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Mechanical Option
Technical Report #3

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Mechanical Systems Existing Conditions Evaluation

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Executive Summary

This report analyzes the existing mechanical systems for the Data Center in Delaware. The design objective is to increase the cooling capacity while simultaneously improving reliability of an existing data center. Energy consumption and utility rates for the facility are outlined. The primary power provided by the electric utility, with secondary power produced by diesel generators. Outdoor design conditions are provided by the American Society of Heating Refrigeration and Air Conditioning Engineers. Indoor design conditions are specified for the building. The majority of the report focuses on the sequence of operations, which is supported by information provided by schedules of major equipment and schematics of air side and water side. A critique of the system includes mechanical system first cost, loss of rentable space, annual energy consumption, maintainability and environmental control.

Design Objectives and Requirements

The most important factor taken into consideration with the data center upgrades was operational down time. The mechanical and electrical system upgrades are designed to maintain and improve reliability. The existing building operated as a "Global" facility on a 24/7 basis. The design is to increasingly serve expanded on-line operations on a national and international basis. The operational shift increases requirements for data center reliability and availability.

The primary objectives of the design effort was to review the existing facility and support systems and general operating methods for elements of risk exposure to continuous technology systems operation, and to improve operations. Redundancy of critical mechanical equipment is designed to provide the total number of units required plus one as standby (N+1). This is classified as Tier III redundancy, meaning systems are served by a single active path, redundant components, and concurrently maintainable. Annual downtime for a Tier III system is 1.6 hours. Table 1, provided by the Uptime Institute, summarizes Tier levels for critical buildings including data centers.

Table 1

This chart illustrates Tier similarities and differences

	TIER I	TIER II	TIER III	TIER IV
Number of delivery paths	Only 1	Only 1	1 active 1 passive	2 active
Redundant components	N	N+1	N+1	2 (N+1) or S+S
Support space to raised floor ratio	20%	30%	80-90%	100%
Initial watts/ft²	20-30	40-50	40-60	50-80
Ultimate watts/ft²	20-30	40-50	100-150	150+
Raised floor height	12"	18"	30-36"	30-36"
Floor loading pounds/ft²	85	100	150	150+
Utility voltage	208, 480	208, 480	12-15kV	12-15kV
Months to implement	3	3 to 6	15 to 20	15 to 20
Year first deployed	1965	1970	1985	1995
Construction $/ft² raised floor*	$450	$600	$900	$1,100+
Annual IT downtime due to site	28.8 hrs	22.0 hrs	1.6 hrs	0.4 hrs
Site availability	99.671%	99.749%	99.982%	99.995%

*Excludes land and abnormal civil costs. Assumes minimum of 15,000 ft² of raised floor, architecturally plain one story fitted out with initial capacity, but with backbone designed to add components to reach the ultimate capacity.

The original system peak cooling load was 570 tons. Mechanical upgrades are intended to serve 2400 tons.

Existing chilled water and condenser water piping systems present single points of failure. Piping enhancements must be done without interruption of chilled water. Looped bi-directional piping is required but shut-downs are to be kept to a minimum.

Provisions are also needed to provide a well water system, configured as the primary makeup water source, to support the cooling tower makeup. DDC controls are also required for automatic switch to the city water system on a loss in makeup water pressure.

Other design objectives include modifications to Air Conditioning units, humidity control systems, building automation and control systems (addition of DDC controls), and fuel oil storage and delivery systems.

Energy Sources and Rates for the Site

Annual Energy Consumption

The data center is designed to run 24 hours a day its primary source of power is the electric utility, and emergency power provided by diesel generators.

The data center operates on an N+1 Redundant Uninterruptible Power Supply (UPS) system.

- Transmission service is provided by Conectiv. Three phase circuits carry a nominal voltage of 34,500 Volts.
  - Monthly charges and rates as obtained by Conectiv power delivery electric Tariffs for Delaware can be viewed in Appendix B.
  - Emissions can be viewed on Table 9.
- Three 17,500 kW diesel powered backup generators are supported by a 10,000 gallon fiberglass underground fuel oil storage tank.
  - The average diesel price provided by the Energy Information Administration (EIA) for 2004 (January-June) $1.198/gallon.
- Battery backup is also provided as part of the UPS System and is used in the case of utility power outage and generator warm-up. In the event of a utility failure the generators are started within 8 seconds. The batteries produce DC power to the UPS system which is then converted to AC. They are designed to last 30 min at 600KW or 12-15 min at 750 kW.
- Natural Gas is not currently used at the site, however the price is supplied in this report as a basis of comparison for future reports.
  - According to the EIA the average cost of natural gas for commercial buildings for 2004 (January-July) is $11.53/ thousand cubic feet.

Outdoor and Indoor Design Conditions

Outdoor

Outdoor weather data was taken from the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) Fundamentals for Wilmington Delaware. This yielded cooling design at 1% conditions 89F drybulb and 74F wetbulb. Heating design at 99.6% conditions is 10F drybulb and 7.7F wetbulb.

Indoor

To maintain 72F computer room space temperatures with 50% relative humidity, the ventilation air must be cooled down to at least 52F so that sufficient moisture is removed. A 49F supply air temperature will is required to maintain 45% relative humidity in the spaces.

Print Room AC units shall be set to a common humiliation setpoint so units do not fight each other. A 45% relative humidity setpoint with a 5% control band is recommended. Insure that ventilation air brought into the room has been cooled down to at least 52F.

Air Side Systems
Heating, cooling and ventilation is provided by 14 air handling units, cooling is supplemented with computer room air conditioning units. Ventilation flow diagrams are illustrated in Appendix B.

Air Handling Units
The mechanical system for this data center is a combination of constant volume and variable volume with fifteen separate air handlers taking care of ventilation. Supplemental computer room air conditioning units (100% recirculated air) are added for additional cooling. Two of these air handlers supply the service floor including the print room. Four air handlers supply the electrical UPS rooms with transfer air to the battery rooms, this includes N + 1 redundancy. Seven air handler units are dedicated to the ventilation of the first and second floor computer rooms and UNIX rooms, this also consists of one redundant unit. Schedules of these units were not obtained because they are part of the existing system. The following are a list of the air handling units and the components of their design.

