operating Cost Summery

	Existing System	Redesign w/ Chiller-Heater
Cooling Cost	$67,577	N/A
HVAC Heating Cost	$23,016	N/A
Hot Water Heating Cost	$58,371	N/A
Combined Heating and Cooling Cost	N/A	$117,370
Air System Fan Cost	$21,303	$12,318
Pump Cost	$29,274	$20,480
Cooling Tower Cost	$9,920	$16,440
Total	**$209,461**	**$166,608**

The table indicates that the redesigned system using the direct fired chiller-heater plant is the least expensive to operate per year. The greatest cost savings come in the pumps, air system fans, and cooling operational cost. Also, since the chiller-heater is able to simultaneously cool and produce hot water, there is a $31,600 savings per year compared to the existing system in heating and cooling cost.

Overall, using the redesigned system with the direct fired chiller-heater plant is $43,000 per year to operate cheaper than the existing system. The first cost of the system now comes into consideration for pay back calculations. Also, a 20 year life cycle cost analysis is required for a long term comparison between systems. Table 9-3 compares the initial cost of the two design options.

Table 9-3 Initial Cost Comparison

Equipment (Quantity and Type)	Existing System	Redesign Chiller-heater Option
Chillers (2 Centrifugal)	178,000	-
Chiller-Heaters (2)	-	450,000
HVAC Boiler (1 4500 MBH)	21,800	-
HW Boiler (2 6500 MBH)	61,000	-
Supplemental Boiler (1 9000 MBH)	-	85,000
Heat Exchangers (for HW system)	10,000	-
DOAS AHUs (2)	-	47,840
VAV AHUs (10)	309,310	-
Plate-Frame HX	10,000	20,000
VAV Boxes w/reheat	32,730	-
Heat Pumps	-	60,045
TOTAL	**$622,840**	**$682,885**

Table 9-3 indicates that the redesigned mechanical system is $60,000 more than the existing system. The costs of absorption chiller-heaters are the most expensive portion of the redesign, but due to the DOAS configuration, first cost is saved in the air handling unit category. The water source heat pumps also drive the cost of the redesign upward.

The 20 year life cycle cost (LCC) analysis provides more evidence in proving why the redesign is practical from an economic stand point. Table 9-4 illustrates the life cycle cost analysis. The table indicates that the redesign has a lower 20 year LCC with a difference of approximately $376,601. The assumed interest rate used in the calculation is 6%. Appendix B includes detailed cost spreadsheets for the entire project.

Table 9-4 LCC Analysis

i = 0.06	Existing System	Chiller-Heater Option
yr 1	209461	169108
yr 2	209461	169108
yr 3	209461	169108
yr 4	209461	169108
yr 5	209461	169108
yr 6	209461	169108
yr 7	209461	169108
yr 8	209461	169108
yr 9	209461	169108
yr 10	209461	169108
yr 11	209461	169108
yr 12	209461	169108
yr 13	209461	169108
yr 14	209461	169108
yr 15	209461	169108
yr 16	209461	169108
yr 17	209461	169108
yr 18	209461	169108
yr 19	209461	169108
yr 20	209461	169108
NPW	**$2,266,510**	**$1,829,863**
Initial Cost	$622,840	$682,885
20 Yr LCC	**$2,889,350**	**$2,512,748**

A side note to the life cycle cost analysis that needs addressed is the subject of maintenance cost. Water source heat pumps, as described above, require more maintenance than VAV boxes. However, according to absorption chiller-heater manufactures, new chiller-heaters have maintenance cost comparable to vapor compression chillers. Therefore, that cost difference per year is negligible. Overall, it is calculated that the chiller-heater option is approximately $2,500 more per year to maintain.

The remaining factor in proving if the redesigned mechanical system is beneficial is determining the pay back period. Table 9-3 indicates that the redesign must prove to payback its extra $60,000 in initial cost, and do so in a reasonable time period (2-4 years). Including interest in the calculation, yearly cost savings created by using the redesign helps pay the system back in 1.48 years. This is well within the desired time frame which makes redesign worth considering as long as the Milton Hershey School is willing to spend a little more money upfront.

9.2 MECHANICAL REDESIGN CONCLUSIONS

The mechanical redesign analysis incorporates a DOAS with water source heat pumps and integrates this air side system with other building systems. Heat is recovered from the walk-in freezer's condenser water loop to pre-heat domestic water and acts as the heat source for the water source loop that serves the heat pumps. Taking advantage of the natural gas service at the supply center, and its competitive prices compared to the electric grid, a direct fired absorption chiller-heater plant is implemented in the supply center. The redesigned plant replaces the separate vapor compression chiller and boiler plants the supply center currently utilizes. The concept keeps to the theme of the redesign of building system integration.

Economic analysis of the initial and yearly cost of each design option paves the way for a life cycle cost analysis. The LCC proves that the least expensive redesign has significant savings compared to existing system over 20 years, and it pays itself back in less than 2 years. Therefore, the proposed mechanical system redesign is a good design option.

Finally, the entire redesign incorporates the idea of system integration. Each piece of the redesign plays an important role, and is necessary to see the significant cost savings. The DOAS system alone will produce energy savings. However around half of the energy savings is seen from the simultaneous production of chilled water and hot water. The energy recovery also lowered the hot water demand and the cooling base load during peak hours. Overall, the entire redesign is required for optimal energy savings.

10.0 STRUCTURAL/CONSTRUCTION BREADTH: ROOF REDESIGN & DETAILED COST ESTIMATES FOR AHU RELOCATION

The entire system redesign proposal focuses primarily on the HVAC systems. However, each change or alteration to the existing mechanical system directly affects other building systems. The building background portion of this report explains that the existing 14 air handling units are housed in an elevated mechanical mezzanine floor. Since the redesigned mechanical system replaced 10 of the 14 air handling units with 2 smaller dedicated outdoor air units, there is now a large amount of empty space in the mezzanine floor. The next phase in the redesign addresses the relocation of the 6 air handling units for the supply center to the large open flat roof. This directly affects the roof structure, and the cost of not having to buy and construct the mezzanine floor is added into the overall redesign cost savings.

Figure 10-1 illustrates where the elevated mechanical mezzanine room is located within the supply center. There are four main areas that housed the air handling units on this mezzanine floor. They are all connected to each other with elevated cross walks.

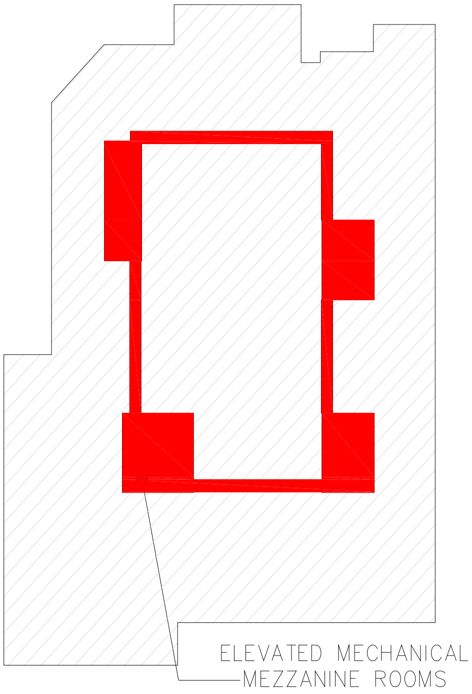

Figure 10-1 Elevated Mechanical Mezzanine Room Location

10.1 AHU RELOCATION STRUCTURAL IMPACT

The roofing of the supply center consists of a flat center core that is located directly above the kitchen and bakery portions of the supply center. The roof over the mezzanine floor is part of a higher, sloped perimeter roof. Figure 10-2 is the Architect's rendering of the supply center. The figure illustrates the high sloped portion of the roof that is above the mezzanine room.

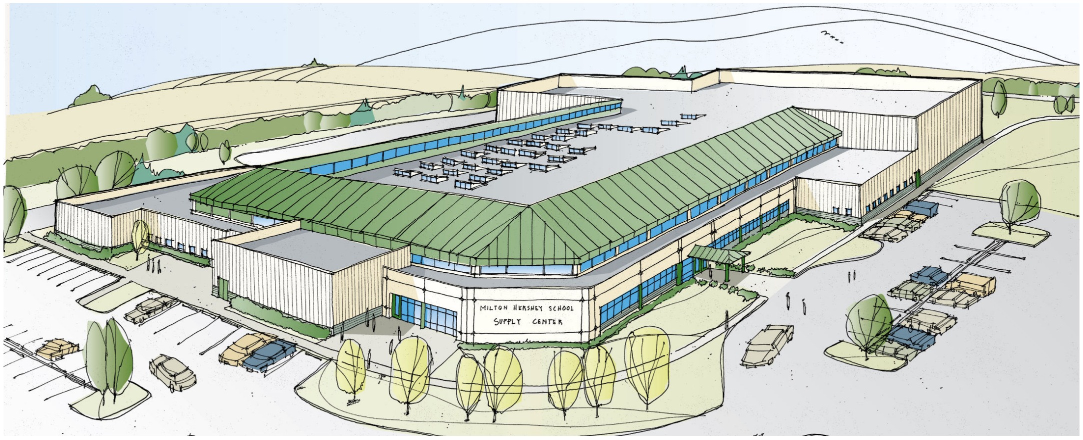

Figure 10-2 Architectural Rendering Illustrating Roofing

This high roof is important because it creates a visual boundary from ground level. The flat center core portion of the roof, where the air handling units are relocating, is hidden by this high roof. Therefore, any mechanical equipment on the roof does not alter the architecture of the building. There are also 21 skylight windows located on this flat portion of the roof. The air handlers' relocation must take the position of these windows into consideration so not to disrupt any natural light entering the building. Figure 10-3 is the roof plan of the supply center that clearly shows the exact location of the flat roof and the skylight windows. The six air handlers that are relocated are also shown in the figure.

