Technical Assignment #3

Mechanical Systems Existing Conditions Evaluation

The Gateway at MICA
Baltimore, MD

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Mechanical Option

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Executive Summary

This report is an in depth analysis of the mechanical system that will be in The Gateway at MICA. All the major parts of the system as well as the operation of the system were looked at and explained in this report.

In order to properly analyze the system background information was gathered and looked at. The information looked at were design factors such as location and cost, energy providers and costs of the site and the design objectives of the project team. The design conditions were also considered.

All major equipment in the building was analyzed as well. Schedules were created for the equipment and operation procedures were studied. After this was accomplished schematics of the water side systems were created and are explained in this report as well.

The system operation procedure is explained in detail in this report. In doing this, how the equipment functions, how it is interfaced with other equipment, and controls as well as the building automation system were looked at.

Overall it was found that the design of the mechanical system in The Gateway at MICA is very reasonable and there is little room for improvement. A few changes could be made that might result in some savings in either initial cost or long term cost, but analyses will have to be performed in order to determine this.

Mechanical System Summary

The air-side system of The Gateway at MICA consists of four, 100% outdoor air economizing, draw thru AHUs. Three of the AHUs are located in the third floor mechanical room while the fourth is in the 10th level penthouse. The three units in the mechanical room service spaces on the first two levels of the building, while the penthouse unit serves the studio space on each floor of the student living level.

AHU-1 serves the public spaces and rooms on level one and two including some parts of the lobby, the café, conference rooms, offices, and other various spaces throughout levels one and two. This unit has a supply max of 14,500 cfm and supply min of 6,000 cfm. The outside air max and min are 14,500 cfm and 2,900 cfm respectively.

AHU-2 serves the multi-purpose performance space including the booth as well as the facilities office. AHU-2 has a supply maximum and minimum of 9,600 cfm and 4,000 cfm respectively. The multi-purpose space is roughly 3,100 ft^2 and located in the center of the building plan. This space is a double height space with a monitoring booth at one of the room on the second level which is also serviced by AHU-2.

AHU-3 provides air for the lobby/pre-function space and the gallery as well. This is the only constant volume AHU in The Gateway at MICA. The gallery is a single height space just inside the main entrance of the building. This space opens to the lobby/pre-function space which is a double height space. The total floor area for these spaces is roughly 3,600 ft^2. The supply maximum and minimum of AHU-3 is 12,000 cfm and 5,000 cfm respectively. The outdoor air maximum is 12,000 cfm and the minimum is 3,200 cfm.

AHU-4 serves the studio spaces on level three through nine. These seven spaces each have an area of 848 ft^2 and are provided for the students to do work without having to leave their living quarters. The maximum supply and outdoor air for this unit is 11,600 cfm while the minimum supply and outdoor air is 7,000 cfm.

All spaces supplied by AHU-1, AHU-2, and AHU-3 are have terminal units equipped with water-side reheat coils to condition the air as per the requirements of that spaces occupants.

All student apartments on level three through nine have operable windows so the only air-side component of the system on these levels is the exhaust fans for the bathrooms. Each room is equipped with its own water source fan coil unit (FCU) to circulate and condition air. The building was originally designed as a four pipe system so each FCU operates independently and can either heat or cool year round, however, due to value engineering it will be constructed as a two-pipe system.

All of the water side equipment is located in the tenth level penthouse. There are two boilers and two air cooled chillers. The two air cooled screw chillers are identical and each provide 200 tons of cooling capacity. The chilled water system is regulated by two 380 GPM end suction pumps with a third 380 GPM standby pump. The boilers are also identical and controlled by one control panel. The cast iron boilers are used for heating purposes and each have a minimum output of 1632 MBH and are regulated by two 150 GPM pumps.

Each stairwell is pressurized with outdoor air from a rooftop mounted fan. The stairwell that goes to the ninth level is pressurized with 15000 CFM and is supplied air on odd numbered levels starting with level three. The stairwell serving the tenth level penthouse is pressurized with 16000 CFM and provides air on even numbered floors starting with the second level. These two stairwells have a gravity controlled relief hood at the roof level.