Units 4, 5: Serve the service level of the data center. These are variable volume units. The AHU's are set up in parallel with the same supplies of return air and outdoor air. Air is exhausted both out of the mixed air duct and through the exhaust fans (EF-1 and EF-2) located in the east corridor. The primary on/off is provided by the building automation system, with start/stop switches also located at the starter. Each AHU has a return air damper and discharge damper, they share a common outside air damper. The supply air fans of each are provided with inlet vanes and are controlled to maintain system static pressure. Return air fans are provided with inlet vanes and are controlled to maintain a set point differential airflow. The supply air temperature is set to 55 F (adjustable). A differential pressure switch is located across each AHU filter. A temperature sensor is located in each AHU mixed air plenum operates a 3-way cooling control valve to modulate temperature. System airflow is 25,850 cfm for each AHU. When halon discharge or purge mode is signaled by the Building Automation System (BAS) the system dampers and fans operate accordingly. A schematic of this system is shown in Figure 1 in Appendix B.

Units 1, 2, 3, 10: Serve the service level UPS and battery rooms. These are constant volume units. The AHU's are set up in parallel and use 100% return air. This air is supplied into the UPS rooms with transfer air into the battery rooms. Air is exhausted through EF-1 and EF-2 in the east corridor. A small amount of outdoor air is supplied through Units 4 and 5. Units 1, 2, 3, and 10 run continuously to serve the UPS room. Primary on/off control of each UPS AHU is provided by the AHU hands off automation (HOA) switch or via the BAS. Each AHU has return and discharge air dampers. Space temperature is controlled by the BAS which modulates each of the AHU's 2-way cooling control valves in unison. The BAS selects system air handlers based on priority ranking. As the control valves close off, the quantity of operating AHU's stage off. A differential pressure switch is located across each AHU filter. Upon a loss of motor current the next available in-line AHU shall be energized. System airflow is 28,000 cfm for each AHU.

When halon discharge or purge mode is signaled by the BAS the system dampers and fans operate accordingly. A schematic of this system is shown in Figure 2 in Appendix B.

Units 8, 9: Serve as ventilation units for the first and second floor UNIX and computer rooms. The outside air system with ducted supply provides approximately 0.1 cfm/ft^2 of 100% outside air to all data center areas. These are variable volume units with ducted distribution. During normal operation, only one of the two central air handlers operates for ventilation. Primary control is the BAS, but manual start/stop switches are located at the starters. Each AHU is equipped with a return and discharge air damper. Supply air fan inlet vanes maintain system static pressure set point. Temperature and humidity is monitored. Air is supplied at 50F and 50% RH for space conditions of 55 F and 53% RH. Humidification is served by humidifiers H-1, 2, 3, and or 4. When humidifiers are on, the corresponding electric duct coils 1, 2, 3, 4 operate to maintain a minimum discharge air temperature of 72 F. A differential pressure switch is located across each AHU filter. A temperature sensor is also located in each AHU mixed air plenum. When halon discharge or purge mode is signaled by the BAS the system dampers and fans operate accordingly. A schematic of this system is shown in Figure 2 in Appendix B.

Units 11-14: The Global Management Center and Global Help Desk are served by four penthouse mounted, variable air volume chilled water air handling units. Two AHU's are sized at 50% of the 100 ton peak cooling load and two are sized at 25%. The loss of any unit will still result in maintaining the overall system. Air distribution is provided through variable air volume terminal units to ceiling mounted diffusers, with return air routed through the ceiling plenum back to the penthouse mechanical room. 17% outside air is ducted directly to each air handling unit's intake plenum to mix with system return air. A schematic of this system is shown in Figure 3 in Appendix B

Units 6, 7: These variable volume direct expansion units serve office space in a separate section of the building and will not be discussed in this report.

Computer Room Air Conditioning Units

Due to high load densities in the computer rooms, supplemental computer room air conditioning units are required. These units are 100% recirculated air and are located on the chilled water system. These all operate at N+1 Redundancy. The load densities due to high equipment loads in critical areas are detailed in Table 2 as follows.

Table 2 Breakdown of Computer Room Load Densities.

Floor	**Room**	**Area**	**Current Installed Cooling Capacity**	**Future *Average* Maximum Load Density**	**Future Room *Peak* Cooling Load Density**
Ground	Print Room	4,600 sf	10 W/sf	10 W/sf	10 W/sf
Ground	Telco Room	2,100 sf	30 W/sf	30 W/sf	30 W/sf
1st Floor	Computer Room	24,500 sf	50 W/sf	65 W/sf	80 W/sf *
1st Floor	UNIX – I/O Computer Room	6,700 sf	33 W/sf	65 W/sf	80 W/sf *
1st Floor	Tape Storage Room	13,300 sf	20 W/sf	20 W/sf	80 W/sf *
2nd Floor	Computer Room (East)	10,400 sf	26 W/sf	65 W/sf	80 W/sf *
2nd Floor	Computer Room (West)	11,200 sf	60 W/sf	65 W/sf	80 W/sf *
2nd Floor	Help Desk	17,000 sf	15 W/sf	15 W/sf	15 W/sf

* Capacity reduction required in remaining computer rooms.

Existing chilled water computer room air conditioning units serving the service level print room, first floor unix area and computer room, second floor global management center and data center expansion are listed in Table 3. Each unit is set to maintain interior space conditions of 72F and 45% RH. Unit capacities are either 252.1 MBH or 346.1 MBH. These units have no latent capacity.

Table 3

CHILLED WATER COMPUTER ROOM AIR CONDITIONING UNIT SCHEDULE

DESIGNATION	SERVES	SPACE CONDITION DB / RH	CHILLED WATER COOLING COIL				FAN SECTION			
			TOTAL BTUH	SENSIBLE BTUH	GPM	PRESS DROP, FT	SUPPLY CFM	ESP IN WG	MOTOR HP	VOLTS/ PHASE
AC-47	SERVICE LEVEL PRINT ROOM	72°F/45%	252.1	252.1	45.8	10.0	12,000	0.3	7.5	460/3
AC-83	1ST FLOOR UNIX AREA	72°F/45%	252.1	252.1	45.8	10.0	12,000	0.3	7.5	460/3
AC-49	1ST FLOOR COMPUTER ROOM	72°F/45%	252.1	252.1	45.8	10.0	12,000	0.3	7.5	460/3
AC-50, AC-52, AC-53	2ND FLOOR GMC	72°F/45%	252.1	252.1	45.8	10.0	12,000	0.3	7.5	460/3
AC-51	2ND FLOOR GMC	72°F/45%	252.1	252.1	45.8	10.0	12,000	0.3	7.5	460/3
AC-54, AC-55	2ND FLOOR GMC	72°F/45%	346.1	346.1	62.7	16.4	16,100	0.3	10	460/3
AC-56 THRU AC-60, AC-61, AC-62 AC-64, AC-65, AC-66 AC-68 THRU AC-70, AC-72, AC-73	2ND FLOOR DATA CENTER EXPANSION	72°F/45%	346.1	346.1	62.7	16.4	16,100	0.3	10	460/3
AC-56, AC-63, AC-67, AC-71	2ND FLOOR DATA CENTER EXPANSION	72°F/45%	346.1	346.1	62.7	16.4	16,100	0.3	10	460/3
AC-74 THRU AC-82	2ND FLOOR GMC	72°F/45%	346.1	346.1	62.7	16.4	16,100	0.3	10	460/3