The blue air handlers represent the 4 existing units that are serving the kitchen, bakery, and loading docks. The red air handlers are the new dedicated outdoor air units. The locations of the air handlers are carefully placed so that they are not within 15 feet of the general building exhaust fans (shown in magenta). The hatched area represents the finished metal paneling that is attached to the sloped high roof. Also seen on the roof plan are the skylight windows. Each window is 10'x10' and provides natural light to the kitchen and bakery spaces since they are interiorly located.

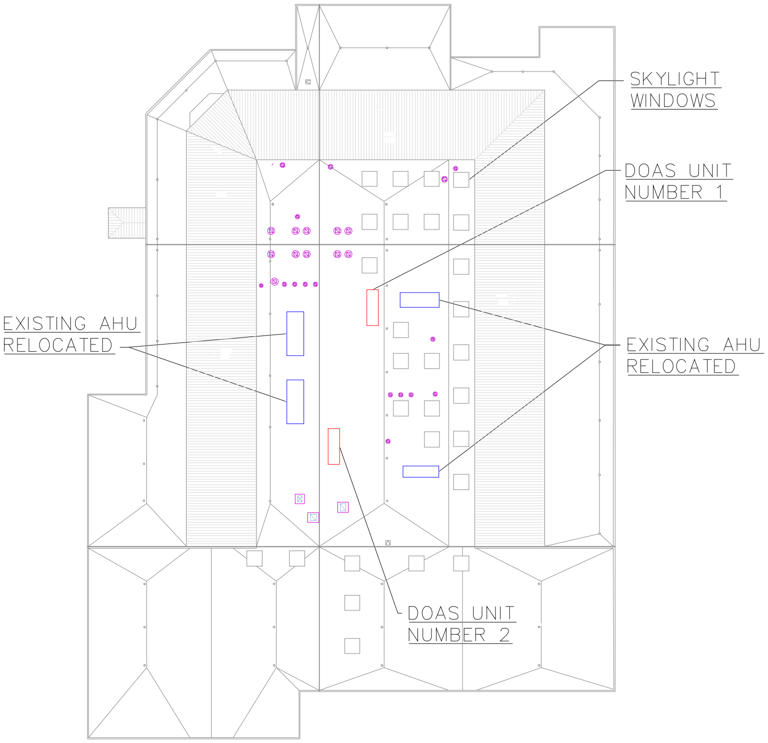

Figure 10-3 Relocated AHU Roof Plan

The next phase of this relocation process is to analyze the impact of the additional weight on the roof structure. Using RAM Structural System software and the structural design documents provided by H.F. Lenz Company and engineered by Barry Isett and Associates, Inc., the flat roof portion of the structural system is modeled.

The loads from the AHUs are inserted into the program at the appropriate locations, and the software calculates any changes required to the existing structure. The existing structure consists of steel columns supporting steel beams that frame out the structural grid. K-series steel joist carry the roof loads to the beams and columns in the open areas of the roof. The area's containing skylight windows consists of W-flanged steel beams framing the opening with K-series joist handling the remaining roof load.

Figure 10-4 is the RAM model used for the calculations. The blue lines represent the steel joist, and the dark green represent the steel beams.

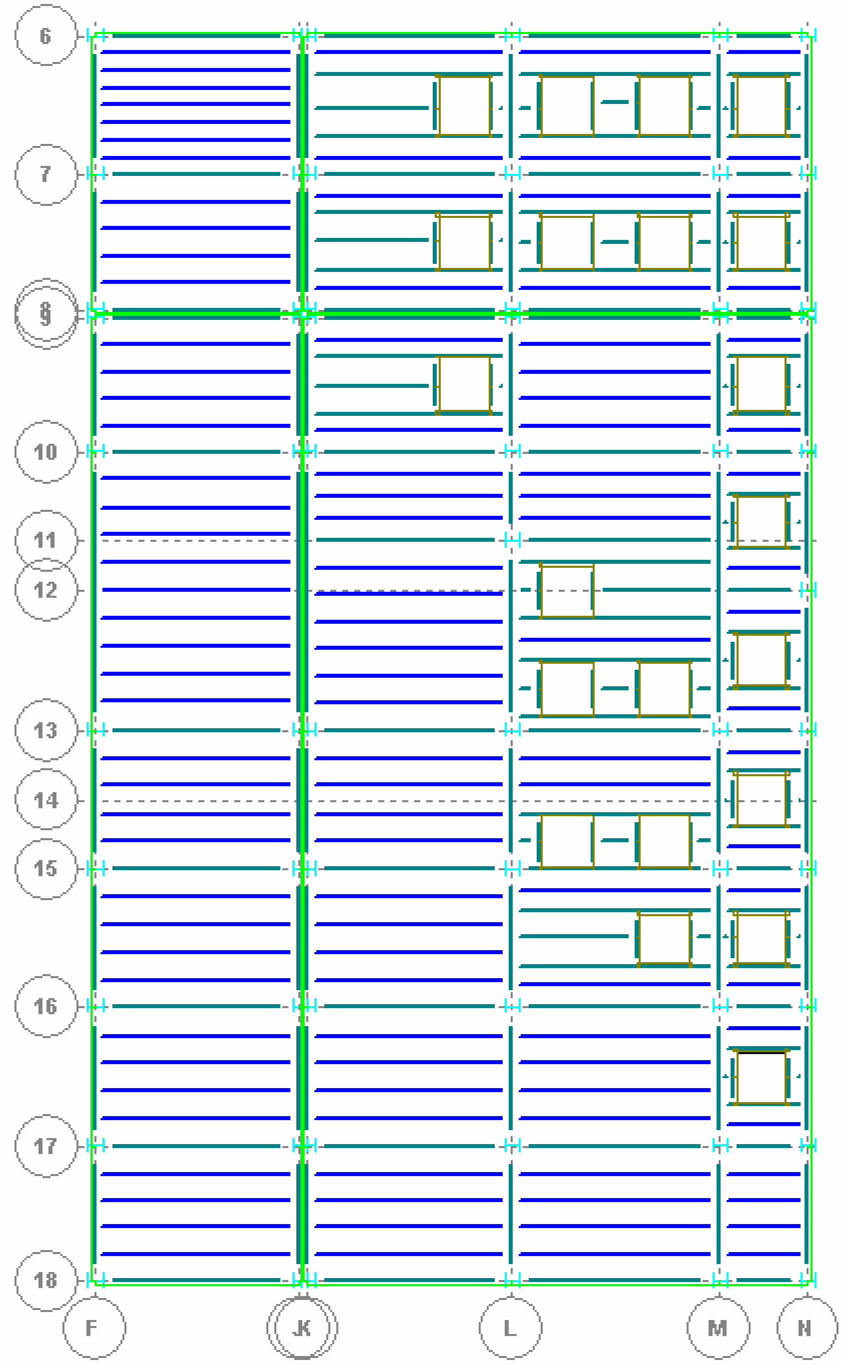

Figure 10-4 Existing Roof Structural System

Figure 10-5 is a 3-D view of the structural system. The figure showcases the open-web steel joist connecting to the W-flanged steel beams.

