Data Center Energy Benchmarking:

Part 1 - Case Studies on Two Co-location Data Centers (No. 16 and 17)

Final Report

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Final Report prepared by

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1 Executive Summary

Data Centers # 16 and #17 were located in a four-story building in San Francisco, California. The data center building had a total floor area of approximately 97,900 ft^2 with 2-foot raised-floors in the data services area. Two out of eight data centers in the building were occupied by computers and equipment, and were in operation at the time of the study conducted between October 15 and October 22, 2004.

Electric power for both data centers was supplied through HITEC power conditioning units without any battery system. Cooling for both data centers was through multiple water-cooled computer room air conditioning (CRAC) units connected to heat exchangers served by cooling towers. Of the total electric demand for both data centers, 40% went to critical computer and equipment load, 32% went to mechanical systems, 9% to UPS losses, and the remaining 19% to miscellaneous systems.

General recommendations for improving overall energy efficiency of the data centers included improving the design, operation, and control of mechanical systems serving the data centers in actual operation. This included primary condenser water system, secondary condenser water system, CRAC units, and airflow management and control in data centers. Specific recommendations for options of improving energy efficiency of the data centers are developed and provided in this report.

- A significant number of CRAC units could be turn off while the rest of the units would be able to provide sufficient cooling to the critical cooling requirements for the data centers.
- Optimize the actual air temperature and humidity set points, e.g., extending the permitted range.
- Optimize the control of supply and/or return air temperature from the CRAC units.
- Optimize air distribution through carefully placing perforated tiles, cable pass-through, equipment layout, and actual operation or non-operation of CRAC units.
- Evaluate and calibrate the monitoring system including the power metering system and secondary water system, e.g., data acquisition and sensing through the EMCS systems.
- Optimize secondary condenser water supply and supply temperatures, e.g., adjusting the control set points, using variable speed drives on the secondary condenser water pumps.

2 Review of Site Characteristics

Data Centers # 16 and #17 were located in a four-story building in San Francisco, California. The data center facility had a total floor area of approximately 97,900 ft^2 with 2-foot raised-floors in the data services area. The data centers were designed to provide co-location data services in areas that are environmentally controlled and monitored. The building includes eight separate data center rooms with raised floors, with two data centers on each of four floors.

The co-location area was designed to house and operate eight data centers simultaneously. At the time of the study, only two out of the eight data centers, both located on the fourth floor - Data Center #16 (Room # 7) and Data Center #17(Room #8)) were occupied and in operation. Each of the data centers housed approximately 10,000-ft^2 floor area for networking equipment.

Both data centers operated 24 hours per day all year-round. The users of the data centers had 24-hour full access to and from their caged spaces. The building has 16,000 ft^2 office space, or about 16% of the total floor area. The equipment in this facility was only two years old at the time of study and the existing building cooling load was primarily limited to the fourth floor data centers.

2.1 Electrical Equipment and Backup Power System

Data Centers #16 and #17 have a main service drop from the electric utility of 1200 A at 38 kV, as shown in Appendix B. This service is stepped down to 480V and distributed to five main switchboards and one reserve switchboard (SWBD).

At the time of the study, only one SWBD-M4 was active due to the limited requirement for load level. The normal real power demand monitored by the site Automatic Logic Corporation (ALC) system was 1,360 kW.

Before the monitoring starting on October 15, 2004, the peak power demand for both centers was observed and recorded as 3,120 kW on October 14, 2004. The reason for observed spike in power demand on October 14 was unknown but may be linked to possible temporary operational testing requirements for the building or simply a reading error.

The electric current to run SWBD-M4 was distributed into two paths: 1) essential power for HVAC and lighting loads, and 2) critical power for computer and equipment loads.

Essential power was fed directly to two SWBDs - D7 and D8, and was then distributed to their loads.

Critical power passed through two HITEC synchronous generators (Model # D85051, 2840 kVA rating). The facility utilized eight HITEC synchronous generators as a uninterruptible power supply (UPS) system without any storage battery. Only two HITECH synchronous generators were in operation at the time of the study. As shown in Figure 1, these UPS units maintained critical power supply for computer loads in the event of electric power outage or disturbance. The UPS power conditioning was a no-break system capable of providing a regulated output while using the utility supply. In the event of power loss, UPS' diesel-powered generators would start and supply electric power to the essential and critical power paths (D7 and D8). While the generator's engine is starting, the unit's flywheel drives the generator to maintain current for the critical loads.

Figure 1. Typical HITEC Diesel UPS/Backup Generator.

2.2 Mechanical System

2.2.1 Cooling Tower

Data Centers # 16 and #17 were cooled by water-cooled computer room air conditioning (CRAC) units that were supplied by a decoupled condenser water system. Appendix B includes a condenser water flow diagram for the system. The office space was conditioned by water-source heat pumps, which rejected heat into the same condenser water system.

Heat rejection for these centers was designed to be provided by six cooling towers, each with a cooling capacity of 800-ton. The Baltimore Air Coil Series V open circuit towers were designed with 91°F entering water temperature and 76°F leaving water temperature with 72 °F wet bulb temperature. The design water flow rate for each cooling tower was 1,280 gallon per minute (GPM). The cooling towers were labeled as CT5-1 to CT5-6 (Figure 2). They were located at the penthouse section of the building. Each cooling tower has two belt-driven centrifugal fans, arranged in a blow-through configuration and driven by 30-hp motors. The fan motor speeds were controlled by variable frequency drives to maintain condenser water supply at a certain set point temperature. Each cooling tower could be isolated from the condenser water system by automatic butterfly valves. These valves and their associated towers are controlled through the ALC system by site personnel.

