Mechanical Systems Existing Conditions

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Central Shared Use Facility
Silver Spring, Maryland

Presented to: Dr. Bahnfleth

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Executive Summary

This report is a detailed summary of the mechanical system for the Central Shared Use Facility (CSUF) located in Silver Spring, Maryland. The building is still under construction, so there is no operating history of the system. The main design requirements of the system was to provide clean, comfortable air to the spaces, and become LEED certified.

The system is supplied by a Central Utility Plant (CUP), which supplies hot water, chilled water, and power. The hot water is supplied by three 9.9 L/s parallel pumps. Hot water is circulated throughout the building to each VAV box, which heat supply air to 35°C during winter. The chilled water is supplied by three 29 L/s parallel pumps, which circulate it to each air handling unit. There are 9 air handling units, each of which has a cooling coil, that cool supply air to 7.16°C. Two rooftop air handlers supply the other seven air handlers with outdoor air.

The indoor air quality is maintained by supplying a minimum amount of outdoor air, but certain spaces may be under supplied.

Aside from the possibility of certain spaces being under ventilated, the mechanical system meets the design criteria, and at an affordable price. The total price of the mechanical system was bid at $3,200,000, only 13% of the total price.

Design Objectives

The main design requirement for the CSUF is to supply clean air to the occupant, while maintaining a comfortable environment. The supply of clean air is outlined in ASHRAE Standard 62. By providing proper ventilation, contaminated air is cycled out of the building. The speculated occupant density was used to determine the proper amount of ventilation supplied to the building. To maintain a comfortable environment, each space is designed to be maintained at about 22°C and 50% relative humidity. During the winter time, the air supplied to each space is actually 35°C. This high supply temperature is due to the 15 foot ceiling height, and because the occupants of the existing buildings on the site complained that they are always cold, even at a room temperature of about 22°C.

Aside from the requirements above, this building was designed to be LEED rated. Although the owner has decided to hold off on the rating process, the CSUF is not only eligible to become rated, it will receive a Silver rating. This high rating is due specially designed features such as a green roof.

Energy Sources and Rates

Since this building is located on the Food and Drug Administration's (FDA) White Oak's campus, they required that the building receive all of this power, hot, and cold water from their Central Utility Plant (CUP). This plant generates electricity, heats the supplied hot water, and chills the supplied cold water. Since the CUP has been previously designed, and was not in the scope of this project, I do not have much information on the CUP. I do know that the main fuel used by the plant is Natural Gas. Natural Gas Turbines are used to generate electricity, and the waste heat is used to boil water. The electricity produced is used to chill water, and power the electrical/lighting loads for the campus. There are also a few solar panels (a system that will be expanded in the future) which also generate electricity, although not much compared to the required load.

Since I do not know the size of the generators, I am not sure how much natural gas is used, more specifically, how much natural gas the CSUF uses alone. I can estimate the rate for natural gas however, using information from the Energy Information Administration (EIA). In 2005, the average price of natural gas for commercial buildings located in Maryland is about $10.7 per 1000 cubic feet. This converts to a rate of $1.05/Therm.
(This information was found at http://www.eia.doe.gov/emeu/states/ngprices/ngprices_md.html)

Although the building operates off natural gas and solar power most of the time, the CUP is also set up to burn oil, in case of the natural gas being cut off. Emergency power is provided by PEPCO as well.

Cost and Site Factors

Aside from the factors mentioned above, the site played an important role in the design of the building. The site is a 700 acre navy base, but the FDA is allotted 135 acres for their campus. There was a strong need to preserve as much of the existing site. Although it had no impact on design, it is interesting to note that the site has been built on so much in the past, that during construction, the ground becomes extremely moist and extremely dry, depending on the weather. The excess mud and dust created has caused GSA to take extra precautions, including adding filters to electrical equipment in the substations.

Design Conditions

The indoor design conditions are listed above. The outdoor design conditions were taken from Carrier's HAP weather data for Washington DC.

Outdoor Design Conditions	
Summer Design Temperatures	
Dry Bulb Design	35.0 °C
Coincident Wet Bulb Design	24.4 °C
Winter Design Temperatures	
Dry Bulb Design	-9.4 °C
Coincident Web Bulb Design	-11 °C

Ventilation

The designed ventilation rates have caused some problems. The designed ventilation rates were taken from the mechanical drawings, by adding up the amount of air supplied to each diffuser at design loads. However, two air handling units are too small to provide each of their diffusers with their design load. AHU 1-1 is supposed to supply 7527 L/s but its max airflow is listed as 5429 L/s. AHU 2-1 is supposed to supply 7172 L/s but its max airflow is listed as 6930 L/s. The basement air handling AHU B-1 is sized to provide 10909 L/s, but is only supplying 3177 L/s for now. This is due to a large data center that is schedule to be added on the ground floor in the future. The future data center will require a lot of cooling, and this is the reasoning behind the over-designed air handling unit.

When looking at the amount of outdoor air designed to circulate the building, the minimum amount of OA supplied is 16,191 L/s which is about 49% of the designed airflow. Although this is enough for the whole building, my Tech. 1 analysis showed that certain areas, such as the cafeteria may not be receiving enough outdoor air.

Heating/Cooling Load

Total Cooling Load (kW)	
AHU B-1	204.5
AHU 1-1	109.1
AHU 1-2	169
AHU 2-1	147.5
AHU 2-2	163.6
AHU S-1	20.8
AHU S-2	40.2
Other	880.3
Total	1735 (493.3 ton)

Total Heating Load (kW)	
Terminal Boxes	630.1
Finned Tube Radiation	159.4
Other	18.6
Total	808.1 (230 ton)

A major source for the cooling load is the future Data Center. The large area will require year round cooling.

Summary of Equipment
(Specific information about each piece of equipment can be found in the Appendix)

Air Handling Units:

There are 8 air handling units located throughout the building. 2 are found on the rooftop, and provide outdoor air to the other air handlers found in the mechanical rooms. Typically, each floor is split into a north and south section, and each section has its own air handler. The ground floor however, is entirely serviced by one air handler. The volume of air passing through each air handler is controlled by a Variable Frequency Drive (VFD).

Pumps:

Six main pumps are found on the ground level of the building. 3 pumps in parallel are used for the chilled water system. The other 3, also in parallel, are used for the hot water system.

Heating Devices:

Most of the heating done in the building is done by the VAV boxes found throughout the building. There are a few spaces that have their own heating device however. These devices can be found in the stairwells, and Pump Room.

Finned Tube Radiation:

The north wall is a glass curtain wall. Along most of the wall are finned tube radiators. These radiators are located in a trench; and hot water is supplied to the trenches from the ceiling of the lower floor.

Computer Room Air Conditioning Units:

The future Data Center will take up about 1/3 of the ground floor. This space will require year round cooling 24/7. These air conditioners aide the air handler in cooling the space, and are able to be located closer to the servers and computers than diffusers would be.

Terminal Boxes

Most of the heating throughout the building is done by the VAV boxes. These boxes not only control the amount of airflow to each space, they are also supplied with hot water from the CUP. This hot water is used in heating coils to heat the air during winter.

Fan Coil Units

The fan coil units are found in the small, unoccupied, electrical rooms, security closets, and elevator mechanical rooms. They cool down the room, but outdoor air is not needed in these sections, so they are excluded from the main cooling system.

Fans

The fans throughout the building are used to control the exhaust. 10 fans on the roof exhaust air from bathrooms, the kitchen, mechanical rooms, and pump rooms.

System Operation

The air side of the system starts on the roof. There are 2 Air Handling Units on the roof, one supplying the North section of the building, the other the South. This can be seen on the Outdoor Air Flow Diagram found in the Appendix. The outdoor air handlers cool the supply air before they send it to the air handlers located below them, in their own mechanical room. A basic view of the mechanical rooms can be found in the Appendix as well. The air handler found in the mechanical room is supplied with outdoor air, and takes in return air from its surroundings. Even through the space is not conditioned; the mechanical room is being supplied return air from the surrounding conditioned spaces. The return air and outdoor air is mixed within the air handler, re-cooled if needed, and then sent to the diffusers. The amount of air flowing through each diffuser is controlled by VAV boxes. The VAV boxes are signaled by thermostats, which can be operated by the occupants. When heat is needed, the air handlers will not condition the supply air, and the VAV boxes will heat the air being supplied to them. After circulating through the space, air is returned via ceiling mounted return diffusers attached to a return plenum. The return plenum empties out into the mechanical room, where the air is either re-circulated, or exhausted to the roof.

The water side of the system is controlled by the CUP. Hot and chilled water are supplied to the building from the CUP and the amount is controlled by the secondary pumps found in the basement. An overview of the Primary/Distributed Secondary system can be found in the Appendix. The chilled water is used for cooling, and is circulated through the air handlers, and computer room air conditioning units. The hot water is used to heat the supply air, and also the domestic hot water. The supply air is heated in the VAV boxes ad described above. The domestic hot water is heated in two large heat exchangers found on the ground floor.

Operating History

The building is still under construction so there is no history of the system operation.