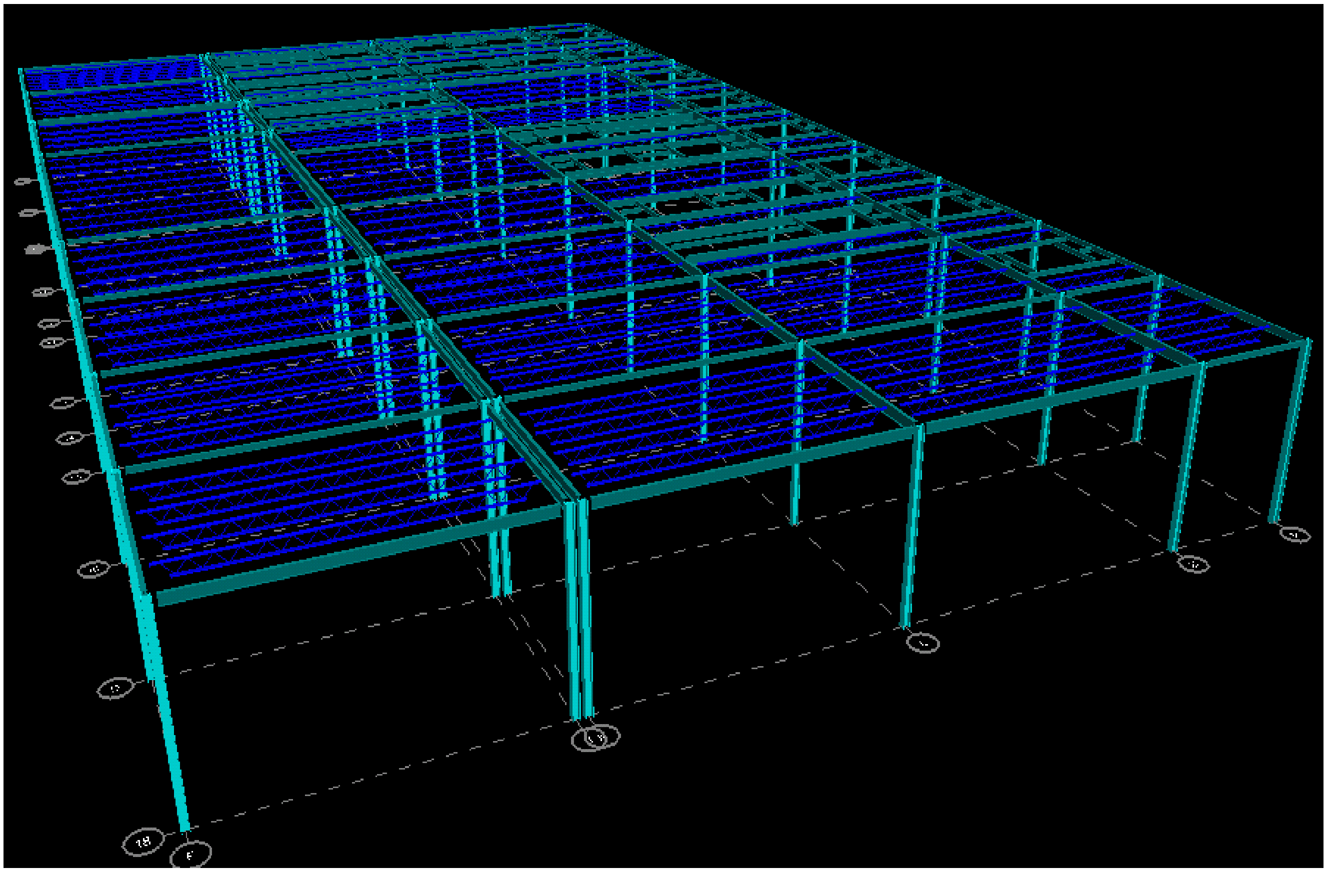

Figure 10-5 3-D View of Structural System

The air handling units are then placed in the appropriate locations as shown in figure 10-3. Table 10-1 outlines the operating weights for each air handling unit. The structural software then recalculates the loads on the each of the steel members.

Table 10-1 AHU Operating Weights

AHU 1	AHU 2	AHU 6	AHU 8	DOAS 1	DOAS 2
11,125 lbs	11,125 lbs	6,404 lbs	5,989 lbs	4,000 lbs	4,700 lbs

The resulting load calculations on the roof structure indicate that the open web K-series joist do not have the capacity to support the additional weight. Therefore, these joists are replaced with W-flanged steel beams. Figure 10-6 illustrates the portions of the structure that fail from the AHU relocation.

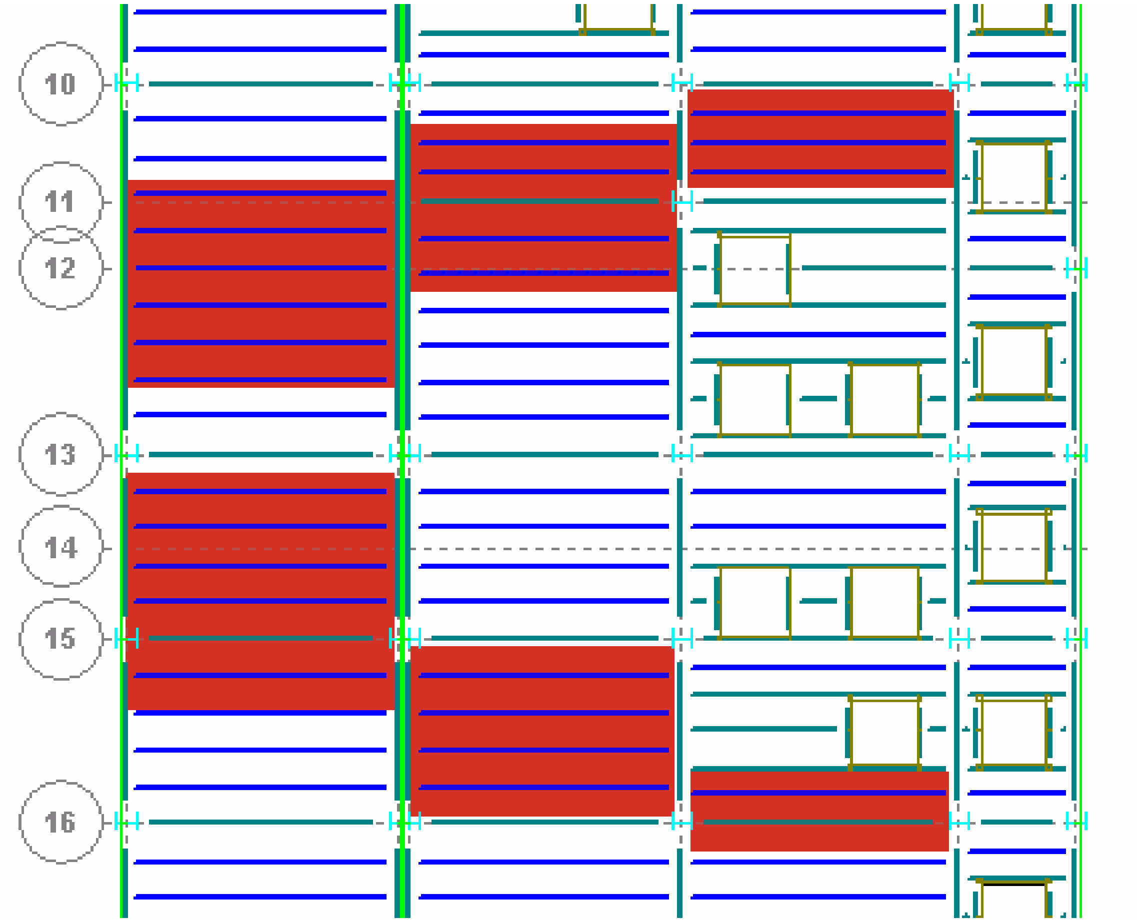

Figure 10-6 Failed Joist to Replace

The RAM program resizes all of the new steel beams and recalculates the self weight of the new structure. The existing beams create the structural bays with the columns are not affected by the changes. These beams along with their respectful columns are already sized large enough to handle the additional load. Therefore, the only adjustments required are deal with the joists.

10.2 STRUCTURAL SYSTEM ALTERATION COST ANALYSIS

The additional cost of upgrading the roof structure from relocating the six air handling units is now calculated. There is no real pay back or benefit to this relocation process until the cost of constructing the elevated mezzanine floor is calculated. Moving the AHUs to the roof is beneficial if the additional cost of roof structural changes is offset by the cost savings of not building the elevated mezzanine floor.

Since the roofing structure is built regardless of the results of this study, the material cost of the K-series joists and the W-flanged beams are in question. The cost to construct is not a factor for this portion of the analysis. The structural system alteration just involves the replacement of 22 joists with more expensive beams. The economic analysis on the cost to construct the mezzanine floor includes labor and equipment as well as the material cost. The overall study focuses on the cost savings from not having to completely construct the mezzanine floor, therefore requires a more detailed estimate.

Table 10-2 illustrates the additional cost of replacing the K-series joists with W-flanged beams. The table indicates that it is only approximately $300 more expensive than the existing structure. This is almost meaningless in the grand picture of the total project cost.

Table 10-2 Structural Alteration Additional Cost

BEAM/JOIST	LENGTH	AMOUNT	$COST/LF	TOTAL COST
28KCS5	37	14	11	$5,698
26K7	37	8	6.35	$1,879.6
			JOIST TOTAL COST	$7,577.6
W 8x10	37	22	9.65	$7,855.1
			Difference	**$277.5**

10.3 ELEVATED MEZZANINE FLOOR ELIMINATION COST ANALYSIS

The intent of the elevated mechanical mezzanine floor is to house the air side HVAC equipment for the supply center. The floor is constructed of structural steel beams and columns supporting a 4" thick 4000psi concrete floor. The entire floor, including its four connecting walkways is approximately 11,300 square feet.

The floor is a good size to house the 14 air handling units. However, the mechanical redesign requires only 6 AHUs to meet the demands. Building this large room for the redesigned mechanical system is a waste of resources and labor. Therefore, the AHUs are moved to the roof which previously did not have the space for all 14 units. The relocation of the AHUs creates a major cost savings opportunity.

The cost of constructing the structure consisting of 217 W-flanged steel beams supporting a 4" concrete floor with a metal roof deck is calculated to estimate the savings of relocating the AHUs. Table 10-3 illustrates the results from the detailed cost estimate. R.S. Means 2005 is used for the estimates, and the prices include material, equipment cost, and labor.

Table 10-3 Elevated Mezzanine Floor Construction Cost

	Total Construction Cost
Steel Members	$122,986.1
1-1/2" Steel Decking	$19,762.75
139 C.Y. of 4000psi Concrete	$11,709.6
TOTAL FLOOR COST	**$154,458.45**

The mechanical redesign proved to save yearly operational cost for the supply center. The redesign, however, affected the buildings structural system. The goal of integrating the mechanical system with other building systems is carried through in this portion of the study. The relocation of the air handling units to the roof structure is totally dependant on the replacement of 10 VAV air handling units with 2 DOAS units. The additive cost in supporting the extra weight on the roof structure is very small, and large cost savings are found in not constructing the mezzanine floor. The mechanical system redesign now sees a first cost savings of $154,000 to go along with its yearly energy cost savings when compared to its original design.

11.0 ELECTRICAL BREADTH: POWER REQUIREMENTS FOR MECHANICAL REDESIGN

The replacement of many electric driven pieces of mechanical equipment with direct fired equipment changes the power requirements for the Milton Hershey School New Supply Center. The air handling units that are replaced with DOAS units also are removed from the electrical panels.

The main distribution panel (MDP) and four other distribution panels are affected by the mechanical work, and the motor control center, which included the electrical requirements for the boilers and chillers is also affected. Added to the distribution panels are the fans for the DOAS units as well as a new panel board that includes the water source heat pumps. The new water source heat pump panel is a 3 phase 480/277V panels that is branched off of one of the 480/277V distribution panels.