Figure 2. Cooling towers

2.2.2 Primary Condenser Water Pumps

Primary condenser water (in the cooling tower loop) was circulated by six centrifugal vertical in-line Armstrong pumps (P4-1, P4-2, P4-3, P4-4, P4-5 and P4-6) arranged in parallel (Figure 3). Each pump has a motor capacity of 50 HP and a design volume flow rate of 1,280 GPM. These pumps are energized by site personnel, and run at constant speed. Only one primary pump was running at the time of this study.

Figure 3. Primary condenser water pumps.

2.2.3 Heat Exchangers

Condenser water was circulated through up to three Alfa Laval model #M30-FG plate/frame heat exchangers labeled HX4-1 to HX4-3 (Figure 4), depending on load. Each Alfa Laval heat exchanger had a rated capacity of 24,000,000 BTU per hour of total heat rejection of 2,000 tons (actual net cooling capacity of 1,600 tons plus the rejection of compressor heat). One of the three heat exchangers, HX4-3, was in operation at the time of the study and dissipated heat from both data centers on the fourth floor.

The primary, cold-side water temperature supply and return from the cooling tower showed a temperature increase (ΔT) of 3.5-4.8°F for primary condenser water across the heat exchanger, compared to the design temperature increase (ΔT) of 15°F. In addition, for the secondary condenser water across the heat exchanger serving the building cooling load system, the monitored temperatures of water supply and return from the cooling tower showed a very small temperature increase (ΔT) of less than 1ºF.

The actual approach temperature, defined as the temperature difference between the secondary water supply and the primary condenser water supply temperature, was mostly within 5ºF. Each heat exchanger was isolated from both the primary and secondary condenser water systems by automatic valves that were controlled by site personnel through the ALC control system.

Figure 4. Heat Exchanger for condenser water.

2.2.4 Secondary Condenser Water Pumps

The secondary condenser water pumps consisted of seven parallel in-line Armstrong centrifugal pumps with a rated capacity of 50 HP. The pumps were identified as P4-7 to P4-13 (Figure 5).

P4-12 was the only pump in active operation at the time of the study. The pressure differential between the pump's suction and discharge was 28 psi, delivering water at the flow rate of 1,680 GPM between the secondary, hot side of heat exchanger and the building cooling units. The pump's operation was set to be either on or off, and was manually controlled through the facility's control system.

Figure 5. Secondary condenser water pumps.

2.2.5 CRAC Units

The Data Center #16 (Room # 7) and #17 (Room # 8) on the fourth floor have 2-ft raised floors through which cold air is supplied and circulated via packaged CRAC units: Data-Aire Model# DAWD-26-34.

Each of the 21 CRAC units was designed to deliver 10,000 CFM conditioned air, with 11 CRAC units serving Data Center #16 and 10 CRAC units serving Data Center #17. Figure 6 shows typical CRAC units in the data center.

Figure 6. Sample CRAC Unit

The CRAC units' supply fans were all operating at their constant speeds. These units are located along the north and south walls of the data center rooms. Each CRAC unit had a net sensible cooling capacity of 20 tons excluding fan heat. The CRAC units had 4-inch throwaway pleated air filters rated at 30% efficiency, and two water-cooled refrigeration systems, consisting of compressors, water-cooled condensers, and controls. No reheat coils or humidifiers were present in these CRACs. Each CRAC unit's internal controls were used to maintain temperature and relative humidity within a range. The unit's control set point for air temperature was 71°F, at the units' return air intake. No explicit humidity control was performed by these units, and there was no remote monitoring of them. The CRAC units delivered conditioned air to the raised floor plenum and returned warm air from upper spaces in the data centers. At the time of the study, all of the CRAC units operated continuously in both data centers. Among all CRAC units, two CRAC units were monitored in Data Center # 16, and one in Data Center # 17.

Conditioned outside air for the data center was provided by two Mammoth model #VCX-252-GXS water-cooled heat pumps, each rated for 8000 cfm. This air was distributed to each data center room through supply ducts. Humidification for this outside air is provided by two operating Nortec model #NH-150 electric steam generators, each of which was rated at 150 pounds per hour. There were two standby humidifiers. Steam generated by these humidifiers was injected into the make-up air supplied to units' supply ducts.

3 Electric Power Consumption Characteristics

The end-use breakdown for both data centers' electric power demand is shown in Table 1.

Table 1. End-Use of Electricity of the Data Centers (16&17 combined)

Description	Electric power demand (kW)	Share of electric energy use (%)	Floor Space (ft^2)	Electric power density (W/ft^2)
Rack Load (Data Center 16)	377	28%	10,000	37.7
Mech Essential Load* (Data Center 16)	300	22%	10,000	30
Rack Load (Data Center 17)	165	12%	10,000	16.5
Mech Essential Load* (Data Center 17)	132	10%	10,000	13.2
Power Losses to UPS'	123	9%	20,000	6.2
Subtotal Loads (Rack, Essential, and Losses Loads)	1097	81%	20,000	54.9
Other	263	19%	97,878	2.7
Overall Building Load	1360	100%	97,878	13.9

*Mechanical essential loads include all HVAC equipment, including CRACs, cooling towers, and condenser water pumps.

A total facility electrical load of 1,360 kW was recorded from building instruments. The power supply to fourth-floor Switchboard M4, including essential and critical loads, was recorded with building instruments (Square D Power Logic). The electrical losses in the UPS units were calculated by subtracting the essential and critical loads of both data centers from the total power supply to Switchboard M4.

Both data centers on the fourth floor housed a total of 502 computer racks, and with an average power demand of 0.75 kW per rack. The highest rack power demand was reported to be 4 kW. In DC #17, the critical equipment was located in just one half of the space while all of the ten CRAC units were in operation. Consideration should be given to turning off CRACs in unoccupied areas of the floor, and blocking off perforated floor tiles in this area.