Critique of System

The first thing that stands out about this system is that hot water is circulated throughout the entire building, to each VAV box. I am curious to know why this was done, instead of heating the air in an air handling unit, and circulating hot air. It takes a lot less energy to circulate air compared to pumping water. It also seems like a high first cost for the extra pipe used to circulate the hot water, when the ductwork circulating the cold air could be used to circulate the hot air. I assume heat loss throughout ductwork was a concern because this design allows virtually no loss of heat in the short span of ductwork after the VAV box. I would like to see a difference in cost of this system, compared to a heating coil in each air handler, coupled with an electric re-heat coil in the VAV boxes.

As mentioned above, I also found a possible cause of concern for indoor air quality. From a previous assignment, I found that certain spaces, such as the cafeteria and auditorium, did not meet ASHRAE Standard 62 requirements, and the air handlers supplying those spaces may be undersized. The system is sufficient to meet the required heating and cooling loads.

While completing the schematics for the system, I noticed that the hot water pumps may be under designed. There are 3 pumps listed, each having a flow rate of 9.9 L/s. However, during the design load's specified off the 100% Design Documents, there is a total required flow rate of 25.43 L/s. The 3 pumps together can handle that flow rate, but the third pump is labeled for "Standby." There may be a higher pump operating cost, if this pump was originally designed as a backup. As it stands now, there are no backup pumps on the hot water system in case one of these three pumps needs to be shut off.

The first cost of the system is a good indication that the mechanical system succeeded in being affordable. The total project was bid at $24,241,000 and the mechanical system only accounted for $3,200,000 of that. This is about 13% of the total building system, and equates to about $85/sq ft. Also, the operating costs are estimated to be low as well, because not only is solar power being used in the building, all of the energy is generated on site, and waste heat is being used to help heat the water.

There are relatively few emissions as well, because Natural Gas and Solar are the main fuels being used in the building. However, during emergencies, oil and off site electricity may be used, which will increase the emissions.

References:

Kling 100% Design Documents for the Central Shared Use Facility

ASHRAE Standard 62 and 90

Carrier's Hourly Analysis Program

Energy Information Administration
http://www.eia.doe.gov/emeu/states/ngprices/ngprices_md.html

Appendix A

INDOOR AIR HANDLING UNIT SCHEDULE									OUTDOOR AIR HANDLING UNITS	
Equipment No		AHU B-1	AHU 1-1	AHU 1-2	AHU 2-1	AHU 2-2	AHU S-1	AHU S-2	OAHU-1	OAHU-2
Location		Gnd Floor	1st Floor	1st Floor	2nd Floor	2nd Floor	3rd Floor	3rd Floor	Roof	Roof
Service		Gnd Floor	1st Flr - N	1st Flr - S	2nd Flr - N	2nd Flr - S	N Stair	S Stair	Ventilation	Ventilation
Total Airflow (L/s)		10,909	5429	7730	6930	7400	1227	2265	26,515	20,680
Min. Outside Airflow (L/s)		1,660	3291	3145	3015	5080			11,765	10,077
Fan	No. of Fans - L/s	10,909	5429	7730	6930	7400	1227	2265	1 - 26,515	1 - 20,680
	External SP - Pa	498	495	498	498	498	125	125	747	747
	Total SP - Pa	1472	1521	1293	1233	1474	387	583	1495	1495
	Max Input - kW	22.37	1270	1560	12.67	16.17	0.768	2.01	55.99	39.55
	Max Outlet Velocity - m/s						11	9.7	16.58	12.93
	RPM	1374	2180	1780	1695	1844	2071	876	1156	1044
	Volume Control	VFD	VFD	VFD	VFD	VFD	VFD	VFD	VFD	VFD
Motor	Motor kW	29.83	14.91	18.6	14.91	18.6	1.49	2.24	75.57	55.93
	RPM	1800	1800	1800	1800	1800	1800	1800		
	Location	inside unit	inside unit	inside unit	inside unit	inside unit	inside unit	inside unit	inside unit	inside unit
	Volts/Phase/Hz	460/3/60	460/3/60	460/3/60	460/3/60	460/3/60	460/3/60	460/3/60	460/3/60	460/3/60
Cooling Coil	Air Quantity - L/s	9,249	4460	6753	9071	6582	1227	2265	11,765	10,077
	EAT - DEG C (DB/WB)	23.8/15.5	23.8/15.15	23.8/15.5	23.8/15.15	23.8/15.5	26.7/15.6	26.7/15.6	33.9/23.9	33.9/23.9
	LAT - DEG C (DB/WB)	7.16/	7.16/	7.33/	7.27/	7.05/	12.7/9.9	11.8/9.6	6.1/6.1	6.1/6.1
	Capacity: Total kW/Sensible kW	204.5/156.9	109.1/91.46	169/142.3	147.5/124.2	163.6/136.3	20.8/20.8	40.2/40.2	688.7/396.7	588.0/338.5
	Max Face Velocity - m/s	2.79	2.79	2.79	2379	2.79	2.68	2.35	1.356	1.351
	Max Air Pressure Drop - Pa	299	299	299	299	299	331.3	256.6	82.2	89.7
	EWT - DEG C / LWT - DEG C	3.9/15.0	3.9/15.0	3.9/15.0	3.9/15.0	3.9/15.0	3.9/15.0	3.9/15.0	3.8/15	3.8/15
	Water Side L/s	5.3	2.33	3.44	3.02	3.53	0.44	0.88	14.7	12.55
	Max Water P.D. - kPa	69.7	29.8	29.8	29.8	29.8	0.6	0.6	1.768	1.768
Heating Coil	Airflow L/s						1227	2265		
	EAT - DEG C / LAT - DEG C						18.3/36.9	18.3/25.3		
	Capacity - kW						24.3	19.3		
	Max Face Velocity - m/s						2.68	2.4		
	Max Air Pressure Drop - Pa						42.5	12.45		
	Water Side L/s						0.19	0.13		
	EWT - DEG C / LWT - DEG C						93.3/60.0	93.3/60		
	Max Water P.D. - kPa						299	299		
Pre Filters (2)	Airflow L/s	9,269	4,444	6,953	6,051	6,555	1,227	2,265	26,515	20,680
	Efficiency - %	30	30	30	30	30	30	30	30	30
	P.D. - Pa (clean/dirty)	74/185	74/185	74/185	74/185	74/185	74/185	74/185	87/162	87/162
	Max Face Velocity - m/s	2.79	2.79	2.79	2.79	2.79	2.79	2.79	3.1	3.1
Final Filters	Airflow L/s	9,249	4,444	6,953	6,051	6,555			26,515	26,515
	Efficiency - %	60-65	60-65	60-65	60-65	60-65			60-65	60-65
	P.D. - Pa (clean/dirty)	124/311	124/311	124/311	124/311	124/311			119/374	119/374
	Max Face Velocity - m/s	2.79	2.79	2.79	2.79	2.79			3.1	3.1
Basis of Design		York	York	York	York	York	York	York	York	York

PUMP SCHEDULE								
	Pump				Motor			
Equip No	L/s	Total Head - kPa	Min. Eff - %	Max input - kW	kW	RPM	V/PH/Hz	Basis of Design
CHP-1	29	255	78	11.4	15	1750	460/3/60	Bell & Gossett 1510 Series
CHP-2	29	255	78	11.4	15	1750	460/3/60	Bell & Gossett 1510 Series
CHP-3	29	255	78	11.4	15	1750	460/3/60	Bell & Gossett 1510 Series
HWP-1	9.9	209	70	4	5.59	1750	460/3/60	Bell & Gossett 1510 Series
HWP-2	9.9	209	70	4	5.59	1750	460/3/60	Bell & Gossett 1510 Series
HWP-3	9.9	209	70	4	5.59	1750	460/3/60	Bell & Gossett 1510 Series

HEATING DEVICES									
	FAN		Coil						
Unit No	L/s	Motor (kW)	HW kW	EAT °C	LAT °C	EWT °C	L/s	P.D. kPa	Basis of Design
UH-2	256	0.03	5.6	15.6	52	93.3	0.34	94	TRANE UHSA
CUH-3	123		6.5	15.6	52	93.3	0.09	8.7	TRANE FFBB

FINNED TUBE RADIATION		
Equip No	Min kW/m	Basis of Design
FTR-1	1.05	Dristeam VCL/Ultrasorb
FTR-2	0.48	

COMPUTER ROOM AIR CONDITIONING UNIT'S (WATER COOLED TYPE)									
		Chilled Water Coil					Supply Air		
Equip No	Type	EWT °C	Total kW	Sensible kW	Flow - L/s	Water P.D. - kPa	L/s	EAT °C (DB/WB)	Total Motor kW
CRAC-1	Upflow	7.2	88.4	64.3	3.8	88.9	4389	26.7/19.4	3.73
CRAC-2	Downflow	7.2	50.5	50.5	1.4	35	4370	22.2/14.6	5.59