The changes of the electrical requirements result in more initial cost savings. Main feeder sizes are reduced from a lesser load on the distribution panels which saves in cost. The circuit breakers for the distribution panels also are smaller in certain cases. Appendix C illustrates all original distribution panels with the loads being removed highlighted. The appendix then shows the adjusted panels with the new calculated loads, wire sizes, and circuit breaker sizes. A side not on the MDP, the total KVA shown appears too high for its wire and circuit breaker size. This is because part of the MDP's load is handled by a diesel generator with its own circuit breaker.

Table 11-1 illustrates the cost of adding the new equipment (WSHPs and DOAS units) and table 11-2 indicates the cost savings created from removing the existing electric driven mechanical equipment.

Table 11-1 Additional Electrical Wiring Cost

ADD ON	Cost per 100 LF	Length (ft)	Total Cost $
(3) #10 & 1#10 GD	229	20	45
(4) # 350 kcmil	2650	65	1722
(3) #6 1#8 GD	379	60	227
(4) #400 kcmil	3000	65	1950
(3) #10 1#10	229	20	45
3 sets of (4) #300 kcmil	9000	15	1350
3#10 & 1#10 GRD	229	30	68
3#12 & 1#12 GRD	137	30	41
3#12 & 1#12 GRD	137	30	41
3#12 & 1#12 GRD	137	30	41
		Total	**$5,534**

Table 11-2 Electrical Wiring Cost Savings

TAKE OFF	Cost per 100 LF	Length (ft)	Total Cost
(3) #8 & 1#10 GD	318	20	$64
(3) #8 1#10 GD	318	20	$64
(3) #10 1#10 GD	229	20	$46
(3) #10 1#10 GD	229	20	$46
(3) #12 1#12 GD	137	20	$27
(3) #10 1#10 GD	229	20	$46
(3) #10 1#10 GD	229	20	$46
(3) #8 1#8 GD	385	20	$77
(3) #10 1#10 GD	229	20	$46
(3) #8 & 1#10 GD	318	20	$64
(4) #500 kcmil	3625	65	$2,356
(4) #500 kcmil	3625	65	$2,356
(3) #12 1#12 GD	137	20	$27
(3) #12 1#12 GD	137	20	$27
(3) #8 1#10	318	20	$64
(3) #10 1#10	229	20	$46
3 sets of (4) #500 kcmil	10875	15	$1,631
3#10 & 1#10 GRD	229	30	$69
3#12 & 1#12 GRD	137	30	$41
3#10 & 1#10 GRD	229	30	$69
3#12 & 1#12 GRD	137	30	$41
3#10 & 1#10 GRD	229	30	$69
3#12 & 1#12 GRD	137	30	$41
3 # 400kCMIL & 1#3 GRD	2400	30	$720
3 # 400kCMIL & 1#3 GRD	2400	30	$720
3 #2 & 1 #6 GRD	647	30	$194
3 #2 & 1 #6 GRD	647	30	$194
		Total	**$9,189**

The total cost savings on the electrical side of the project from the mechanical system redesign is approximately $3,600. The mechanical system redesign proves to integrate and affect most building systems at the supply center. However, after analyzing the structural system, electrical system, the construction process, and all forms of the mechanical system, the overall project sees cost savings in all categories.

12.0 CONCLUSIONS AND RECOMMENDATIONS

The redesign of the Milton Hershey School New Supply Center's mechanical system met all of its design criteria. The redesign, from a mechanical systems standpoint, has a higher initial cost than the existing system, however, the annual operating cost for the redesign is lower. When looked at over 20 years, the redesign saves over $376,000 and pays itself back in less than 2 years.

Most importantly, the redesign kept to the design goal of building system integration. Mechanically, the redesign takes the hot water, chilled water, and walk-in-freezer condenser water, and domestic hot water systems and integrates them through energy recovery techniques and direct fired absorption chiller-heaters. The DOAS with water source heat pumps configuration also aids in building system integration scheme. Using this method of space conditioning integrates the new water source loop with the condenser water heat recovery system.

The redesigned mechanical system also affects other buildings systems, and further integrates them in the overall project. Replacing the VAV air handling units with dedicated outdoor air units saves on first cost, but also paves the way for structural and construction work. Relocating the remaining 6 air handling units from the steel and concrete elevated mezzanine room to the roof requires structural system adjustments, but also saves in first cost. Not having to construct the 11,000 square foot mezzanine floor saves on first cost, and that completely covers the additional cost of upgrading the roof structural system. When analyzed, the relocation of the air handling units saves approximately $150,000 of initial cost.

The redesigned mechanical system included replacing 10 electric driven VAV supply fans with 2 dedicated outdoor air system fans. Also, the electric driven vapor compression chillers are replaced with natural gas fried absorption chillers. This affects the power requirements at the supply center and the electrical breadth analyzes the effected distribution panels. Small cost savings are found in the electrical wiring work as well.

Table 12-1 indicates the overall project initial cost and 20 year life cycle cost when the structural and construction breadth topics are merged with the mechanical work. The electrical breadth's cost savings are very small relative to the other topics and therefore ignored in this comparison.

Table 12-1 Total Project Cost Analysis

	EXISTING SYSTEM	REDESIGN SYSTEM
Mechanical	$622,840	$682,885
Structural/Construction	$154,458	$288
Total First Cost	$777,298	$683,173
20 Year Life Cycle Cost	$3,043,808	$2,512,748
20 Year LCC Difference	**+$531,060**	

Table 12-1 illustrates that the overall project redesign saves approximately $530,000 over a 20 year life cycle. Since the overall project redesign is also less expensive than the existing system, no payback period is required for analysis. Therefore, since savings are found in energy, initial cost, operating cost, and the lowest 20 year life cycle cost is calculated, the total redesign is beneficial for the Milton Hershey School New Supply Center.

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APPENDIX A – ASHRAE STANDARD 62.1 VENTILATION CALCULATIONS

AHU - 1	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Prep Area	5910	8	7.5	0.18	60	1063.8	1124	22000	22000	11000	0.10	1	1	1								
															8	1	1124	22000	0.05	0.10	1	1123.8

AHU - 2	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Dishwasher	405	3	7.5	0.18	22.5	72.9	95.4	1370	1370	685	0.14	1	1	1								
Pot Wash	383	3	7.5	0.18	22.5	68.9	91.4	1380	1380	690	0.13	1	1	1								
Storage	2000	3	7.5	0.18	22.5	360	383	10990	10990	5495	0.07	1	1	1								
Insulated Container Storage	1884	4	0	0.12	0	226	226	8260	8260	4130	0.05	1	1	1								
															13	1	795	22000	0.04	0.14	1	795

AHU - 3	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Dining	1213	100	7.5	0.18	750	218	968	1800	1800	1800	0.54	1	1	1								
Decoration Storage	96	0	0	0.12	0	11.5	11.5	75	75	40	0.29	1	1	1								
Women's Toilet	186	0	0	0.5	0	93	93	200	200	200	0.47	1	1	1								
Men's Toilet	172	0	0	0.5	0	86	86	200	200	200	0.43	1	1	1								
Storage	233	0	0	0.12	0	28	28	75	75	75	0.37	1	1	1								
Office 108	174	2	5	0.06	10	10.4	20.4	250	250	125	0.16	1	1	1								
Office 110	150	2	5	0.06	10	9	19	250	250	125	0.15	1	1	1								
Work Area 111	297	3	5	0.06	15	17.8	32.8	125	125	62.5	0.53	1	1	1								
Work Room 112	132	3	5	0.06	15	7.92	22.9	250	250	125	0.18	1	1	1								
Waiting 114	155	3	5	0.06	15	9.3	24.3	225	225	115	0.21	1	1	1								
Reception 113	160	2	5	0.06	10	9.6	19.6	250	250	125	0.16	1	1	1								
Lobby 115	315	2	5	0.06	10	18.9	28.9	312	312	156	0.19	1	1	1								
Waiting	169	3	5	0.06	15	10.1	25.1	100	100	75	0.34	1	1	1								
Reception	160	2	5	0.06	10	9.6	19.6	250	250	125	0.16	1	1	1								
Work Room	132	2	5	0.06	10	7.92	17.9	250	250	125	0.14	1	1	1								
Conference	244	10	5	0.06	50	14.6	64.6	450	450	225	0.29	1	1	1								
Work Area	516	3	5	0.06	15	31	46	250	250	125	0.37	1	1	1								
Office 123	152	2	5	0.06	10	9.12	19.1	250	250	125	0.15	1	1	1								
Office 124	175	2	5	0.06	10	10.5	20.5	250	250	125	0.16	1	1	1								
Office 125	228	2	5	0.06	10	13.7	23.7	250	250	125	0.19	1	1	1								
Servery	969	10	5	0.06	50	58.1	108	850	850	551	0.20	1	1	1								
Training	612	15	10	0.12	150	73.4	223	600	600	600	0.37	1	1	1								
Entry	105	0	0	0.06	0	6.3	6.3	75	75	50	0.13	1	1	1								
Corridor	2280	0	0	0.06	0	137	137	988	988	500	0.27	1	1	1								
Storage	114	0	0	0.12	0	13.7	13.7	175	175	90	0.15	1	1	1								
Office 144	96	1	5	0.06	5	5.76	10.8	175	175	90	0.12	1	1	1								
Office 145	96	2	5	0.06	10	5.76	15.8	175	175	90	0.18	1	1	1								
															171	1.00	1956.98	9100	0.22	0.53	0.6	3215