From these measurements, it was observed that 40% of the overall electric power was consumed by fourth floor critical loads in both data centers, 32% of the power was consumed by HVAC systems, and 9% of the power was consumed by UPS units, and the remaining 19% was created by lighting, office, and miscellaneous loads in the building.

Power demand breakdown for each data center is shown in Table 2 and Table 3. The ratios of HVAC to IT power demand in each of the data centers in this study were approximately 0.8. The density of installed computer loads (rack load) in DC#16 and DC#17 was 38 W/ft^2 and 16 W/ft^2, respectively. This was relatively lower compared to other data centers previously studied. In addition, the actual mechanical infrastructure in place to serve the critical loads seemed to be relatively high.

Table 2 End-Use of Electricity of Data Center 16

Description	Electric power demand (kW)	Share of electric energy use (%)	Floor Space (ft^2)	Electric power density (W/ft^2)
Total Load-DC 16	763	100%	10000	76.3
Rack Load	377	49%	10,000	37.7
Mech Essential Load	300	40%	10,000	30
UPS	86	11%	10,000	8.6

Table 3 End-Use of Electricity of Data Center 17

Description	Electric power demand (kW)	Share of electric energy use (%)	Floor Space (ft^2)	Electric power density (W/ft^2)
Total Load DC 17	334	100%	10,000	33.4
Rack Load	165	49%	10,000	16.5
Mech Essential Load	132	40%	10,000	13.2
UPS	37	11%	10,000	3.7

An estimate of "rack-cooling load" may be calculated based upon the data center critical power load, assuming 100% of the critical power becomes heat to be rejected by cooling. For example, Q = kW * 3413 / 12000 (ton). Using the critical power of 377 kW and 165 kW in each data center, the rack-cooling loads of the data centers would be approximately 110 ton and 45 ton, respectively. This indicates that for both data centers, a significant number of CRAC units could be turn off while the rest of the units would be able to provide sufficient cooling to the critical cooling requirements.

Figures 7&8 show the power density of critical power loads, essential mechanical loads, losses from UPS' serving the fourth floor data centers. The power density was presented in terms of Watts per square foot of raised-floor.

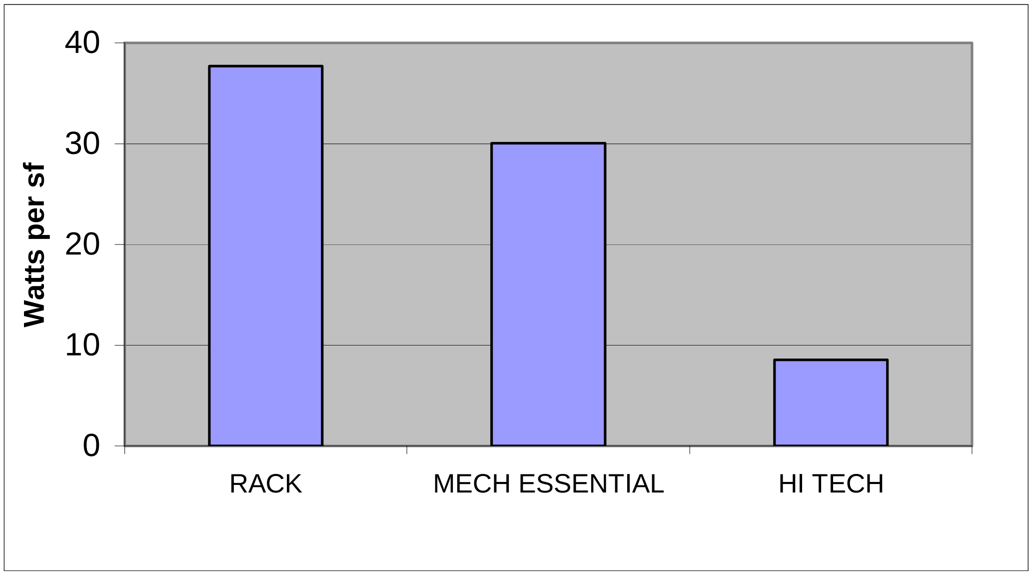

Figure 7. Data Center 16 Power Density

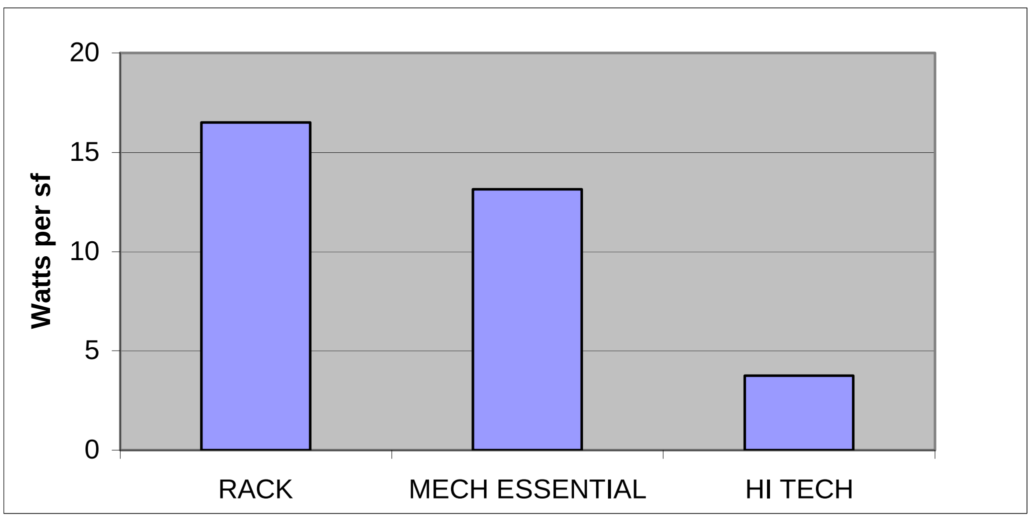

Figure 8. Data Center 17 Power Density

Critical electric power supplied to each data center was through six power distribution units (PDUs) located within each of the data centers: PDU-7A thru PDU-7F in DC16 and PDU-8A thru PDU-8F in DC 17. All of the 200 kVA-rated PDUs had Level 3 Model # RPC-1C-200-BD at 480/208 volts.