TERMINAL BOX - VARIABLE VOLUME SUPPLY													
	Primary Air Valve		Secondary Air Valve		Discharge SP	Hot Water Heat Coil							
Equip No	Max Airflow	Min Airflow	Max Airflow	Min Airflow	Pa	L/s	kW	Water L/s	EAT - C	LAT - C	EWT - C	LWT - C	Basis of Design
VVS-1	95	47			125	53	1.7	0.012	8	35	93	69.8	Nailor Series 3000
VVS-2	465	83			125	83	2.7	0.019	8	35	93	75	Nailor Series 3000
VVS-3	236	118			125	118	3.8	0.027	8	35	93	74	Nailor Series 3000
VVS-4	306	154			125	154	5	0.035	8	35	93	63	Nailor Series 3000
VVS-5	425	212			125	212	6.9	0.049	8	35	93	60	Nailor Series 3000
VVS-6	496	248			125	248	8	0.057	8	35	93	59.7	Nailor Series 3000
VVS-7	661	330			125	330	10.7	0.077	8	35	93	56.7	Nailor Series 3000
VVS-8	1132	566			125	566	19	0.16	8	35	93	55.7	Nailor Series 3000
DDB-1	212	64	212	64	125	212	6.9	0.049	8	35	93	59.2	Nailor Series 3000
DDB-2	248	74	248	74	125	248	8.07	0.057	8	35	93	59.7	Nailor Series 3000
DDB-3	330	99	330	99	125	331	10.7	0.077	8	35	93	57.6	Nailor Series 3000
DDB-4	495	160	495	160	125	495	16.7	0.11	8	35	93	58	Nailor Series 3000

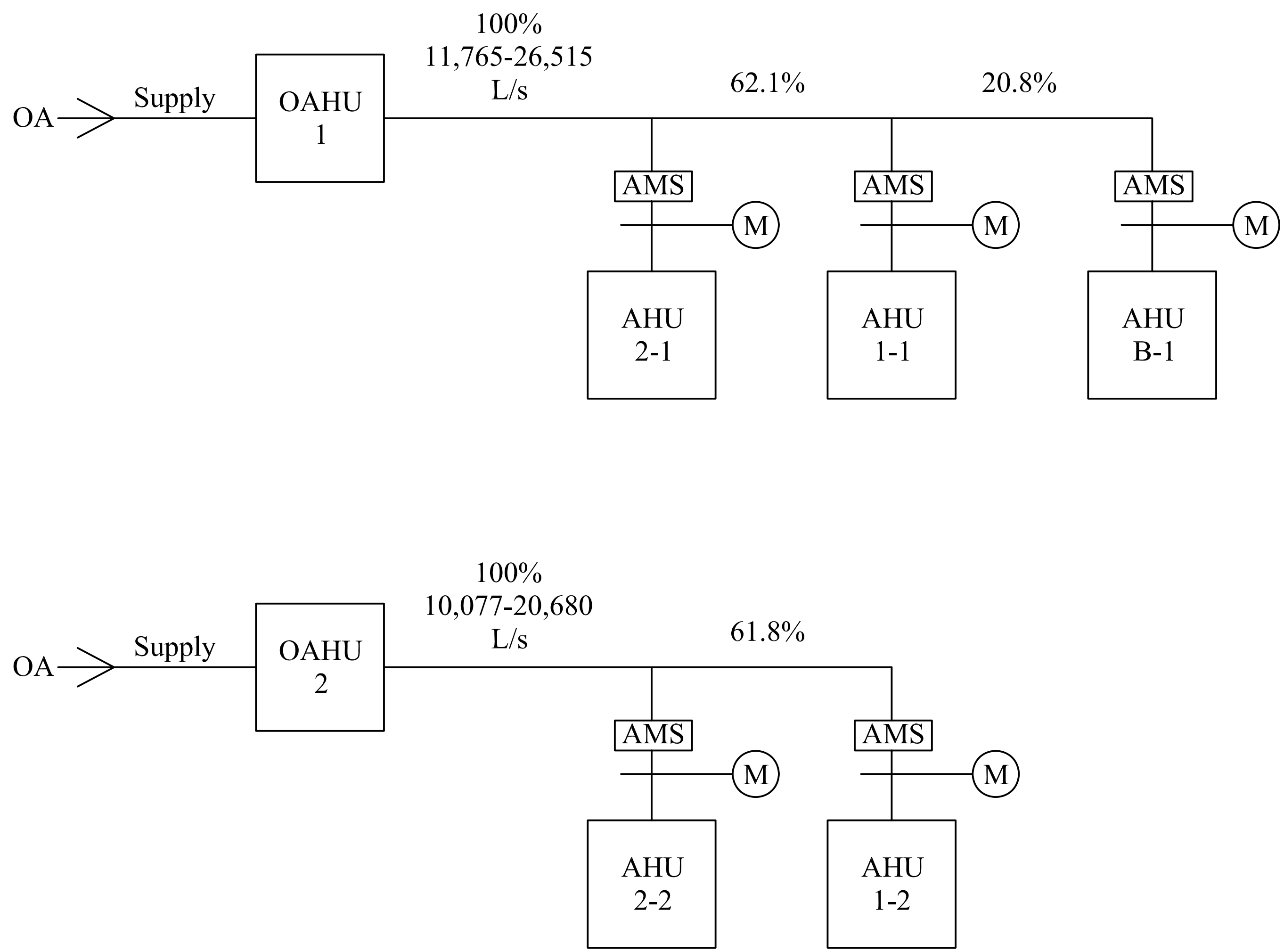
FAN COIL UNITS											
		Cooling Coil									
Equip No	Airflow L/s	Sens. Cooling - kW	EWT - C	Water Flow - L/s	EXT. P.D. Pa	LWT - C	EAT - C (DB/WB)	LAT - C	Motor kW	Fan RPM	Basis of Design
FCU-A	435	6.8	7.2	0.46	65	13	24/15.3	13	0.14	1080	TRANE FCDB
FCU-B	296	4.3	7.2	0.28	65	13	24/15.3	13	0.1	1080	TRANE FCDB
FCU-C	100	0.9	7.2	0.07	125	13	24/15.3	13	0.02	980	TRANE FCDB
FCU-D	850	12.9	7.2	0.83	125	13	24/15.3	13	0.37	1500	TRANE FCDB
FCU-E	435	6.8	7.2	0.46	65	13	24/15.3	13	0.14	1080	TRANE FCDB
FCU-F	566	7.5	7.2	0.54	65	13	24/15.3	13	0.18	1800	TRANE FCDB

FAN SCHEDULE							
	Fan					Motor	
Equip No	L/s	S.P. - Pa	RPM	Max Outlet Vel. - m/s	Max input kW	kW	Basis of Design
RF-1	26,627	685	719	16.93	35.78	44.74	Greenheck BISW
RF-2	20,766	685	614	13.24	22.8	29.83	Greenheck BISW
EF-1	1,239	249	1214		0.58	0.745	Greenheck Cube
EF-2	1,239	249	1214		0.58	0.745	Greenheck Cube
EF-3	772	373	1609		3552	0.745	Greenheck Cube
EF-4	906	373	1635		0.656	0.745	Greenheck Cube
EF-5	3354	622	1267		3.6	5.6	Greenheck Cube
EF-6	425	622	2249		0.67	1.12	Greenheck Cube
SEF-1	11,750	249	1497		10.3	11.2	Greenheck TBRU
SEF-2	11,750	249	1497		10.3	11.2	Greenheck TBRU
SEF-3	11,750	249	1497		10.3	11.2	Greenheck TBRU
SEF-4	11,750	249	1497		10.3	11.2	Greenheck TBRU

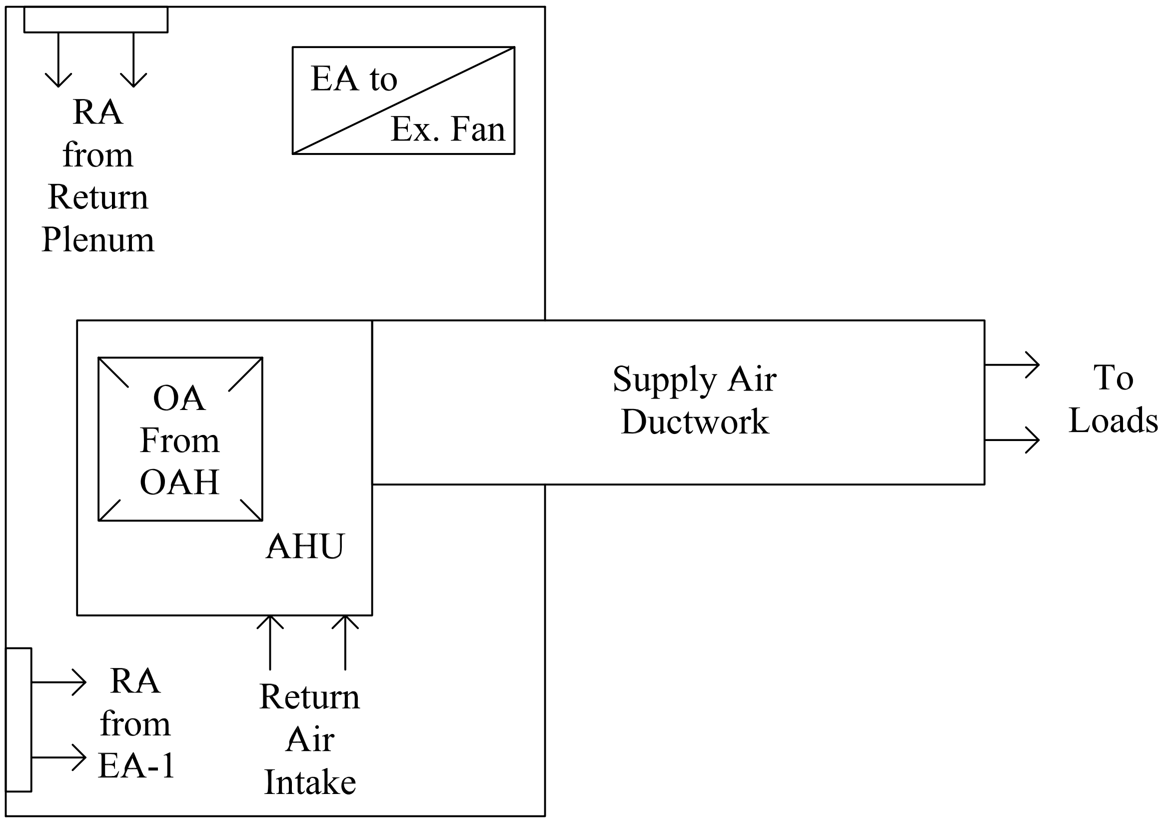
PLATE AND FRAME HEAT EXCHANGER								
	Hot Water Side				Cold Water Side			
Equip No	L/s	EWT - C	LWT - C	Max P.D. kPa	L/s	EWT - C	LWT - C	Max P.D. kPa
HX-1&2	17.25	93.3	60	66.32	10.13	4.4	60	28.88

