Final Report

Defense Information Systems Agency Headquarters Facility

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Mechanical Option

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April 5, 2010

Acknowledgements

First of all I would like to thank my parents, George & Denise Slavik for all they have done for me. I am forever indebted to them. My parents brought me up the right way and taught me the values of hard work and respect for all people, for this I could not be more grateful. They sent me to this amazing University where I have met so many amazing and inspirational people.

Thanks to my father, my Uncle Luciano, and Michael for introducing me to the Mechanical Contracting business, which led me to choose this major. I have greatly benefitted from this experience, and will continue to work hard to advance the business.

I would like to thank the Architectural Engineering Staff for all the help along the way. Everyone from teachers to the ladies in the office made this experience much easier. Special thanks to Moses Ling for always being there for guidance from the time I visited as a senior in high school until I left this place.

I would like to thank all the great people at Southland Industries helped me not only gain permission to use such an interesting project for my thesis, but helping me along the way. Also, thank you to the many strangers I cold called on the phone from all over the country to help me figure this project out. Without you, I don't know what I would have done.

Special thanks to all my friends that I have met along the way. I joined the Lambda Chi Alpha fraternity at this school and met some amazing people. The crazy stories will never be forgotten, I thank you for teaching me to work really hard, and play even harder. I have realized this is the way to live life. Thanks to my friends I have made in the AE program, especially my Roma crew. We shared the most incredible experience of my life together, and we will be family for life now. Thanks for all your help along the way in and out of the classroom.

I have many, many people to thank and I probably have forgotten some in here. I am extremely lucky to be blessed with such amazing friends, family, and colleagues. You are my inspiration, you are the reason I do this, and you are the reason I have fun.

THANK YOU!

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1.0 EXECUTIVE SUMMARY

The Defense Information Systems Agency (DISA) Headquarters building is an integrated campus of six buildings located in Ft. Meade, MD. The facility consists mostly of office space and a high security TE lab with support spaces such as a wellness center and a cafeteria. In the previous technical reports, this building was found to exceed ASHRAE expectations and has been labeled a L.E.E.D silver building. Due to the fact that the project is under the jurisdiction of the Army Core of Engineer's strict policies, this building was well designed.

The TE Lab has extremely high loads due its function as a home to high density servers. In fact, the lab contributes to over 30% of the facilities cooling load. Due to this, the Mechanical redesign was focused on the Lab building. The lab is currently under extremely high loading (55 W/SF) and is expected to rise as high as 125 W/SF.

The focus of this redesign was the server racks. The racks are the reason the cooling loads are so high in this building and they are extremely important. These servers contain very sensitive and sometimes classified information. A failure would be catastrophic; therefore it is extremely important we not only provide enough cooling now, but also for the future.

In the original design, the engineer provided oversized mains and branch piping to accommodate for the future loads. Originally, this redesign was going to include a built up chiller plant separate from the central utility plant to meet the current loads and to prepare for the future. After initial calculations showed this would not be economical, the focus was shifted to the source of the loads, the servers.

The mechanical redesign included designing water cooled server racks fed from the central utility plant. The first cost, energy savings, and payback were calculated. The result was that this system could be installed and has a significant energy reduction. There would be a high first cost, but that could be paid back within five years. The only potential red flag was in the event of a water leak, equipment could possibly be damaged.

This led me to evaluate the effects of DX refrigerant cooled server racks. Again the first cost, energy savings, and payback were calculated. The result indicated an even higher energy reduction than the previously investigated water cooled racks. There would also be a higher first cost which would lead to a payback period of 8 years.

Also investigated in this report was a feasibility study on rainwater collection. As an attempt to receive L.E.E.D points and to reduce water the landscape architect has only specified plants which do not require irrigation. Therefore, the water collection was investigated to flush toilets which are allowed by the International Plumbing Code. The result was that every toilet in the facility could be flushed 100% by rainwater, but due to the cheap cost of water it was not worth the investment which was reflected by a payback period of over 60 years.

Finally, an acoustic solution was found for a problem with the roof top units. The units were causing disturbances in the rooms surrounding the shafts. This problem was solved by adding fiberglass duct liner to the supply plenums of the air handling units in question.

2.0 PROJECT INFORMATION

The overall concept for the Defense Information Systems Agency (DISA) Headquarters Facility is the creation of an integrated campus environment in a consolidated facility. The population for the facility is currently operating at several individual sites and the ability to combine their resources will bring operational facilities. The campus is organized by six integrated buildings. The site chosen for the facility was formerly a golf course at the Ft. George G. Meade Military Base in Ft. Meade, MD. The site can be found below in Figure 2.0.1 where the Department of Defense Logo is shown.

Figure 2.0.1- Site Map

The six integrated buildings create a 1,070,000 SF complex. Although most of the complex is office space, the architectural program is diverse as it also includes a TE lab, conference areas, kitchens, fitness center, cafeterias to name a few.

Figure 2.0.2=Site Plan

Primary Project Team

Role	Company
Owner	DISA
Architect	RTKL Assoc.
General Contractor	Hensel Phelps Construction
CM	Hensel Phelps Construction
Mechanical Engineer	Southland Industries
Plumbing Engineer	Southland Industries
Electrical Engineer	M.C. Dean Inc.
Structural Engineer	Thornton Thomasetti, Inc.

Figure 2.0.3=Primary Project Team

2.1 ARCHITECTURAL OVERVIEW

The DISA HQ facility is comprised of six connected buildings: Command, Operations, Acquisitions, Lab, Warehouse and Central Plant. They are interconnected by a Concourse at Level 2 (primarily service circulation and utilities) and Level 3 (primary internal pedestrian circulation).

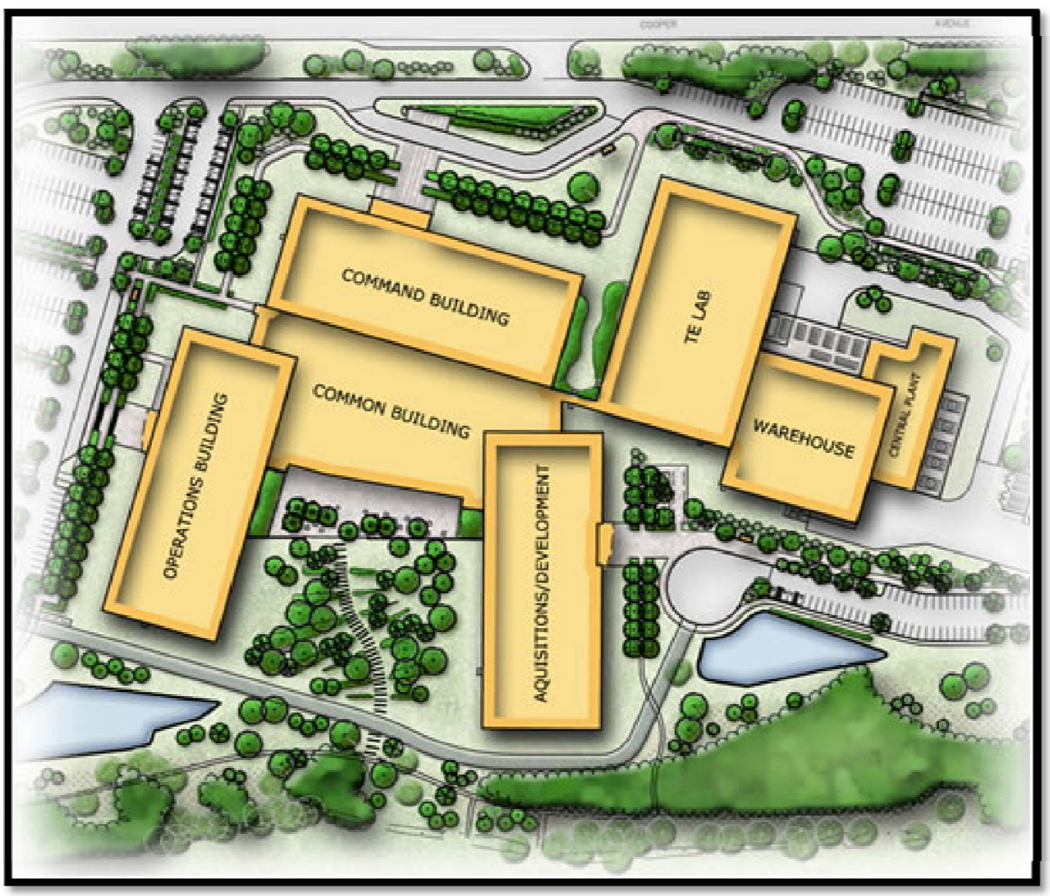


Figure 2.1.1=Site Plan

The project is a complex with approximately 70% office space, 7% Lab Space, 10% Common (Multiuse) area, and 13% Special Use Spaces, based on program floor area. The Central Utility Plant (CUP) is shown attached to the Warehouse in Figure 1 above. This building contains the Boilers and Chillers which distribute Campus chilled and heating water to the entire complex.

2.2 MECHANICAL OVERVIEW

The HVAC system selection for the DISA HQ was driven by the following criteria:

- The need for flexibility to accommodate future change
- The project goal of 30% energy conservation compared to ASHRAE Standard 90.1 – 2004.
- Employee Comfort
- Best life cycle cost

The design indoor air conditions were specified by the RFP, while the outdoor air conditions were obtained from the ASHRAE Handbook of Fundamentals 2005 and are noted below in Figure 2.

Outside Temperature and Humidity Conditions (ASHRAE Fundamentals 2005)	
Outside Design Conditions	Summer
Dry bulb and coincident wet bulb - Envelope	93.6°F DB/75.0°F WB
Wet bulb and Coincident dry bulb – 100% OA Coils	77.2°F DB/82.4°F WB
Wet bulb for evaporative heat rejection	78.1°F WB
Outside Design Conditions	Winter
Dry bulb and Humidity Ratio (HR)	12.3°F at 4.6 gr/lb

Figure 2.2.1 - Design Outdoor Conditions- Baltimore, MD.

Indoor Design Conditions	
Space	Summer T°F / % RH/ Winter Temp°F
Open Offices	75/50/72
Private Offices	75/50/72
Server Rooms	65-68/MAX 60/65-68
Lab Areas	65-68/MAX 60/65-68
Ftiness	68/MAX 60/68
Dining	75/MAX 60/72

Figure 2.2.2 - Design Indoor Conditions

2.3 CONSTRUCTION OVERVIEW

To maximize the benefits of a design-build fast track process, the team implemented a process which completely integrates the design and construction at every phase of the DISA HQ. Labor saving methods such as reducing the number of steel pieces, precast exterior skin, pro-press mechanical fittings, and pre-fabrication.

The short interval project scheduling system (sips) has been known to bring a production line approach to constructing buildings which require a great deal of repetitive activities. With over 800,000 sq. ft. of typical office space to construct, the DISA HQ was perfect for this technique.

Each office floor will be conceptually divided into six areas of approx. 10,000 sq. ft. the work activities will be sequenced in one week intervals and a specific crew will be developed for each group of activities. The crews will complete their activities from material staging to clean up in a production line type matter.

2.4 STRUCTURAL OVERVIEW

The foundations will consist of a spread footing foundation system with an allowable bearing pressure of 3,000 psf. column grids were developed with the goal of creating as much column free space as possible between the cores and perimeter. The typical column spacing for admin areas is a repetitive 38' bay in the buildings longitudinal direction and 27' bays at the center core with 29' and 32' bays in the open office plan. The column grid presents the added benefit of allowing the use of repetitive member sizing for 90% of the interior beams which takes advantage of uniformity in detailing, fabrication, and erection. The framed floors are 2-1/2" of normal weight concrete on 3" deep 20 gauge galvanized composite steel deck.

2.5 ELECTRICAL OVERVIEW

The Electrical service to the DISA Headquarters will be primary service at 33 kV. There will be two services connected on the load side by a tie breaker to allow manual transfer between the two. Each feeder is capable of carrying full load; therefore one service is redundant for increased reliability.

**The services will be normal power type of service connected to two 20/25MVA transformers via a 33KV/1200A circuit breaker. The estimated electrical load for the DISA site in the RFP was 16 MW initially, and will increase to 21 MW in the future when the Lab power increased to 125 W/SF.
All mission critical, life safety and other loads are backed up by diesel generators, 13.8kV; 2000KW/2500KVA standby rating.**

Each of three (3) main buildings is fed from a normal power 480-277V Secondary Unit Substation. Each of the substations is fed from 13.8kV breakers. The secondary unit substations are 480V/277V rated, in a double ended Main-Tie-Main configuration and are classified under two (2) main categories according to their primary source of power as Normal Power Substations and Emergency Power Substations respectively.

Secondary Unit Substations

Command Building Normal Power Rated 2000kVA

Acquisition Building Normal Power Rated 2000kVA

Common Building Normal Power Rated 1500kVA

Operations Building Normal Power Rated 2000kVA

CUP Building Normal Power Rated 2500/3333kV

Laboratory Building Normal Power #1 Rated 2500/3333kVA feeds laboratory building Level 2,

Laboratory Building Normal Power #2 Rated 2500/3333kVA feeds laboratory building Level 3

Power distribution throughout the buildings will be achieved using copper riser bus in vertically stacked electrical closets. Each floor will have two electrical closets each closet being fed from its own riser bus. The bus will feed a consolidated switchboard which will house one 277V Lighting Panel, one 480:208/120V K-13 transformer and multiple 120V power panels as required feed to receptacle loads.

A separate 3 phase, 3 wire power distribution system powered from the secondary unit substation will be provided to serve all HVAC equipment, including Computer Room Air Conditioning (CRAC) units.

2.6 LIGHTING OVERVIEW

The lighting was carefully design for the DISA HQ to promote energy efficiency, meet ASHRAE 90.1-2007 and earn L.E.E.D credits. The office buildings were arranged in order to maximize day lighting, to enhance the work environment for the occupants. The benefits of natural day lighting and views are therefore available to the general open office cubicles as well as private offices.

The Building Automation System will harvest the natural light to conserve energy. These strategies will ensure the maximum LEED points are obtained for the use of day lighting.
Circuiting of exterior light fixtures has been coordinated with the Building Automation System controls, to maximize use of day lighting as much as possible. Occupancy sensors will be installed in all private offices, conference rooms, and other intermittent use spaces. Timed on/off control for all general lighting, not already controlled by occupancy sensors will be used as well.

Fluorescent type fixtures utilizing electronic ballasts and energy efficient lamps will be used throughout the DISA HQ. All lamps must have a color rendering of 85 or higher, and the typical color temperature will be 4100k. All electronic ballasts must have a total harmonic distortion of less than 10%.

2.7 TELECOMMUNICATION OVERVIEW

The proposed state-of-the-art Information Technology (IT) infrastructure for the new DISA HQ Facility will provide a Voice, Data, and Video cabling system. The voice, data, and video cabling system will connect the user to voice, data, and video services via installed horizontal cabling, placed in appropriately sized and classed pathways to the designated Telecommunications Room. IT infrastructure includes pathways, spaces, cabling, and termination equipment required for signal distribution for voice, data, video, cellular telephone, and grounding.

2.8 FIRE PROTECTION OVERVIEW

A complete wet pipe sprinkler system is provided throughout the DISA HQ Facility, except in the loading dock next to the warehouse, where a dry pipe system will be installed. The dry pipe system will be installed to provide freeze protection.

Two horizontal split-cases 2000 GPM, 140 psi electric driven fire pumps will be provided. The first pump is a primary while the other is the reserve to meet the demand of 25% of the hydraulically most remote area of the facility. The water supply will be drawn from a 640,000 gallon, aboveground water storage tank.

3.0 DETAILED MECHANICAL SYSTEMS DESCRIPTION

3.1 CENTRAL UTILITY PLANT

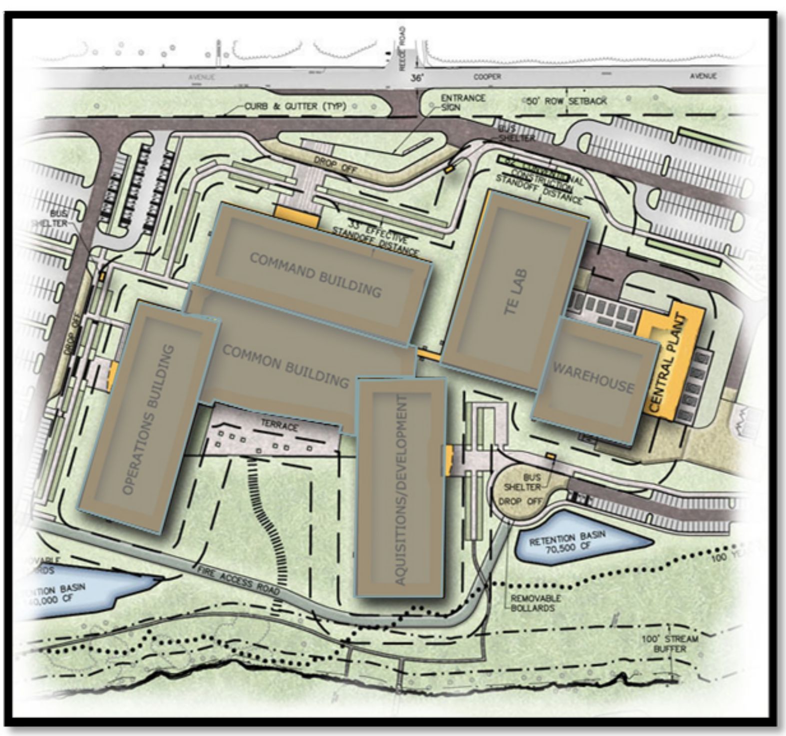


Figure 3.1.1=Central Utility Plan

A Central Utility Plant is attached to the Warehouse building and contains the DISA HQ's Central Heating and Cooling Plants. The Central Cooling Plant consists of four (4) Centrifugal chillers each with a capacity of 950 tons piped in two (2) pairs of series/counter flow configuration for highest possible chiller efficiency. The chillers will deliver CHW at 42°F, with return water at 60°F, and the plant will meet the entire cooling loads of the facility. Space in the plant will be allocated for a future chiller, pumps, and cooling tower as expansion is expected.

Four (4) Cooling towers will be located in a cooling tower yard adjacent to the plan and will be equipped with fan VDS's and electric sump heaters. The towers are piped to a suction header from which four (4) centrifugal vertical split case CW pumps will be piped to a distribution header, then finally to the individual chiller condensers. Non-chemical water treatment will be provided for the CW system.

Four (4) CHW pumps will serve the entire facility, while a fifth (5) pump will be on standby. Each CHW pump has a VSD. A system of insulated supply and return CHW piping will be provided to serve the entire facility.

The route of the piping will be through the Warehouse into the Service Corridor, where it will run overhead, with isolation valve branches to each major building along the route. To serve the roof mounted AHU's in the office buildings CHW supply and return risers will be located in the return air shafts to the units. Telecommunications closet CRAC units will be served by separate risers adjacent to the CRAC units. The CRAC units and risers will be in separate enclosures with access from the corridor.