With the exception of the global management center, new chilled water computer room air conditioning units are added to the rooms with existing CRAC units as supplements for increasing electric load and N+1 redundancy. These areas include the service level print room, first floor UNIX area and computer room, and second floor data center. New units were also installed in the first floor tape room. Each unit is set to maintain interior space conditions of 72F and 45% RH. Unit capacities are all 252.1 MBH. These units have no latent capacity. These units are shown in Table 4.

Chilled water coils are selected for 45F entering water temperature and 12F rise. Each unit is provided with an automatic reversing dual source disconnect switch. Return air is provided by a 40" acoustically lined return air plenum and automatic return air dampers. Return dampers, interlocked with unit motor operation, shall automatically open during unit operation.

Table 4

CHILLED WATER COMPUTER ROOM AIR CONDITIONING UNIT SCHEDULE											
		SPACE	CHILLED WATER COOLING COIL				FAN SECTION			
DESIGNATION	SERVES	CONDITION DB / RH	TOTAL BTUH	SENSIBLE BTUH	GPM	PRESS DROP, FT	SUPPLY CFM	ESP IN WG	MOTOR HP	VOLTS/ PHASE
AC-48	SERVICE LEVEL PRINT ROOM	72°F/45%	252.1	252.1	45.8	10.0	12,000	0.3	7.5	460/3
AC-1 THRU AC-3 AC-33	1ST FLOOR UNIX AREA	72°F/45%	252.1	252.1	45.8	10.0	12,000	0.3	7.5	460/3
AC-4, AC-5 AC-13 THRU AC-15	1ST FLOOR TAPE ROOM	72°F/45%	252.1	252.1	45.8	10.0	12,000	0.3	7.5	460/3
AC-6 THRU AC-12 AC-16 THRU AC-27 AC-44 THRU AC-46	1ST FLOOR COMPUTER ROOM	72°F/45%	252.1	252.1	45.8	10.0	12,000	0.3	7.5	460/3
AC-28 THRU AC-32 AC-34 THRU AC-43	2ND FLOOR COMPUTER ROOM	72°F/45%	252.1	252.1	45.8	10.0	12,000	0.3	7.5	460/3
AC-86, AC-87	1ST FLOOR COMPUTER ROOM	72°F/45%	252.1	252.1	45.8	10.0	12,000	0.3	7.5	460/3

The telecommunication room is served by direct expansion up-flow computer room air conditioning units as shown in Tables 5a,b. The units are propped on 12" floor stands. Though the evaporator unit is located indoors and the condenser is located outdoors, they are both supplied by the same electric source. Each evaporator unit contains a fuse block and terminal lugs for wiring to their associated condensing units.

Table 5a

DX CRAC UNIT SCHEDULE – EVAPORATOR

INDOOR EVAPORATOR / FAN UNIT SECTION

DESIGNATION	SERVES	SPACE CONDITION DB / RH	DX COOLING COIL				COMPRESSOR				FAN SECTION			
			TOTAL BTUH	SENSIBLE BTUH	EAT (°F) DB / WB	LAT (°F) DB / WB	QTY	STAGES	FLA (RLA)	LRA	SUPPLY CFM	ESP IN WG	MOTOR HP	VOLTS/ PHASE
AC–50	TELE RM	72°F / 45%	117,700	117,700	72 / 58.6	52 / 50.6	2	2	25	35	5,650	0.5	3.0	460/3
AC–51	TELE RM	72°F / 45%	117,700	117,700	72 / 58.6	52 / 50.6	2	2	25	35	5,650	0.5	3.0	460/3
AC–84	TELE RM	72°F / 45%	58,400	58,400	72 / 58.6	–	1	N/A	10	62	2,800	0.3	1.5	460/3
AC–85	TELE RM	72°F / 45%	58,400	58,400	72 / 58.6	–	1	N/A	10	62	2,800	0.3	1.5	460/3

Table 5b

DX CRAC UNIT SCHEDULE – CONDENSER

OUTDOOR CONDENSING UNIT SECTION							SYSTEM ELECTRICAL	
DESIGNATION	CONDENSER TEMP (°F)	CONDENSING FANS			CONDENSING COIL		VOLTS/ PHASE/Hz	FLA
		QTY	HP	AIRFLOW (CFM)	TOTAL HEAT REJECTION (MBH)	EAT (°F) DB		
ACCU–1	124.6	2	0.75	10,443	156.4	105	480/60/3	4.4
ACCU–2	124.6	2	0.75	10,443	156.4	105	480/60/3	4.4
ACCU–1	–	2	?	5,400	77.6	105	480/60/3	2.4
ACCU–2	–	2	?	5,400	77.6	105	480/60/3	2.4

Water Side Systems
Chilled water and condenser systems water originate at 5 parallel chillers. These systems are described below and illustrated in Appendix C.

Chilled Water and Condenser Water Sequence of Operations
Starter HOA switches control the chillers, chilled water pumps, cooling tower water pumps, and cooling tower fans. On/off control of plant equipment is provided by a HOA switch or the building automation system (BAS). Following the initial startup, the chiller plant is in continuous operation.

The BAS selects chillers, cooling towers and pumps based on a priority ranking. Although the chillers, cooling towers and pumps typically run 'in line', plant operation with unmatched plant equipment is provided through the BAS as follows. When an operating chiller, pump or cooling tower fails, an alarm is sent to the BAS and the equipment next in line to be enabled without de-energizing the remaining equipment.