Appendix B

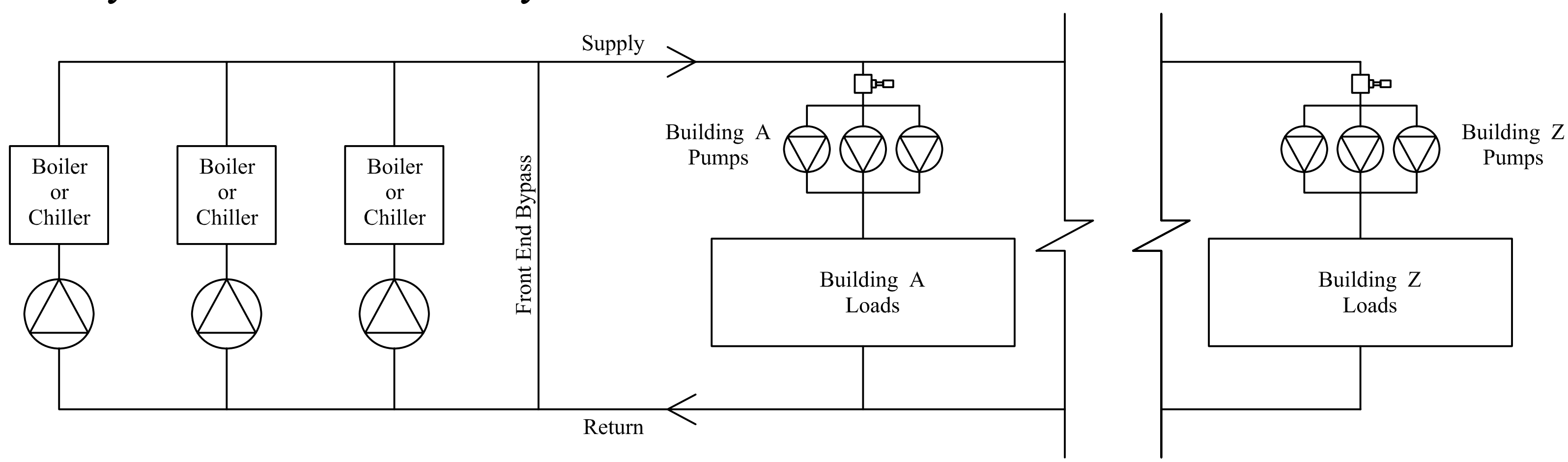
Outdoor Air Flow Diagrams



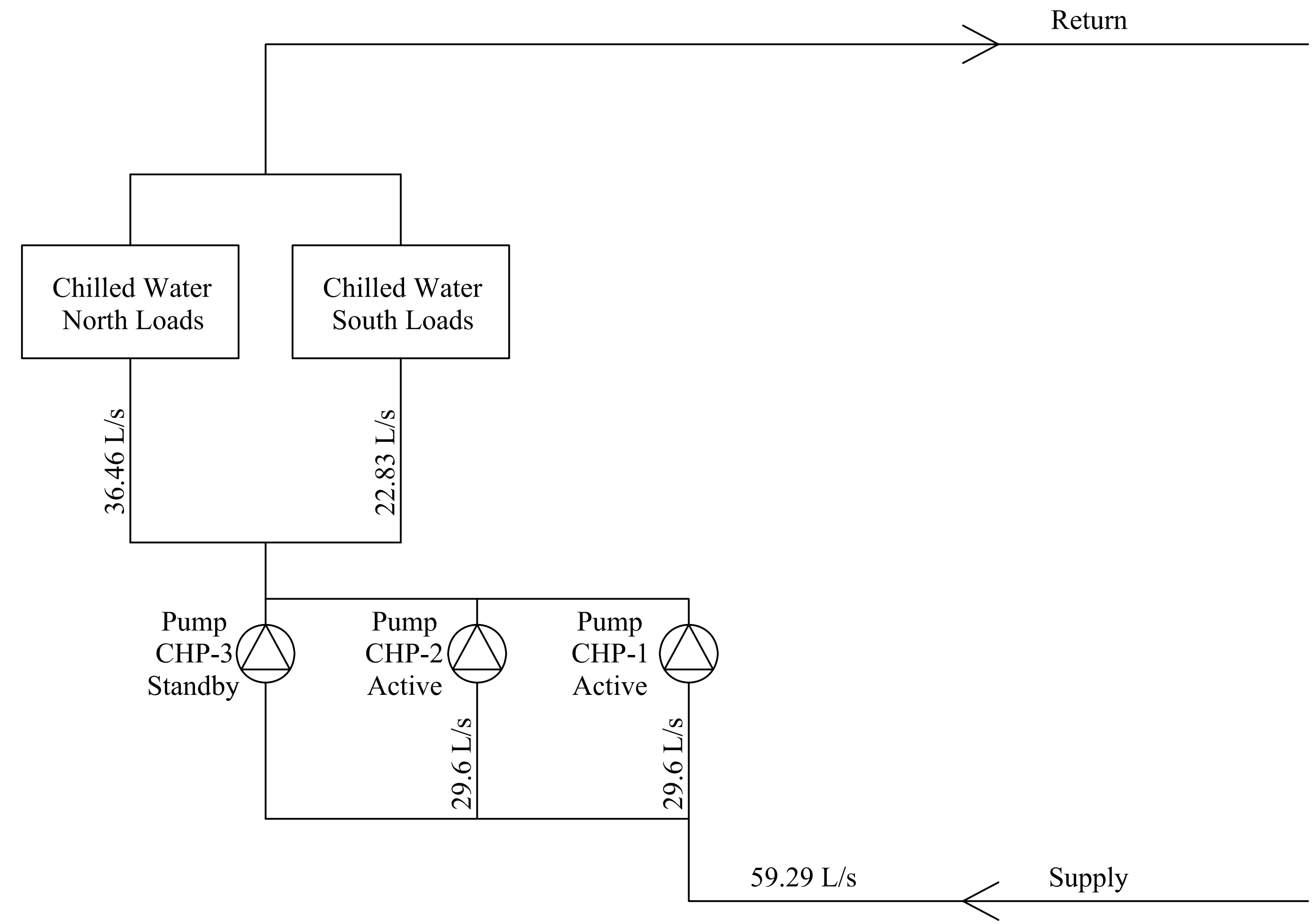
Typical Mechanical Room and Air Handling Unit



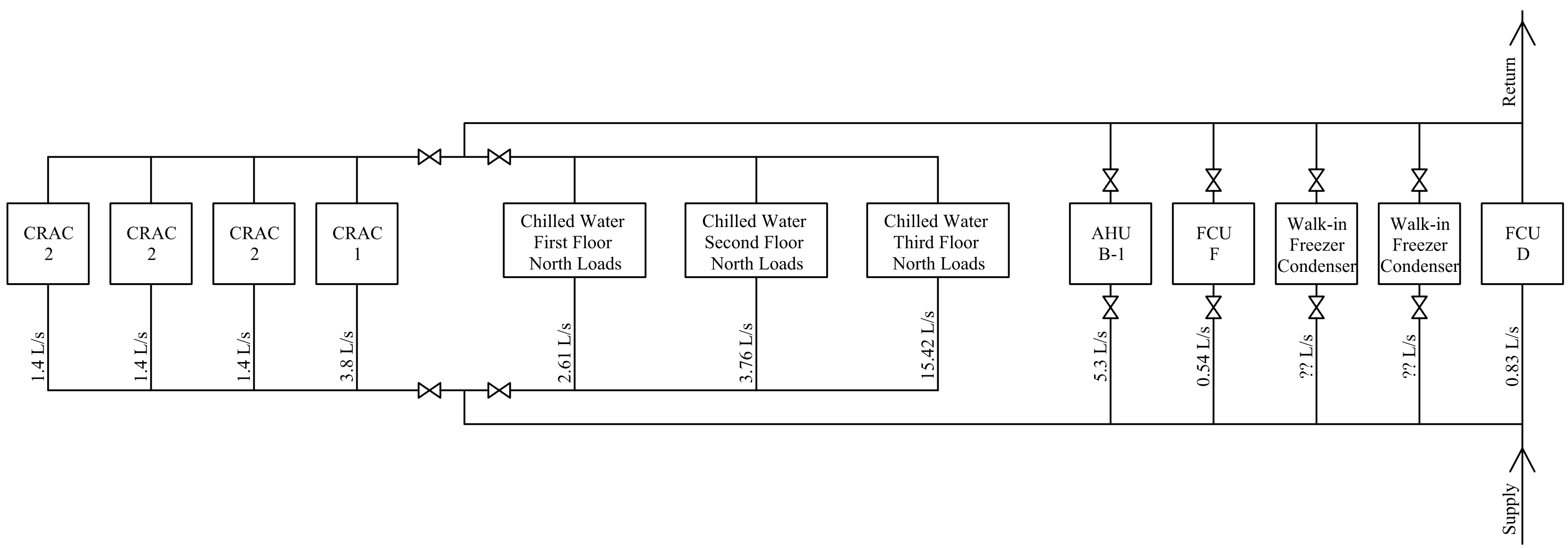
Hot Water and Chilled Water Primary/Distributed Secondary