Figure 9 shows one of these power distribution units. Typically, the PDUs were recorded to be 96%.

Figure 9. Typical PDU

4 Mechanical System Operation

During the one-week monitoring period, the following HVAC equipment was operating:

- Primary condenser water pump (constant speed)
- Secondary condenser water pump (constant speed)
- Cooling tower (s), with fans on variable speed drives (VFDs). Only one tower, with two fans, was operating at a time to serve the loads
- Plate/Frame heat exchanger
- All CRAC units in both data centers (DC #16 and DC #17)

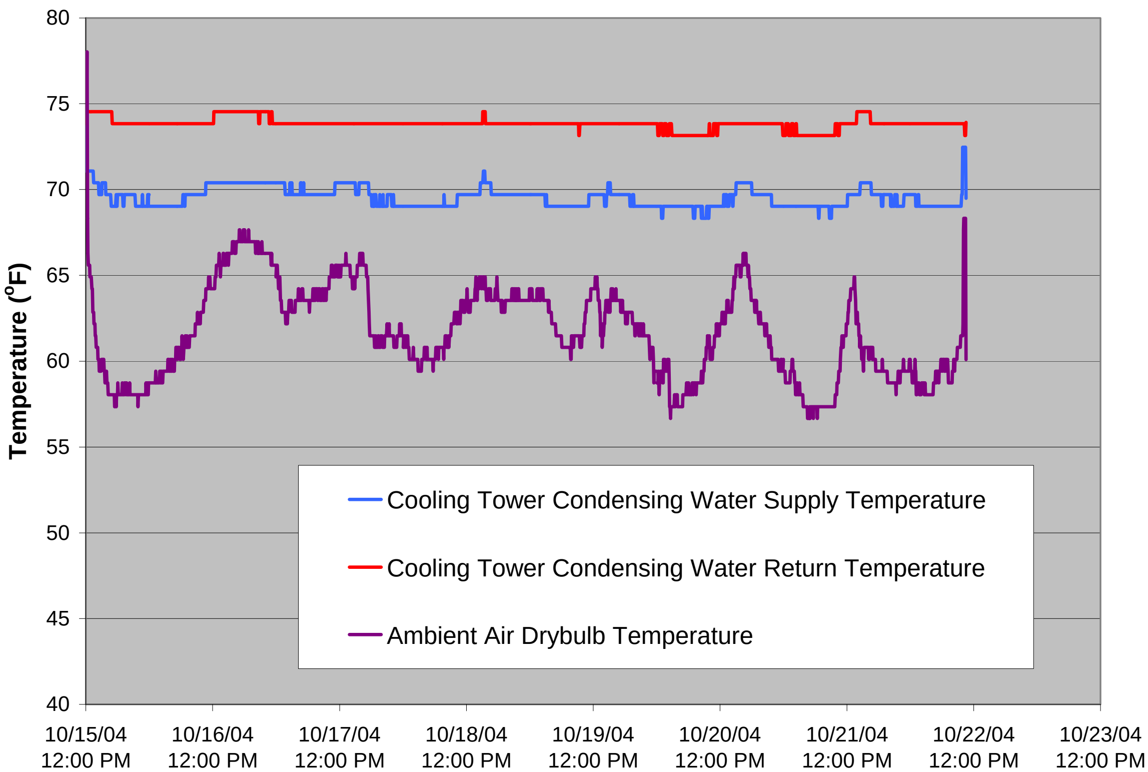

Figure 10. Cooling Tower Condenser Water Temperatures

Figure 10 shows the primary condenser water temperatures and outside air temperature monitored and recorded for a period of one week. The primary (cooling tower) condenser water supply and return temperature exhibited typical temperature differential ranging from 3.5 to 4.8°F.

The cooling tower fan speeds were controlled by the primary condenser supply water temperature through a variable speed drive. The exact temperature set point was not known. The VFD was operating at within a range around approximately 40 Hz.

Using the average water temperature rise and the primary pump water flow rate, the calculated cooling tonnage can be calculated by the following equation:

$$Tonnage = \frac{60 \rho Q C_p \Delta T}{12000}$$

Where

P: water density in lb/gal, 8.32 lb/gal

Q: water flow rate in gallon per minute, 1280gpm

ΔT: water temperatures rise in °F

Cp: water thermal conductance, 1BTU/lb°F.

With the ΔT ranging from 3.5 to 4.8°F, the estimated total cooling produced by the cooling tower was within approximately 190-260 cooling tons. This was approximately one quarter to one-third of the designed cooling capacity of a cooling tower at the design water flow rate.

Figure 11 shows the recorded water temperatures for secondary (building) condenser water system along with outside air temperature during the monitoring period. Little difference was observed in the recorded supply and return water temperatures, i.e., both near 74°F with the difference mostly within 1°F. Given certain heat transfer efficiency, the heat transfer at both sides of the heat exchangers must be balanced. Apparently, there were errors in temperature sensors or EMCS system monitoring signals concerning the secondary water temperatures. Therefore, we suggest that the monitoring system be examined and calibrated, e.g., data acquisition through the EMCS systems.