The BAS monitors the chilled water system flow rates, chilled water system supply, and chilled water system return temperatures. The BAS also calculates and indicates chiller plant cooling demand based on flows and temperatures as measured at each chiller. Chiller operation and alarm status is also monitored by the BAS.

Chillers are staged on by the bas based on a 30 minute rise in the calculated building load above 100% capacity of the operating chillers. Thus, the chillers are staged in 600 ton intervals up to 2,400 tons. Chillers are to be staged off in 30 minute intervals based on building load below 90% capacity of the operating chillers. For example, four chillers will run until the load decreases to 1,920 tons, at which point the quantity of chillers decreases to three.

Chilled water system differential pressure is monitored by two differential pressure sensors located on the chilled water distribution system located on the second floor. Chilled water system pressure is maintained by two differential pressure bypass valves located in the chilled eater distribution system on the service level. The BAS monitors the position of both differential pressure bypass valves.

Chillers: Are each 600 Ton units. The chillers are connected in parallel with 1,200 gpm flowing through the evaporator and 1,800 gpm through the condenser. The chillers have unit mounted variable frequency drives. They operate on refrigerant 134a (1,1,1,2-Tetrafluoroethane) which is an ethane series halocarbon that conforms to international standards. Chiller details are listed in Table 6.

Table 6

LIQUID CHILLER SCHEDULE														
DESIG.	NOM TONS	MAXIMUM COMPRESSOR INPUT (kW)	EVAPORATOR					CONDENSER					VOLTS/PH
			GPM	MAX WPD FT	EWT °F	LWT °F	PASSES	GPM	MAX WPD FT	EWT °F	LWT °F	PASSES	
CH-1	600	330	1,200	25	57	45	2	1,800	25	85	95	2	460/3
CH-2	600	330	1,200	25	57	45	2	1,800	25	85	95	2	460/3
CH-3	600	330	1,200	25	57	45	2	1,800	25	85	95	2	460/3
CH-4	600	330	1,200	28	57	45	2	1,800	26	85	95	2	460/3
CH-5	600	330	1,200	28	57	45	2	1,800	26	85	95	2	460/3

Chilled Water Pumps: Flow on the chilled water side is supported by five 75 hp, 1,200 gpm, constant speed pumps. Each pump has a 13.05 inch impeller. Design motor efficiency is 79.23%. Design Break horse power is 57.37 hp.

Cooling Tower Water Pumps: Flow on the cooling tower water side is supported by five 60 hp, 1,800 gpm, constant speed pumps. Each pump has a 10.66 inch impeller. Design motor efficiency is 79.88%. Design Break Horse Power is 51.21 hp.

PUMP SCHEDULE							
DESIG.	SERVES	GPM	HEAD FT.	MAX NPSH FT.	MOTOR HP	RPM	VOLTS/PH
CTWP-1	COOLING TOWER WATER SYSTEM	1,800	95	13	60	1,750	460/3
CTWP-2	COOLING TOWER WATER SYSTEM	1,800	95	13	60	1,750	460/3
CTWP-3	COOLING TOWER WATER SYSTEM	1,800	95	13	60	1,750	460/3
CTWP-4	COOLING TOWER WATER SYSTEM	1,800	95	13	60	1,750	460/3
CTWP-5	COOLING TOWER WATER SYSTEM	1,800	95	13	60	1,750	460/3
CWP-1	CHILLED WATER SYSTEM	1,200	150	9	75	1,750	460/3
CWP-2	CHILLED WATER SYSTEM	1,200	150	9	75	1,750	460/3
CWP-3	CHILLED WATER SYSTEM	1,200	150	9	75	1,750	460/3
CWP-4	CHILLED WATER SYSTEM	1,200	150	9	75	1,750	460/3
CWP-5	CHILLED WATER SYSTEM	1,200	150	9	75	1,750	460/3

Cooling Tower Operation

Condenser water supply set point is manually adjusted through the BAS. During mechanical cooling operation, set point is based on outside air wetbulb temperature, but no less than minimum allowable by chiller for stable operation. During free cooling operation, set point is set to 42F.

The BAS monitors the condenser water supply temperature from each tower, as measured at its sump discharge. The BAS also monitors each tower's fan status and speed, isolation valve status, fan vibration alarm status and general alarm status.

Position of system cooling tower bypass valves STBV-1A, 1B and CTBV-2A, 2B are based on condenser water supply temperature measured in the mains as compared to condenser water supply temperature set point. When the measured temperature is below set point, valves are positioned to bypass all water around the towers and all tower fans are locked out. When measured temperature is at or above set point, valves are positioned to flow all water through the towers and tower fans are enabled.

When a cooling tower has been selected by the BAS, and before selected condenser water pump starts, the towers isolation valve open.

Each cooling tower fan operates independently based on the condenser water supply temperature measured at its sump discharge. On a rise in condenser water supply temperature above set point, the tower's variable speed fan starts and modulates up to maximum speed to maintain condenser water supply temperature. On a fall in condenser water supply temperature, the tower fan modulates down to minimum speed. On a further fall, after a 30 second time delay the tower fan starts up.

Cooling towers: Two independent basin level controls and makeup water valve assemblies are provided for each 1,800 gpm cooling tower. The cooling tower schedule is shown in Table 7.

Table 7

COOLING TOWER SCHEDULE												
DESIG.	CELL (QTY)	GPM/ CELL	EWT (°F)	LWT (°F)	EAT (°F WB)	FAN				BASIN HEATER		
						MOTOR (QTY)	HP EA	RPM EA	VOLTS/PH	QTY	KW EA	VOLTS/PH
CT-1	1	1,800	95	85	79	1	30	1,800	460 / 3	1	24	480 / 3
CT-2	1	1,800	95	85	79	1	30	1,800	460 / 3	1	24	480 / 3
CT-3	1	1,800	95	85	79	1	30	1,800	460 / 3	1	24	480 / 3
CT-4	1	1,800	95	85	79	1	30	1,800	460 / 3	1	24	480 / 3
CT-5	1	1,800	95	85	79	1	30	1,800	460 / 3	1	24	480 / 3

Free Cooling Operation

Automated changeover between mechanical and free cooling are enabled manually through the BAS.

Changeover from mechanical to free cooling mode is accomplished as follows. Condenser water temperature set point is reset to 42F. When condenser water supply temperature measured in either main falls to 60F, or minimum allowable by chiller for stable operation, chillers are de-energized, chilled and condenser water pumps remain energized, and heat exchanger isolation valves open. Cooling towers and tower bypass valves operate as outlined above.