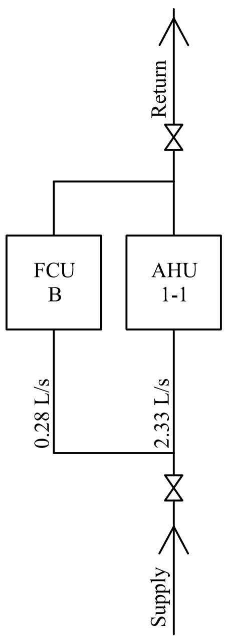
Chilled Water Fow Diagram



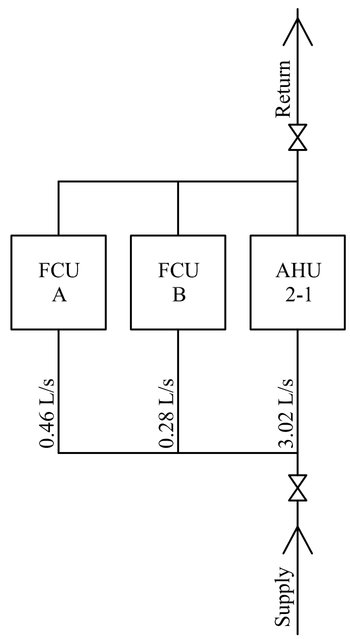
Chilled Water North Loads



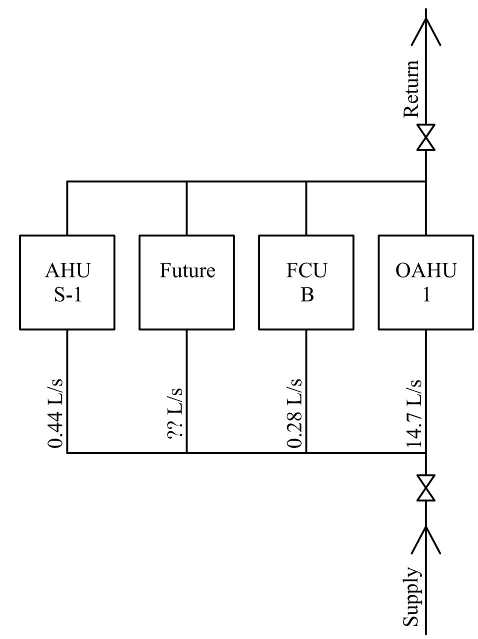
Chilled Water First Floor North Loads



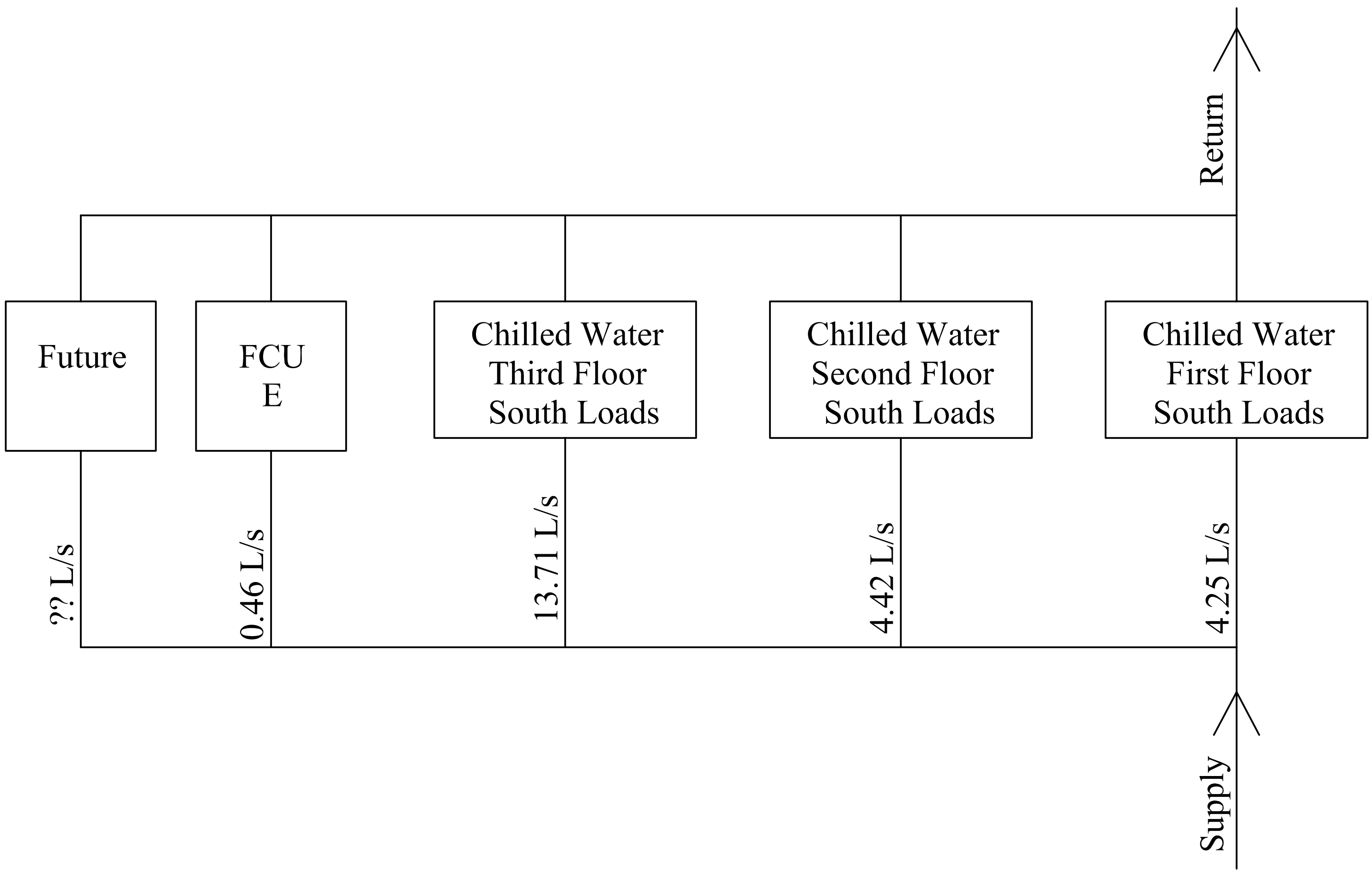
Chilled Water Second Floor North Loads



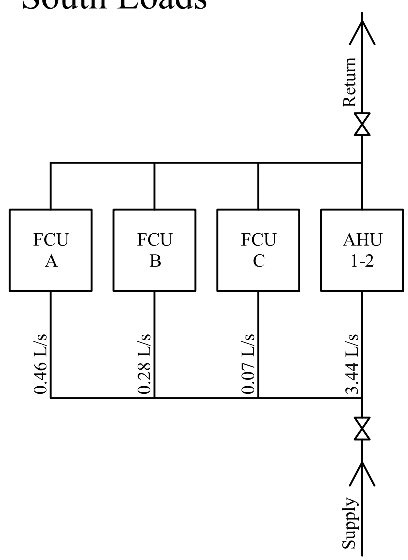
Chilled Water Third Floor North Loads



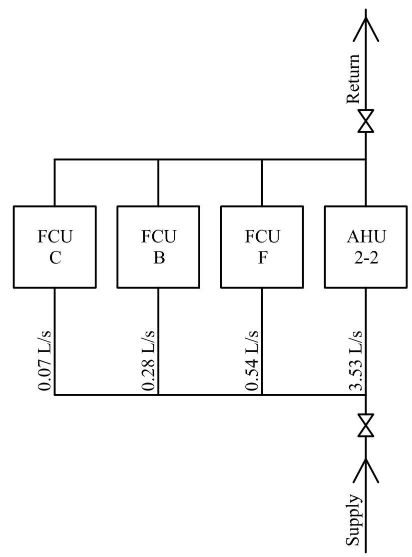
Chilled Water South Loads



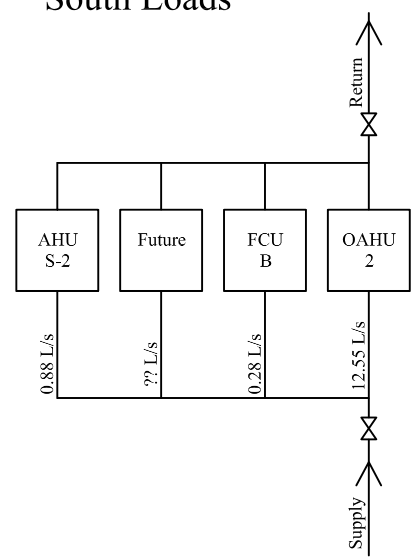
Chilled Water
First Floor
South Loads