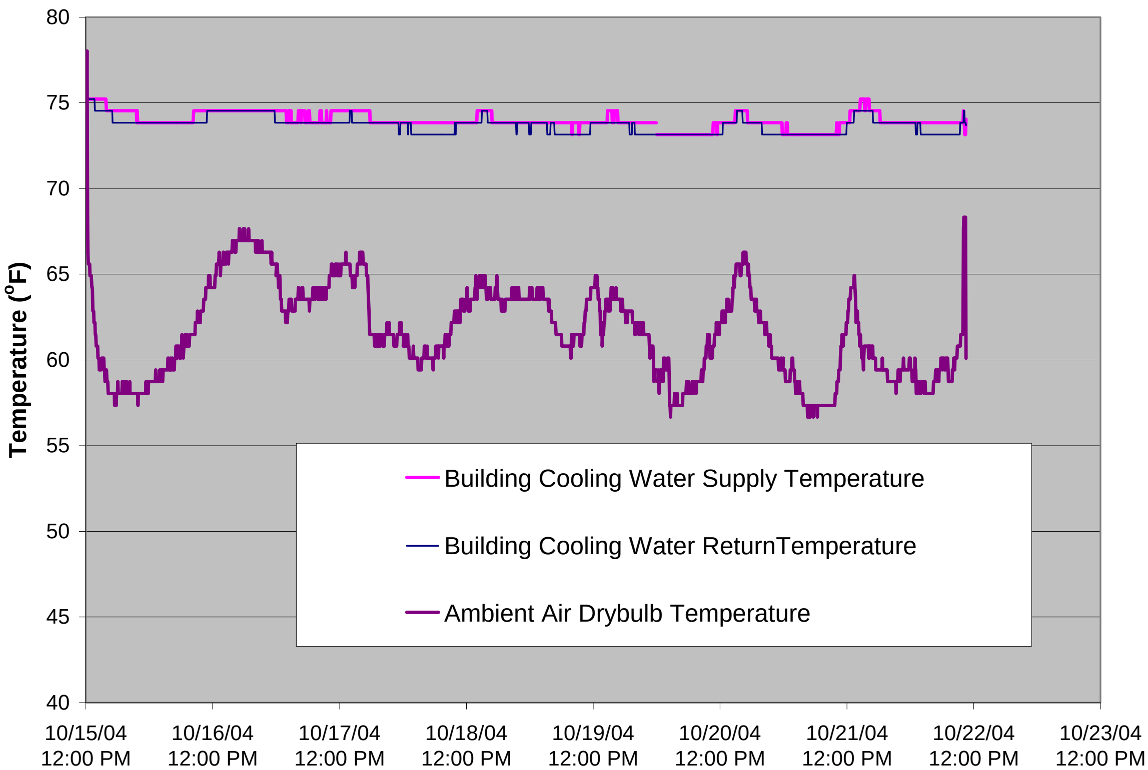

Figure 11. Secondary Condenser Water Temperatures

Air temperature monitoring for three selected sample CRAC units was taken for a period of one week (October 15 to October 22). Room air temperature and relative humidity were measured in the center of the data centers at a height of six feet above the raised floor.

Figure 12 shows supply and return air temperatures for one of the CRAC units, along with space air temperature and relative humidity in Data Center #16 (CRAC 7-3). During the monitoring period (October 15 to October 22), the return air temperatures were constant when the HVAC systems were in normal operation. When the supply air temperature fluctuated, the return air temperature also fluctuated although within a smaller range. In the meanwhile, the data center room RH also changed significantly. When supply air temperature was maintained at a more constant range, the return air temperature to the unit and the room RH became less fluctuated. Most of the time, RH was within 50-60% range. This indicates that temperature control of supply and return air to the individual CRAC unit was significant in maintaining the stability of room air temperature and relative humidity.

In addition, the temperature of return air to the CRAC unit was consistently lower that the space air temperature by approximately 5-6°F. This exhibits large difference between room temperature and return air temperature, perhaps partly due to a "short-circuit" of cold and hot air surrounding this CRAC unit. This indicates that there is noticeable deficiency in cooling effectiveness induced by operating this CRAC unit. Therefore, the air management of this CRAC unit and perhaps others should be optimized to reduce the waste of cooling provided by the units.