To handle the Mission Critical spaces, two (2) chillers, with two (2) cooling towers, CW & CHW pumps will be available on emergency power.

Figure 3.1.2=Chiller Schedule

ID TAG	MANUFACTURER/ MODEL	TYPE	NOMINAL CAPACITY (Tons)	kW / TON AT DESIGN (ARI)	REFRIG TYPE	NPLV	EVAPORATOR				CONDENSER			
							FLOW (gpm)	EWT (°F)	LWT (°F)	dPW (ft wc)	FLOW (gpm)	EWT (°F)	LWT (°F)	dPW (ft wc)
CHLR-1	CARRIER 19XRV	WATER COOLED HERMETIC CENTRIFUGAL	975	0.521	R-134A	0.297	2,535	59.9	50.7	16.2	3,500	90.8	98.5	20.2
CHLR-2	CARRIER 19XRV	WATER COOLED HERMETIC CENTRIFUGAL	925	0.551	R-134A	0.353	2,535	50.7	42.0	16.6	3,500	83.5	90.8	20.4
CHLR-3	CARRIER 19XRV	WATER COOLED HERMETIC CENTRIFUGAL	975	0.521	R-134A	0.297	2,535	59.9	50.7	16.2	3,500	90.8	98.5	20.2
CHLR-4	CARRIER 19XRV	WATER COOLED HERMETIC CENTRIFUGAL	925	0.551	R-134A	0.353	2,535	50.7	42.0	16.6	3,500	83.5	90.8	20.4

ID TAG	MANUFACTURER/ SERIES	MODEL	SERVICE	FLOW (gpm)	HEAD (ft wc)	NPSH REQ'D (ft wc)	IMPELLER DIAMETER (in)	PUMP EFFICIENCY (%)	RPM	PUMP MOTOR SHAFT POWER (Bhp)	PUMP MOTOR MOTOR SIZE (Hp)	PUMP MOTOR Volt/Hz/Ph
CHWP-1	ARMSTRONG 4030	8x6x15	CHILLED WATER	1,265	175	6.9	13.24	80.01	1,780	69.9	100	460/60/3
CHWP-2	ARMSTRONG 4030	8x6x15	CHILLED WATER	1,265	175	6.9	13.24	80.01	1,780	69.9	100	460/60/3
CHWP-3	ARMSTRONG 4030	8x6x15	CHILLED WATER	1,265	175	6.9	13.24	80.01	1,780	69.9	100	460/60/3
CHWP-4	ARMSTRONG 4030	8x6x15	CHILLED WATER	1,265	175	6.9	13.24	80.01	1,780	69.9	100	460/60/3
CHWP-5	ARMSTRONG 4030	8x6x15	CHILLED WATER	1,265	175	6.9	13.24	80.01	1,780	69.9	100	460/60/3
CWP-1	ARMSTRONG 4030	8x6x11.5	CONDENSER WATER	1,750	90	8.1	10.80	87.15	1,770	45.6	60	460/60/3
CWP-2	ARMSTRONG 4030	8x6x11.5	CONDENSER WATER	1,750	90	8.1	10.80	87.15	1,770	45.6	60	460/60/3
CWP-3	ARMSTRONG 4030	8x6x11.5	CONDENSER WATER	1,750	90	8.1	10.80	87.15	1,770	45.6	60	460/60/3
CWP-4	ARMSTRONG 4030	8x6x11.5	CONDENSER WATER	1,750	90	8.1	10.80	87.15	1,770	45.6	60	460/60/3
CWP-5	ARMSTRONG 4030	8x6x11.5	CONDENSER WATER	1,750	90	8.1	10.80	87.15	1,770	45.6	60	460/60/3

Figure 3.1.3=Chilled Water Pump Schedule

ID TAG	MANUFACTURER/ MODEL	TYPE	DESIGN TOWER CAPACITY (MBH)	DESIGN AMBIENT WB (°F)	DESIGN FLUID FLOW PER CELL (gpm)	EWT (°F) (DESIGN)	LWT (°F) (DESIGN)	dPW (ft wc)	AIRFLOW PER CELL (cfm)
CT-1	EVAPCO AT-114-0324	INDUCED DRAFT COUNTERFLOW	13,125	78.0	1,750	98.5	83.5	1.8	163,200
CT-2	EVAPCO AT-114-0324	INDUCED DRAFT COUNTERFLOW	13,125	78.0	1,750	98.5	83.5	1.8	163,200
CT-3	EVAPCO AT-114-0324	INDUCED DRAFT COUNTERFLOW	13,125	78.0	1,750	98.5	83.5	1.8	163,200
CT-4	EVAPCO AT-114-0324	INDUCED DRAFT COUNTERFLOW	13,125	78.0	1,750	98.5	83.5	1.8	163,200

Figure 3.1.2=Cooling Tower Schedule

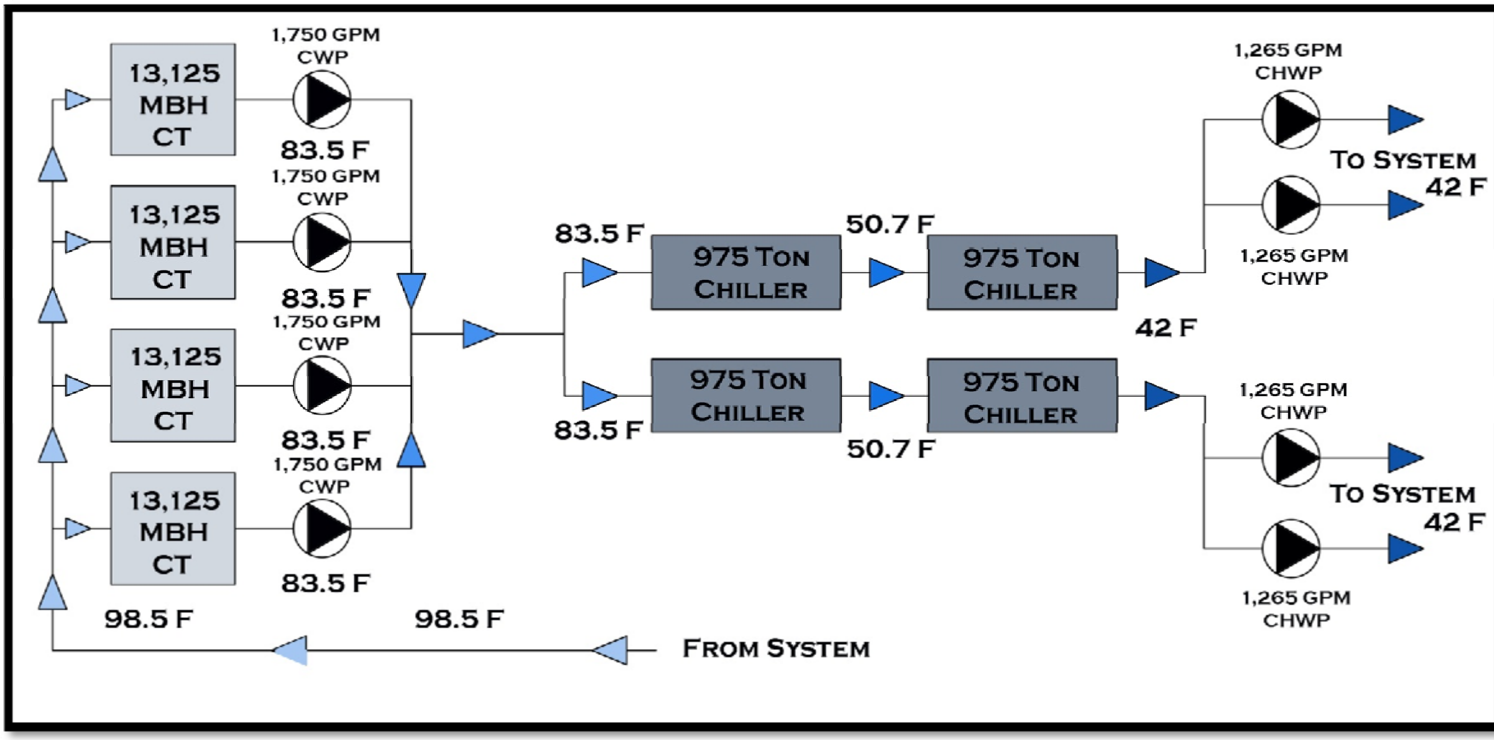


Figure 3.1.3=Cooling Plant Schematic

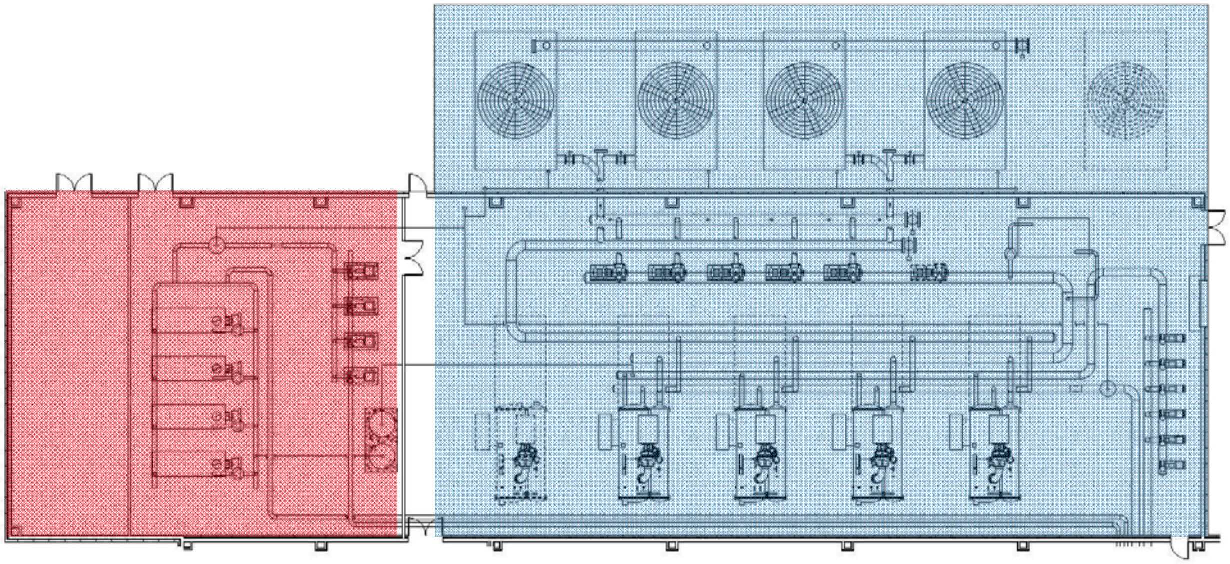
A Heating Plant will be provided adjacent to the Cooling Plant, in a separate enclosed room. The plant consists of four (4) gas fired HW boilers, three (3) of which will handle the entire facility's heating capacity with one (1) as standby. The plant will operate at a maximum HW supply temperature of 200°F and a return water temperature of 160°F with reset capability down to 180ºF supply temperature during mild weather. Each boiler will be provided with a primary in-line circulating pump, piped individually to each boiler. Three (3) end suction secondary pumps will serve as the HW distribution for the entire facility. A system of insulated Supply and Return HW piping will run with the CHW piping, with isolation valves at branches to each major building.

ID TAG	MANUFACTURER/ SERIES	MODEL	CAPACITY INPUT (MBH)	CAPACITY OUTPUT (MBH)	FLOW (gpm)	EWT (°F)	LWT (°F)
BLR-1	BRYAN RV SERIES	RV800-W	8,000	6,720	310	160	200
BLR-2	BRYAN RV SERIES	RV800-W	8,000	6,720	310	160	200
BLR-3	BRYAN RV SERIES	RV800-W	8,000	6,720	310	160	200
BLR-4	BRYAN RV SERIES	RV800-W	8,000	6,720	310	160	200

Figure 3.1.3-Boiler Schedule

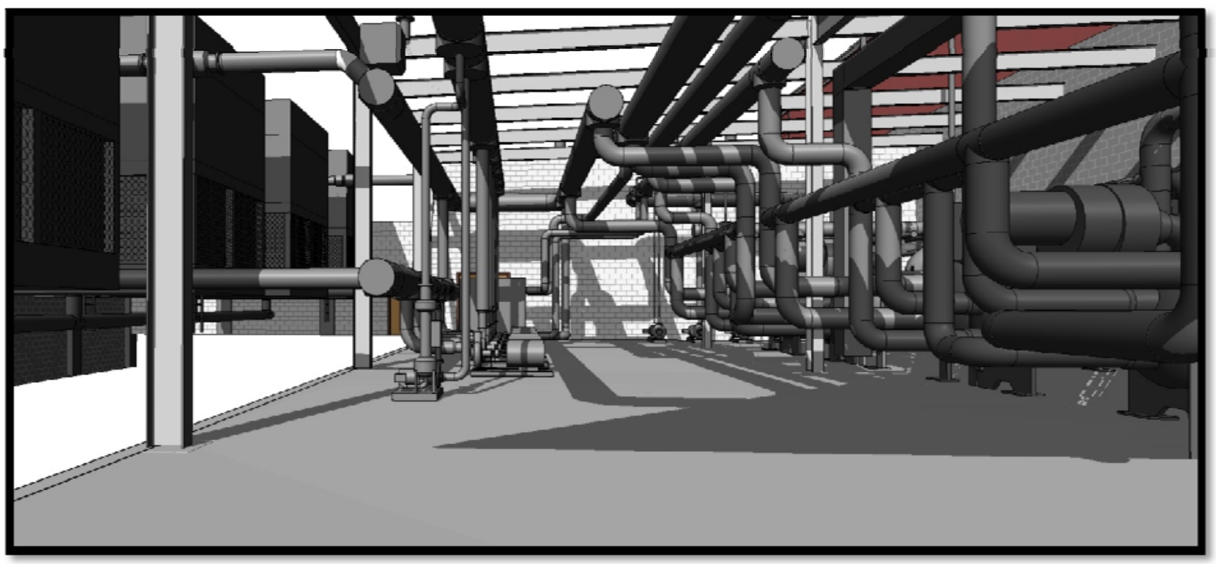
ID TAG	MANUFACTURER/ SERIES	MODEL	SERVICE	FLOW (gpm)	HEAD (ft wc)	NPSH REQ'D (ft wc)	IMPELLER DIAMETER (in)	PUMP EFFICIENCY (%)	RPM	PUMP MOTOR SHAFT POWER (Bhp)	PUMP MOTOR MOTOR SIZE (Hp)	PUMP MOTOR Volt/Hz/Ph
PHWP-1	ARMSTRONG 4030	6x4x8	PRIMARY HEATING HOT WATER	310	15	3.8	6.83	81.59	1,150	1.4	2	460/60/3
PHWP-2	ARMSTRONG 4030	6x4x8	PRIMARY HEATING HOT WATER	310	15	3.8	6.83	81.59	1,150	1.4	2	460/60/3
PHWP-3	ARMSTRONG 4030	6x4x8	PRIMARY HEATING HOT WATER	310	15	3.8	6.83	81.59	1,150	1.4	2	460/60/3
PHWP-4	ARMSTRONG 4030	6x4x8	PRIMARY HEATING HOT WATER	310	15	3.8	6.83	81.59	1,150	1.4	2	460/60/3
SHWP-1	ARMSTRONG 4030	3x2.5x6	SECONDARY HEATING HOT WATER	310	115	10.3	6.09	75.70	3,500	11.9	15	460/60/3
SHWP-2	ARMSTRONG 4030	3x2.5x6	SECONDARY HEATING HOT WATER	310	115	10.3	6.09	75.70	3,500	11.9	15	460/60/3
SHWP-3	ARMSTRONG 4030	3x2.5x6	SECONDARY HEATING HOT WATER	310	115	10.3	6.09	75.70	3,500	11.9	15	460/60/3
SHWP-4	ARMSTRONG 4030	3x2.5x6	SECONDARY HEATING HOT WATER	310	115	10.3	6.09	75.70	3,500	11.9	15	460/60/3

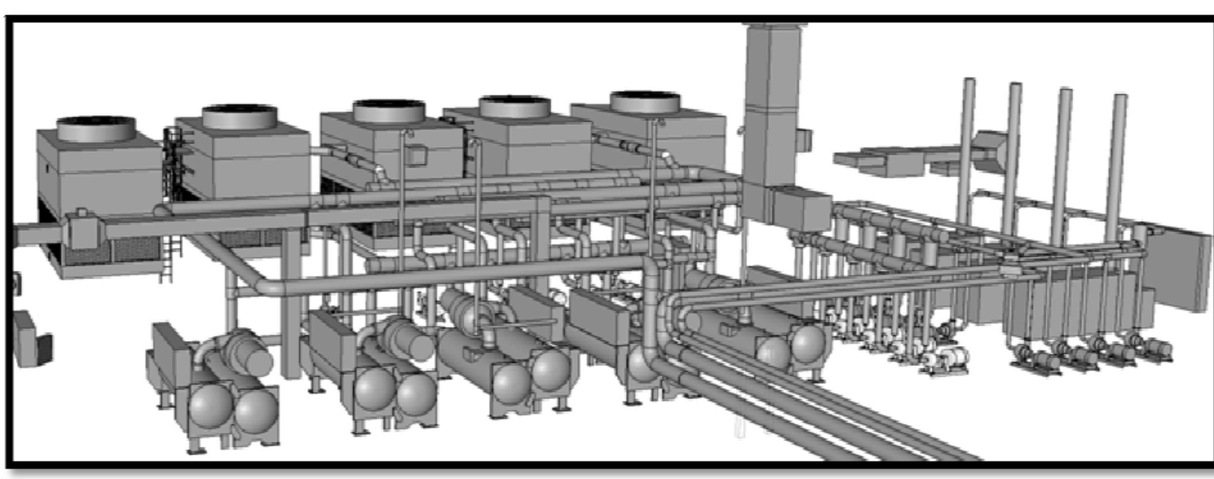
Figure 3.1.2=**Heating HW Primary & Secondary Pump Schedule**



Central Heating Plant (Shown in Red) & Central Cooling Plant (Shown in Blue)