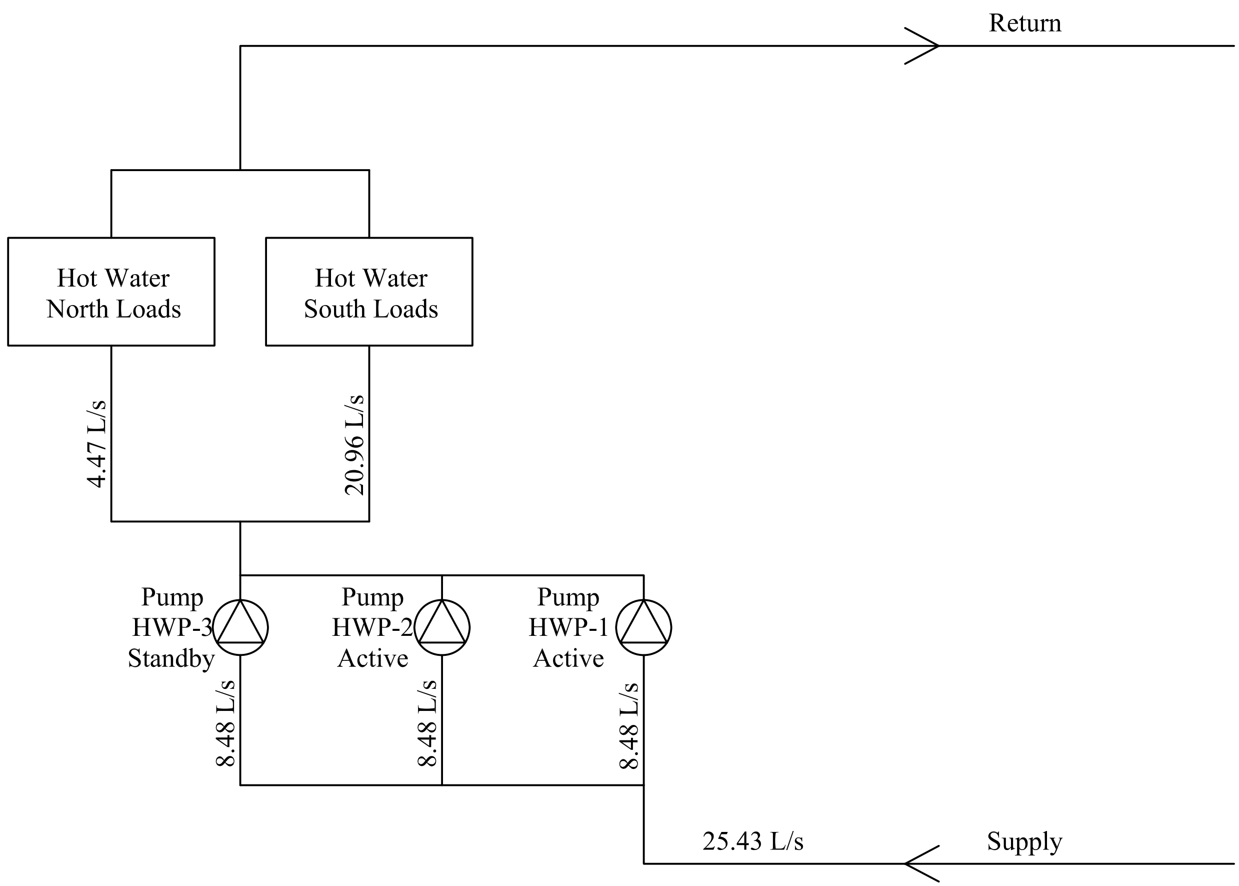
Chilled Water
Second Floor
South Loads



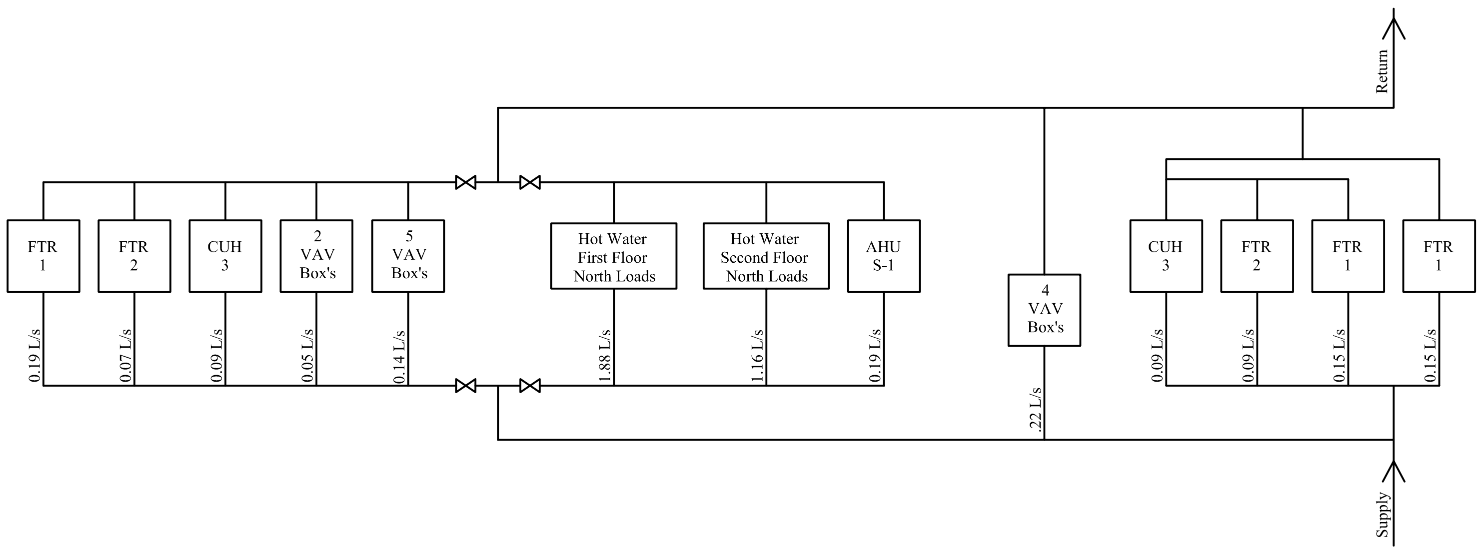
Chilled Water
Third Floor
South Loads

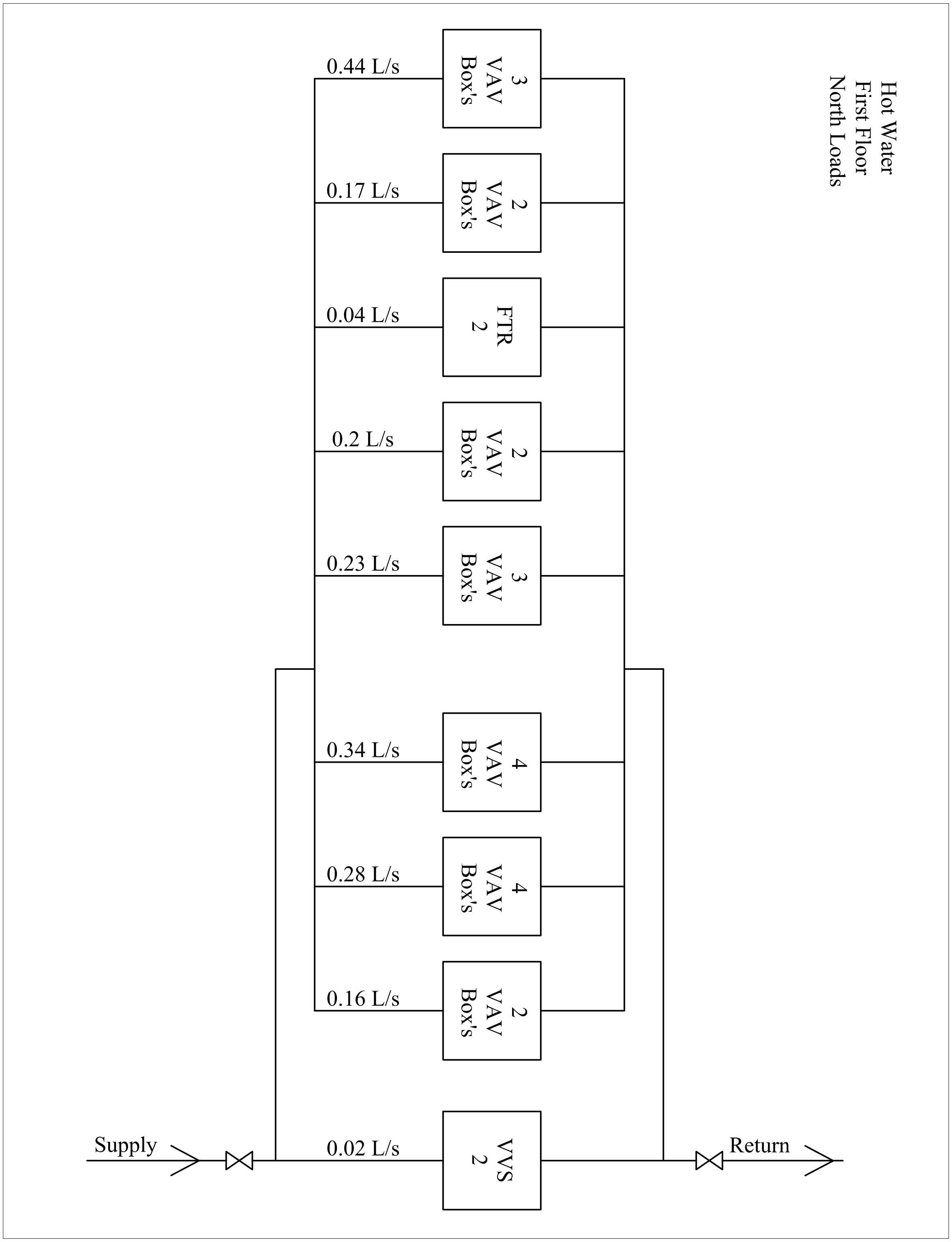


Hot Water Fow Diagram

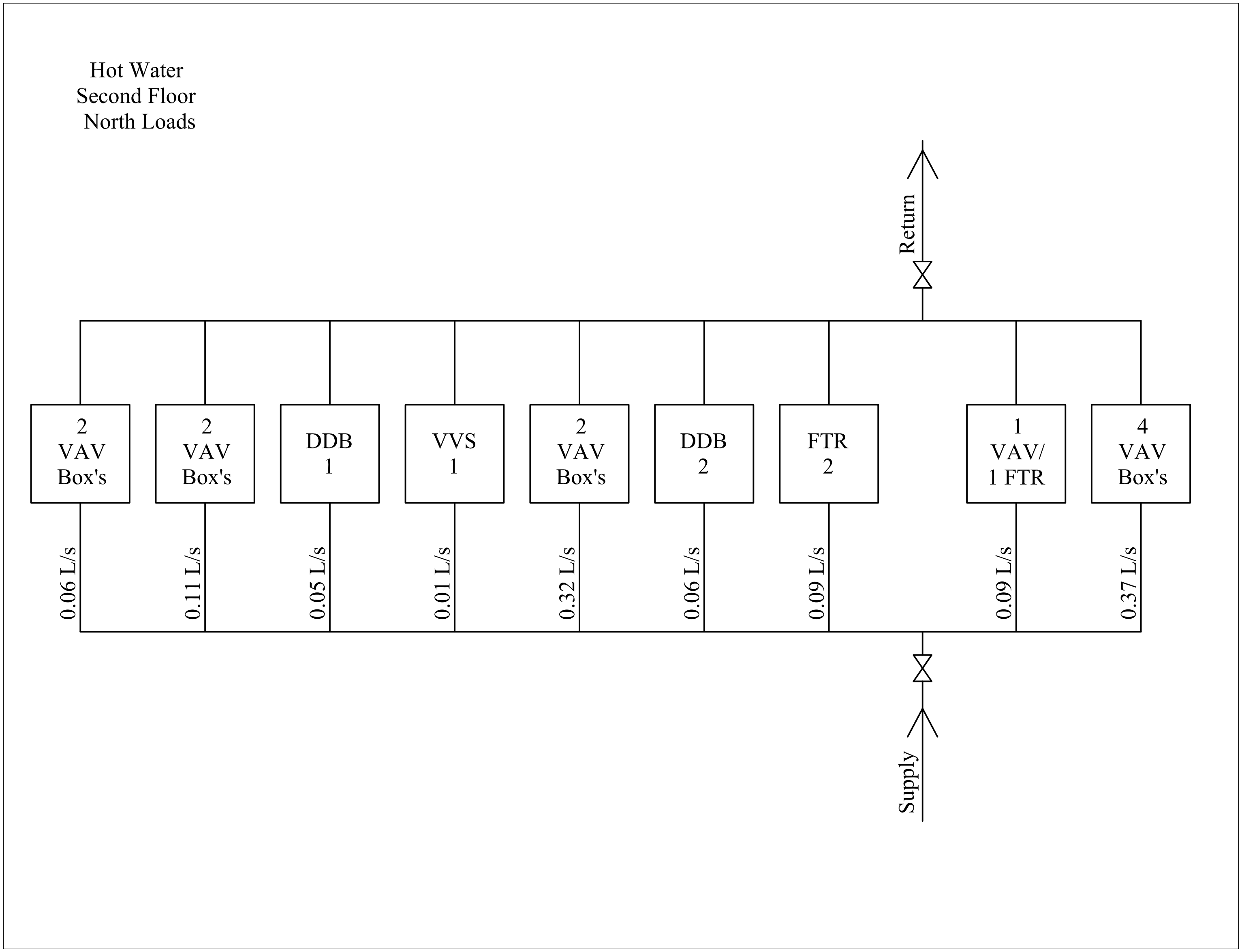


Hot Water North Loads



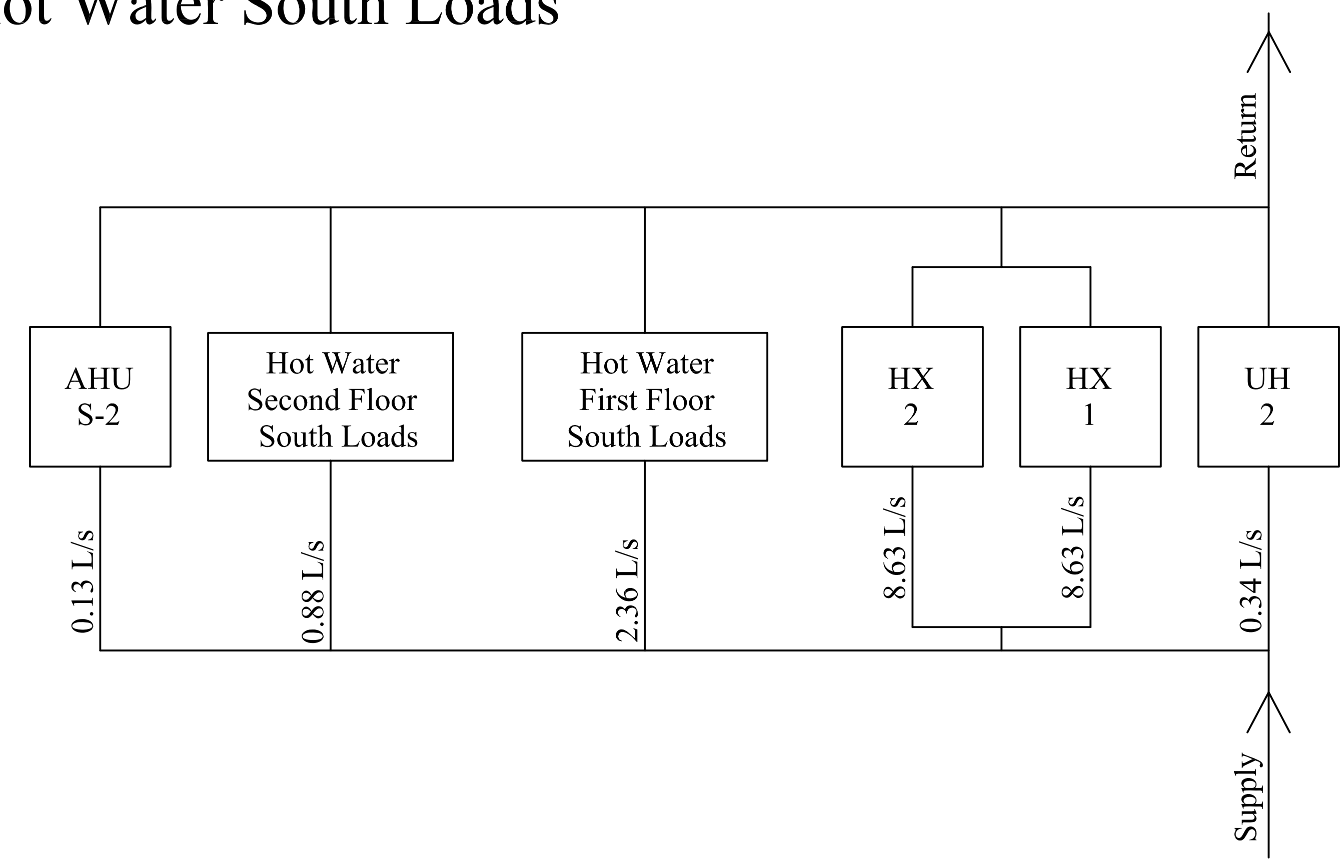


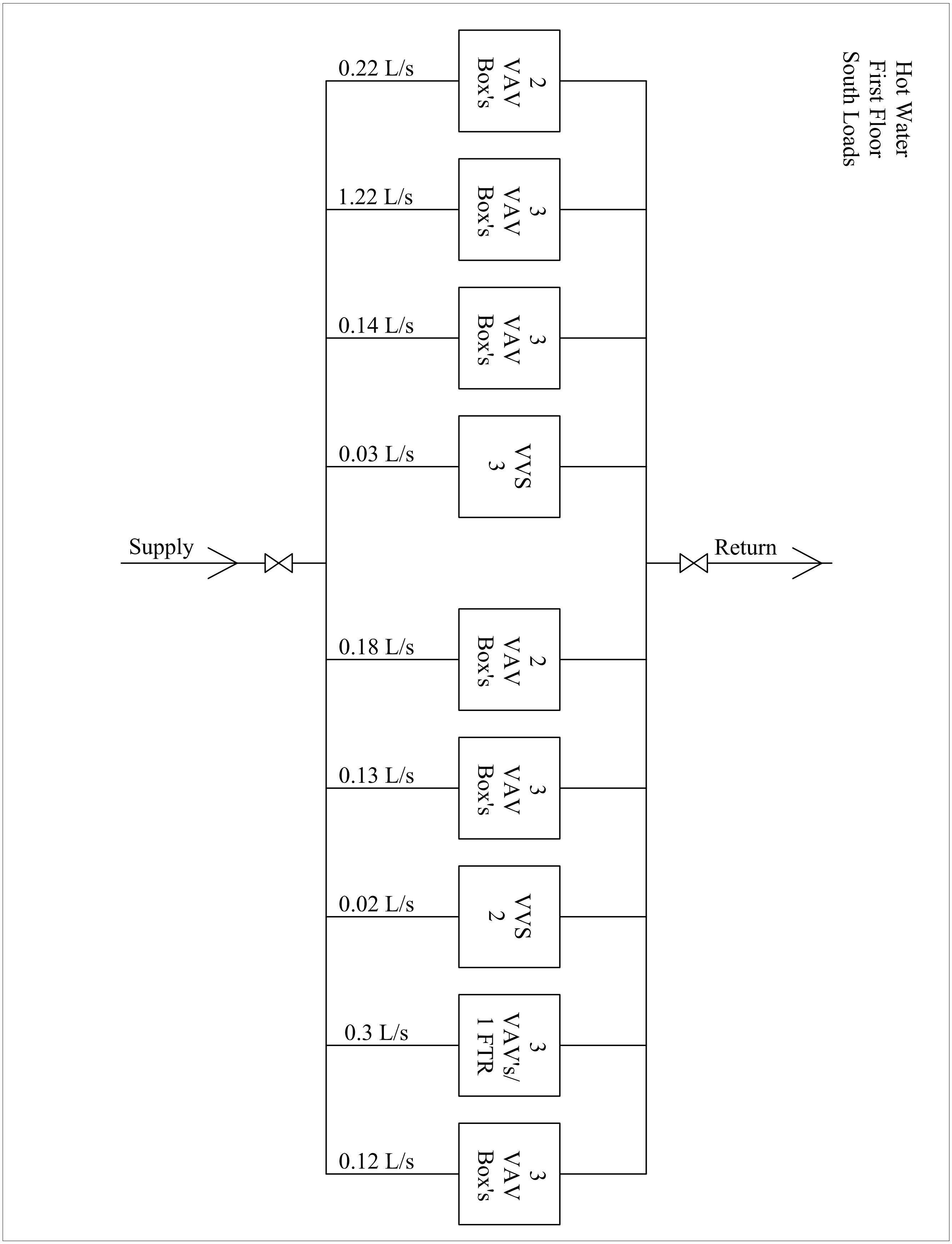
Hot Water
First Floor
North Loads
0.44 L/s
3 VAV Box's
0.17 L/s
2 VAV Box's
0.04 L/s
FTR 2
0.2 L/s
2 VAV Box's
0.23 L/s
3 VAV Box's
0.34 L/s
4 VAV Box's
0.28 L/s
4 VAV Box's
0.16 L/s
2 VAV Box's