AHU - 4	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Janitor/Storage Storage	245	0	0	0.12	0	29.4	29.4	275	275	140	0.21	1	1	1								
Washer/Dryer Room	166	2	7.5	0.06	15	9.96	25	375	375	190	0.13	1	1	1								
Catering Storage	381	4	0	0.12	0	45.7	45.7	235	235	120	0.38	1	1	1								
Corridor	1060	0	0	0.06	0	63.6	63.6	300	300	150	0.42	1	1	1								
Custodial	726	0	0	0.12	0	87.1	87.1	450	450	225	0.39	1	1	1								
It	305	2	10	0.12	20	36.6	56.6	1680	1680	1680	0.03	1	1	1								
Break Room	895	12	7.5	0.18	90	161	251	900	900	500	0.50	1	1	1								
Mail Room	1235	6	5	0.06	30	74.1	104	930	930	465	0.22	1	1	1								
Insulated Container Washing	950	4	7.5	0.18	30	171	201	1500	1500	750	0.27	1	1	1								
Mens Locker Room	839	10	0	0.5	0	420	420	800	800	800	0.52	1	1	1								
Womens Locker Room	817	12	0	0.5	0	409	409	800	800	800	0.51	1	1	1								
Office	160	2	5	0.06	10	9.6	19.6	210	210	105	0.19	1	1	1								
Transportation Team Room	530	6	7.5	0.06	45	31.8	76.8	800	800	400	0.19	1	1	1								
Dispatcher	116	2	5	0.06	10	6.96	17	200	200	100	0.17	1	1	1								
															62	1.00	1817	9455	0.19	0.52	0.6	3008

AHU - 5	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Washing Area	110	1	0	0.5	0	55	55	250	250	250	0.22	1	1	1								
Recycling	1556	1	0	0.5	0	778	778	3000	3000	3000	0.26	1	1	1								
															2	1	833	3250	0.26	0.26	0.8	1041

AHU - 6	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Delivery	9063	12	0	0.12	0	1088	1088	13195	13195	6600	0.16	1	1	1								
Storage	177	0	0	0.12	0	21.2	21.2	135	135	70	0.30	1	1	1								
Storage	201	0	0	0.12	0	24.1	24.1	170	170	85	0.28	1	1	1								
															12	1	1133	13500	0.08	0.30	0.8	1416

AHU - 7	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Order Assembly/Storage	1351	4	0	0.12	0	162	162	1500	1500	750	0.22	1	1	1								
Corridor	3931	0	0	0.06	0	236	236	2400	2400	1200	0.20	1	1	1								
Catering/Storage	570	4	7.5	0.18	30	103	133	900	900	450	0.29	1	1	1								
Passage	300	0	0	0.06	0	18	18	200	200	100	0.18	1	1	1								
															8	1	549	5000	0.11	0.29	0.8	686

AHU - 8	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Bakery 169	1610	6	7.5	0.18	45	290	335	7400	7400	3700	0.09	1	1	1								
															6	1	335	7400	0.05	0.09	1	335

AHU - 9	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Kitchen Dry Storage	890	4	0	0.12	0	107	107	1005	1005	505	0.21	1	1	1								
Dry Storage	6250	4	0	0.12	0	750	750	4545	4545	2275	0.33	1	1	1								
Storage	721	0	0	0.12	0	86.5	86.5	450	450	225	0.38	1	1	1								
															8	1	943	6000	0.16	0.38	0.7	1348

AHU - 10	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Office 127	157	2	5	0.06	10	9.42	19.4	175	175	90	0.22	1	1	1								
Alterations	2535	8	7.5	0.12	60	304	364	2680	2680	1340	0.27	1	1	1								
Work Room	290	6	5	0.06	30	17.4	47.4	350	350	175	0.27	1	1	1								
Girls Fitting	100	6	7.5	0.06	45	6	51	180	180	100	0.51	1	1	1								
Boys Fitting	100	6	7.5	0.06	45	6	51	180	180	100	0.51	1	1	1								
Clothing	350	4	7.5	0.12	30	42	72	1955	1955	980	0.07	1	1	1								
Clothing Storage	863	6	7.5	0.12	45	104	149	1000	1000	500	0.30	1	1	1								
Used Clothing	350	4	7.5	0.12	30	42	72	400	400	200	0.36	1	1	1								
Corridor	385	0	0	0.06	0	23.1	23.1	580	580	290	0.08	1	1	1								
															42	1	849	7500	0.11	0.51	0.6	1414

AHU - 11	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
IT	285	2	10	0.12	20	34.2	54.2	1605	1605	805	0.07	1	1	1								
Year Round Experience	640	4	7.5	0.06	30	38.4	68.4	600	600	300	0.23	1	1	1								
Laundry	432	2	7.5	0.06	15	25.9	40.9	900	900	450	0.09	1	1	1								
Program Support Inventory	1064	4	0	0.12	0	128	128	2140	2140	1070	0.12	1	1	1								
Corridor	1051	0	0	0.06	0	63.1	63.1	900	900	450	0.14	1	1	1								
															12	1	354	6145	0.06	0.23	0.9	394

AHU - 12	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Storage	1094	6	0	0.06	0	65.6	65.6	1500	1500	750	0.09	1	1	1								
Mezzanine Storage	7182	6	0	0.06	0	431	431	4820	4820	2410	0.18	1	1	1								
Clothing	3266	4	7.5	0.12	30	392	422	4530	4530	2265	0.19	1	1	1								
															12	1	497	10850	0.05	0.19	0.9	552

AHU - 13	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Receiving	5810	6	0	0.12	0	697	697	5625	5625	2812	0.25	1.00	1.00	1								
General Building Storage	1660	4	0	0.12	0	199	199	1875	1875	938	0.21	1.00	1.00	1								
															10	1	896	7500	0.12	0.25	0.9	996

AHU - 14	Az	Pz	Rp	Ra	Pz*Rp	Az*Ra	Voz	Vpz	Vdz	Vdzm	Zp	Fa	Fb	Fc	Ps	D	Vou	Vps	Xs	Zp(max)	Ev	Vot
Household Goods Storage	4850	2	0	0.12	0	582	582	6500	6500	3250	0.18	1	1	1								
															2	1	582	6500	0.09	0.18	0.9	647

APPENDIX B – COST ANALYSIS SPREADSHEETS

	Initial Cost	
		Redesign
	Existing System	Chiller-Heater Option
Chillers	178000	
Chiller-Heaters		298000
HVAC Boiler	21800	
HW Boiler	61000	
Supplemental Boiler		85000
Heat Exchangers	10000	
DOAS AHUs		47840
VAV AHUs	309310	
Plate-Frame HX	10000	20000
VAV Boxes w/reheat	32730	
Heat Pumps		80045
TOTAL	**622840**	**530885**

		Operating Cost Present Worth	
			Redesign
I =	0.06	Existing System	Chiller-Heater Option
	yr 0	0	0
	yr 1	209461	169108
	yr 2	209461	169108
	yr 3	209461	169108
	yr 4	209461	169108
	yr 5	209461	169108
	yr 6	209461	169108
	yr 7	209461	169108
	yr 8	209461	169108
	yr 9	209461	169108
	yr 10	209461	169108
	yr 11	209461	169108
	yr 12	209461	169108
	yr 13	209461	169108
	yr 14	209461	169108
	yr 15	209461	169108
	yr 16	209461	169108
	yr 17	209461	169108
	yr 18	209461	169108
	yr 19	209461	169108
	yr 20	209461	169108
	NPW	$2,266,510.54	$1,829,863.62

Mezzanine Floor Structural Cost Analysis				
Beam	**Length (ft)**	**Amount**	**$Cost/LF**	**Total Cost $**
W 24x55	36	19	53	36252
	25	2	53	2650
	43	1	53	2279
W 16x26	15	1	25	375
	7	2	25	350
	25	16	25	10000
	10	4	25	1000
	12.5	1	25	312.5
W 21x44	36	10	42.5	15300
	25	1	42.5	1062.5
	37.5	2	42.5	3187.5
W 8x10	7	85	9.65	5741.75
	2	9	9.65	173.7
	4	2	9.65	77.2
	8	2	9.65	154.4
	5	6	9.65	289.5
W 12x16	23	2	14	644
	16	2	14	448
	7	1	14	98
W 14x22	25	26	23.5	15275
	12.5	2	23.5	587.5
W 27x84	50	2	81	8100
	36	1	81	2916
W 24x62	25	2	59.5	2975
W 18x40	25	1	38.5	962.5
W 21x57	25	1	56	1400
W 18x35	25	2	33.5	1675
W 14x30	25	12	29	8700
			Total Cost	**122986.1**

Concrete Slab Cost Analysis			
Metal Deck	SF	Cost/SF	Total Cost + Labor
	11,293	1.75	$19,762.75
Concrete	Cubic Yard	Cost/CY	Total Cost + Labor
	139.4	84	$11,709.6
		Total Cost	**$31,472.35**
	Total Mezzanine Cost		**$154,458.4**

APPENDIX C - ELECTRICAL PANEL ADJUSTMENTS

Existing panels

MAIN DISTRIBUTION SWITCHBOARD MDP ORIGIANAL

VOLTAGE: 480 / 277V Wire Size 6 sets of (4) #500 Kcmil
3 -Ph 4 -W in concrete cond

CKT #	ITEM SERVED	POLE	KVA	
1	MAIN CIRCUIT BKR 1	3		
2	MAIN CIRCUIT BKR 2	3		
3	DISTRIBUTION PANEL 'DPAH'	3	297.7299	
4	DISTRIBUTION PANEL 'DPBH'	3	626.7837	
5	DISTRIBUTION PANEL 'DPCH'	3	286.5893	
6	DISTRIBUTION PANEL 'DPDH'	3	307.6747	
7	MOTOR CONTROL CENTER 'MCC'	3	1249.737	
8	LIFE SAFETY DIST PANEL 'LSDP'	3	133	
9	EXTERIOR PANEL	3	26.4192	
10	SPARE	3	-	
11	SPARE	3	-	
12	SPARE	3	-	
13	SPARE	3	-	
14	SPARE	3	-	
15	SPACE W/ PROVISIONS	3	-	
16	SPACE W/ PROVISIONS	3	-	