Figure 3.1.2=Central Utility Plant





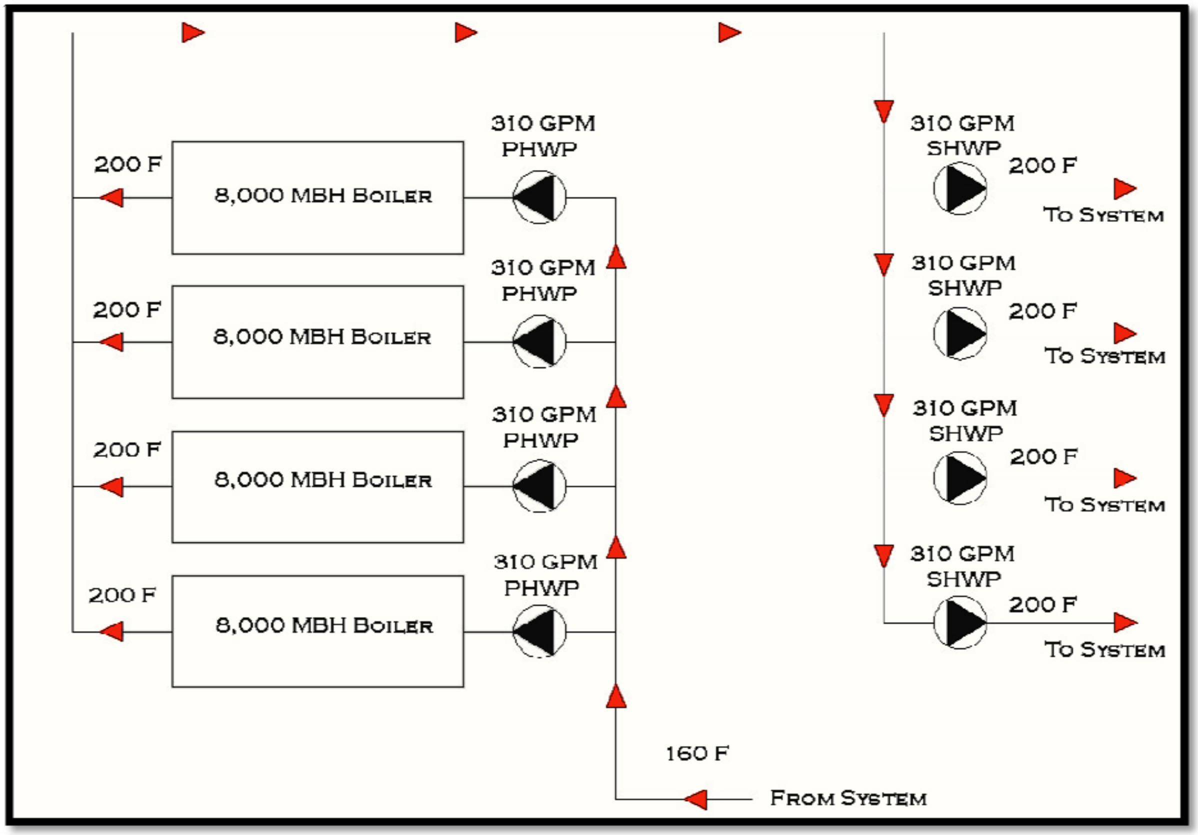


Figure 12- Heating Plant Schematic

Main Street/Service Corridor:

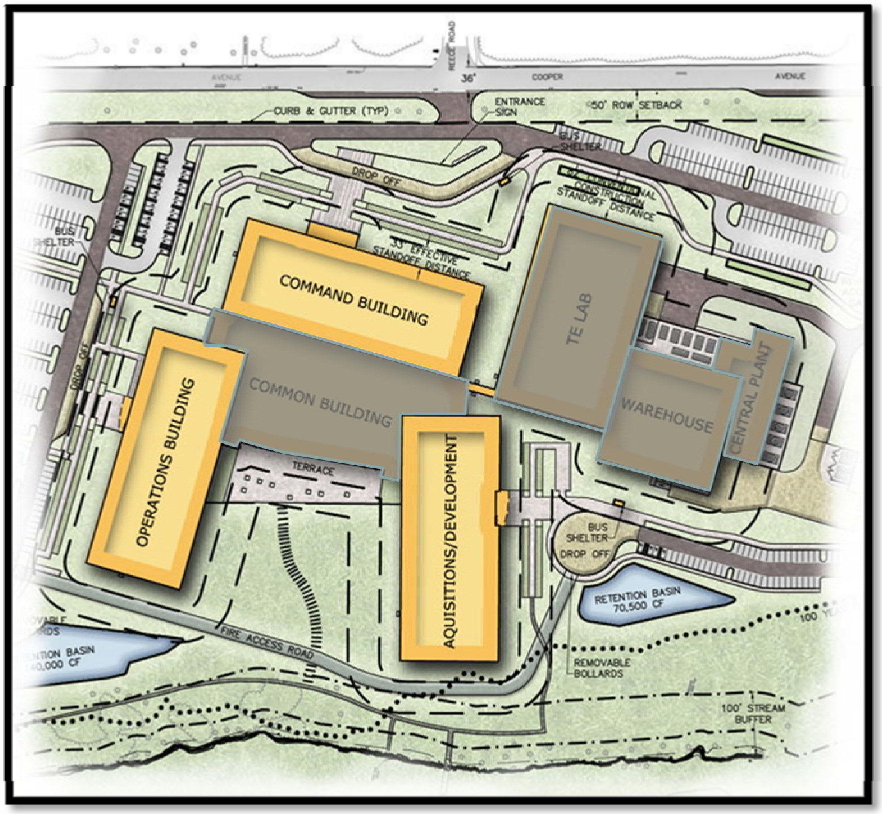
Main Street is a two story connecting circulation for all buildings and occurs at Level 1. This area doubles as the main circulation spine on the top level for all occupants, and as a service corridor on the level below. All CHW/HW distribution from the CUP in the Warehouse runs through this corridor and branches into the other buildings.

DISA HQ Energy Sources

Water Supply- The site is serviced by a 10" PVC connection.

Electrical Service- Provided by Baltimore Gas & Electric (BG &E). The peak and off peak rates and breakdown can be found in the attached appendix A.

Natural Gas Service is Provided by BG & E. The Customer Charges include a $35.00/mo flat rate plus $0.1975/therm (1st 10,000 therms) & $0.0948/therm for remaining



3.2 OFFICE BUILDINGS (COMMAND, ACQUISITIONS, OPERATIONS)

An Under Floor Air Distribution (UFAD) system will be provided for all typical office spaces via an 18" raised access floor. The UFAD system will pressurize the under floor plenum using supply air at a temperature between 62°F and 68°F. This UFAD system was implemented due to an increased energy efficiency compared to a conventional overhead system, reduced maintenance costs, increased occupant comfort as well as improved IAQ & ventilation. The ability to save energy while giving each employee ultimate control of their comfort via swirl diffusers along with the potential for LEED points were the driving factors of this decision.

The perimeter was treated as a "skin" system or a narrow exterior zone within which handles only the exterior envelope heat gains and losses. Perimeter Under Floor Terminal Units (UFT's) were installed, with a system of insulated flexible supply air duct connected to linear bar type floor diffusers located under the windows. HW coils in each UFT will provide perimeter heating.

By controlling the perimeter as a skin system, a large cooling only interior zone was created for the rest of the air handling zone. Each office floor is divided into three (3) air handling zones served by risers. All UFT HW coils will be served by insulated copper HW piping within the raised floor. A typical office layout is shown below in Figure II.2-2.

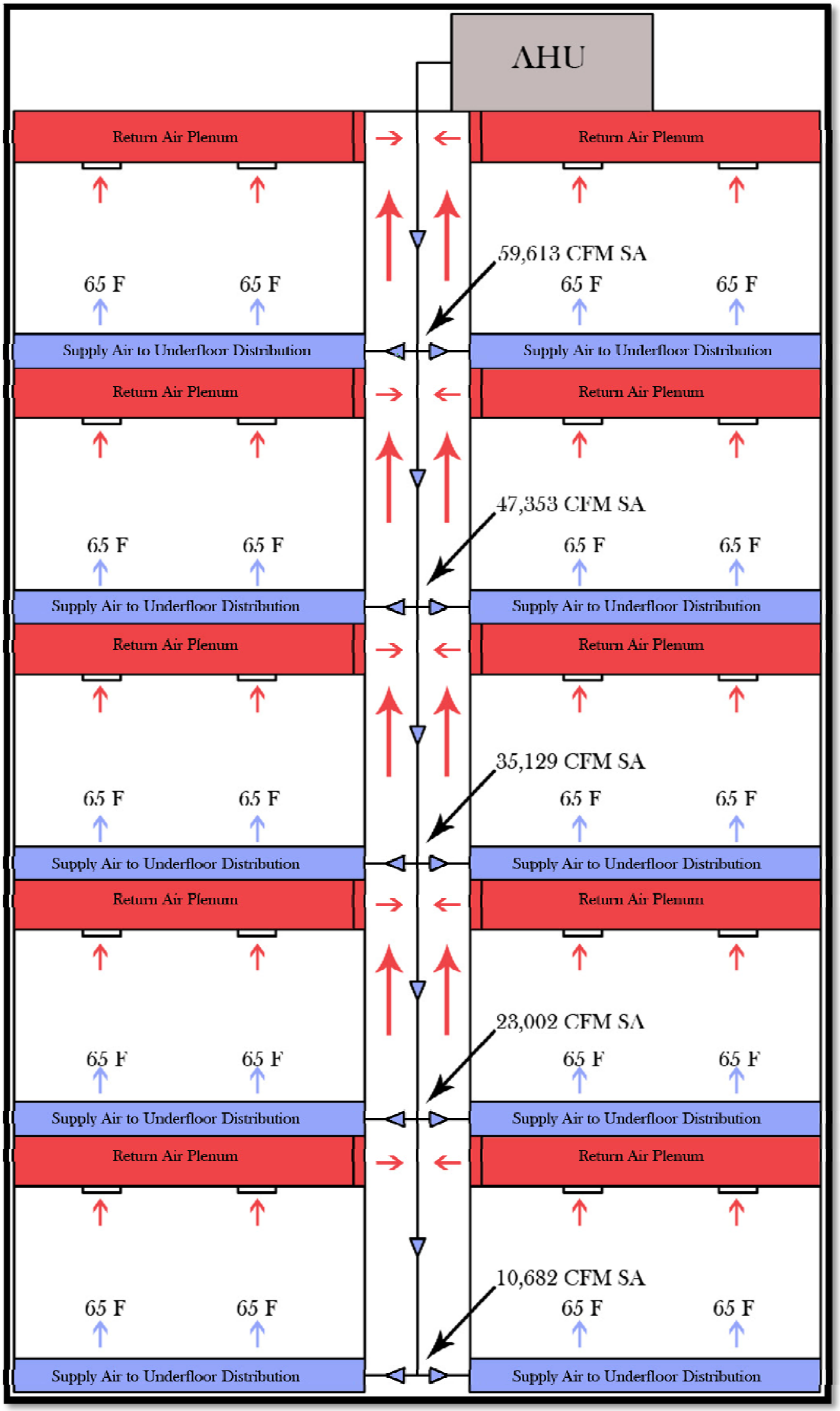


Figure 3.2.1-Riser

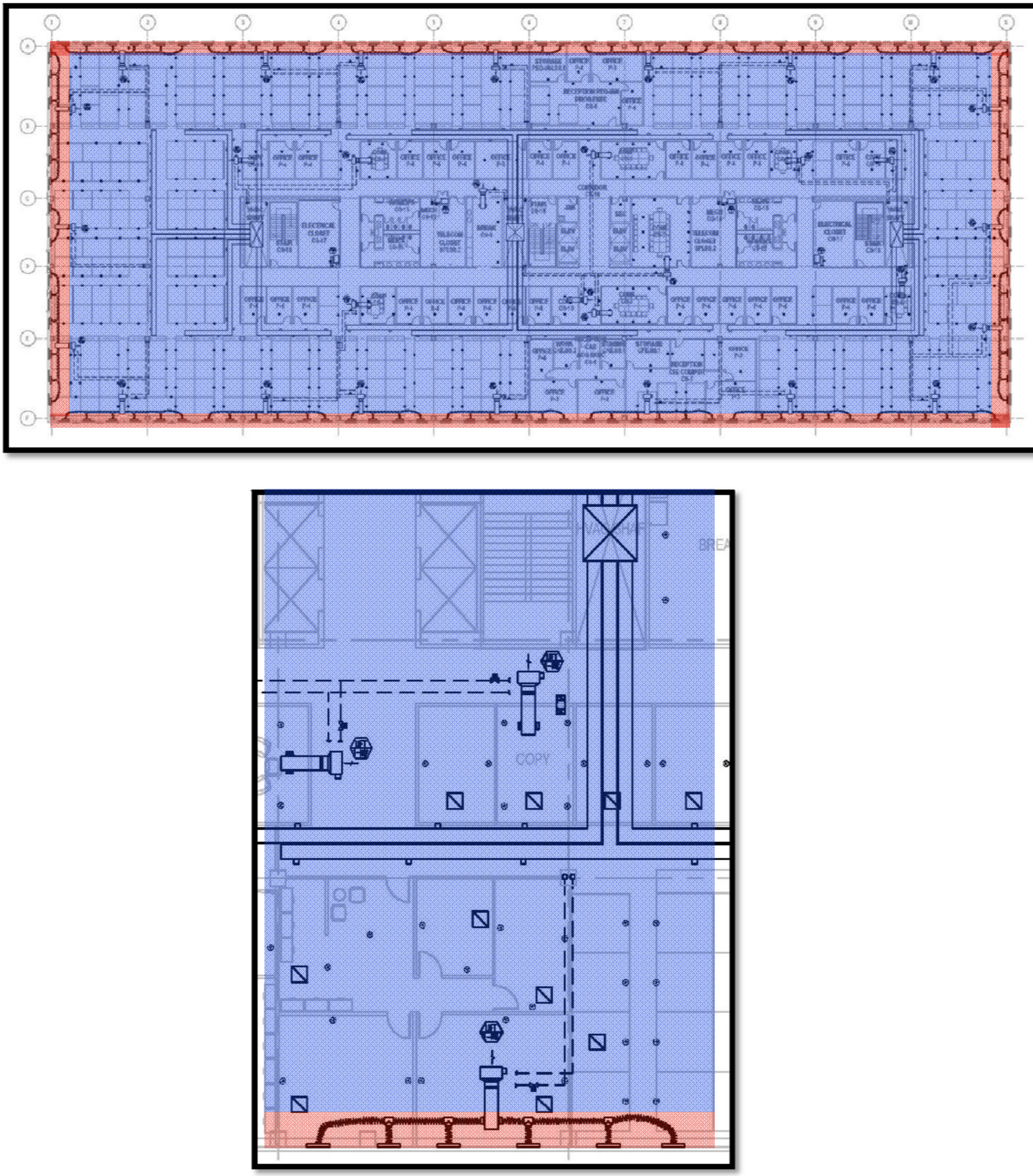


Figure 3.2.2- Typical Office UFAD Layout: Perimeter Skin (Red), Core (Blue)

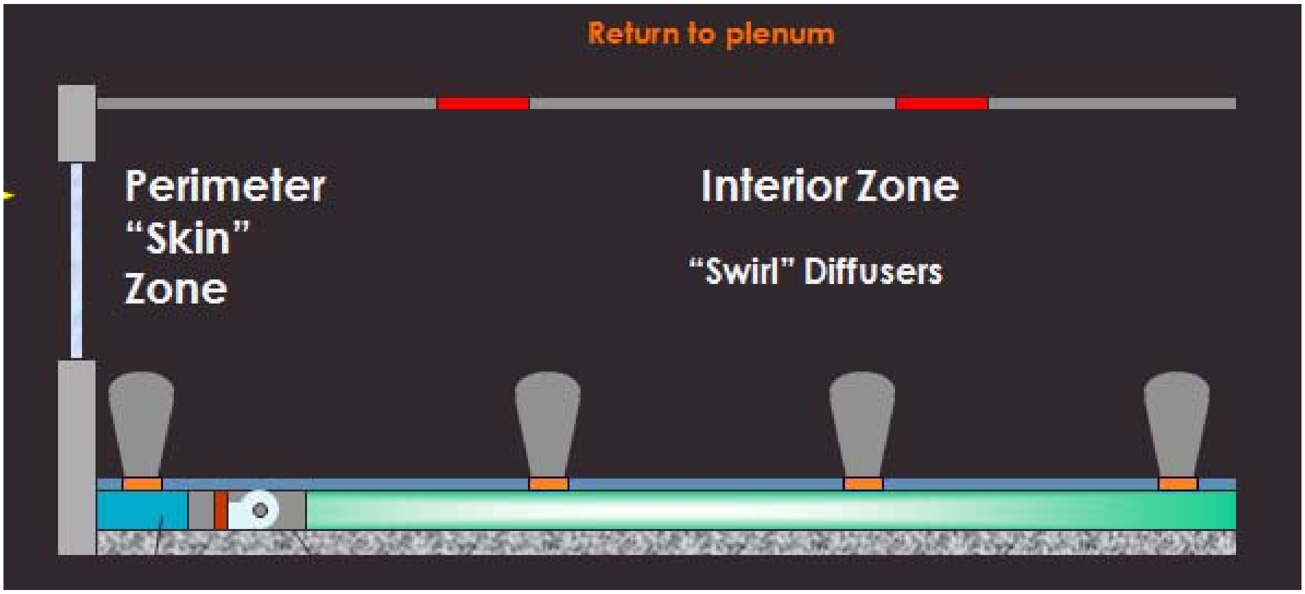


Figure 3.2.4-UFAD Detail

For each building there will be a total of three (3) roof level custom AHU's that will connect to ducted supply air risers in the central core shafts. The supply fan in each AHU will be installed with a VSD, controlled from downstream duct pressure. Return air enters the ceiling plenum and continues to the riser shaft which conveys the air to the roof level AHU's

The AHU's were placed on the roof to ensure that the Outside Air Intakes were well above the minimum 10' above grade for increased Anti-Terrorism/Force Protection. Also, the rooftop mechanical space was not deducted from the building square footage resulting in a maximum program area for occupants.