Design Objectives and Requirements

The Gateway at MICA started out as a design competition in the offices of RTKL Associates, Inc. The requirements for the building were sent to seven of their offices with the winning design being built.

The building was to include a black box, or multi-use performance space, that would seat up to 200 people as well as student apartments. MICA had in mind what they wanted for the black box and many studies were done of existing spaces of similar nature to determine what would and would not work in The Gateway at MICA. After these studies of other black boxes in the area were completed a design that was suitable was agreed upon.

Being an art school there was also a need for a gallery space in the building. The gallery space, incorporated into the lobby space, had to be of adequate size to display various works of art in different medias. This was easily accomplished because of the adjacency to the lobby space.

The main design objective of the building was student housing. The building was to be able to house 200+ students. These spaces were organized in a community space on the levels above the public spaces of the buildings.

The last main objective was studio space for the students to do work. This was incorporated into the design in a large rectangular tower on the north end of the building. This serves as a buffer for the community area from the busy North Avenue. It made sense to put this space on the north side of the building to utilize the northern light and, as mentioned, shield the community space from the noise of the street.

Energy Sources and Rates for the Site

The Gateway at MICA is still under construction so the energy sources and rates will be assumed for the purposes of this report. It is assumed that the electricity and gas will be provided by BGE since it is inside the city of Baltimore. The rate information was obtained from the BGE website (http://www.bge.com). Electric rates are listed in Table-1A.

The information for the natural gas was also obtained from the BGE website as well. This information can be found in Table-1B.

Electric Rates

Delivery Service Customer Charge $110 / Month

1.239 ¢/kWh

Demand Charges	**Summer**		**Non-Summer**	
	Type II-A	**Type II-B**	**Type II-A**	**Type II-B**
Transmission Market-Priced Service (/ kW)	$0.98	$0.98	$0.98	$0.98
Delivery Service (/kW)	$2.67	$2.67	$2.67	$2.67

Energy Charges	**Summer**		**Non-Summer**	
Generation Market-Priced Service(¢/kWh):	**Type II-A**	**Type II-B**	**Type II-A**	**Type II-B**
Peak	15.138	13.672	12.236	12.401
Intermediate	11.835	10.52	10.662	10.545
Off-Peak	10.34	9.137	8.646	9.054

Table-1A: BGE Electric Rates

Natural Gas Rates

Customer Charge $35 / Month

Delivery Price:

First 10,000 therms (¢/therm)	19.75
Over 10,000 therms (¢/therm)	9.48

For Daily Metered Customers

AMR Required — Estimated Installed Cost

Information Fee — $65 / Month

Table-1B: BGE Natrual Gas Rates

For the Table-1A and Table-1B, the rating periods are as follows.

Summer:

Peak – Between 10am and 8pm on weekdays, excluding National holidays.

Intermediate – Between 7am and 10am, and 8pm and 11pm on weekdays, excluding National holidays.

Off-Peak – All times other than those defined above.

Non-Summer:

Peak – Between 7am and 11am, and 5pm and 9pm on weekdays, excluding National Holidays.

Intermediate – Between 11am and 5pm on weekdays, excluding National holidays.

Off-Peak – All times other than those defined above.

Hoildays are defined as Saturdays and Sundays as well asNew Year's Day, President's Day, Good Friday, Memorial Day, Independence Day, Labor Day, Thanksgiving, Christmas and the Monday following any of these that fall on a Sunday.

Design Decisions Influenced By Cost

This information was unavailable at the time of this writing. Although it is unavailable it is known that the building went through an extensive value engineering period to cut cost. Because of this it is assumed that there were no initial design decisions that were influenced by cost.

Design Decisions Influenced By Site Factors

The location of the site in reference to the campus had a major influence on the design of the building. The site is the north gateway to campus and probably the main entrance for all people entering the campus from outside of the city. Because of this, the building needed to be somewhat of a signature building.