Sum KVA 2927.934
I = KVA/√3*KV: 3521.757

DISTRIBUTION PANEL DPAH

VOLTAGE: 480 / 277V Wire Size (4) #500 Kcmil
3 -Ph 4 -W in 4" C

CKT #	ITEM SERVED	POLE	KVA	Wire Size
1	MAIN BKER - 400A	3		
2	PANEL 'BAH6'	3	35	(4) #6 1#8 GD
3	PANEL 'BAH7'	3	35	(4) #6 1#8 GD
4	112.5 KVA XFRMER	3	112.5	(3) #2/0 & 1#6 GD
5	AHU-1-SF (40 HP)	3	43.23199	(3) #6 & 1#6 GD
6	AHU-2-SF (40 HP)	3	43.23199	(3) #6 & 1#6 GD
7	AHU-3-SF (20 HP)	3	22.44738	(3) #8 & 1#10 GD
8	RF-2 (5 HP)	3	6.318521	(3) #12 & 1#12 GD
9	SPARE	3	-	-
10	SPARE	3	-	-
11	SPACE W/ PROVISIONS	-	-	-
12	SPACE W/ PROVISIONS	-	-	-
13	SPACE W/ PROVISIONS	-	-	-

Sum KVA 297.7299
I = KVA/√3*KV: 358.1134
CKT BKR: 400 A

DISTRIBUTION PANEL DPBH

VOLTAGE: 480 / 277V Wire Size 2 set of (4) #500 kcmil
3 -Ph 4 -W in 4" C each

CKT #	ITEM SERVED	POLE	KVA	Wire Size
1	MAIN BKER - 800 A	3		
2	NEW PANEL 'BBH2'	3	35	(4) #6 1#8 GD
3	NEW PANEL 'BBH4'	3	66.5	(4) #2 1#8 GD
4	NEW PANEL 'BBH5'	3	66.5	(4) #2 1#8 GD
5	NEW PANEL 'BBH7'	3	66.5	(4) #2 1#8 GD
6	300KVA XFRMER	3	300	2 set of (3) 4/0
7	AHU-4-SF (20 HP)	3	22.44738	(3) #8 1#10 GD
8	AHU-4-RF (10 HP)	3	11.63938	(3) #10 1#10 GD
9	AHU-6-SF(25 HP)	3	28.26707	(3) #8 1#8 GD
10	AHU-7-SF (10 HP)	3	11.63938	(3) #10 1#10 GD
11	AHU-7-RF (3 HP)	3	3.990645	(3) #12 1#12 GD
12	EF-19 (7.5 HP)	3	9.145228	(3) #10 1#10 GD
13	SPARE	3	-	
14	SPARE	3	-	
15	SPARE	3	-	
16	HWP-4 - 3/4HP	3	1.163938	(3) #12 1#12 GD
17	ERP-1 - 3HP	3	3.990645	(3) #12 1#12 GD
18	SPARE	3	-	
19	SPARE	3	-	
20	SPACE W/ PROVISIONS	-	-	
21	SPACE W/ PROVISIONS	-	-	

Sum KVA 626.7837
I = KVA/√3*KV: 753.9036
CKT BKR: 800 A

DISTRIBUTION PANEL DPCH				
VOLTAGE: 480 / 277V 3 -Ph 4 -W			Wire Size (4) #500 kcmil in 4" C	
CKT #	ITEM SERVED	POLE	KVA	Wire Size
1	MAIN BKER - 400A	3		
2	NEW PANEL 'BCH6'	3	35	(4) #6 1#8 GD
3	NEW PANEL 'BCH7'	3	35	(4) #6 1#8 GD
4	112.5KVA XFRMER	3	112.5	(3) #2/0 1#6 GD
5	AHU-9-SF (10 HP)	3	11.63938	(3) #10 1#10 GD
6	AHU-10-SF (15 HP)	3	17.45907	(3) #10 1#10 GD
7	AHU-10-RF (3 HP)	3	3.990645	(3) #8 1#8 GD
8	AHU-11-SF (15 HP)	3	17.45907	(3) #10 1#10 GD
9	AHU-12-SF (20 HP)	3	22.44738	(3) #8 & 1#10 GD
10	SF-1 (25 HP)	3	28.26707	(3) #8 1#8 GD
11	RF-1 (2 HP)	3	2.826707	(3) #8 1#8 GD
12	SPARE	3	-	
13	SPARE	3	-	
14	SPACE W/ PROVISIONS	-	-	
15	SPACE W/ PROVISIONS	-	-	

Sum KVA 286.5893
I = KVA/√3*KV: 344.7134
CKT BKR: 400 A

DISTRIBUTION PANEL DPDH				
VOLTAGE: 480 / 277V 3 -Ph 4 -W			Wire Size (4) #500 kcmil in 4" C	
CKT #	ITEM SERVED	POLE	KVA	Wire Size
1	MAIN BKER - 400A	3		
2	NEW PANEL 'BDH2'	3	20	(4) #6 1#8 GD
3	NEW PANEL 'BDH5'	3	20	(4) #6 1#8 GD
4	NEW PANEL 'BDH7'	3	50	(4) #2 1#8 GD
5	150KVA XFRMER	3	150	(3) #4/0 1#4 GD
6	AHU-5-SF (5 HP)	3	6.318521	(3) #12 1#12 GD
	AHU-5-EF (3 HP)	3	3.990645	(3) #12 1#12 GD
7	AHU-8-SF (15 HP)	3	17.45907	(3) #10 1#10
8	AHU-13-SF (20 HP)	3	22.44738	(3) #8 1#10
9	AHU-14-SF (15 HP)	3	17.45907	(3) #10 1#10
12	SPARE	3	-	
13	SPARE	3	-	
14	SPACE W/ PROVISIONS	-	-	
15	SPACE W/ PROVISIONS	-	-	

Sum KVA 307.6747
I = KVA/√3*KV: 370.0751
CKT BKR: 400 A

MOTOR CONTROL CENTER - MCC

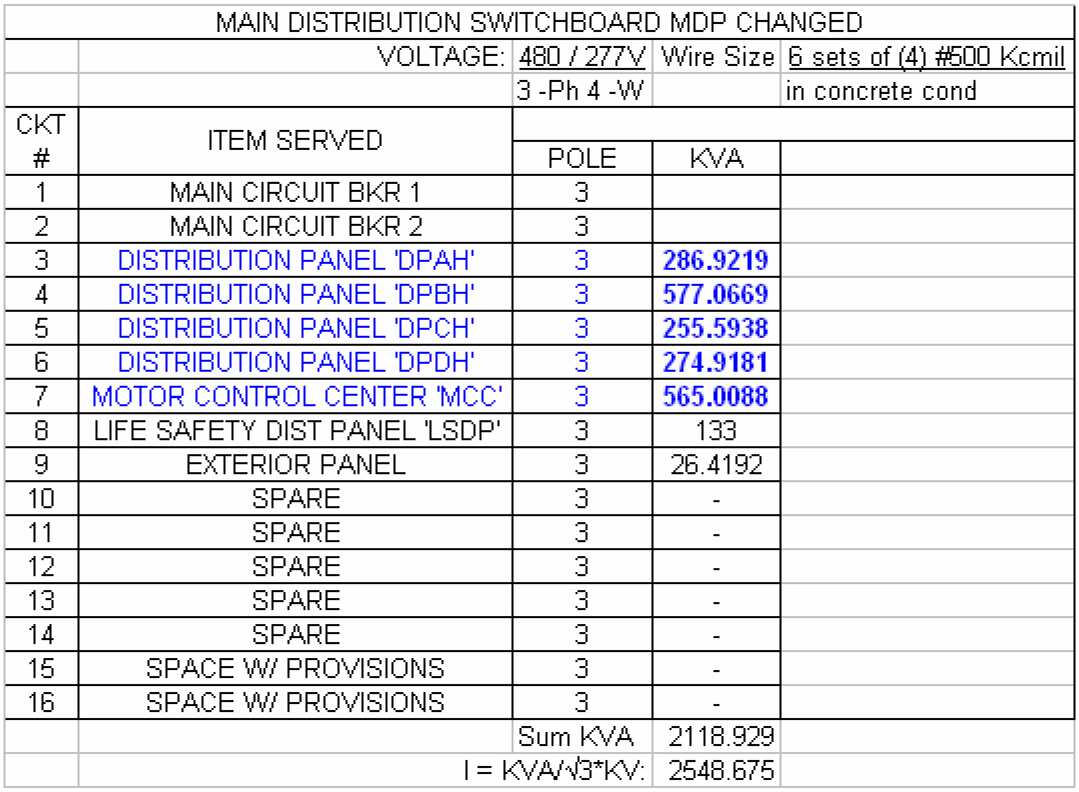
VOLTAGE: 480 / 277V BUSING : 1200 A
3 -Ph 4 -W