Changeover from free to mechanical cooling mode is accomplished as follows. Condenser water temperature set point is automatically set to 60F, or minimum allowed by chiller for stable operation. Cooling towers and other bypass valves operate as outlined above. Once condenser water supply temperature rises to set point in both mains, chillers are indexed on and heat exchanger isolation valves close.

Heat exchanger: Plates are to be added to the existing heat exchanger to yield the performance as scheduled in Table 8.

Table 8

PLATE TYPE HEAT EXCHANGER SCHEDULE								
DESIG.	LOW TEMP WATER SIDE				HIGH TEMP WATER SIDE			
	GPM	EWT (°F)	LWT (°F)	MBH	GPM	EWT (°F)	LWT (°F)	MBH
HX–1	3,600	57	45	14,400	2,400	42	50	14,400

Makeup Water System Sequence of Operations

The BAS provides control of both the existing city makeup water system and the new well makeup water system as outlined below. Selection of the primary and backup makeup water system (city or well) is provided by the BAS. Upon sensing a critical low water level in any cooling tower water basin, the backup makeup water system is enabled following a ten second time delay.

Each cooling tower basin is provided with redundant level control systems, one to serve each makeup water system. Both cooling tower level control systems include a solid state controller, and adjustable four position electronic water level sensor, and a slow closing solenoid valve. The BAS provides override capability for water level sensors in each basin to facilitate tower maintenance.

The BAS monitors the following parameters for each makeup water system: tower basin water levels (low alarm, fill, full, and high alarm), tower makeup water solenoid valve status, makeup water (MUW) system pressure, MUW system flow rate, and cumulative makeup water volume (resetable by the operator). Domestic (city) water pump and well pump status shall be provided with current sensors. There is a probe type water level control system with slow closing solenoid valve.

City Makeup water system: Existing city makeup water is provided from the building's city water service. The existing domestic water booster pump provides city makeup water to each of the cooling tower basins. When city makeup water service is designed as primary, well makeup water service is designated as backup, well pumps are locked out, and the following sequence occurs. When the water level in any cooling tower basin drops below the full level, the tower's city makeup water solenoid valve open. On a rise in water level to full level in a cooling tower basin, the tower's city makeup water solenoid valve close. On a city water solenoid valve failure or low basin water level, an alarm is sent to the BAS and the well water system is enabled.

Well Makeup Water System: An alternate source of makeup water is provided from a hydropneumatic tank fed by three wells.

When well service is designated as primary, city water is designated as backup, and the following sequences occur. When the water level in any tower basin drops below the full level, the tower's well makeup water solenoid valve open. On a rise in water level to full level in a cooling tower basin, the tower's well makeup water solenoid valve close. On a well makeup water solenoid valve failure or low basin water level, an alarm is sent to the BAS and the city makeup water system is enabled.

The BAS maintains hydropneumatic tank pressure between a minimum 30 psi and 70 psi charge as follows. The BAS operates three well makeup water pumps based on the following operational sequence with an automatic alteration of the sequence at restart: WP-2,3,1: WP-3,1,2: WP-1,2,3. On a fall in tank pressure below 30 psi, the first well pump energizes. On a further fall in tank pressure below 25 psi, the second well pump energizes. Upon further tank pressure loss below 20 psi, the third well pump energizes. Upon a rise in tank pressure above 70 psi, all well makeup water pumps de-energize.

Critique of System

Mechanical System First Cost

The approved mechanical system first cost is $3,336,952. The cost per square foot of the 119,894 SF renovation is $28/sf.

Loss of Rentable Space

There is a significant amount of lost rentable floor space lost due to the mechanical equipment room, vertical shafts (chases), and computer room air conditioning units. These areas also include clearance requirements for equipment. The total area of renovation for the data center is 118,894 SF. Lost rentable space due to vertical shafts is 0.126%. Mechanical rooms use 7.01% of rentable space, and computer room air conditioning units consume 4.13%. In all, there is a 11.27% loss in rentable space due to mechanical equipment. These areas are outlined in Table 9.

Table 9 Mechanical Equipment Space Breakdown

	Number	Total Area
Service Level		
Mech Room	1	8,330
CRAC units	4	72
AHU's	2	256
Shafts	7	50
First Floor		
CRAC Units	35	2,688
Shafts	7	50
Second Floor		
CRAC Units	30	2,155
Shafts		
Help Desk		
	TOTAL:	13,651

Annual Energy Consumption

A brief summary of energy consumption is listed as follows. Though there are 5 cooling tower water pumps, chilled water pumps, and chillers, due to N+1 redundancy, only four of each type of equipment are to be run at any given time. Annual energy consumption by the mechanical system can be viewed in Table 10. The mechanical system utilizes approximately 21,773 MWh/year. This number may have a small error since the existing air handler energy utilization was approximated.

Table 10

Equipment Name	Capacity	kWh/ year	Quantity	Total kWh/year
Cooling Tower Water Pump	1800 gpm	394200	4	1576800
Chilled Water Pump	1200 gpm	490560	4	1962240
Cooling Tower	5400 gpm	192720	1	192720
Chiller	600 ton	2890800	4	11563200
Computer Room AC	252.1 MBH	49056	*45	2207520
Computer Room AC	346.1 MBH	65700	*25	1642500
AHU 1-14		175200	15	2628000
Total kWh/year				**21772980**

*Approximately 80% of CRAC units in use at any given time.
** Values for AHU's are not supplied at this point, 20 kW will be assumed.

The total energy for the 6.6MW building is 57,738 MWh/year. Annual Utility Fee is summarized in Tables 11,12.