Supply
0.02 L/s
VVS 2
Return

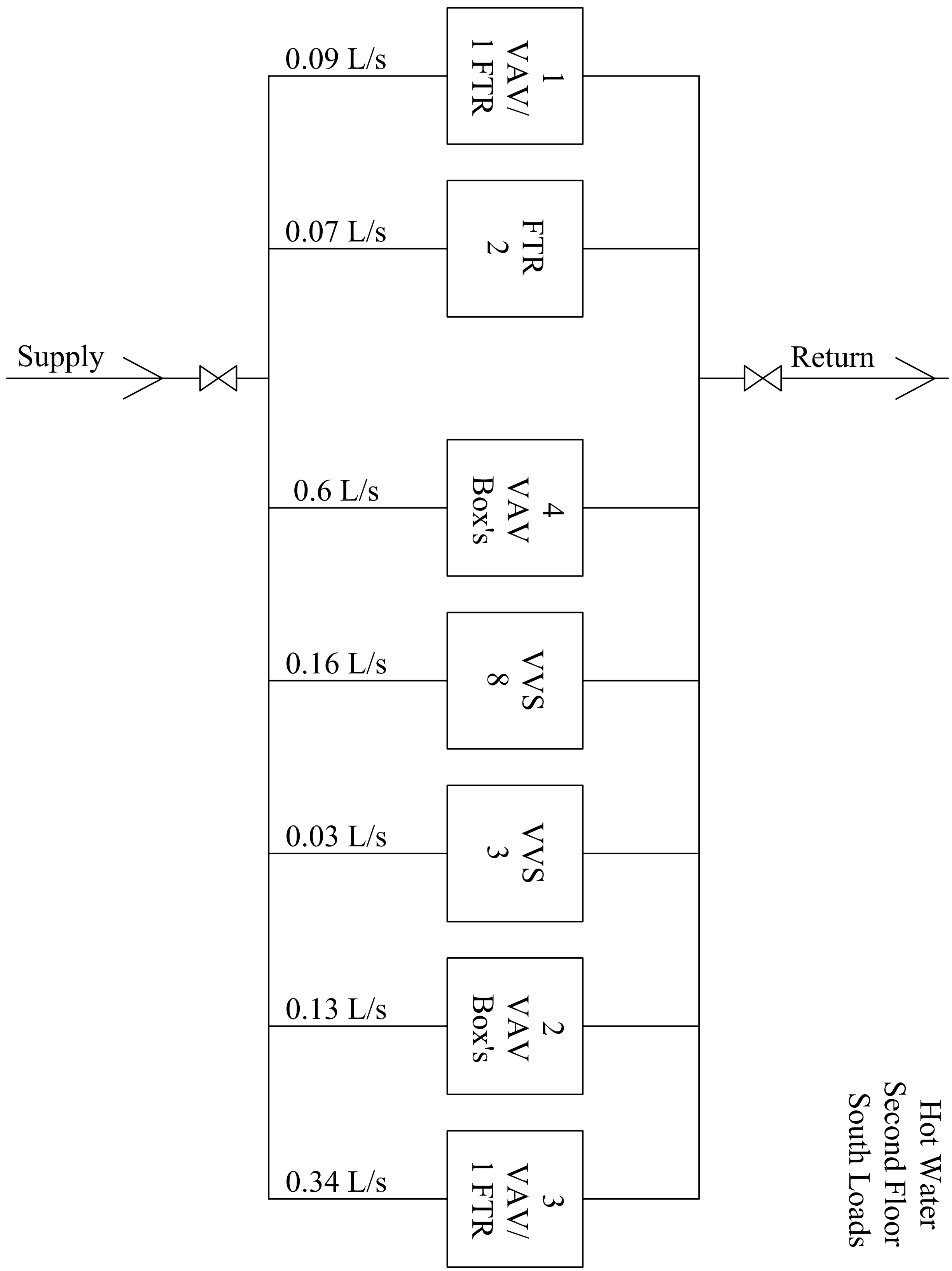


Hot Water
Second Floor
North Loads
Return
Supply
2 VAV Box's
0.06 L/s
2 VAV Box's
0.11 L/s
DDB 1
0.05 L/s
VVS 1
0.01 L/s
2 VAV Box's
0.32 L/s
DDB 2
0.06 L/s
FTR 2
0.09 L/s
1 VAV/ 1 FTR
0.09 L/s
4 VAV Box's
0.37 L/s

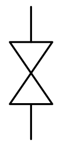
Hot Water South Loads

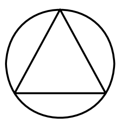


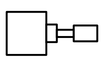

Hot Water
First Floor
South Loads
Supply
Return
0.22 L/s
2 VAV Box's
1.22 L/s
3 VAV Box's
0.14 L/s
3 VAV Box's
0.03 L/s
VVS 3
0.18 L/s
2 VAV Box's
0.13 L/s
3 VAV Box's
0.02 L/s
VVS 2
0.3 L/s
3 VAV's/ 1 FTR
0.12 L/s
3 VAV Box's


Supply
Return
0.09 L/s
1 VAV/ 1 FTR
0.07 L/s
FTR 2
0.6 L/s
4 VAV Box's
0.16 L/s
VVS 8
0.03 L/s
VVS 3
0.13 L/s
2 VAV Box's
0.34 L/s
3 VAV/ 1 FTR
Hot Water
Second Floor
South Loads

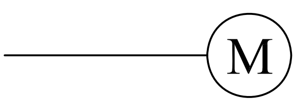
Legend


Shut off Valve

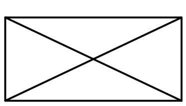

Pump

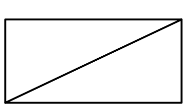

Flow Meter

Air Flow Measuring Station



Motor Operated Damper


Supply Air Ductwork


Return Air Ductwork