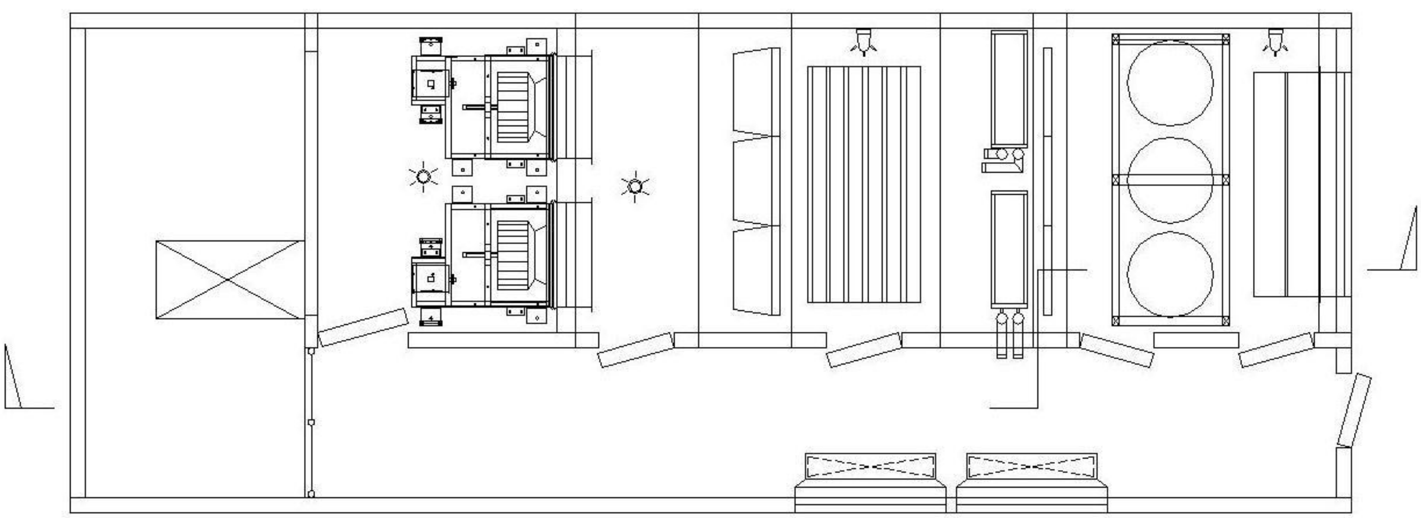


Figure 3.2.5 – Typical Custom AHU Plan View

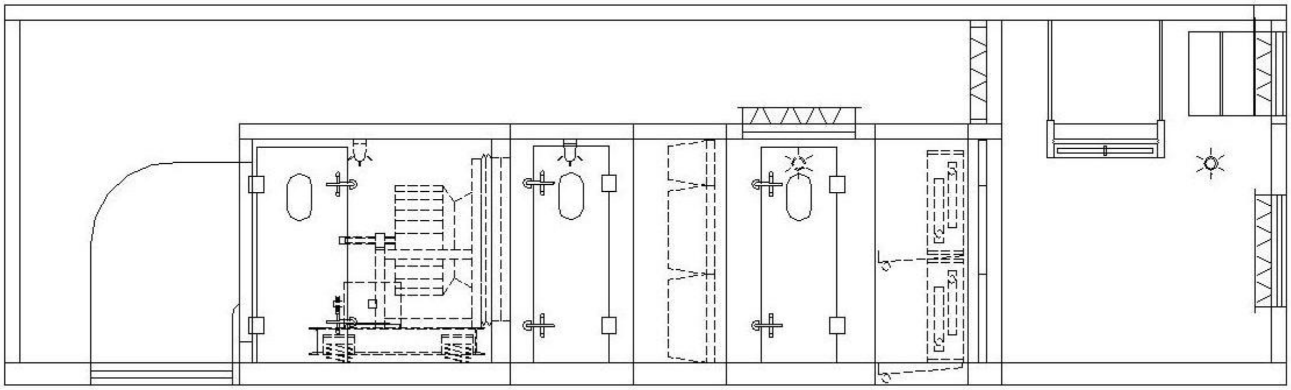


Figure 3.2.6- Typical Custom AHU Elevation

ID TAG	MANUFACTURER/ MODEL	LOCATION	SERVICE	SUPPLY AIR FAN # FANS	FAN AIRFLOW (cfm)	OUTSIDE AIR (cfm)	SA TEMP (°F)	MOTOR SIZE (hp)
O-AHU-1	BUFFALO	OPERATIONS ROOF	OFFICE UFAD LEFT CORE	1	38,000	7,030	62	40
O-AHU-2	BUFFALO	OPERATIONS ROOF	OFFICE UFAD CENTER CORE	2	25,250	9,345	62	2 @ 20
O-AHU-3	BUFFALO	OPERATIONS ROOF	OFFICE UFAD RIGHT CORE	2	22,500	8,325	62	2 @ 20
A-AHU-1	BUFFALO	ACQUISITIONS ROOF	OFFICE UFAD LEFT CORE	2	27,250	10,085	62	2 @ 25
A-AHU-2	BUFFALO	ACQUISITIONS ROOF	OFFICE UFAD CENTER CORE	2	31,000	11,470	62	2 @ 25
A-AHU-3	BUFFALO	ACQUISITIONS ROOF	OFFICE UFAD RIGHT CORE	2	24,250	8,975	62	2 @ 20

Figure 3.2.7- Custom AHU Schedule

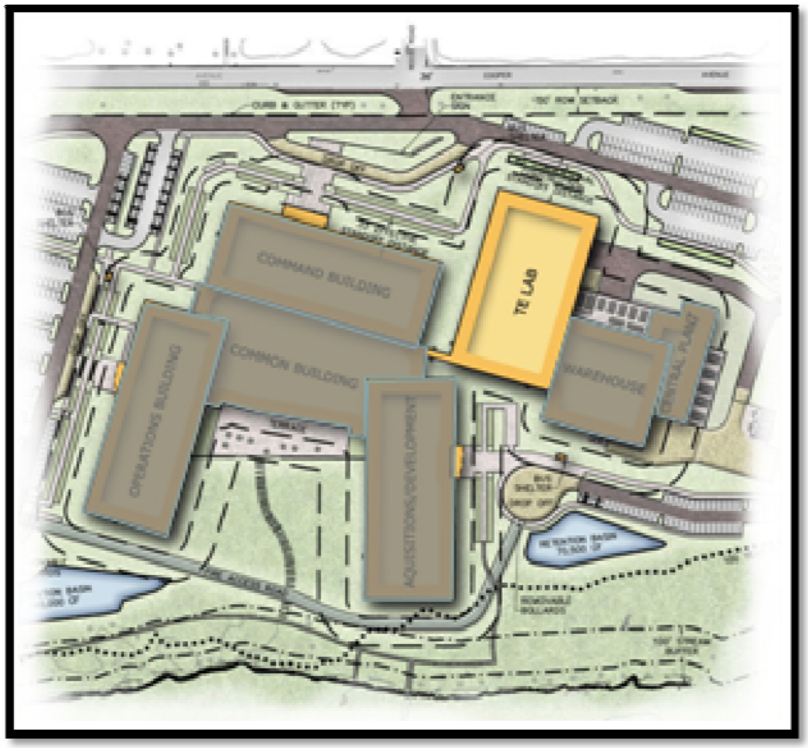
UFAD System Operation:

The Central Utility Plant produces Heating Hot & Chilled Water which is piped through the warehouse and into the Main Service Corridor. This piping branches off at the Operations, Command, and Acquisitions Buildings. Upon entering the building, the piping is routed to the core shafts.

The Heating Hot Water piping risers branch off at each floor of the Office buildings and are routed underneath the raised access flooring. This piping then feeds the heating coils located in the perimeter Under Floor Terminal Units (UFT's).

The Chilled Water piping risers extend through the shaft to feed the cooling coils of the rooftop AHU's. The air is then cooled to 62°F and enters the supply duct. The supply ductwork extends down the shaft and branches off at each floor. At each floor, the supply air enters and pressurizes the under floor plenum. Each occupant has an adjustable swirl diffuser in their cubicle or office in which they can control how much air is being supplied to their area.

The core of the office buildings receive only cooling due to the high loads created by the equipment, lighting, and high occupancy of the office space. As the air in the plenum reaches the perimeter, a fan coil unit (Under Floor Terminal) pulls in the air and provides reheat if necessary. This air is then supplied to the space via linear slot diffusers located on the floor. This is known as an exterior perimeter "skin" system and is utilized to combat exterior heat gains/losses depending on the season.



3.3 TE LAB

The TE Lab HVAC load requirements are 30% of the total cooling load for the entire facility, so energy efficiency for these systems is extremely important. Vertical air flow, Chilled Water AHU's designed specifically for data centers are coupled with direct injection outdoor air systems to provide both ventilation and humidity control to satisfy the unique demands of a data center with high personnel occupancy. These units will be located in two (2) secure equipment rooms.

This system requires less maintenance, offers great flexibility for lab configurations, and provides greater energy efficiency than provided by traditional Computer Room Air Conditioning (CRAC) units.

Each floor has nine (9) AHU's plus one (1) standby for a total of 20. The supply air is supplied to the TE Lab via perforated floor tiles with manual balancing dampers. Return air will be extracted from the space via RA grilles and into the ceiling plenum until finally reaching the CHW AHU's in the equipment room.

Two (2) 100% OA constant volume AHU's, located in the same equipment rooms as the vertical AHU's distribute air to the TE Lab space and to the individual "hotel" rooms via Constant Air Volume (CAV) terminal units.

The purpose of the CAV terminals is to allow OA quantities to be re-directed to areas of higher occupancy in the future by digital entry at the BAS control console. A system of under floor CHW supply and return piping (sized for future loads of 70 W/SF) was installed as well.

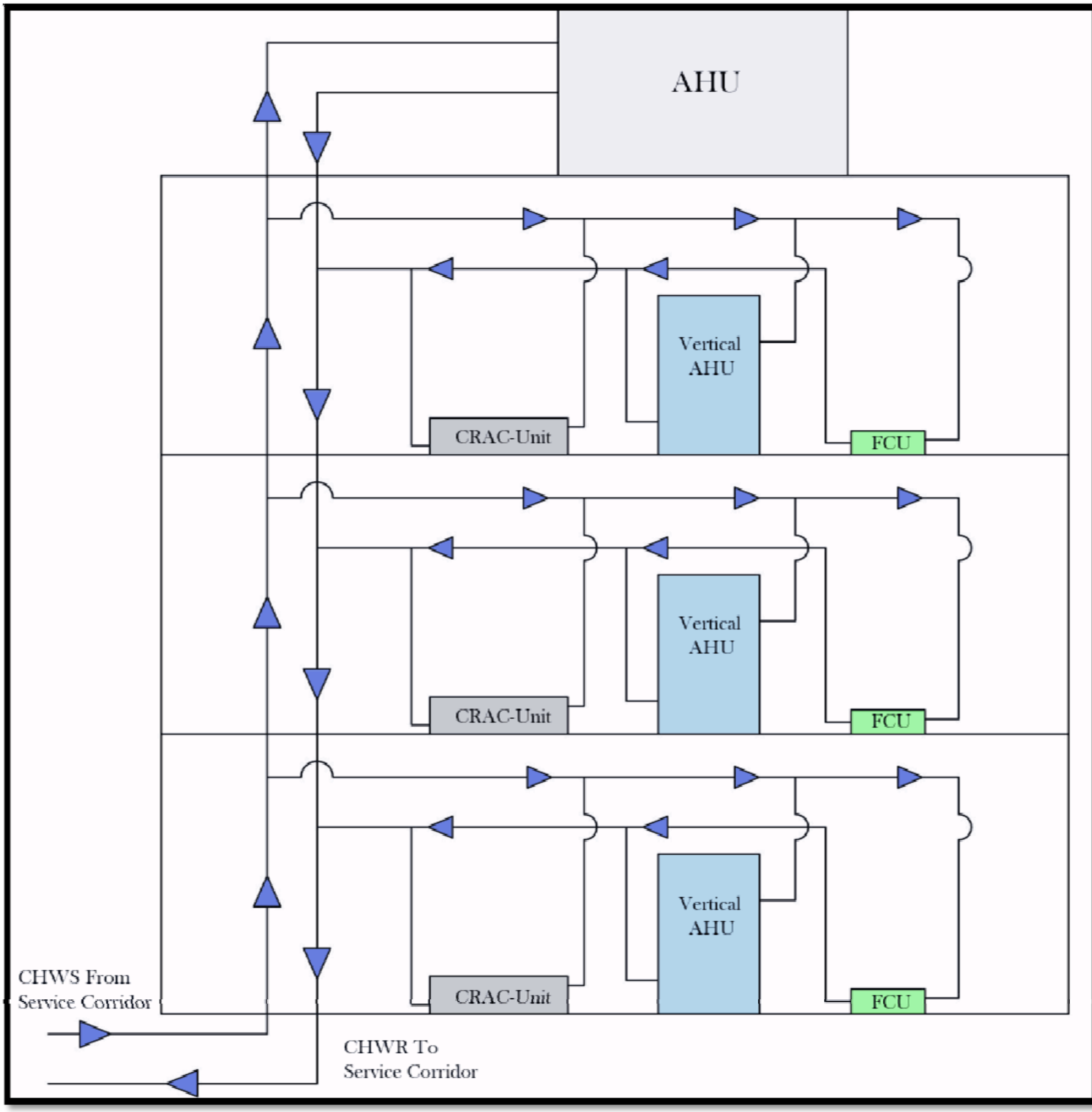


Figure 3.3.1- Lab Chilled Water Schematic

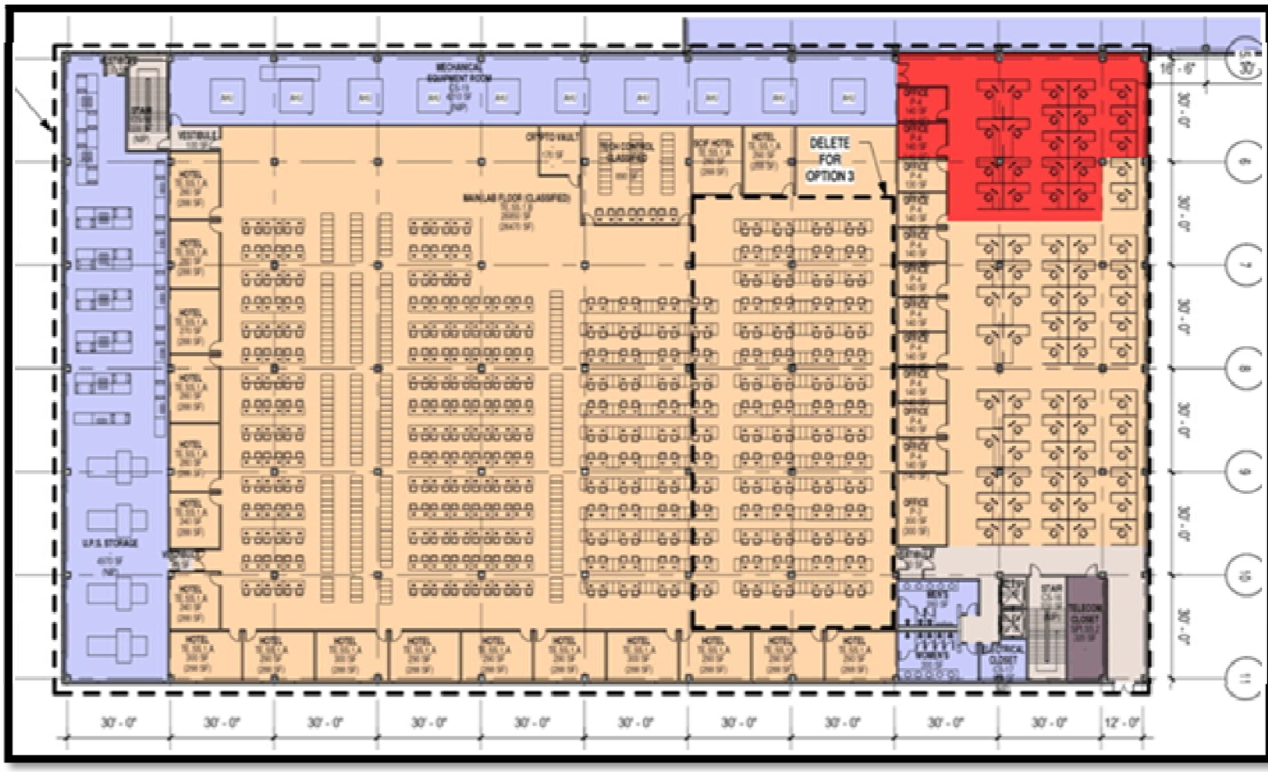
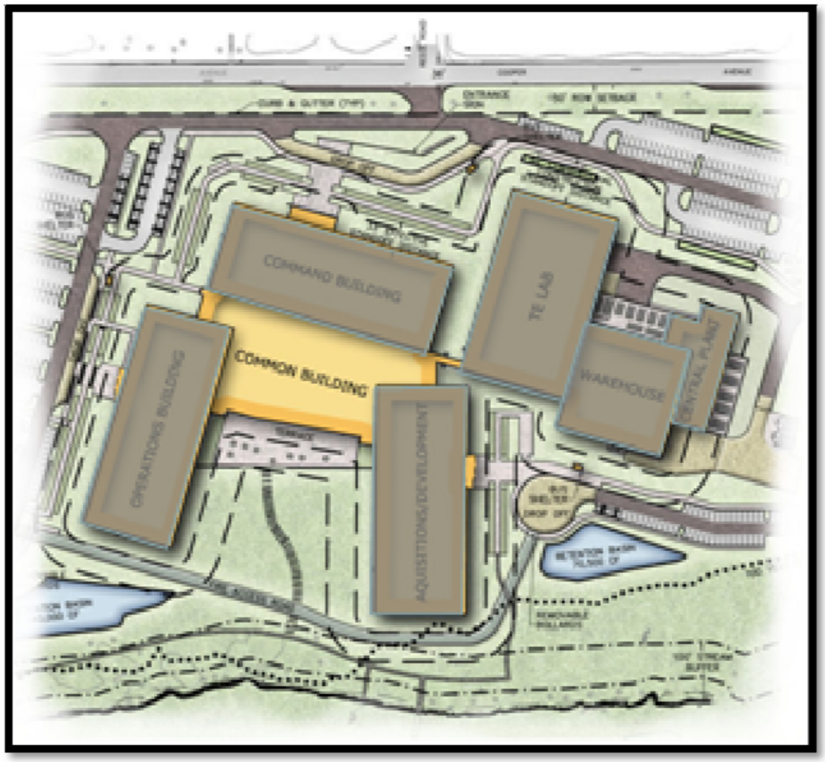


Figure 3.3.2- Lab Floor Plan

ID TAG	MANUFACTURER/ MODEL	LOCATION	SERVICE	SUPPLY AIR FAN # FANS	UNIT AIRFLOW (cfm)	OUTSIDE AIR (cfm)	SA TEMP (°F)	MOTOR BRAKE HP (bhp)	MOTOR SIZE (hp)	MOTOR Volt/Ph/Hz	COOLING COIL TOTAL CAPACITY (MBH)	COOLING COIL SENSIBLE CAPACITY (MBH)
L-OHU-1	CARRIER 39 M	LAB	DOAS SYSTEM	1	10,500	10,500	52	11.2	15	460/60/3	868	511
L-AHU-(1-10)	RACAN	LAB MECH. RM.	LAB MLFS & HOTELS	1	34,000	-	65	15.7	20	460/60/3	805	794
L-AHU-(11-20)	RACAN	LAB MECH. RM.	LAB MLFS & HOTELS	1	32,000	-	65	14.3	20	460/60/3	768	757
L-AHU-21	CARRIER 39 M	LAB ROOF	LAB ADMIN	1	7,900	2,150	55	8.7	10	460/60/3	356	257

Figure 3.3.3- LAB AHU Schedule



3.4 COMMON BUILDING

The Common Building upper level will be serviced by UFAD via RAF. The lower level will be serviced by overhead VAV systems to accommodate dining, kitchen, fitness and locker room functions.

The Exercise Room will be provided with a separate overhead VAV system that operates in conjunction with the Locker Rooms. A separate roof mounted AHU will serve this area. The system will be similar to that described for the Dining Area. Locker Rooms will be ventilated by roof mounted exhaust fans. Transfer air from the Exercise Room will provide make-up air.