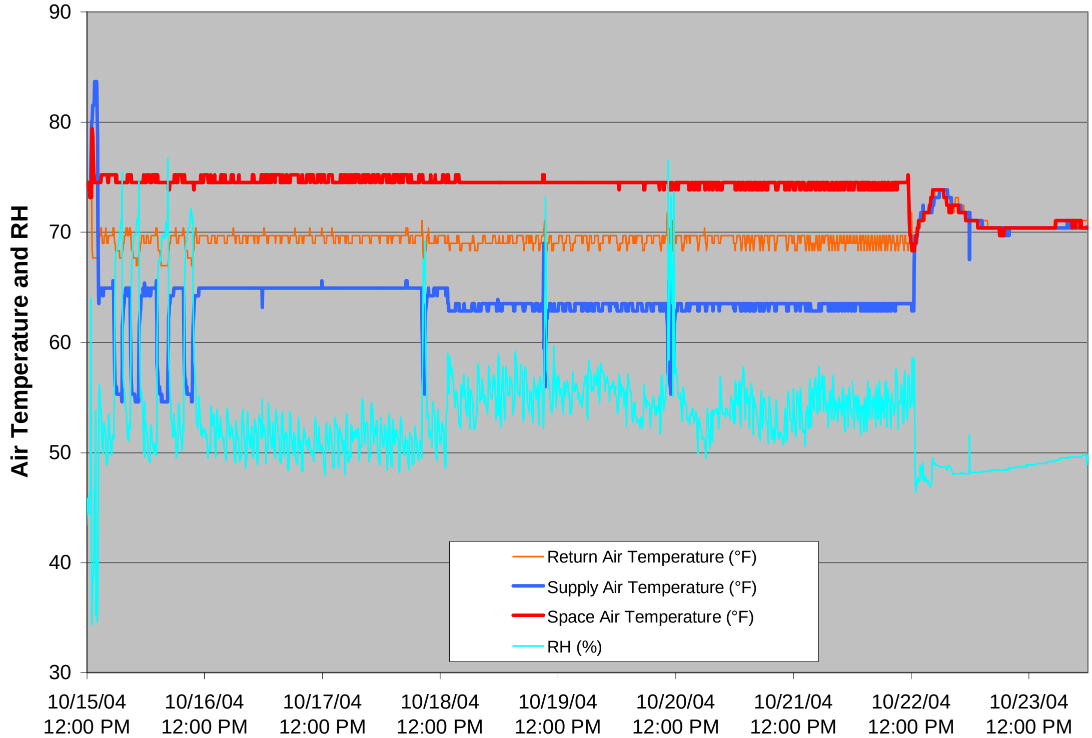

Figure 12. DC #16 CRAC 7-3 Air Temperature and Humidity

Figure 13 shows another CRAC unit's supply air and return air temperatures and the room air temperature in Data Center #16 (CRAC unit 7-12). During the monitoring period (October 15 to October 22 noontime), the return air temperatures were constant when the HVAC systems were in normal operation. Different from CRAC unit 7-3 in the same data center, the temperature of return air to CRAC unit 7-12 was consistently closer to the room air temperature, i.e., mostly within 1-2°F. This suggests that cooling induced by this CRAC unit was more effective in removing heat than was CRAC unit 7-3 in the same data center. However, the large temperature differential between supply and return air temperatures may indicate 1) that the supply air temperature could be elevated to improve heat-exchanging efficiency, and 2) that operation and layout of this CRAC could be further improved to avoid overcool or short-circuiting cold air with return, warmer air.

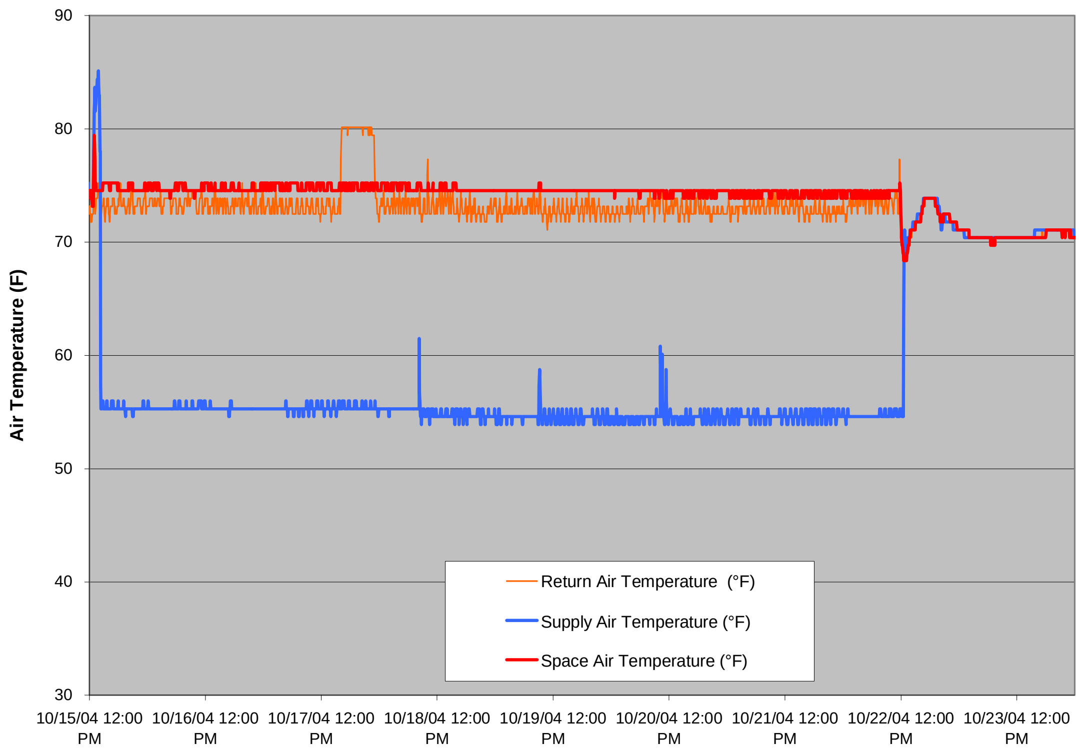

Figure 13. DC #16 CRAC 7-12 Air Temperature

Figure 14 shows the trending of an additional CRAC unit's supply air and return air temperatures and the room ambient temperature in data center #17 (CRAC unit 8-3). Similar to the CRAC unit 7-12 in DC #16, during the monitoring period (October 15 to October 22 noontime), the temperature of return air to CRAC unit 8-3 in this data center was consistently close to the space air temperature, i.e., within 2-3°F, while the supply air temperature was around 55°F. This suggests that while the cooling induced by this CRAC unit was effective, the large temperature differential between supply and return air temperature may indicate that the supply air temperature could be elevated and that operation and layout of this CRAC unit could as well be improved.