Wire Size 3 sets of (4) #500 kcmil
in 4" C each

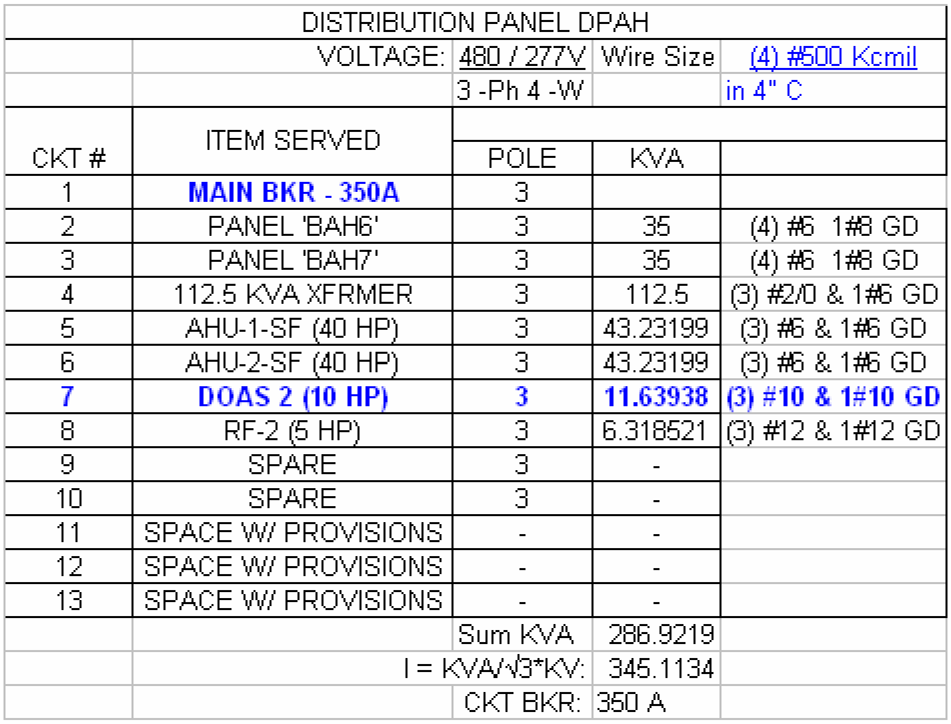
CKT #	ITEM SERVED	HP	VOLTAGE	AMPS	KVA	WIRE SIZE
1	Boiler BLR-1	15	480	21	17.45907214	3#10 & 1#10 GRD
2	BLR 1 COMB FAN	3	480	4.8	3.990645061	3#12 & 1#12 GRD
3	Boiler BLR-2	15	480	21	17.45907214	3#10 & 1#10 GRD
4	BLR 2 COMB FAN	3	480	4.8	3.990645061	3#12 & 1#12 GRD
5	Bolier BLR-3	10	480	14	11.63938143	3#10 & 1#10 GRD
6	BLR 3 COMB FAN	3	480	4.8	3.990645061	3#12 & 1#12 GRD
7	COOLING TOWER	25	480	34	28.26706918	3#8 & 1#8 GRD
8	SUMP HEATERS	-	480	33.7	28.01765386	3#8 & 1#10 GRD
9	COOLING TOWER	25	480	34	28.26706918	3#8 & 1#8 GRD
10	SUMP HEATERS	-	480	33.7	28.01765386	3#8 & 1#10 GRD
11	CHILLER CH-1	-	480	298	247.7525475	3 # 400kCMIL & 1#3 GRD
12	CHILLER CH-2	-	480	298	247.7525475	3 # 400kCMIL & 1#3 GRD
13	CHILLER CH-3	-	480	100	83.13843876	3 #2 & 1 #6 GRD
14	CHILLER CH-4	-	480	100	83.13843876	3 #2 & 1 #6 GRD
15	PUMP CHWP	40	480	52	43.23198816	3#6 & 1#6 GRD
16	PUMP CHWP	40	480	52	43.23198816	3#6 & 1#6 GRD
17	PUMP CHWP	10	480	14	11.63938143	3#10 & 1 # 10 GRD
18	PUMP CHWP	10	480	14	11.63938143	3#10 & 1 # 10 GRD
19	PUMP CHWP	10	480	14	11.63938143	3#10 & 1 # 10 GRD
20	PUMP CHWP	3	480	4.8	3.990645061	3#12 & 1 # 12 GRD
21	PUMP CHWP	3	480	4.8	3.990645061	3#12 & 1 # 12 GRD
22	PUMP CHWP	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
23	PUMP CHWP	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
24	COND PUMP	30	480	40	33.25537551	3#6 & 1 # 8 GRD
25	COND PUMP	30	480	40	33.25537551	3#6 & 1 # 8 GRD
26	COND PUMP	15	480	21	17.45907214	3#8 & 1 # 10 GRD
27	COND PUMP	15	480	21	17.45907214	3#8 & 1 # 10 GRD
28	COND PUMP	15	480	21	17.45907214	3#8 & 1 # 10 GRD
29	COND PUMP	3	480	4.8	3.990645061	3#12 & 1 # 12 GRD
30	COND PUMP	3	480	4.8	3.990645061	3#12 & 1 # 12 GRD
31	COND PUMP	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
32	COND PUMP	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
33	COND PUMP	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
34	COND PUMP	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
35	HW PUMP	40	480	52	43.23198816	3#6 & 1#6 GRD
36	HW PUMP	40	480	52	43.23198816	3#6 & 1#6 GRD
37	CTP PUMP	3	480	2.1	1.745907214	3#12 & 1 # 12 GRD
38	CTP PUMP	3	480	2.1	1.745907214	3#12 & 1 # 12 GRD
39	FWP PUMP	3	480	7.6	6.318521346	3#12 & 1 # 12 GRD
40	FWP PUMP	3	480	7.6	6.318521346	3#12 & 1 # 12 GRD
41	FWP PUMP	3	480	7.6	6.318521346	3#12 & 1 # 12 GRD
42	FAN SF-2	1	480	2.1	1.745907214	3#12 & 1 # 12 GRD
43	FAN SF-3	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
44	FAN EF-28	1	480	2.1	1.745907214	3#12 & 1 # 12 GRD
45	FAN EF-29	3	480	4.8	3.990645061	3#12 & 1 # 12 GRD

Sum KVA 1249.737011
I = KVA/√3*KV: 1503.2
CKT BKR: 1200 A

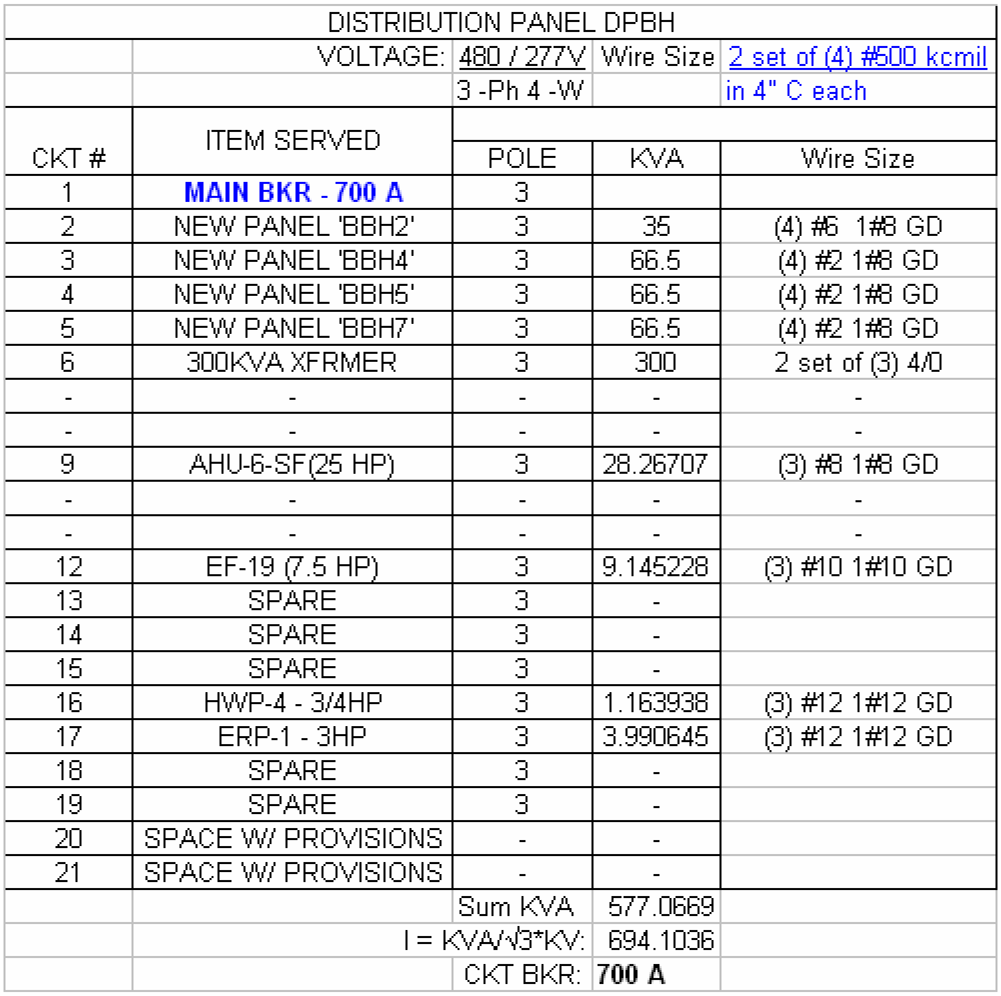
Altered Panels



MAIN DISTRIBUTION SWITCHBOARD MDP CHANGED				
	VOLTAGE:	480 / 277V	Wire Size	6 sets of (4) #500 Kcmil
		3 -Ph 4 -W		in concrete cond
CKT #	ITEM SERVED	POLE	KVA	
1	MAIN CIRCUIT BKR 1	3		
2	MAIN CIRCUIT BKR 2	3		
3	DISTRIBUTION PANEL 'DPAH'	3	**286.9219**	
4	DISTRIBUTION PANEL 'DPBH'	3	**577.0669**	
5	DISTRIBUTION PANEL 'DPCH'	3	**255.5938**	
6	DISTRIBUTION PANEL 'DPDH'	3	**274.9181**	
7	MOTOR CONTROL CENTER 'MCC'	3	**565.0088**	
8	LIFE SAFETY DIST PANEL 'LSDP'	3	133	
9	EXTERIOR PANEL	3	26.4192	
10	SPARE	3	-	
11	SPARE	3	-	
12	SPARE	3	-	
13	SPARE	3	-	
14	SPARE	3	-	
15	SPACE W/ PROVISIONS	3	-	
16	SPACE W/ PROVISIONS	3	-	
		Sum KVA	2118.929	
		I = KVA/√3*KV:	2548.675	