3.5 L.E.E.D ANALYSIS

The DISA HQ is projected to receive a LEED Silver Certification. The LEED for New Construction v2.2 checklist has been filled out and can be found in Appendix A.

The building's mechanical systems design and construction helped the DISA HQ project receive the following points:

-<u>Energy & Atmosphere</u>

- Optimize Energy Performance: 14% New Buildings- 2 points
- Enhanced Commissioning- 1 point
- Enhanced Refrigerant Management- 1 point

-<u>Indoor Environmental Quality</u>

- **Outdoor Air Delivery Monitoring: 1 point**
- **Construction IAQ Management Plan: During Construction & Occupancy-2 points**
- **Controllability of Systems, Thermal Comfort: 1 point**
- **Thermal Comfort Design & Verification: 2 points**

The mechanical system design and construction received 10 points of the total 34 points expected; however the actual mechanical system did not have an incredible effect on the LEED rating. Two points were awarded for making sure the ductwork was protected during construction to manage IAQ. Two points were also awarded for enhanced commissioning, and refrigerant management which is more of a reflection of building operation & management rather than mechanical design. A total of three points were also awarded for thermal comfort & controllability, which are a direct result of the UFAD system used in the office buildings.

4.0 MECHANICAL DEPTH- WATER COOLED SERVER RACKS

4.1 DESCRIPTION

The mechanical design changes are being focused on the TE Lab building. This was chosen due to the fact that the lab has extremely high cooling loads (30% of entire facility's cooling load). The lab is expected to expand in the future, and therefore to handle these loads the central cooling plant and distribution piping has been oversized. The oversized equipment has been installed up front, so when the expansion takes place the infrastructure is already there to handle the new loads. This seemed inefficient, to spend more money buying larger chillers, pumps, and distribution piping.

I originally proposed the installation of a built up chiller plant to handle the Lab's cooling loads. This built up chiller plant would consist of water cooled condensers and an integral fluid cooler which offers economizer hours. I thought this would help solve the problem of the inefficiency of the oversized cooling plant, which is a waste of upfront costs as well as operating costs.

In this scenario, a separate chiller plant would be built to handle the Lab's cooling. This would lead to a decrease in size and equipment of the main central utility plant. In this plan, the cooling plant could be built now to handle just the current loads, not the future. In the future, when expansion occurs, more chillers can be added to the built up chiller plant to handle these loads. Therefore, you only have the extra capacity when it is needed. This would be helpful due to the fact the expansion is eminent, but the date of expansion is not known.

After research and calculations, I decided this was not the best option. The central utility plant's design ultimately suits the Lab building very well for current loads and future expansion. I did cost analysis calculations and as I estimated the cost of a new built up chiller plant there was no way the energy savings would make this feasible. The new plant would be a huge increased cost and the energy savings from pumping/oversized equipment would not be that great. It would lead to a payback period of well over 60 years.

I decided that the focus of this thesis design should be on installing water cooled server racks. These racks could be installed with a significantly smaller impact on schedule and upfront cost while having a much larger effect on the energy savings of the lab building.

4.2 BACKGROUND INFORMATION

Experts have grown increasingly worried about how much energy the nation's data centers use. In 2006, the U.S. Environmental Protection Agency estimated that data centers consumed 1.5 percent of the nation's electricity -- more than all the color TVs in the country. And without significant changes, energy use at data centers was expected to double by 2011, according to EPA's report.

The server racks in the lab building create huge interior heating gains. This led to the lab building consuming 30% of the facility's cooling load, while only taking up 10% of the facility's programmable area. Google and Syracuse University are two examples of recently constructed lab spaces which have utilized water cooled server racks to offset the huge heat gains these pieces of equipment give off.

Syracuse University recently teamed with IBM to construct what is known as one of the most energy efficient computer operations in the world. Syracuse was able to receive over $2 million in public grants for installing such an efficient system. The potential tax credits could help drive down the additional upfront cost of adding these water cooled chiller racks.

As more data needs to be backed up, servers are growing every day. As server size and density increases, the heat load increases at the same rate. Figure XXXX below shows this relationship.

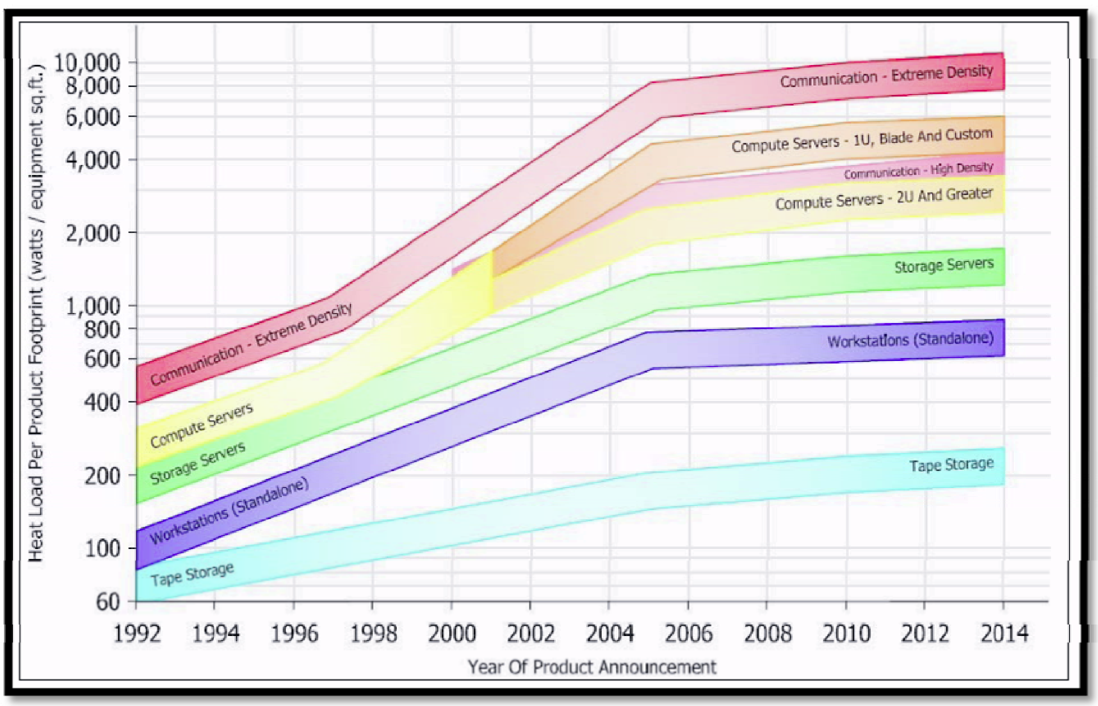


Figure 4.2.1- Data Center Growth

Currently, the lab space is utilizing a hot/cold aisle configuration to remove the heat from the servers. In this system, cold air is supplied along the front of the rack to cool the equipment, while the return is located behind the equipment to remove the heat. Essentially, hot and cold aisles are formed. An example of this system can be found below in Figure XXX.

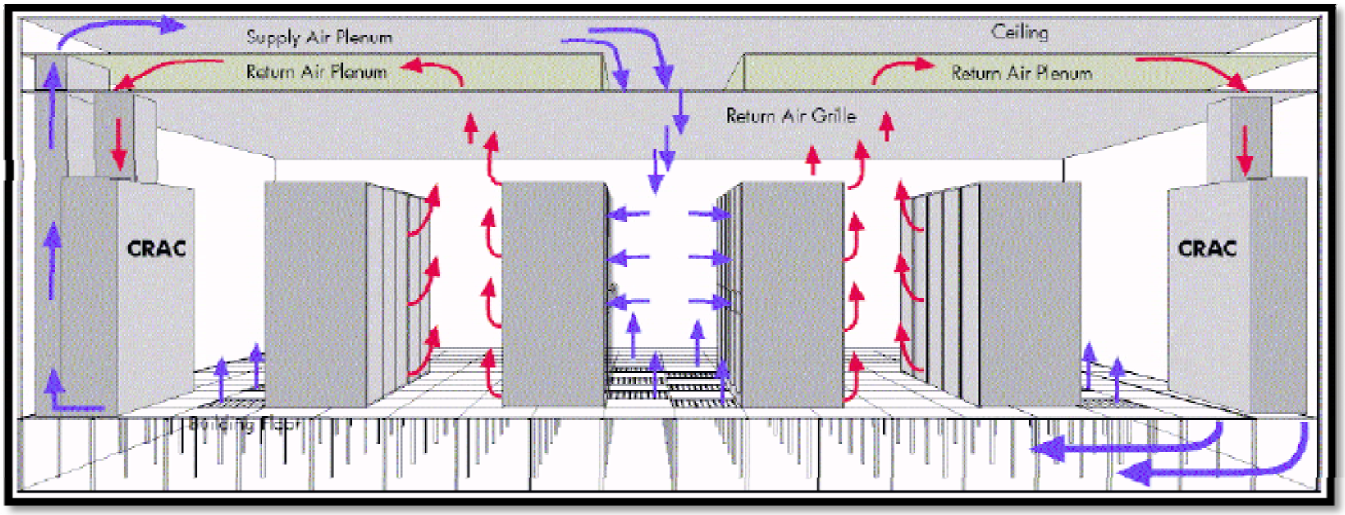


Figure 4.2.2-Hot & Cold Aisle Configuration

Although this is an effective method to remove heat from the equipment, the installation of water cooled server racks could have a profound effect on the heat gain of the space. An example of a water cooled rack can be found below.

Figure 4.2.3- Water Cooled Server Rack

The controlled airflow inside a relatively small enclosed space enables the evenly distributed cool air supply for all servers, regardless of their installation position in the rack. The top server is cooled exactly as much as the lowest. In the current configuration, studies find that the top of the racks do not receive adequate cooling.

Initially, I was looking at this lab space all wrong. I looked to design a built-up chiller plant to cut upfront costs and save a little bit of energy. Then after research, I realized that it is much more important to cut the loads down and ensure that in the future the building will be able to handle the density needed. The densities of severs are increasing exponentially, and these water cooled racks will allow more equipment in a smaller amount of space. It is particularly important for our Defense System to ensure that this facility will be able to handle the future loads.

4.3 DESIGN

Currently, there are 929 server racks at 10 KW each for a total of 9290 KW in the Lab space. The server racks are located on the first and second level of the lab building. Currently, the servers are designed to have a hot/cold aisle configuration. In such a configuration, a supply diffuser supplies cold air to the front of the server and a return diffuser is behind the unit to pull the hot air off the server. Servers are placed back to back so essentially a hot aisle exists in the middle where all the return diffusers are located. See figure XXX below

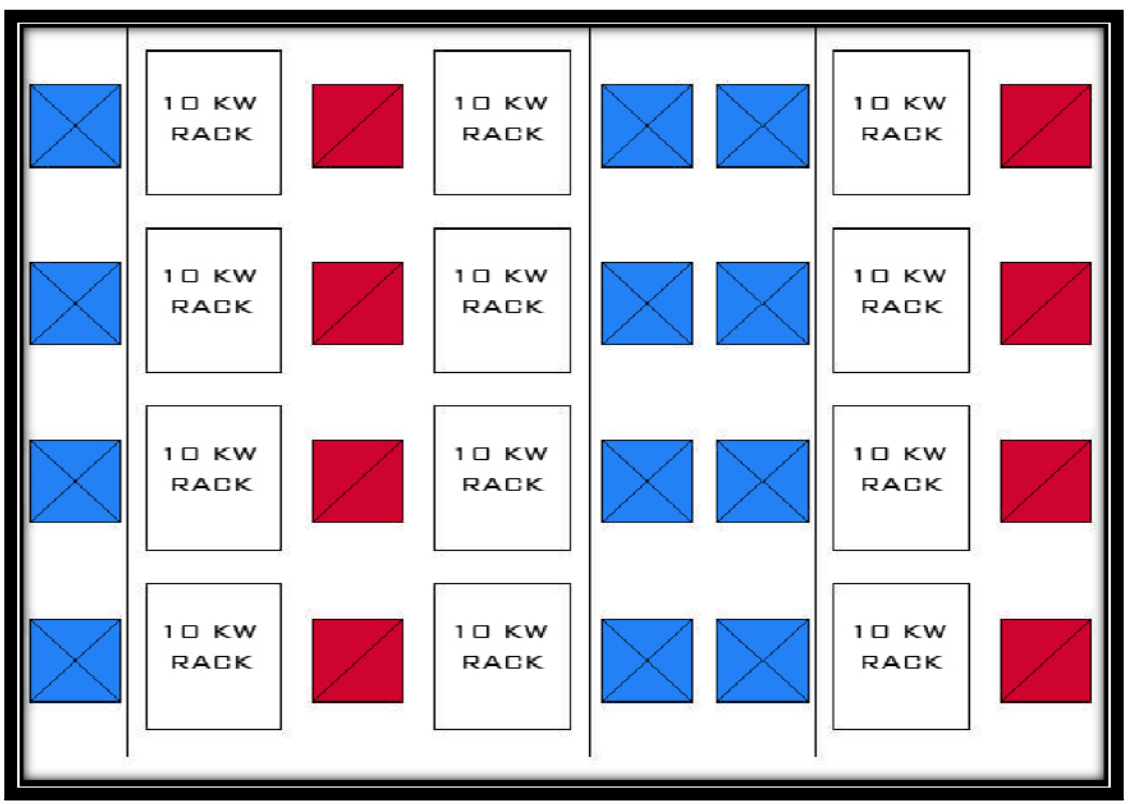


Figure 4.3.1 Rack Layout

Chilled Water from the CUP feeds 20-Stand up AHU's (10 on each level. The AHU's feed the space via a 18" RAF and handle the sensible cooling for the lab. The ventilation is provided by a dedicated outdoor air handling unit on the roof. The chilled water plant also feeds CRAC units which help combat the heat gain from the servers.

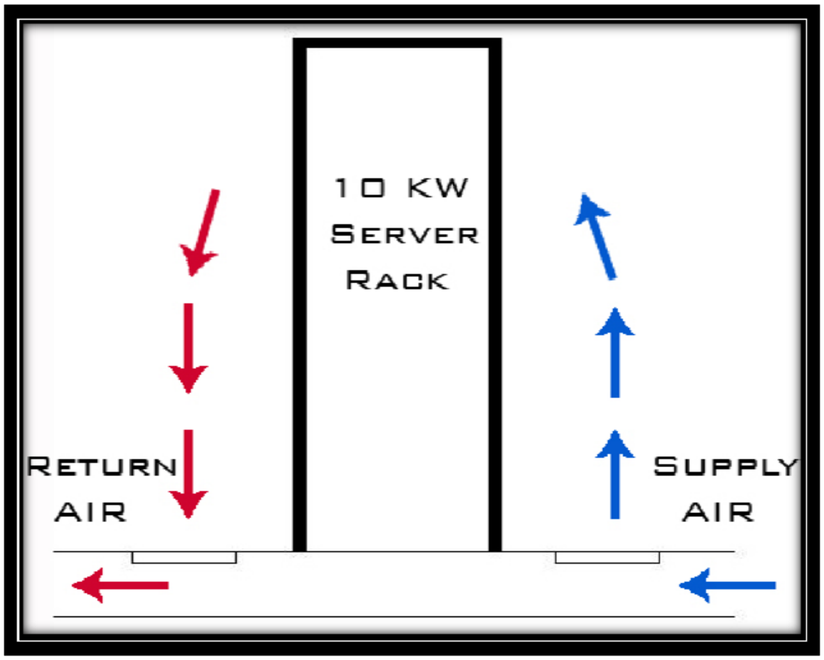


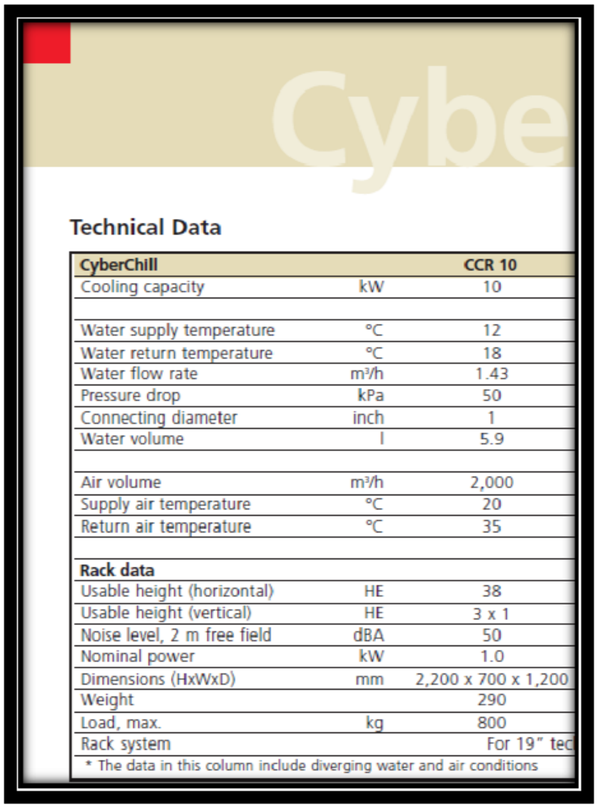
Figure 4.3.2 Rack Layout

The servers mainly contribute to the cooling load, and the server density is expected to rise in the future. Below is the load summary.

	Overall Current Total	Overall Future Total
BTU/h	12,463,405	27,369,785
Tons	1,039	2,281
Future Growth (BTU/h)		14,906,380
		1,242
Future Flowrate @ 18F dT (gpm)		1,656

Figure 4.3.3 Load Summary

To ensure the future loads are met, while cutting the current loading of the lab I propose adding water cooled server racks. We currently have 929 racks at 10 KW each. The technical data on the new water cooled racks can be found below.



Technical Data

CyberChill		CCR 10
Cooling capacity	kW	10
Water supply temperature	°C	12
Water return temperature	°C	18
Water flow rate	m³/h	1.43
Pressure drop	kPa	50
Connecting diameter	inch	1
Water volume	l	5.9
Air volume	m³/h	2,000
Supply air temperature	°C	20
Return air temperature	°C	35
Rack data		
Usable height (horizontal)	HE	38
Usable height (vertical)	HE	3 x 1
Noise level, 2 m free field	dBA	50
Nominal power	kW	1.0
Dimensions (HxWxD)	mm	2,200 x 700 x 1,200
Weight		290
Load, max.	kg	800
Rack system		For 19" tec

* The data in this column include diverging water and air conditions

Figure 4.3.4 Rack Detail

I propose installing new chilled water piping to each unit via the RAF and converting each rack to one that is water cooled. The current chiller plant has the capacity to cool the water needed for the racks as well as pump it. The piping in the corridor will be increased to 20" before the lab. Below is the updated schematic of the lab building.