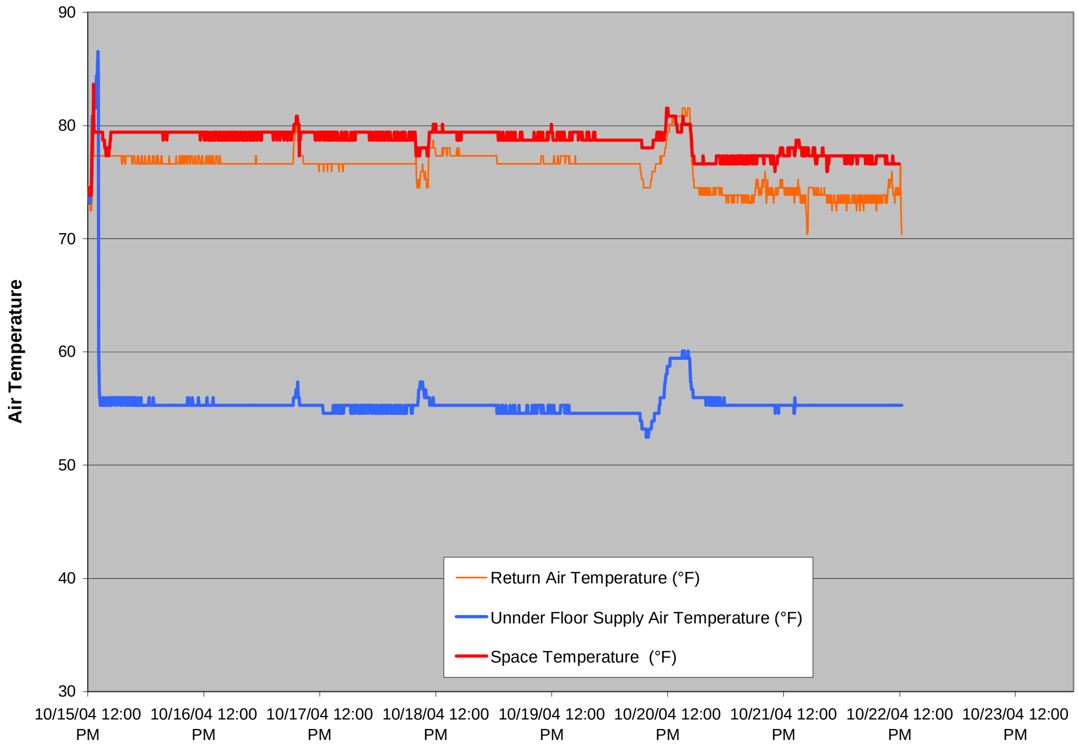

Figure 14. DC# 17 CRAC 8-3 Air Temperatures

In summary, the temperature difference between the data center air and the return air to CRAC unit was found to be significant in one out of three CRAC units selected in the study. This suggests perhaps short-circuiting or mixing of the cold supply air into the return air to the CRAC unit(s). Although arranging hot aisle/cold aisle design to separate airflow streams would be difficult in such a co-location data center, optimizing air distribution should be pursued and would be possible through carefully placing perforated tiles, cable pass-through, and CRAC units. The benefits include achieving greater CRAC effectiveness, in the meanwhile perhaps less humidification and cooling would be required.

Figure 15 shows the cooling tower supply and return temperatures and the fan VFD speed, for a 24-hour period. A slight diurnal variation can be seen in the action of the VFD. The drive was also operating at frequencies varying between 20 HZ and 60 HZ at the beginning of the period, which may indicate a control problem that needed tuning.