DISTRIBUTION PANEL DPAH				
	VOLTAGE:	480 / 277V	Wire Size	(4) #500 Kcmil
		3 -Ph 4 -W		in 4" C
CKT #	ITEM SERVED	POLE	KVA	
1	**MAIN BKR - 350A**	3		
2	PANEL 'BAH6'	3	35	(4) #6 1#8 GD
3	PANEL 'BAH7'	3	35	(4) #6 1#8 GD
4	112.5 KVA XFRMER	3	112.5	(3) #2/0 & 1#6 GD
5	AHU-1-SF (40 HP)	3	43.23199	(3) #6 & 1#6 GD
6	AHU-2-SF (40 HP)	3	43.23199	(3) #6 & 1#6 GD
7	**DOAS 2 (10 HP)**	3	**11.63938**	**(3) #10 & 1#10 GD**
8	RF-2 (5 HP)	3	6.318521	(3) #12 & 1#12 GD
9	SPARE	3	-	
10	SPARE	3	-	
11	SPACE W/ PROVISIONS	-	-	
12	SPACE W/ PROVISIONS	-	-	
13	SPACE W/ PROVISIONS	-	-	
		Sum KVA	286.9219	
		I = KVA/√3*KV:	345.1134	
		CKT BKR:	350 A	



DISTRIBUTION PANEL DPBH

	VOLTAGE:	480 / 277V	Wire Size	2 set of (4) #500 kcmil
		3 -Ph 4 -W		in 4" C each
CKT #	ITEM SERVED	POLE	KVA	Wire Size
1	**MAIN BKR - 700 A**	3		
2	NEW PANEL 'BBH2'	3	35	(4) #6 1#8 GD
3	NEW PANEL 'BBH4'	3	66.5	(4) #2 1#8 GD
4	NEW PANEL 'BBH5'	3	66.5	(4) #2 1#8 GD
5	NEW PANEL 'BBH7'	3	66.5	(4) #2 1#8 GD
6	300KVA XFRMER	3	300	2 set of (3) 4/0
-	-	-	-	-
-	-	-	-	-
9	AHU-6-SF(25 HP)	3	28.26707	(3) #8 1#8 GD
-	-	-	-	-
-	-	-	-	-
12	EF-19 (7.5 HP)	3	9.145228	(3) #10 1#10 GD
13	SPARE	3	-	
14	SPARE	3	-	
15	SPARE	3	-	
16	HWP-4 - 3/4HP	3	1.163938	(3) #12 1#12 GD
17	ERP-1 - 3HP	3	3.990645	(3) #12 1#12 GD
18	SPARE	3	-	
19	SPARE	3	-	
20	SPACE W/ PROVISIONS	-	-	
21	SPACE W/ PROVISIONS	-	-	
		Sum KVA	577.0669	
		I = KVA/√3*KV:	694.1036	
		CKT BKR:	**700 A**	

DISTRIBUTION PANEL DPCH				
	VOLTAGE:	480 / 277V	Wire Size	**(4) # 350 kcmil**
		3 -Ph 4 -W		**in 3" C**
CKT #	ITEM SERVED	POLE	KVA	
1	**MAIN BKER - 350A**	3		
2	NEW PANEL 'BCH6'	3	35	(4) #6 1#8 GD
3	NEW PANEL 'BCH7'	3	35	(4) #6 1#8 GD
4	112.5KVA XFRMER	3	112.5	(3) #2/0 1#6 GD
5	**WSHP NEW PANEL**	**3**	**42**	**(3) #6 1#8 GD**
-	-	-	-	
-	-	-	-	
-	-	-	-	
-	-	-	-	
10	SF-1 (25 HP)	3	28.26707	(3) #8 1#8 GD
11	RF-1 (2 HP)	3	2.826707	(3) #8 1#8 GD
12	SPARE	3	-	
13	SPARE	3	-	
14	SPACE W/ PROVISIONS	-	-	
15	SPACE W/ PROVISIONS	-	-	
		Sum KVA	255.5938	
		I = KVA/√3*KV:	307.4315	
		CKT BKR:	350 A	

DISTRIBUTION PANEL DPDH				
	VOLTAGE:	480 / 277V	Wire Size	**(4) #400 kcmil**
		3 -Ph 4 -W		**in 3" C**
CKT #	ITEM SERVED	POLE	KVA	Wire Size
1	**MAIN BKER - 350A**	3		
2	NEW PANEL 'BDH2'	3	20	(4) #6 1#8 GD
3	NEW PANEL 'BDH5'	3	20	(4) #6 1#8 GD
4	NEW PANEL 'BDH7'	3	50	(4) #2 1#8 GD
5	150KVA XFRMER	3	150	(3) #4/0 1#4 GD
6	**DOAS 1 FAN (15 HP)**	**3**	**17.45907**	**(3) #10 1#10**
-	-	-	-	
7	AHU-8-SF (15 HP)	3	17.45907	(3) #10 1#10
-	-	-	-	
-	-	-	-	
12	SPARE	3	-	
13	SPARE	3	-	
14	SPACE W/ PROVISIONS	-	-	
15	SPACE W/ PROVISIONS	-	-	
		Sum KVA	274.9181	
		I = KVA/√3*KV:	330.6751	
		CKT BKR:	350A	

MOTOR CONTROL CENTER - MCC						
	VOLTAGE:	480 / 277V		Wire Size	**3 sets of (4) #300 kcmil**	
		3 -Ph 4 -W			**in 3" C each**	
CKT #	ITEM SERVED					
		HP	VOLTAGE	AMPS	KVA	WIRE SIZE
1	**New Boiler BLR-1**	**15**	**480**	**21**	**17.45907214**	**3#10 & 1#10 GRD**
2	**New BLR 1 COMB FAN**	**3**	**480**	**4.8**	**3.990645061**	**3#12 & 1#12 GRD**
3	**New Chill-heat COMB FAN**	**-**	**480**	**8.5**	**7.066767295**	**3#12 & 1#12 GRD**
4	**New Chill-heat COMB FAN**	**-**	**480**	**8.5**	**7.066767295**	**3#12 & 1#12 GRD**
5	-	-	-	-	-	-
6	-	-	-	-	-	-
7	COOLING TOWER	25	480	34	28.26706918	3#8 & 1#8 GRD
8	SUMP HEATERS	-	480	33.7	28.01765386	3#8 & 1#10 GRD
9	COOLING TOWER	25	480	34	28.26706918	3#8 & 1#8 GRD
10	SUMP HEATERS	-	480	33.7	28.01765386	3#8 & 1#10 GRD
11	-	-	-	-	-	-
12	-	-	-	-	-	-
13	-	-	-	-	-	-
14	-	-	-	-	-	-
15	PUMP CHWP	40	480	52	43.23198816	3#6 & 1#6 GRD
16	PUMP CHWP	40	480	52	43.23198816	3#6 & 1#6 GRD
17	PUMP CHWP	10	480	14	11.63938143	3#10 & 1 # 10 GRD
18	PUMP CHWP	10	480	14	11.63938143	3#10 & 1 # 10 GRD
19	PUMP CHWP	10	480	14	11.63938143	3#10 & 1 # 10 GRD
20	PUMP CHWP	3	480	4.8	3.990645061	3#12 & 1 # 12 GRD
21	PUMP CHWP	3	480	4.8	3.990645061	3#12 & 1 # 12 GRD
22	PUMP CHWP	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
23	PUMP CHWP	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
24	COND PUMP	30	480	40	33.25537551	3#6 & 1 # 8 GRD
25	COND PUMP	30	480	40	33.25537551	3#6 & 1 # 8 GRD
26	COND PUMP	15	480	21	17.45907214	3#8 & 1 # 10 GRD
27	COND PUMP	15	480	21	17.45907214	3#8 & 1 # 10 GRD
28	COND PUMP	15	480	21	17.45907214	3#8 & 1 # 10 GRD
29	COND PUMP	3	480	4.8	3.990645061	3#12 & 1 # 12 GRD
30	COND PUMP	3	480	4.8	3.990645061	3#12 & 1 # 12 GRD
31	COND PUMP	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
32	COND PUMP	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
33	COND PUMP	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
34	COND PUMP	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
35	HW PUMP	40	480	52	43.23198816	3#6 & 1#6 GRD
36	HW PUMP	40	480	52	43.23198816	3#6 & 1#6 GRD
37	CTP PUMP	3	480	2.1	1.745907214	3#12 & 1 # 12 GRD
38	CTP PUMP	3	480	2.1	1.745907214	3#12 & 1 # 12 GRD
39	FWP PUMP	3	480	7.6	6.318521346	3#12 & 1 # 12 GRD
40	FWP PUMP	3	480	7.6	6.318521346	3#12 & 1 # 12 GRD
41	FWP PUMP	3	480	7.6	6.318521346	3#12 & 1 # 12 GRD
42	FAN SF-2	1	480	2.1	1.745907214	3#12 & 1 # 12 GRD
43	FAN SF-3	5	480	7.6	6.318521346	3#12 & 1 # 12 GRD
44	FAN EF-28	1	480	2.1	1.745907214	3#12 & 1 # 12 GRD
45	FAN EF-29	3	480	4.8	3.990645061	3#12 & 1 # 12 GRD
				Sum KVA	565.0088298	
			I = KVA/√3*KV:		679.6	
				CKT BKR:	700 A	