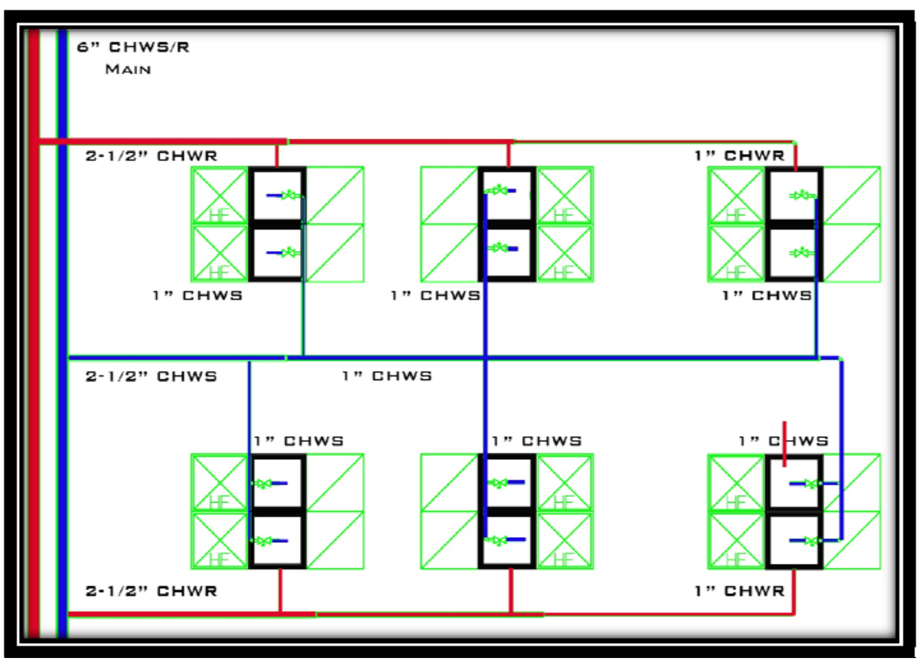


Figure 4.3.5 Rack Distribution Piping

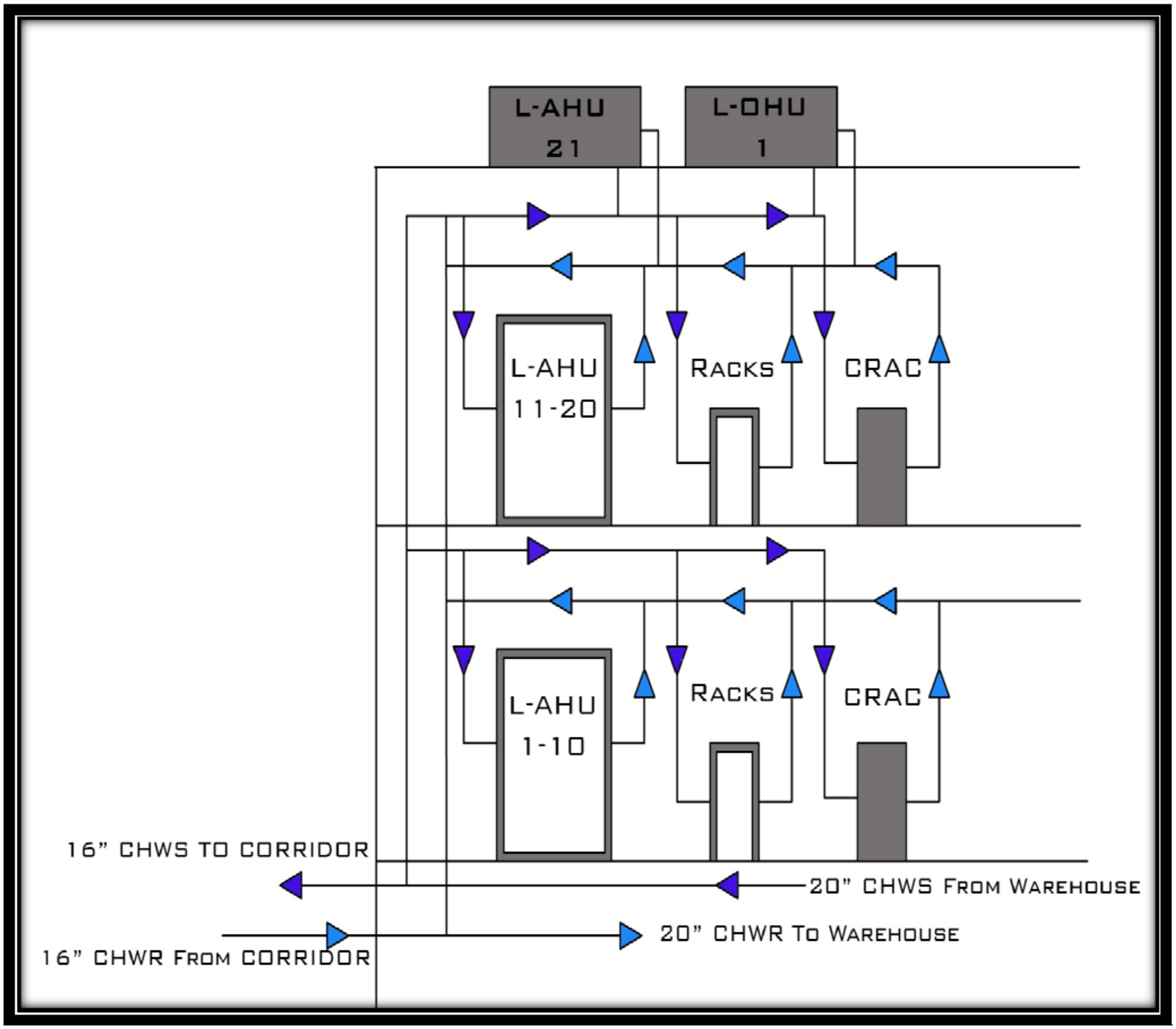


Figure 4.3.6 Proposed Lab Riser

I have also sized new main and branch piping to each server, which will not have a huge impact on scheduling. The fact that the piping will be located under the raised access floor and running through the aisles will help cut the man hours. I have included the piping material and labor to install the equipment in my payback period calculations.

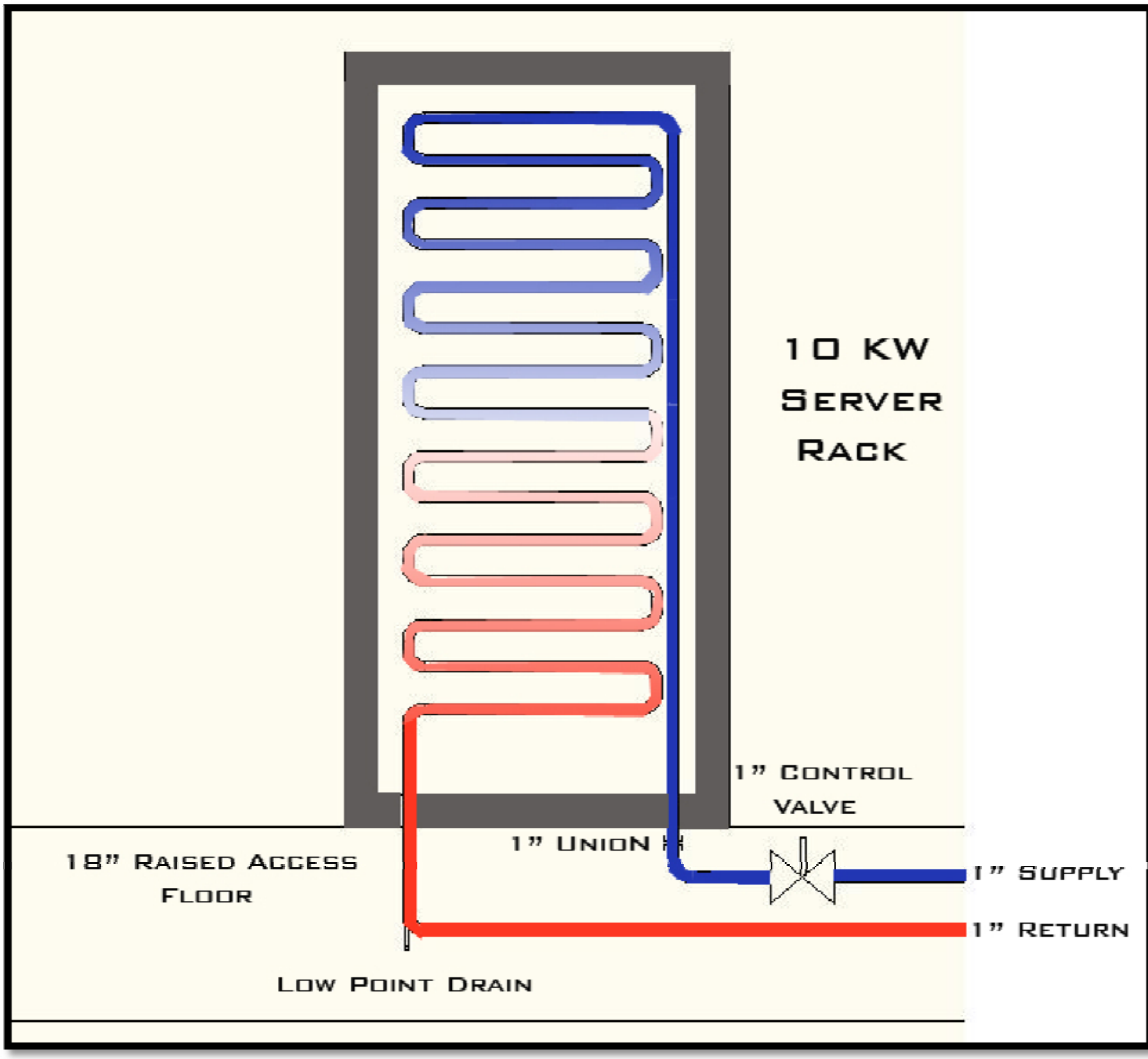


Figure 4.3.7 Server Rack Detail

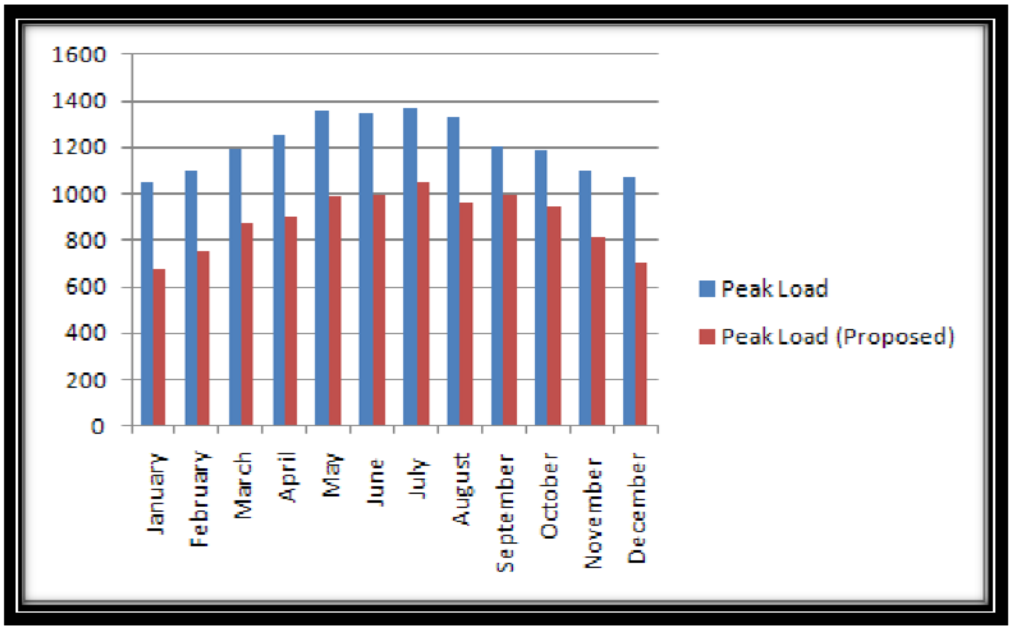
4.4 RESULTS

The total cost of installing the water cooled server racks was found to be $1,063,400.00, the breakdown can be found below.

ITEM	COST
Racks	$ 743,200.00
Piping/ Valves/Fittings	$ 200,000.00
Controls	$ 95,000.00
Labor	$ 25,200.00
Total	$ 1,063,400.00

Figure 4.4.1 Cost Breakdown

The water cooled server racks will lead to a 21% reduction in cooling load and will save $180,000.00/year on electricity costs.



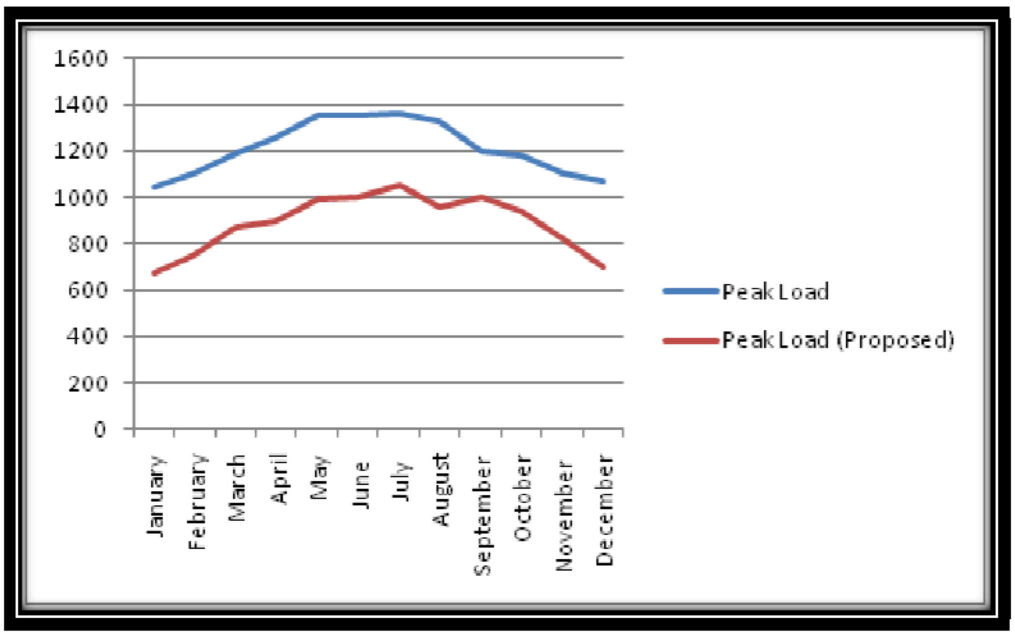


Figure 4.4.1&2 Proposed Changes Energy Summary

	Original System as Designed		Proposed System	
Energy Source	Energy (10^6 BTU/yr)	$/yr	Energy (10^6 BTU/yr)	$/yr
Electricity	113,775.80	$2,926,771	100,122.70	$2,746,771.00
Gas	6,988.30	$90,913.00	6,988.30	$90,913.00
TOTAL	**120,764.10**	**$3,017,684**	**$107,111**	**$2,837,684**

Figure 4.4.3 Energy Consumption Summary

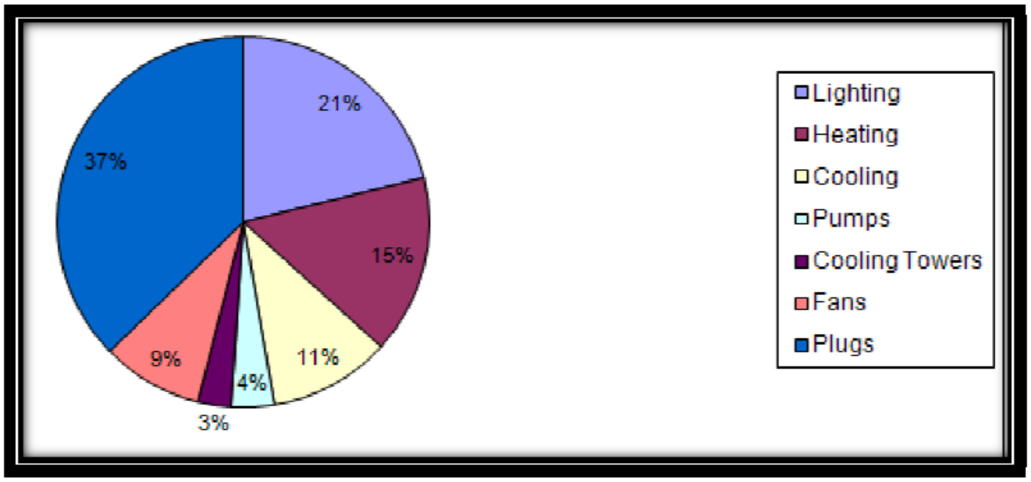


Figure 4.4.4 DISA HQ Electricity Breakdown

Pollutant	MD (lb/kWh)	Total Pollutants From Electricity
CO_{2e}	1.82E+00	6.07E+07
CO_2	1.71E+00	5.70E+07
CH_4	4.02E-03	1.34E+05
N_2O	3.54E-05	1.18E+03
NO_X	3.10E-03	1.03E+05
SO_X	1.11E-02	3.70E+05
CO	1.19E-03	3.97E+04
TNMOC	7.74E-05	2.58E+03
Lead	1.16E-07	3.87E+00
Mercury	3.56E+08	1.19E+16
PM10	9.25E-05	3.08E+03
Solid Waste	1.69E+01	5.64E+08

Pollutant	MD (lb/kWh)	Total Pollutants From Natural Gas
CO_{2e}	1.23E+02	8.60E+08
CO_2	1.22E+02	8.53E+08
CH_4	2.50E-03	1.75E+04
N_2O	2.50E-03	1.75E+04
NO_X	1.11E-01	7.76E+05
SO_X	6.03E-03	4.22E+04
CO	9.33E-03	6.52E+04

Figure 4.4.5 Emmissions Analysis

4.5 PAYBACK

The installation of the water cooled server racks will reduce the cooling load by 21%, therefore the current system can be downsized. Currently, 18 AHU's maintain the under floor plenum at a pressure of 1"WC. With a 21% reduction in cooling load needed, the amount of CFM will be reduced by 21%. This is the equivalent of removing 2 AHU's from each level. Therefore, with the installation of these water cooled server racks we will essentially be able to remove 4 AHU's. Each AHU costs $50,000.00, so there will be a $200,000.00 reduction in cost immediately. The new upfront cost would have been $863,400.00.

Upfront Cost	$ 1,063,400.00
Energy Savings Per Year	$ 180,000.00
Mechanical Equipment Offset- AHU's	$ 200,000.00

Figure 4.5.1 Payback

The installation of the water cooled server racks will lead to $180,000.00 in energy savings per year. This would lead to a payback period of 4.79 years which is very reasonable.