Table 11 Annual Building Costs

	Charge ($)	Unit	Summer	Winter
Monthly charge	432.86	month	1,731.44	5,194.32
Distribution charge	0.916	kw	6,037.356	18,112.07
Transmission demand rate	1.138	kw	7,500.558	22,501.67
Ancillary service energy rate	0.002419	kwh	46,555.4	139,666.2
Summer/Winter	9.0342/6.5941	kw	59,529.91	129,896.9
On-peak	0.033246	kwh	62,164.7	186,494.1
Off-peak	0.026341	kwh	381,949.8	1,145,849
		Totals:	565,469.1	1,647,715
		Total/year:		**$2,213,184**

Table 12 Annual Mechanical System Costs

	Charge ($)	Unit	Summer	Winter
Monthly charge	432.86	month	1,731.44	5194.32
Distribution charge	0.916	kW	2,276.718	682.878
Transmission demand rate	1.138	kW	2,828.499	8,485.497
Ancillary service energy rate	0.002419	kWh	17,556.28	52,668.84
Summer/Winter	9.0342/6.5941	kW	59,529.91	48,984.81
On-peak	0.033246	kWh	20,550.02	61,650.05
Off-peak	0.026341	kWh	96,023.48	288,070.4
		Totals:	200,496.3	465,736.8

Total/year:	**$666,233**

Maintainability

The system must be maintained on a 24/7 basis as outlined in the design objectives section of this document. At any time a critical piece of equipment can be isolated for maintenance without disruption to the rest of the mechanical system.

Environmental control

Indoor environmental issues are particularly important to computer rooms. Electrical equipment must operate within a narrow band of drybulb temperatures and relative humidity to avoid overheating, static electricity, etc. Typical optimum conditions are 72F-75F and 45-50% relative humidity. Measures must be taken to keep indoor conditions within this range.

Appendix A
Monthly Charges and Rates

P.S.C. Del. No. 8 - Electric
Delmarva Power & Light Company d/b/a Conectiv Power Delivery Fifth Revised Leaf No. 47

MONTHLY CHARGES AND RATES

SERVICE CLASSIFICATION	SUMMER Billing Months June Through September	WINTER Billing Months October Through May
GENERAL SERVICE – TRANSMISSION "GS-T"		
Delivery Service Charges:		
Customer Charge	$432.86	$432.86
Distribution Charge		
Demand Rate Eff 10/1/03	$0.916000/kW	$0.916000/kW
On-Peak Rate Eff 10/1/03	$0.000000/kWh	$0.000000/kWh
Off-Peak Rate Eff 10/1/03	$0.000000/kWh	$0.000000/kWh
Power Factor Charge or Credit	$0.030000/kW	$0.030000/kW
Environmental Fund Rate	$0.000178/kWh	$0.000178/kWh
Low-Income Fund Rate	$0.000095/kWh	$0.000095/kWh
Supply Service Charges:		
Standard Offer Service with Transmission and Ancillary Services:		
Transmission Demand Rate	$1.138000/kW	$1.138000/kW
Ancillary Service Energy Rate	$0.002419/kWh	$0.002419/kWh
Supply Capacity and Energy		
Demand Rate Eff 10/1/03	$9.034200/kW	$6.569410/kW
On-Peak Rate Eff 10/1/03	$0.033246/kWh	$0.033246/kWh
Off-Peak Rate Eff 10/1/03	$0.026341/kWh	$0.026341/kWh
Or:		
Market Priced Supply Service:		
Supply with Transmission and Ancillary Services for All "returning" Customers.	Refer to the "MPSS" tariff	Refer to the "MPSS" tariff

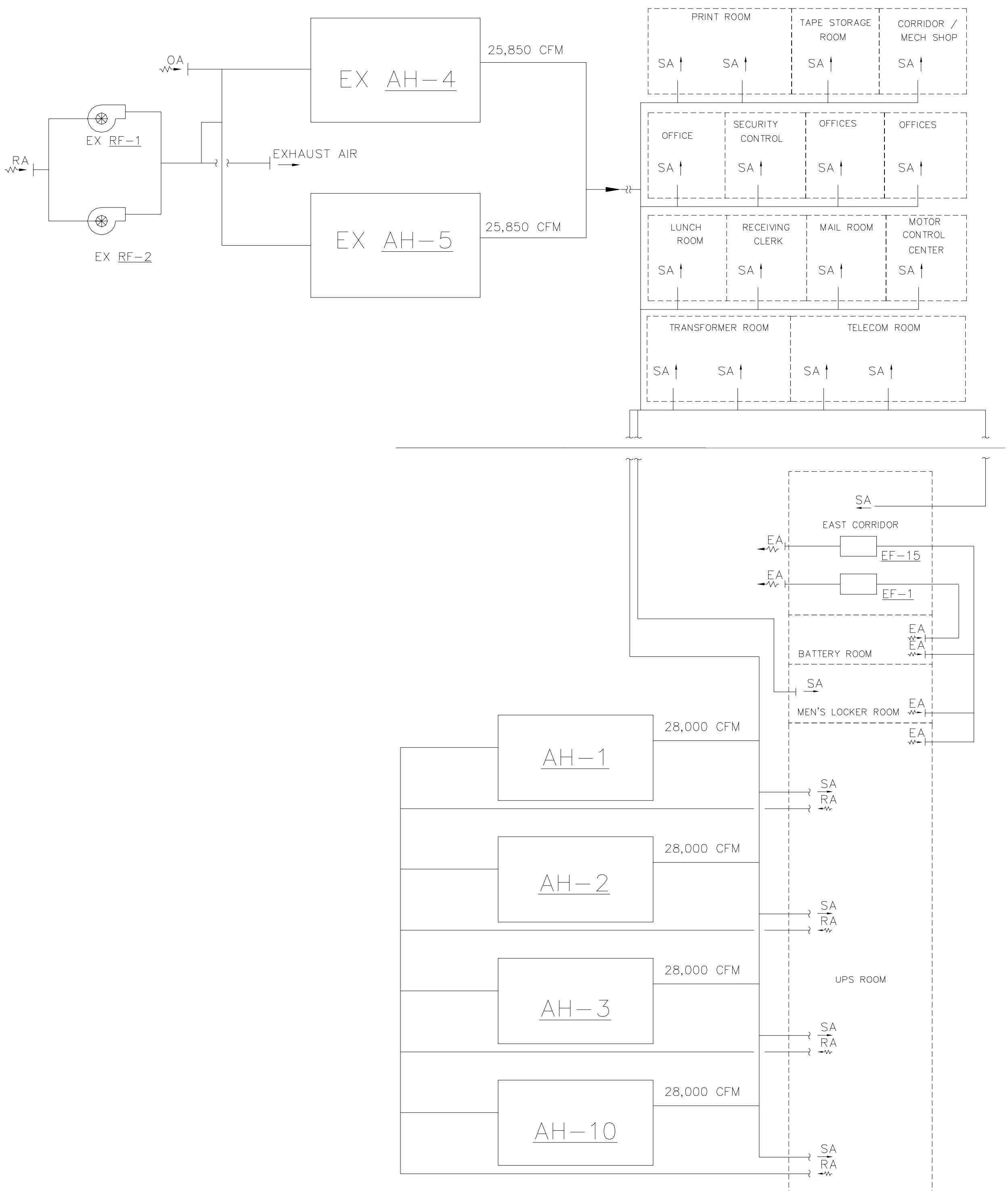
Note: The above Delivery Service charges apply when the Customer has an Electric Supplier, other than the Company, as its energy provider. The above Delivery and Standard Offer Service with Transmission Service charges apply when the Customer has the Company as its energy provider. For billing format purposes, the Delivery Service, Transmission Service and Standard Offer Service charges may be separately stated.