Another major impact on the design of the building was that of the Brown Center. The Brown Center is the main building on campus. It is the building where students congregate between classes and where the College Administration offices are.

The Brown Center façade is comprised entirely of glass. The glass is semi-transparent and the façade of the building is constructed at angles as opposed to vertical sides. The building somewhat looks like a few pyramids built together. The glass façade has obviously carried over into The Gateway at MICA. Another similarity between the buildings is the idea of different objects fused together. The Brown Center gives the impression of pyramids fused together while The Gateway at MICA gives the impression of a rectangular cube fused with a cylinder.

What has changed between the structures is the several different types of glass on The Gateway at MICA as opposed to just one type like The Brown Center. The drum-like shape of The Gateway at MICA also contrasts that of The Brown Center. Where The Brown Center is angular in shape and has points on it The Gateway at MICA is round and smooth in shape.

Outdoor and Indoor Design Conditions

Outdoor Design Conditions

The outdoor design information was obtained from the2001 AHSRAE Fundamentals Handbook. The Design Location used was Baltimore, BWI Airport in the state of Maryland.

Summer Design Conditions

The summer design conditions used were 0.4%

Design Dry Bulb: 93°F
Design Wet Bulb: 78°F

Winter Design Condition

The winter design condition used was 99.6%

Design Dry Bulb: 11°F

Indoor Design Conditions

The indoor design information was obtained from the drawings and specs for The Gateway at MICA. The indoor design conditions are divided into two categories, winter and summer. Winter conditions are defined as conditions when the outdoor air temperature is below 52°F and summer conditions are defined as an outdoor air temperature above 55°F.

All rooms in The Gateway at MICA are equipped with thermostats that have certain temperature set points. The bidding specs do not list the set points for the spaces and it is assumed that not all spaces will have the same temperature set points. Because no specific temperature is given an occupied temperature of 74°F for summer and 70°F for winter will be assumed.

When the space is unoccupied a temperature set point is given. For winter conditions the space will be maintained at a temperature of 55°F and for summer conditions a temperature of 85°F will be maintained. These conditions apply to all spaces with supply air.

There was no data available for the relative humidity design condition so a RH of 50% was assumed for both summer and winter conditions.

Design Ventilation Requirements

Design ventilation requirements were found in Technical Report #1. Table-2 below shows the outdoor air flow as per the construction documents and the outdoor air flow as calculated according to AHSRAE Standard 62.1-2004. All values listed are in CFM and the design outdoor air and total air flow taken from the design documents are the minimum values listed for the equipment.

As Table-2 shows, all AHUs meet the requirements for outdoor air according to ASHRAE Standard 62.1-2004.

	Design OA	Calculated OA	Total Air Flow
AHU-1	2900	2857	6000
AHU-2	3250	919	4000
AHU-3	3200	1253	5000
AHU-4	7000	2434	7000
TOTAL	16350	7463	22000

Table-2: Ventilation Rates for The Gateway at MICA

Design Heating and Cooling Loads

The heating and cooling loads calculated by the engineer could not be obtained so the data listed is what was calculated for Technical Report #2. The data was calculated using Carrier HAP 4.20 and was taken from the annual coil loads.

The design heating load is: 47,168 BTU/hr

The design cooling load is: 201464 BTU/hr or 16.8 tons

Annual Energy Use

The annual energy use for The Gateway at MICA was calculated for Technical Report #2. The actual energy use could not be obtained because the building is not yet constructed.

The energy data is listed in Table-3. It is separated into HVAC and non-HVAC components.

	Electric (kWh)	Natural Gas (Therm)
HVAC Components	192,741	5,191
Non-HVAC Components	261,229	0
TOTAL	453,970	5,191

Table-3: Annual Energy Use

Major Equipment

The major equipment in the building is of the typical nature. There are 2 chillers, 2 boilers, 4 AHUs, and various pumps for the water systems.