4.6 RECOMMENDATION

With a payback period of 4.79 years, it seems that the installation of water cooled server racks would be a good investment. Not only will this system lead to $180,000.00 per year in savings, it will also give the owner a sense of confidence. The lab building's servers are expected to increase greatly in the future in density and this system will help ensure that that density can be met. Server densities are increasing at an exponential rate, this will also ensure that if the demand grows higher than expected the space will still be sufficient. Also, due to the fact that this building is owned by the Department of Defense, these chilled racks will provide more security against failures commonly caused by overheating. This system could be installed with limited impact on schedule and could tie into the existing chilled water plant with no problem.

Overall, this system is an excellent fit for the loading. My only concern is a potential water leak ruining equipment, and in this case extremely important and confidential information. For this reason, I am going to also consider refrigerant based in rack cooling and then make a final recommendation based on the results.

5.0 MECHANICAL DEPTH- REFRIGERANT IN RACK COOLING

5.1 BACKGROUND INFORMATION

There are two main advantages to using a waterless refrigerant to provide the in rack cooling in data center. First, many data center managers are reluctant to re-introduce water into their facilities because of the possibility of equipment damage from leakage. Secondly, the refrigerant used in the system is more efficient than water and has advantages in system design and reducing energy costs associated with cooling.

5.2 DESIGN

The Liebert DS downflow configurations are designed for use in raised floor applications so that is the system that will be evaluated. This system addresses my main concern of the possible water leaking causing damage to the equipment. The low pressure coolant becomes a gas at room temperature; therefore the owner will not have to worry about a possible damage. There will also be many possible economizer hours to be taken advantage of.

This seems to be an excellent fit for this application and if the payback period is similar to the water cooled racks, this may be a better option. Before making a decision an evaluation on upfront cost and energy usages must be executed.

In this case, the racks will be very similar, but refrigerant will run through the coil rather than chilled water. The Liebert DS system is a total package unit which includes the compressor, pumps, evaporators on the racks, and refrigeration piping. The refrigerant used is the environmentally friendly R-407C. An example of the self contained unit is found below.

Figure 5.1.1 Liebert DS Unit

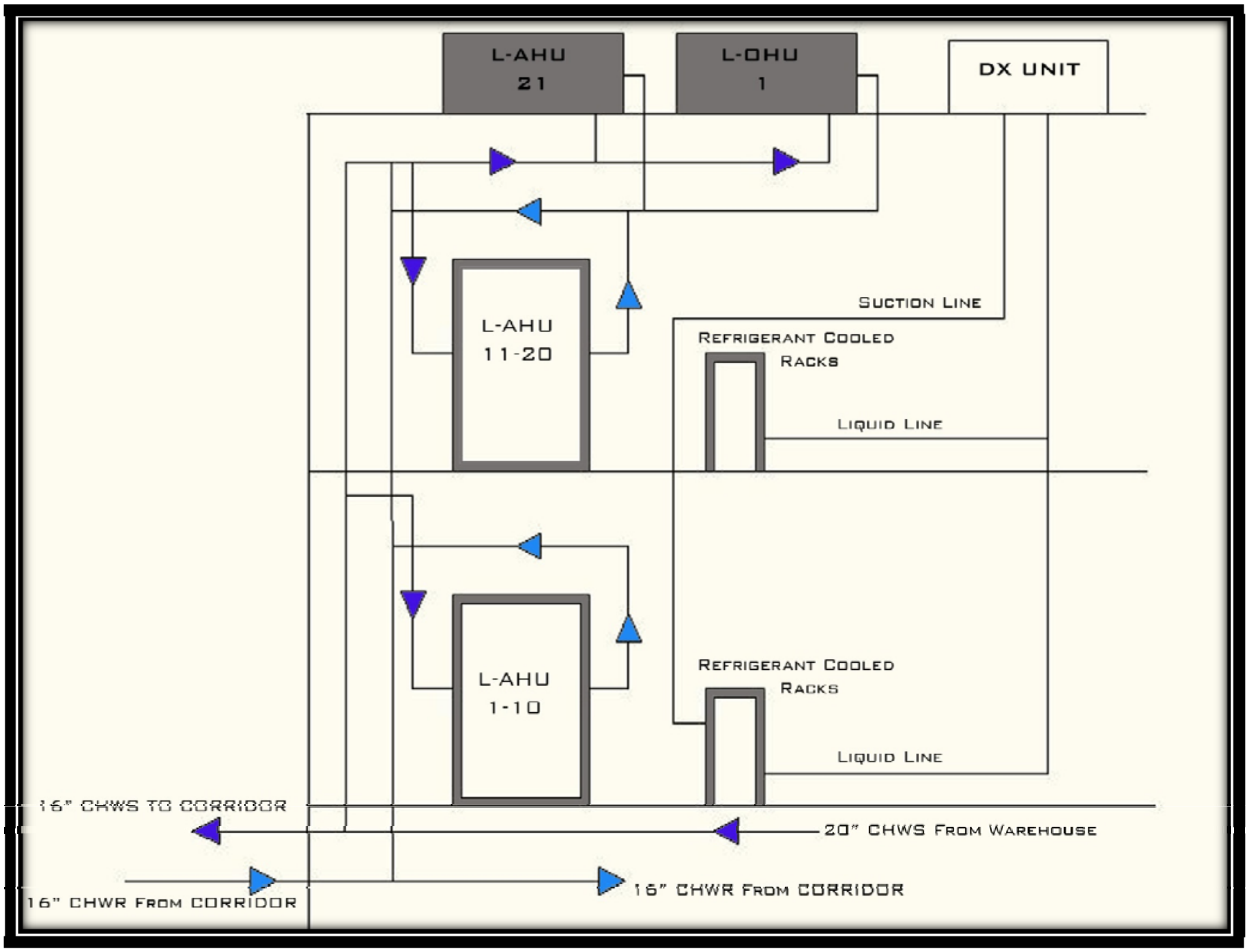
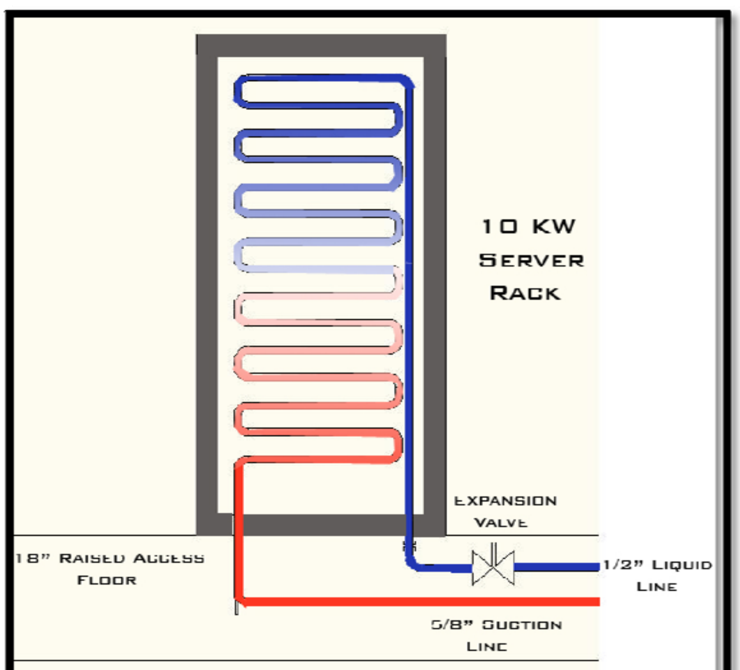
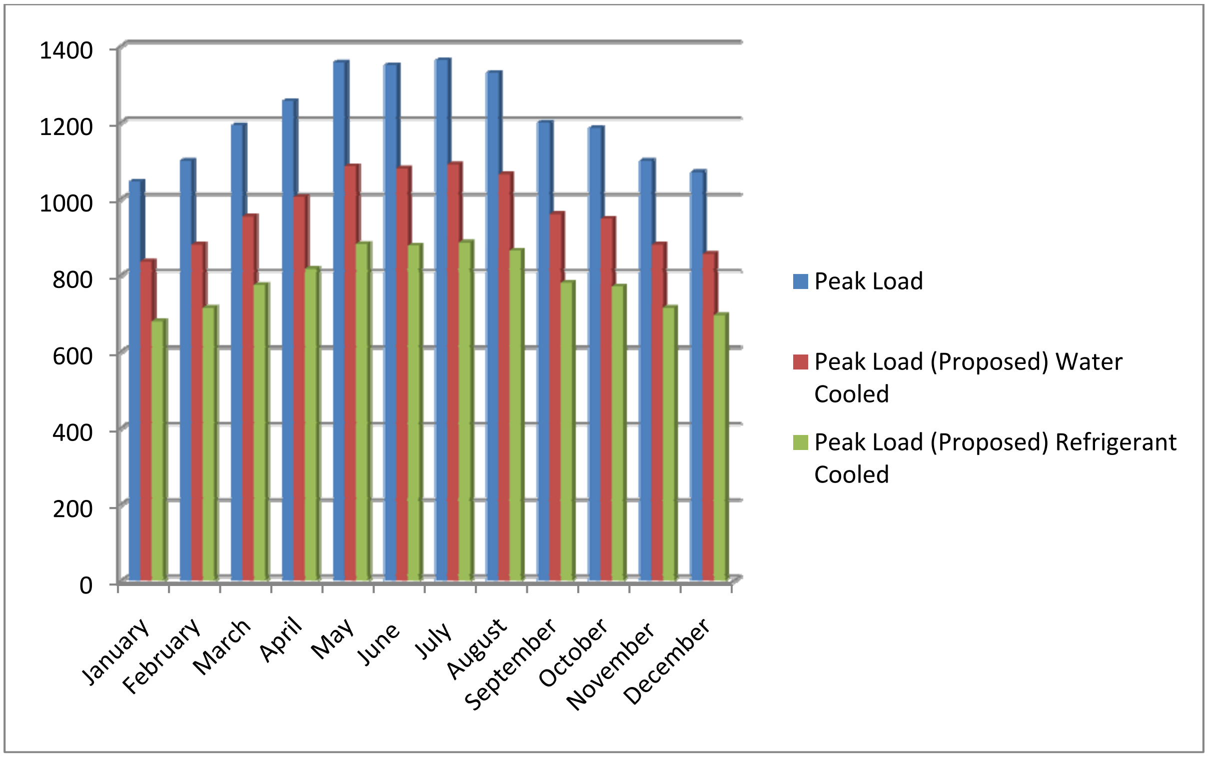


Figure 5.1.2 Updated Lab Riser



5.3 RESULTS



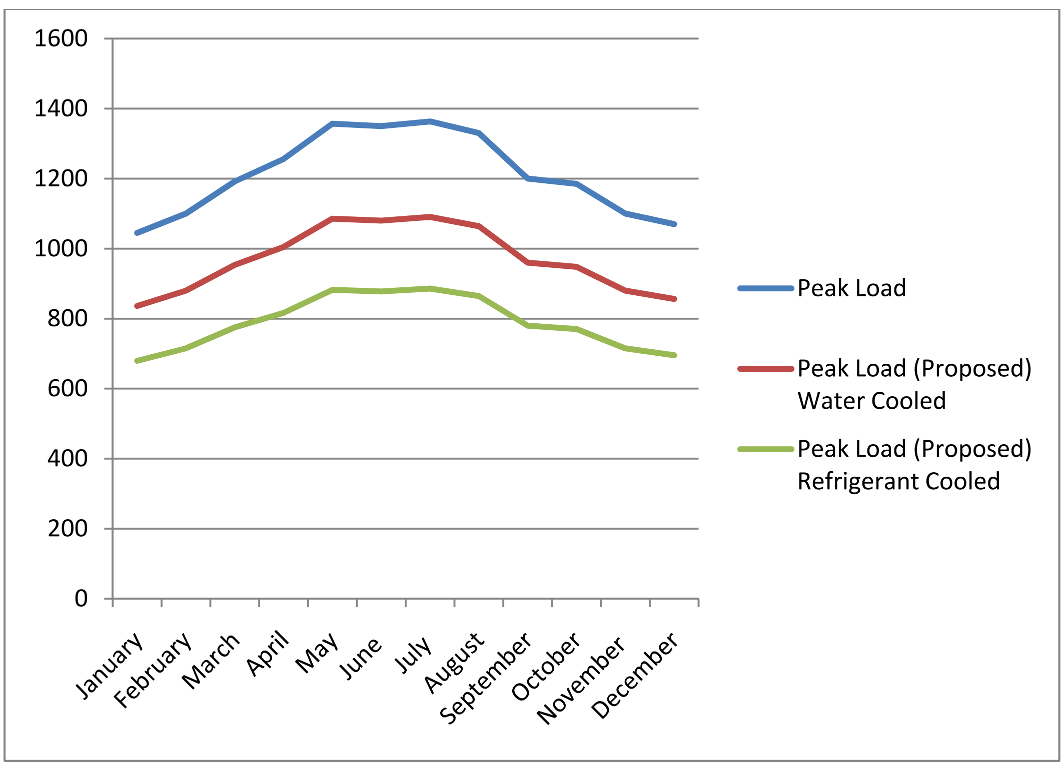


Figure 5.3.1 & 2- Proposed Loads vs. Peak Loads

	Original System as Designed		Proposed System- Water		Proposed System- Refrigeration	
Energy Source	Energy (10^6 BTU/yr)	$/yr	Energy (10^6 BTU/yr)	$/yr	Energy (10^6 BTU/yr)	$/yr
Electricity	113,775.80	$2,926,771	100,122.70	$2,746,771.00	88,107.98	$2,629,771.00
Gas	6,988.30	$90,913.00	6,988.30	$90,913.00	6,988.30	$90,913.00
TOTAL	**120,764.10**	**$3,017,684**	**107,111.00**	**$2,837,684**	**95,096.28**	**$2,720,684**

Figure 5.3.2- Energy Consumption

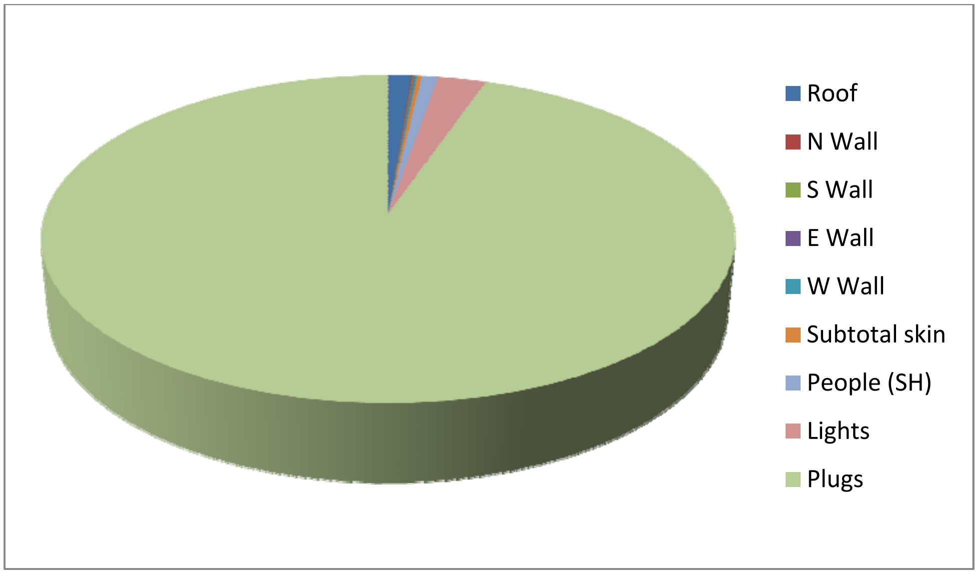


Figure 5.3.3- Cooling Load Breakdown

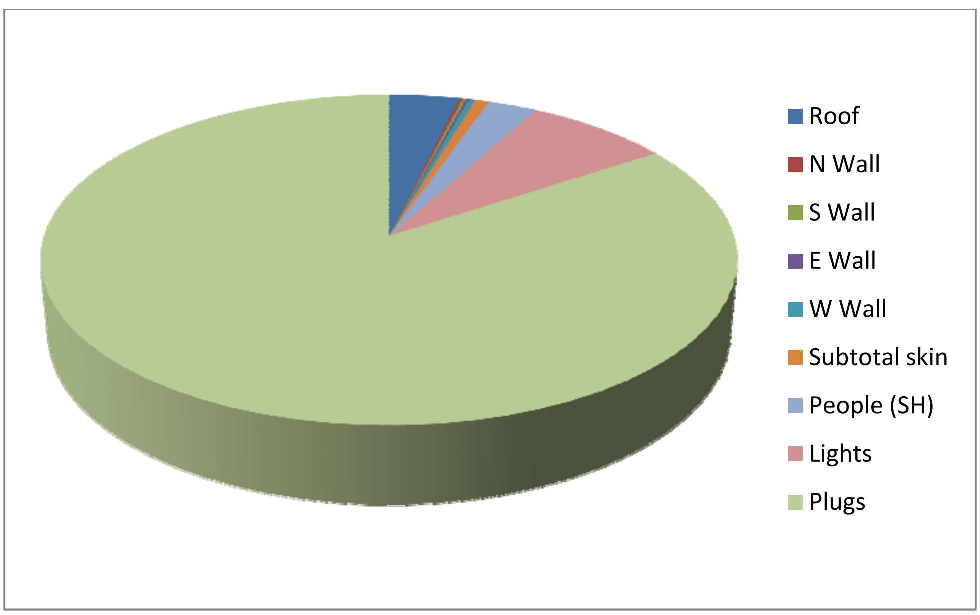


Figure 5.3.3-Proposed Cooling Load Breakdown

5.4 PAYBACK

The installation of the refrigerant cooled server racks will reduce the cooling load by 33%, therefore the current system can be downsized. Currently, 18 AHU's maintain the under floor plenum at a pressure of 1"WC. With a 33% reduction in cooling load needed, the amount of CFM will be reduced by 33%. This is the equivalent of removing 5 AHU's from each level. Therefore, with the installation of these water cooled server racks we will essentially be able to remove 10 AHU, which will result in a reduction in initial cost by $700,000.00. The new upfront cost would have been $2,425,000.

Upfront Cost	$ 3,125,000.00
Energy Savings Per Year	$ 297,000.00
Mechanical Equipment Offset- AHU's	$ 700,000.00

Figure 5.4.1-Payback

The installation of the refrigerant cooled server racks will lead to $297,000.00 in energy savings per year. This would lead to a payback period of 8.16 years

5.5 RECOMMENDATION

With a payback period of 8.16 years, it seems that the installation of refrigerant cooled server racks may be a good investment. Not only will this system lead to $297,000.00 per year in savings, it will also give the owner a sense of confidence. This system could be installed with limited impact on schedule and could tie into the existing chilled water plant with no problem.

Overall, both the water and refrigerant cooled racks are a great fit for this application. The water cooled racks have a lower upfront cost, but also save less energy. The refrigerant cooled racks have a larger upfront cost and save more energy. Both have reasonable paybacks (4-8 years) for a facility of this type. I recommend the installation of one of these two systems in the DISA HQ. Which system would be chosen would be up to the owner as there are advantages and disadvantages to both. I would personally recommend the installation of the refrigerant cooled racks as more energy will be saved and there will be a greater sense of security for the owner. They will be confident that energy will be saved immediately, there will be a reasonable payback, the future loads will be met, and there is less of a chance of failure due to overheating or water damage.