In addition to the charges and rates stated above, the Delaware State Public Utilities Tax of 4.25% shall apply to all applicable services, rendered hereunder, unless the Customer is exempt from such tax.

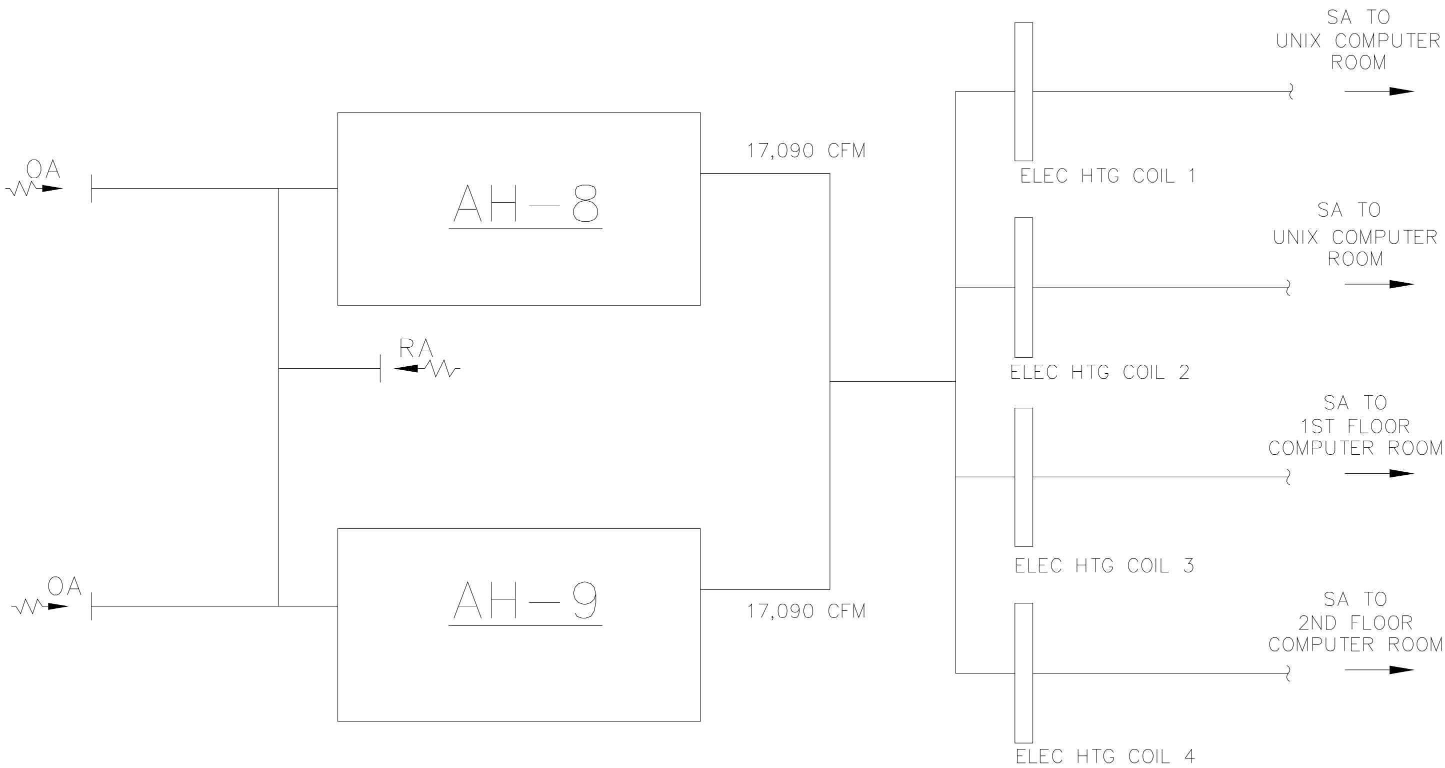
Appendix B

Figure 1

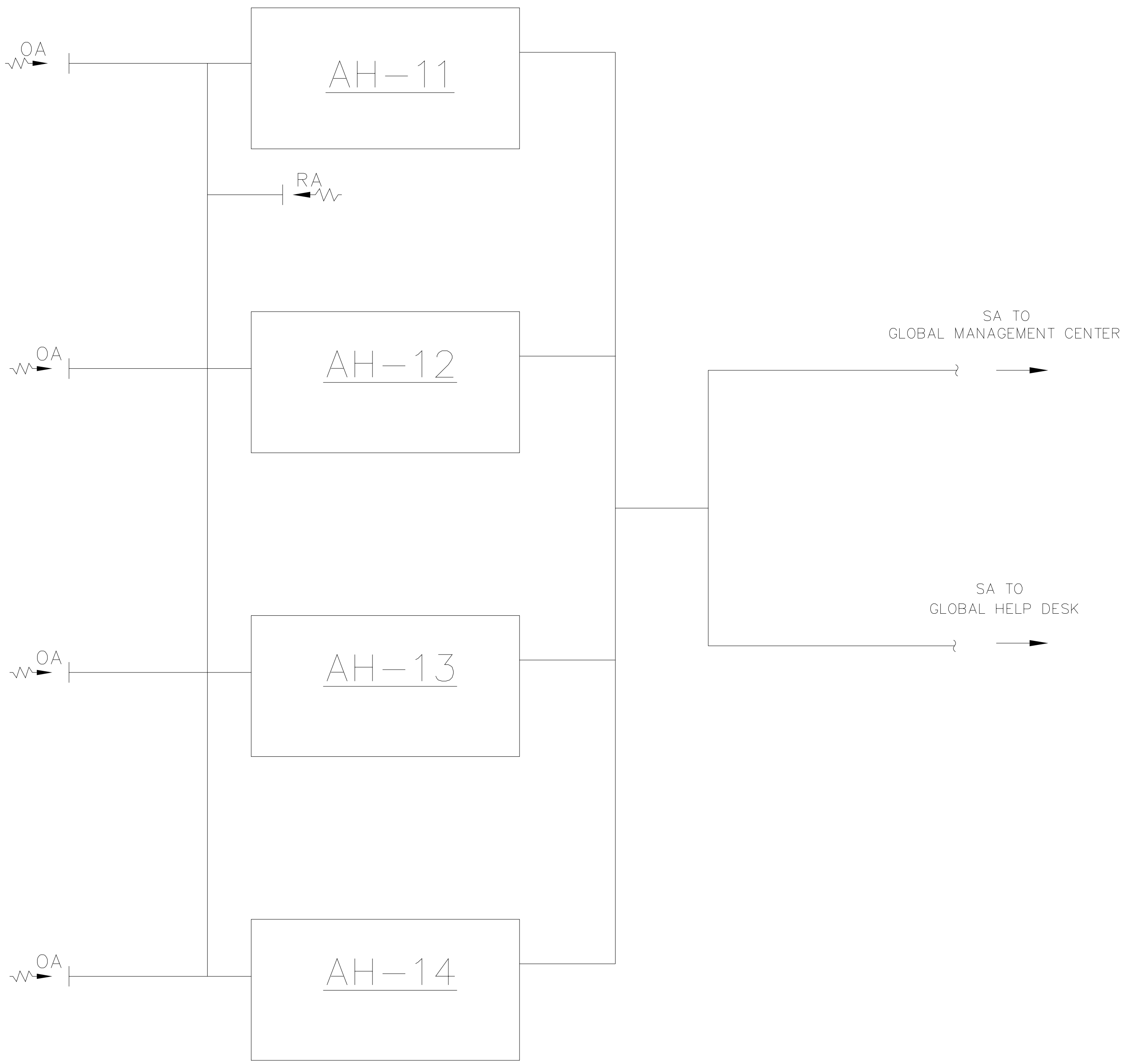