Of the AHUs in the building 3 of the 4 are VAV systems while the last is a CAV system. These units supply conditioned air via ducts to the public spaces of the building on the first two levels. The air is returned to the AHUs via open-ended ducts in return plenum. Detailed information in the AHUs can be found in Appendix B, Table-4.

The two chillers identical and are both air-cooled chillers. This eliminates the need for cooling towers and heat exchangers for the chilled water system. The chillers supply chilled water to the various coils throughout the building. Detailed information on the chillers can be found in Appendix B, Table-5.

The boilers in the building are also identical. They are natural gas fired and supply hot water to the various coils throughout the building including the AHU coils and the fan coil units in all student apartments. Detailed information for the boilers can be found in Appendix B, Table-6.

There are 13 pumps for the chilled water and hot water systems in the building. 3 of the 13 pumps are for chilled water and the rest are for the hot water system. 1 of the 3 pumps for the chilled water is a standby pump and the various pumps for the hot water system have different functions. Detailed information on the pumps can be found in Appendix B, Table-7.

System Schematics

For the building there is a chilled water loop and a hot water loop. There was no schematic drawn for the air system because the AHUs supply air through the ducts to the spaces and then it is returned to the AHUs. This is very self explanatory so it was decided that there was no need for an air system schematic.

The chilled water loop in the building starts with 2, 380 GPM air-cooled chillers which are located on the 10th floor. The chillers send chilled water down a vertical shaft to the various pieces equipment on the floors below. Chilled water is supplied to the AHU on the 10th level, the 3 AHUs on the 2nd level, and the various FCUs throughout the building. After the water passes through the equipment is then piped back to the chillers. The pumps are on the return side of the chillers therefore the water is pumped into the chillers. A system schematic can be found in Appendix A, Figure 1.

The hot water loop starts with the two boilers on the 10th level. Each boiler is a minimum of 1632 MBH and the hot water is pumped out of the boilers. The hot water is then piped to the equipment throughout the building. It is piped to the radiators and terminal units on the first and second floor as well as AHUs on the second floor. Hot water is also piped to the FCUs on the student apartment levels and the AHU on the 10th level. The water is then returned to the boilers where it is mixed with hot water by a recirculation loop before it enters the boiler to be heated again. A system schematic can be found in Appendix A, Figure 2.

Description of System Operation

The mechanical system of The Gateway at MICA contains both air-side and water-side components. While the air-side system consists of four air handling units, water source terminal units, and rooftop fans for exhaust and stairwell pressurization, the water-side system is comprised of two air-cooled chillers, two boilers, an expansion tank and various pumps.

The operation schedule of The Gateway at MICA will be determined by the owner with occupied and unoccupied hours. The system will operate according to this schedule and will be controlled by the building automation system.

All information on how the systems work was obtained from the Sequence of Operation section of the specs and construction documents.

<u>Air-Handling Units</u>
There are four air-handling units (AHU) at The Gateway at MICA. AHUs 1, 2 & 3 service all spaces on the first and second levels. AHU 4 serves all studio spaces on levels three through nine. Of the AHUs servicing levels one and two, AHU-1 and AHU-2 two are VAV systems while AHU-3 is a CAV system. AHU-4 serving the studio spaces on resident floors is a VAV system.

AHU-1, 2 & 4 are equipped with heating and cooling coils as well as a minimum outdoor air control. These units are controlled by VFDs and provide supply air to VAV boxes equipped with hot water reheat coils. The AHUs supply 55°F air to the VAV boxes which are controlled by a space-temperature sensor. The supply air damper is modulated to maintain the thermostat set point for the space for which it is supplying air. The air is returned to the AHUs by way of a ceiling space return plenum.

All VAV boxes are controlled by thermostats that are in each zone. Most spaces in The Gateway at MICA are their own zone; therefore most spaces have their own thermostat. Spaces like closets, corridors and storage spaces are not equipped with thermostats. Some of the smaller offices are also combined into one zone so one thermostat controls the set point for all offices in that zone.