6.0 SUSTAINABILITY BREADTH: RAINWATER COLLECTION

6.1 BACKGROUND INFORMATION

Rainwater collection for re-use is an ancient practice which was been gaining popularity again in sustainable design. There are many potential uses for rainwater/grey water collection and recycling. Reducing storm water runoff through collection helps protect our streams, creeks, and rivers from pollution. As you know, water is a finite resource and we must take every possible aim to reduce our water consumption in the United States.

With over 300,000 SF of roof area and being a LEED accredited project, I believe this project should aim to collect and recycle rainwater. Rainwater could be used for irrigation purposes, but in this case the Landscape Architect has only designed vegetation on site which will not require irrigation. This already has provided a huge reduction in water demand, especially due to the amount of vegetation on site. According to the International Plumbing Code 2006, which was used to design this project grey water or rainwater may be used to flush toilets if a filtration system with the correct controls are installed.

6.2 DESIGN

According to historical data, Baltimore, MD averages about 44" of rain per year and the DISA HQ has a total of 337,566 SF of roof area. To calculate the amount of rainwater that could be collected each year from the site the following steps were taken.

1. **Determine available rainfall for the building site. For rainfall collection purposes assume that a dry year will produce 2/3 the amount of precipitation as an average year. Therefore, design precipitation=2/3(average precipitation).**
    1. **Design Precipitation=2/3(44")= 30"**
2. **Next the amount of rain fall available for collection based on roof area was found using the following graph. If you follow the 30" line, you will find that for every 10,000 SF of roof area you will collect 140,000 Gallons of Water annually.**

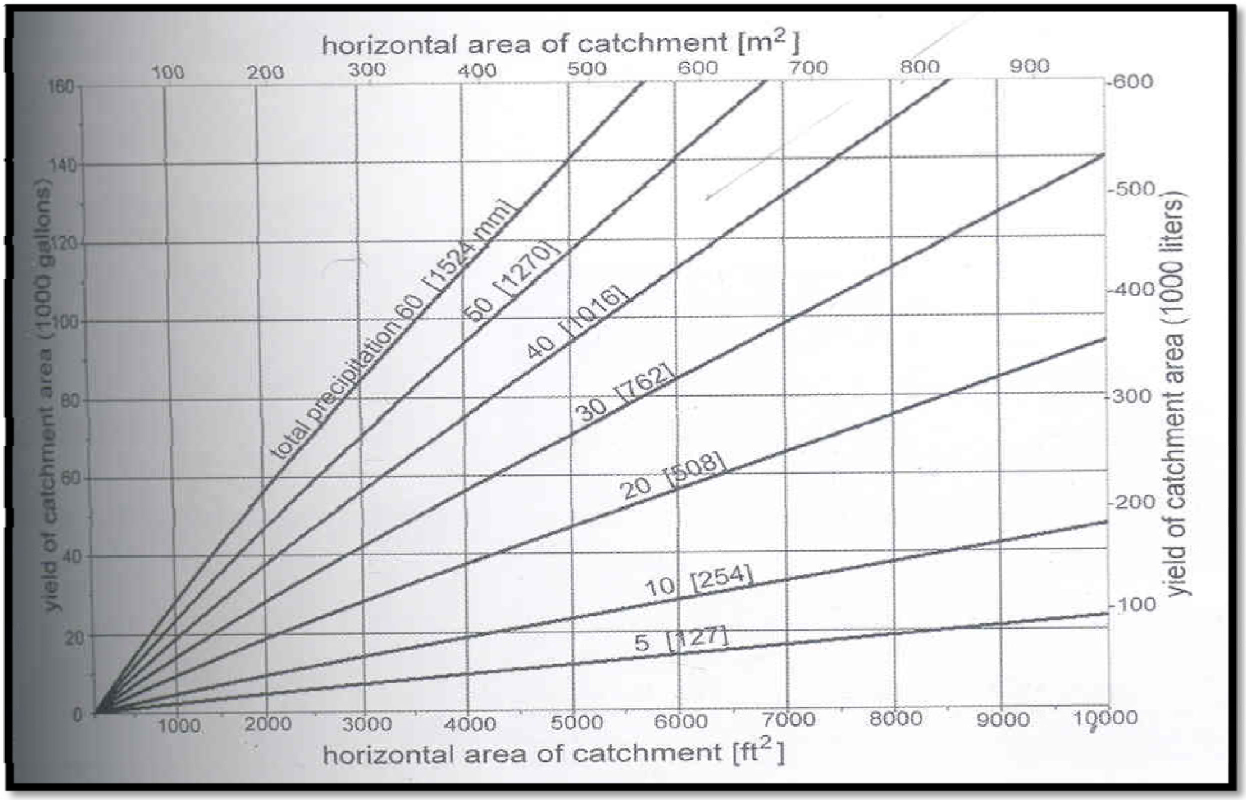


Figure 6.2.1-Rainwater Catchment Calculator

3. **A building by building area breakdown was used to see how much rain each building in the complex could collect.**

Building	Roof Area (SF)	Yield of Catchment Area (Gallons/Year)
Acquisitions	58,216	815,024
Command	58,520	819,280
Commons	56,000	784,000
Operations	58,216	815,024
Lab	56,160	786,240
Warehouse	50,454	706,356
TOTAL	**337,566**	**4,725,924**

Figure 6.2.2-Yield of Catchment Area

4. **Next this was compared to the number of water closets in each building and the domestic water demand. The water demand (GPM) was calculated using the Hunter's Curve found below. Each water closet is 6 fixture units, while each urinal is 4 fixture units.**

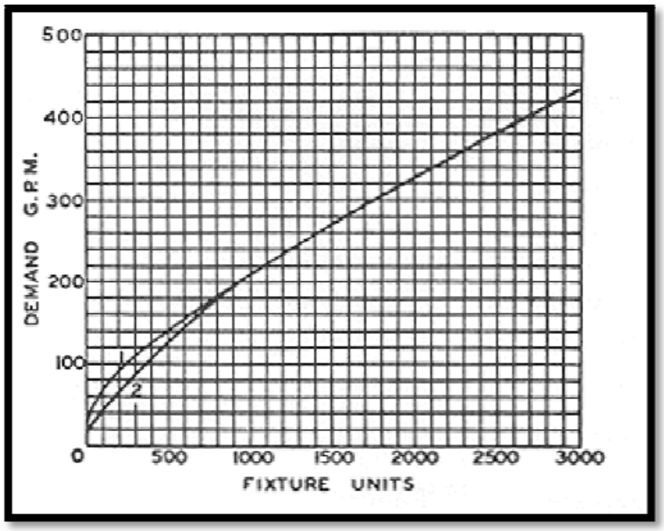


Figure 6.2.3-Hunter's Curve

Building	Water Closets	Urinals	Fixture Units	Demand (GPM)
Acquisitions	60	20	440	120
Command	52	16	376	90
Commons	43	8	290	83
Operations	48	16	352	88
Lab	16	4	112	42
Warehouse	7	2	50	23
		TOTAL	1620	290

Figure 6.2.4-Domestic Water Usage

5. **The urinals are proposed to be replaced with waterless urinals. This will immediately cut the necessary water demand for each building substantially. The figure below reflects those changes on the domestic water demand.**

Figure 6.2.5- Waterless Urinal

Building	Water Closets	Urinals	Fixture Units	Demand (GPM)
Acquisitions	60	0	360	89
Command	52	0	312	80
Commons	43	0	258	66
Operations	48	0	288	68
Lab	16	0	96	37
Warehouse	7	0	42	18
		Total	1356	220

Figure 6.2.6-Water Demand After Waterless Urinals Installed

6. **The rainwater collection was compared to the amount of water required to flush a commercial water closet (1.6G/flush) and the following figure shows how many times each water closet could be flushed each day from the rainwater collected.**

Building	Roof Area (SF)	Yield of Catchment Area (Gallons/Year)	Flushes Per Year	Flushes Per Day
Acquisitions	58,216	815,024	**509,390**	1,395.59
Command	58,520	819,280	**512,050**	1,402.88
Commons	56,000	784,000	**490,000**	1,342.47
Operations	58,216	815,024	**509,390**	1,395.59
Lab	56,160	786,240	**491,400**	1,346.30
Warehouse	50,454	706,356	**441,473**	1,209.51
TOTAL	**337,566.00**	**4,725,924**		

Figure 6.2.7-Rainwater Catchment Calculator

Building	Roof Area (SF)	Yield of Catchment Area (Gallons/Year)	Safety Factor (0.7)	Flushes Per Year	Flushes Per Day
Acquisitions	58,216	815,024	**570,517**	356,573.00	976.91
Command	58,520	819,280	**573,496**	358,435.00	982.01
Commons	56,000	784,000	**548,800**	343,000.00	939.73
Operations	58,216	815,024	**570,517**	356,573.00	976.91
Lab	56,160	786,240	**550,368**	343,980.00	942.41
Warehouse	50,454	706,356	**494,449**	309,030.75	846.66
TOTAL	**337,566**	**4,725,924**	**3,308,147**		

Figure 6.2.7-Yield of Catchment vs. Usage

These calculations show that it is definitely possible to flush the toilets in each building with the rainwater collection. A system must be designed to collect the water, treat the water in accordance with the International Plumbing Code 2006, and re distribute the water to the building to feed the water closets. Also to meet code, the toilets must have a sensor in which automatically flushes if they are not used within 24 hours to prevent bacteria growth. Also, a bypass must be included in the pumping system to add domestic water in the event of inadequate water in the storage tank.

7. **The tank shall be sized for ¼ (maximum yield), therefore each building would need about 200,000 Gallons of Storage. After speaking with a water storage representative, the largest tank that can feasibly be shipped in this area of the country is 75,000 Gallons. Therefore, each building would need three (3)-75,000 Gallon tanks.**

Due to the fact that all the buildings have roughly the same amount of roof area, I have decided to design a water catchment system for one building. If the owner likes the design, and would like to continue the other buildings could implement the same exact system.

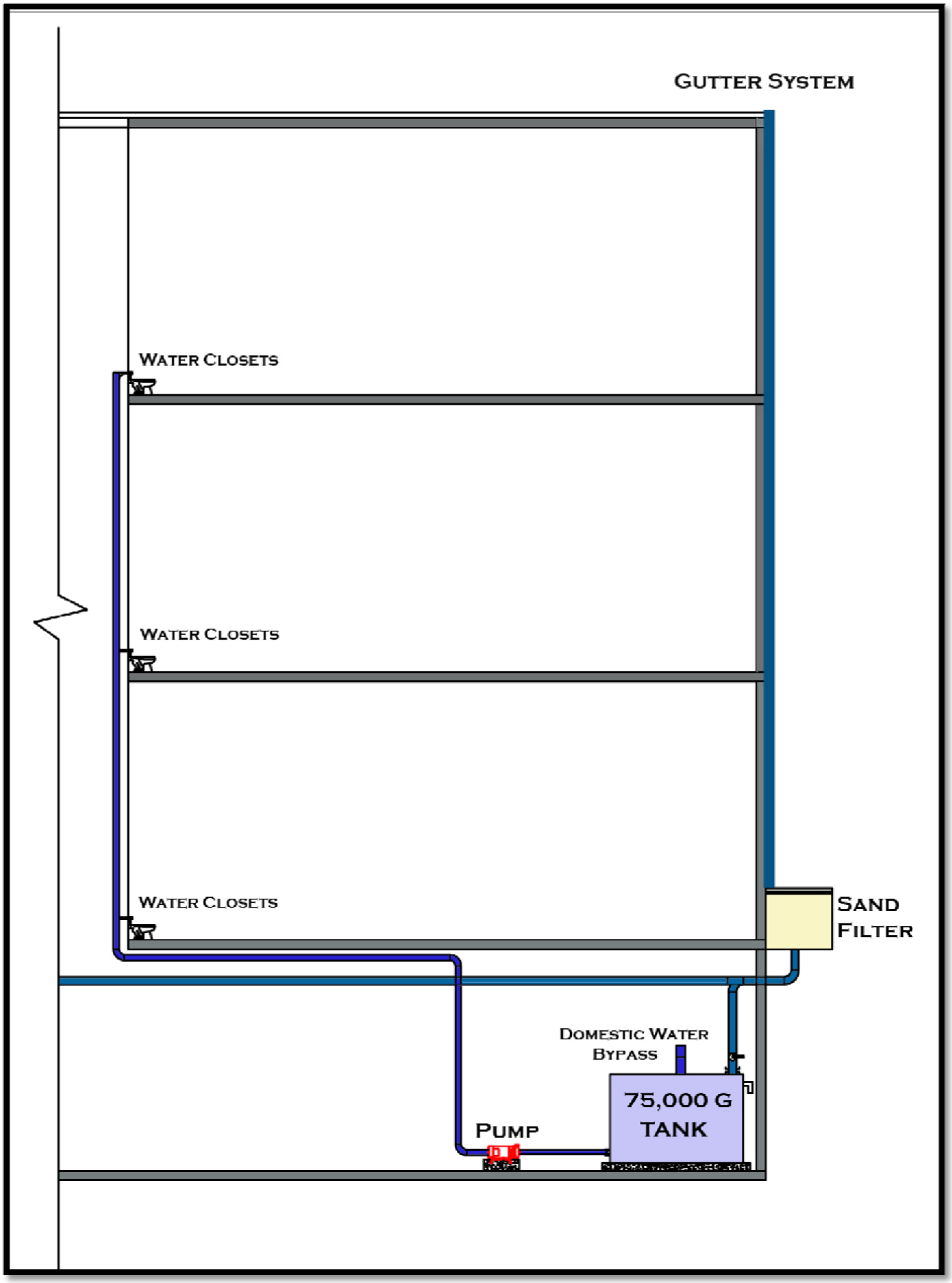


Figure 6.2.8-Rainwater Schematic

6.3 RESULTS

First, the total cost of the installation of the waterless urinals was evaluated.

ITEM	COST	QUANTITY	MATERIAL	LABOR	TOTAL
Waterless Urinals	$360.00	66	$23,760.00	$ 2,904.00	$26,664.00
Water Urinal	$150.00	66	$9,900.00	$ 5,808.00	$15,708.00
					$10,956.00

URINALS	Gal/Flush	Quantity	Flushes/Yr	Savings/Yr
Cost of Water	1.5	66	26,000.00	$ 104.00

Figure 6.3.1-Water Cost

As you can see from above the payback period for the waterless urinals alone would be almost 100 years. The only perceived benefit of this installation is the addition of 1 LEED credit.

Next, the total cost of the installation of the water collection system (tanks, piping, pumps) for the acquisitions building was evaluated.

ITEM	COST	QUANTITY	MATERIAL	LABOR	TOTAL
75,000 GALLON WATER TANKS	$50,000.00	3	$150,000.00	$75,000	$225,000.00

Building	Water Closets	Urinals	Fixture Units	Demand (GPM)	Gallons/YR	Cost/YR	Packback (YRS)
Acquisitions	60	20	440	120	234,000.00	936.00	63.03

Figure 6.3.2-Feasibility Study

As you can see, the upfront cost of this system is astronomically large compared to the potential savings in water costs. The problem here lies how cheap water is in the United States (around $4/1000 gallons in this area). It makes the payback period in this case 63 years, which does not make any economical sense.

Overall, this was a very educational study. I found that this complex could easily flush all the toilets in the complex with collected rainwater. The site already has all vegetation which does not require landscaping. This would result in an enormous savings in water usage, which is awesome. But the problem lies in the numbers. Water is extremely cheap in America, about $4/1000 gallons which is absurd when you think about the fact that many countries do not even have running water. I will highlight the economics of this study.

Each of these water storage tanks costs $60,000.00, bringing the total cost to $180,000.00 per building. This could flush every toilet in the facility and save over 2,000,000 gallons of water per year. But the problem is saving 2,000,000 gallons of water only equates to a savings of $8,000.00 per year. This leads to an unfathomable payback period, which makes this highly unlikely.

6.4 RECOMMENDATION

This design would help save over 2,000,000 gallons of water per year for this facility, and would also give 2 additional LEED points. With that being said, the building will only save $8,000.00 per year and still be in the LEED silver category. The system has a payback period of over 60 years; therefore I do not recommend the installation of this system. A valuable lesson was learned in this study, that although green is in style and it is undoubtedly great for the environment, sometimes the economics just will not allow a project to happen. This will save tons of water, and could make the owner all warm and fuzzy inside, but at this price I do not see many building owners approving this design.

7.0 ACOUSTICAL BREADTH- ROOF TOP UNITS

7.1 BACKGROUND INFORMATION

After setting the Roof Top Units the project team discovered an acoustical problem was present. The rooms surrounding the mechanical shafts in the Common Building would be disturbed by unacceptable noise levels. This would not be acceptable in this facility, especially due to its use as an office building. A solution must be found to reduce noise levels in these problematic rooms before the facility may be opened.

The following observations were found:

-The rooms in which noise levels are unacceptable are located adjacent to shafts.

-Disturbance is high frequency, not a vibration issue.

-M-AHU-1-7 are the units causing problems.

The fact that the noise disturbance is high frequency proves that this is not an issue with the roof construction and or the setting of the unit. Based on these observations there must be an issue with the supply fan in the air handlers. A fan producing unacceptable noise levels will give off high frequency disturbance.

7.2 DESIGN

This problem could be addressed in one of two ways. First, the owner could replace all supply fans in these roof top units in question with fans which produce lower noise levels. This could be very expensive, and often the lead time on new equipment is very long which could hold up construction. The more practical solution would be to add fiberglass duct liner to the supply duct outlet on air handlers M-AHU-1-7. This could be a much more cost & schedule effective solution if adequate reduction could be achieved. Noise Reduction calculations were used to prove whether or not this was a viable option.

The noise reduction calculations below reflect the addition of 7’ of fiberglass duct liner to the supply duct outlet of each air handler (M-AHU-1-7).

Equation: NR = TL + Log ((A)/S)
TL = Transmission Loss of element
NR=Noise Reduction
A = total absorption in receiving room
S = Surface are of receiving room

Dynamic Insertion Loss (dB)							
63	125	250	500	1000	2000	4000	8000
8	21	26	39	49	38	29	21

7.3 RESULTS

The installation of 7' of fiberglass duct liner to the supply duct outlet of each air handler (M-AHU-1-7) will do an excellent job of addressing the acoustical problem in the office space. As shown above in FIGURE XXX, the noise reduction (dB) is substantial (up to 49 dB in the 1000 Hz wavelength). This will definitely lead to acceptable noise levels in the rooms in question. The installation of duct liner will solve the problem with the roof top units in questions and therefore should be installed.

7.4 RECOMMENDATION

I recommend the installation of 7' of fiberglass duct liner to be installed in the supply air outlets of M-AHU-1-7. This is the most practical and cost effective solution to this problem.