AHU 4,5 and AHU 1,2,3,10 Systems



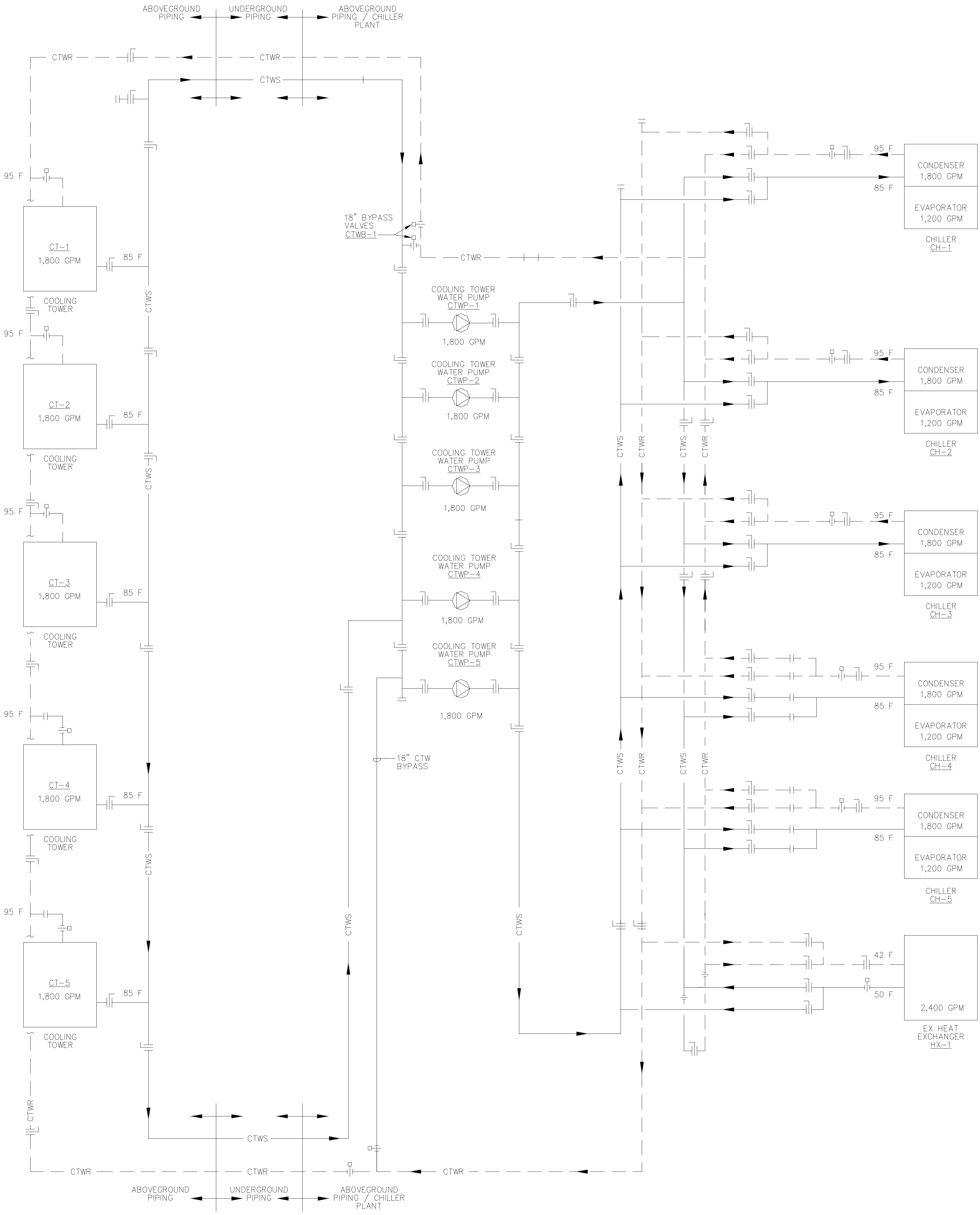
Appendix B
Figure 2
AHU 8, 9 System



Appendix B
Figure 3
AHU 11, 14 System
** AHU 11-14 are existing, supply air volumes cannot been obtained.



Appendix C
Figure 1
Cooling Tower Water Piping



Appendix C
Figure 2
Chilled Water Piping