AHU-3 is a CAV system that supplies conditioned air to the lobby/ pre-function and gallery space. This unit is equipped with a heating and cooling coil and is controlled by a VFD. AHU-3 supplies air to the spaces through linear diffusers and registers. There is a single reheat coil in the duct that conditions the air before it reaches the space, there are no VAV boxes for this system. The air is returned to the AHU through an open ended duct in the space. The set point sensor is in the duct and this controls the flow of water through the coil.

All AHUs are controlled by the building automation system (BAS) and started and stopped by either an operator or a scheduled time of day. The BAS controls all valves for the heating and cooling coils in the AHUs by analog and digital inputs and is monitored by the outputs. The BAS also controls the VFD of the fans to maintain a constant static pressure in the ducts and the BAS monitors the airflow by controlling the dampers in the AHUs.

Fan Coil Units

The fan coil units are found in all student residencies. These units are all water source units due to the operable windows found on these levels of the building. This system was originally designed as a 4-pipe system, but due to value engineering this has changed to a 2-pipe system. The two pipe system is switched from hot water to chilled water with the seasons.

Each fan coil unit has its own wall mounted thermostat that controls the supply air temperature for that unit. The controller will be microprocessor based and will perform onboard calculations to determine the supply air temperature to meet the requirements.

Exhaust Fans

There are several exhaust fans throughout the building that are monitored in different ways. Regardless of how they are operated, they are all controlled by the BAS.

Exhaust fans 1 and 2 are started and stopped by the BAS either by an operator or based on the building occupancy schedule.

Exhaust fans 3, 6, 8 & 9 are operated through the BAS by an operator or a temperature sensor. The fan will start when either the space temperature rises above 80°F or a drop in space temperature below 75°F.

Exhaust fan 7 is operated through the BAS by an operator and run continuously.

Unit Heaters and Cabinet Heaters

These heaters are controlled by wall mounted thermostats that are equipped with an “on-off-auto” switch. When the thermostat is set to auto the fan in the unit will cycle to maintain the space temperature set point. When set to on the fan will run continuously and when off it will stop.

Chillers & Pumps

There are 2 chillers at The Gateway at MICA and these are air cooled, because of this there is no need for cooling towers. This also eliminates the need for heat exchangers in the system because it is a closed loop system.

The chillers and pumps are controlled by the Thermal Energy Control System (TECS). This system is integrated with the BAS to monitor signals and equipment status.

The TECS continuously monitors and controls the chilled water system to optimize energy consumption as measured in the total system kW per ton of cooling. The

TECS will operate the chilled water system when the OA temperature is above 50°F, and from 3 hours before and after the building occupied times. This system monitors the building and will make changes to the system as needed. It will sequence the chillers as well as reset the supply water temperature.

Boilers & Pumps

The TECS also controls the heating water system. The heating water system operates a lot like the chilled water system. The BAS is more involved in controlling the heating water system though. The actual boiler operation is controlled by the BAS while other operations are controlled by the TECS.

The hot water pumps are regulated as far as pressure, speed and sequencing to optimize the system. Each zone of the system is monitored to determine the controlling pressure. This then regulates the speed of the pumps to maintain that pressure and the pumps are then sequenced to minimize energy consumption. This is all continuously monitored and reset as needed to maximize the system.

Stair Pressurization Fans

The stair pressurization fans are controlled by the Fire Alarm System (FAS). They are operated when a signal is sent from the FAS and will only be turned off manually by the Fire Marshall or an operator.

Fintube Radiation

The fintube radiators used to heat the exterior space of the first two levels are controlled by wall mounted thermostats. When the space temperature drops the valves will automatically open to allow for the flow of hot water. The flow is regulated by the thermostat to maintain the space set point temperature.

Critique of System

Overall the system seems to be a pretty good solution for the building. There are a lot of things in place to monitor energy use and optimize the equipment.

The air system in the building definitely meets the needs and requirements for the building. At this point it does not seem like there is too much that can really be changed for this system. A redesign could possibly open up some doors and other options. Possibly doing something with the CAV system could produce an energy savings. The could be done by closely monitoring the space and system with the controls or maybe adding more fintube coils to the space to reduce the heating load for this system in the winter. As far as the VAV systems go, it doesn't seem like there is anything that can really be changed at this point.

The FCUs on the resident levels seem to be where the system can be improved most. The original 4-pipe system was adequate for the building because of the various heating and cooling needs throughout the building due to solar heat gain. When the system was changed to a 2-pipe system this creates a lot of problems in the winter. When the sun is heating part of the building cooling will be needed and because hot water is flowing through the FCUs cooling will be unavailable for that space. This could be corrected with a reheat in the FCU and pumping chilled water through the system year round. This would allow the system to act as a 4-pipe system while running a 2-pipe system. An energy analysis would have to be done to compare costs. It would probably work out in the favor of the reheat in the unit because electricity is cheaper than gas and doing this to the system would eliminate the need for hot water. With this done the boilers would only need to run for the AHUs and fintube radiators throughout the building.

I think the air-cooled chillers were an excellent solution for this building. With limited space on the roof and the need for architectural aesthetics, eliminating the cooling towers worked well. As far as optimization of the system goes, an energy analysis would have to be done to see if the air cooled chillers are more efficient than chillers with cooling towers.

Overall there is little room for improvement of this system. Minor tweaking of the system could result in some savings and improvements, but it seems not to any great savings.

Appendix A – Mechanical System Schematics

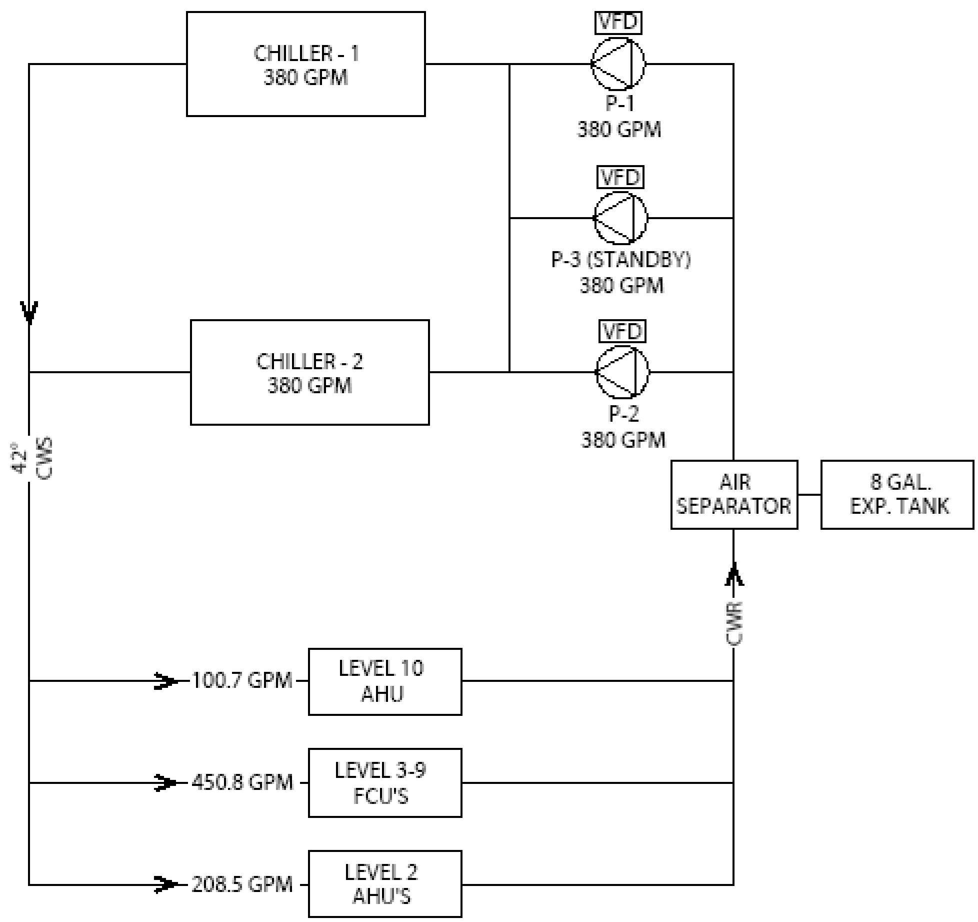

Figure 1: Chilled Water Schematic

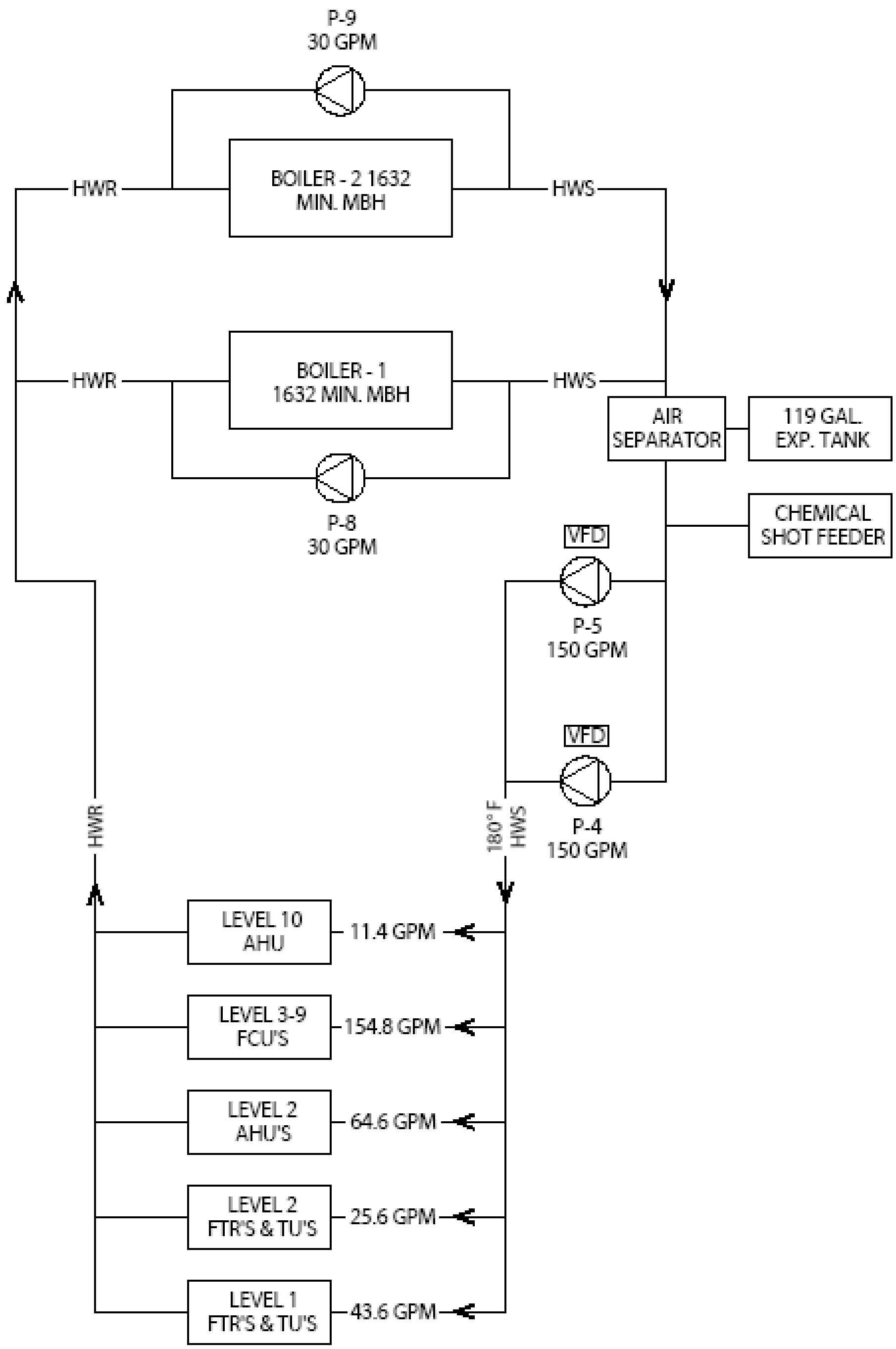

Figure 2: Hot Water Schematic

Appendix B – Equipment Schedules

Air Handling Unit Schedule									
Unit	System	Type	Air Quantities CFM				Fan Characteristics		
			Supply Max	Supply Min	Outdoor Max	Outdoor Min	SP IN WG	HP	V - Φ - HZ
AHU-1	VAV	DRAW THRU	14500	6000	14500	2900	4.10	20	460/3/60
AHU-2	VAV	DRAW THRU	9600	4000	9600	3250	3.75	10	460/3/60
AHU-3	CAV	DRAW THRU	12000	5000	12000	3200	3.40	15	460/3/60
AHU-4	VAV	DRAW THRU	11600	7000	11600	7000	4.50	15	460/3/60

Table-4: Air Handling Unit Schedule

Air Cooled Chiller Schedule														
Unit	Type	Nominal Tons	Evaporator Section				Compressor				Condensor Fans		Electrical	
			GPM	EWT °F	LWT °F	PD FT	QTY	MAX KW	RLA	LRA	QTY	RLA	MAX KW	V - Φ - HZ
CH-1	Screw	200	379.7	54	42	8	2	224.7	168/168	285/285	12	3 EA	242.8	460/3/60
CH-2	Screw	200	379.7	54	42	8	2	224.7	168/168	285/285	12	3 EA	242.8	460/3/60

Table-5: Air Cooled Chiller Schedule

Boiler Schedule								
Unit	Boiler HP	Design Press PSI	Fuel Type	Net Min Output MBH	Firing Rate	Gas Press. IN WG Min	Electrical	
					Gas MBH		Motor HP	V - Φ - HZ
B-1	48.8	15	Natural Gas	1632	2049	4.8	0.5	120/3/60
B-2	48.8	15	Natural Gas	1632	2049	4.8	0.5	120/3/60

Table-6: Boiler Schedule

Pump Schedule									
Unit	System	Type	GPM	TDH FT	MIN NPSH FT	MIN EFF %	Motor		
							HP	RPM	V - Φ - HZ
P-1	Chilled Water	End Suction	380	100	7.8	76.4	20	1750	460/3/60
P-2	Chilled Water	End Suction	380	100	7.8	76.4	20	1750	460/3/60
P-3	Chilled Water	End Suction	380	100	7.8	76.4	20	1750	460/3/60
P-4	Heating Water	End Suction	150	100	7.6	65.1	10	1750	460/3/60
P-5	Heating Water	End Suction	150	100	7.6	65.1	10	1750	460/3/60
P-6	Dual-Temp	End Suction	375	90	7.8	76.1	15	1750	460/3/60
P-7	Dual Temp	End Suction	375	90	7.8	76.1	15	1750	460/3/60
P-8	Heating Water	In-Line	30	10	4.1	43.9	0.25	1725	115/1/60
P-9	Heating Water	In-Line	30	10	4.1	43.9	0.25	1725	115/1/60
P-10	Heating Water	In-Line	35	40	10.2	59.1	1.5	1750	460/3/60
P-11	Heating Water	In-Line	25	35	10.1	47.4	0.75	1750	460/3/60
P-12	Heating Water	In-Line	30	35	10.2	49.3	0.75	1750	460/3/60
P-13	Heating Water	In-Line	75	40	12.6	63.5	2	1750	460/3/60

Table-7: Pump Schedule

References

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