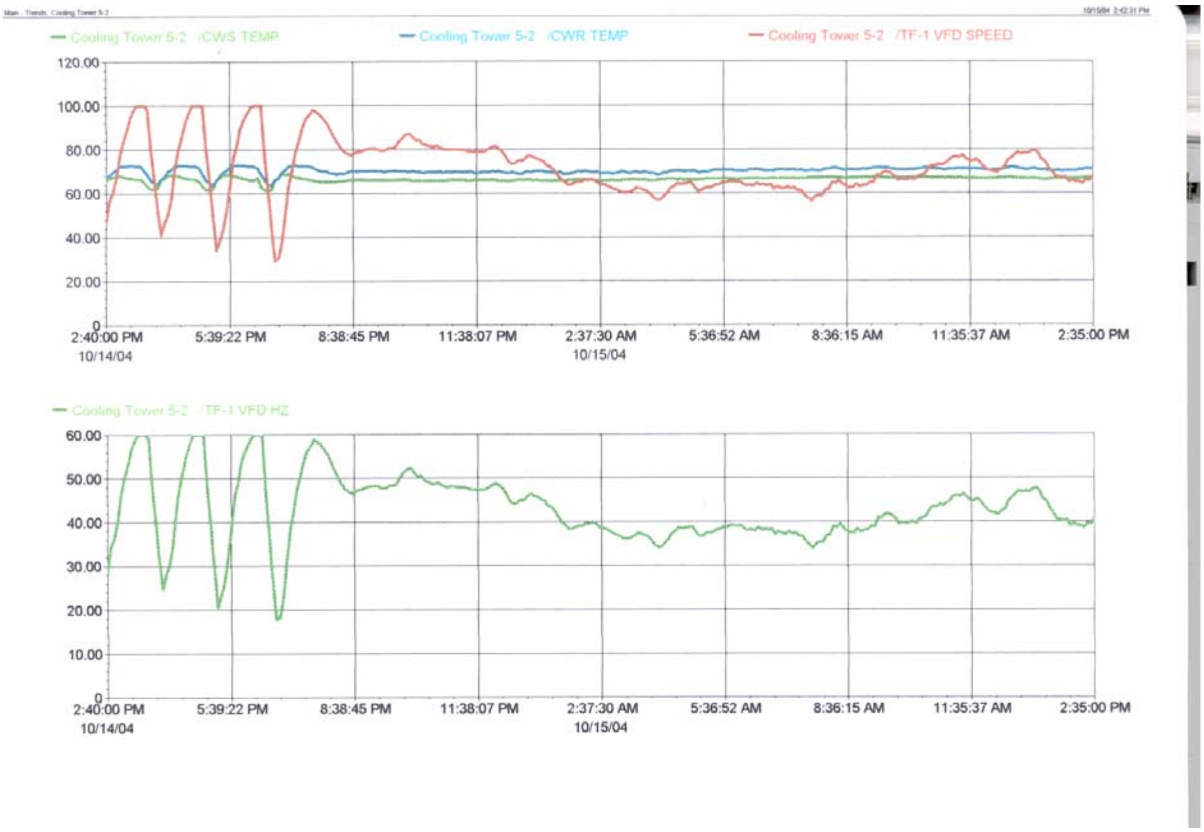

Figure 15. Cooling Tower Supply and Return Temperatures and Fans VFD (Hz)

5 Recommendations

The density of installed computer loads (rack load) was 38 W/ft^2 in data center 16 and 16 W/ft^2 in data center 17, respectively. This was relatively lower compared to other data centers previously studied. In addition, the actual mechanical infrastructure serving the critical loads seemed to be relatively high, with an HVAC to IT power demand ratio of 0.8 in each of the data centers in this study. A significant number of CRAC units could be turn off while the rest of the units would be able to provide sufficient cooling to the critical cooling requirements.

In addition, general recommendations for improving overall data center energy efficiency include improving the design, operation, and control of mechanical systems serving the data centers in actual operation. This includes primary condenser water system, secondary condenser water system, CRAC units, and airflow management and control in data centers.

For the primary condenser water system, cooling plant optimization strategy should be developed. For example, control logic could be improved for cooling tower operation sequences. Operating both fans at lower speeds in a tower may be typically more efficient than operating one tower staged with another. Integrating VFD device and operation in cooling tower water system can improve the efficiency. This would be more useful, especially when the cooling load increases. Similarly, using more than one heat exchanger in parallel may lower pumps' power demand. In addition, optimizing water temperature differential and pump head required would collectively contribute to minimizing total power demand for water systems.

For the building (secondary) condenser water system, supply water temperature and water flow rate from the heat exchanger may be optimized by providing variable-speed drives to the building condenser water pumps. The variable-speed drives on the secondary pumps can be controlled to provide a differential pressure control across the supply and return runs located at the end of the lines. The installed CRAC units were equipped with two-way modulating valves in the condensers controlled by compressor head pressures. Therefore, at lower cooling loads, these valves could reduce the flow rate of condenser water to the units.

Additional specific recommendations include:

- Optimize the actual air temperature and humidity set points, e.g., extending the permitted range. The make-up air unit's humidification system should be checked to ensure it is operating to maintain a minimum of 35% RH in the space.

- Optimize the control of supply and/or return air temperature from the CRAC units.

- Optimize air distribution through carefully placing perforated tiles, cable pass-through, equipment layout, and actual operation or non-operation of CRAC units. The benefits include achieving greater CRAC effectiveness, in the meanwhile perhaps less humidification and cooling would be required. For example, re-arrange CRAC DC 7 – 3 location and optimize its control. In addition, some CRAC units could be turned off.

- There was an observed difference in power demand readings before monitoring (3120 kW) and during monitoring period (1360 kW). It is worthwhile looking into calibration of the power metering device and/or fine-tuning operation to avoid or minimize electric demand charges for the data centers.

- Observing a discrepancy between the products of flow and temperature difference on the two sides of the heat exchanger, we suggest that the monitoring system be examined and calibrated, e.g., data acquisition for the secondary condenser system through the EMCS systems.

- Re-adjust the secondary condenser water supply temperature set point may be necessary, e.g., based upon outdoor air wet bulb temperature. This strategy allows a lower condenser water temperature to be delivered to the CRACs during most of the year, when the outdoor wet bulb temperature is lower than design conditions. A lower condenser water supply temperature would make it possible to lower the water flow rate to the CRAC units through reducing energy demand for water pumps. Considering the partial occupancy of the facility, the building cooling supply water temperature may be optimized using variable speed drives on the secondary condenser water pumps.

- The existing blow-through cooling towers were inefficient; therefore, considerations should be given to replace lead units with induced-draft towers.

6 Acknowledgements

This report on data center energy benchmarking was finalized based upon the field data collection performed by EYP Mission Critical Facilities and Landsberg Engineering and the draft report produced in the course of performing work subcontracted for the Lawrence Berkeley National Laboratory (LBNL).

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7 Appendix A: Data Facility Definitions and Metrics

The following definitions and metrics are used to characterize data centers:

Air Flow Density	The airflow (cfm) in a given area (ft^2).
Air Handler Efficiency 1	The airflow (cfm) per power used (kW) by the CRAC unit fan.
Air Handler Efficiency 2	The power used (kW), per ton of cooling achieved by the air-handling unit.
Chiller Efficiency	The power used (kW), per ton of cooling produced by the chiller.
Computer Load Density – Rack Footprint	Measured Data Center Server Load in watts (W) divided by the total area that the racks occupy, or the “rack footprint”.
Computer Load Density per Rack	Ratio of actual measured Data Center Server Load in watts (W) per rack. This is the average density per rack.
Computer/Server Load Measured Energy Density	Ratio of actual measured Data Center Server Load in watts (W) to the square foot area (sf) of Data Center Floor. Includes vacant space in floor area.
Computer/Server Load Projected Energy Density	Ratio of forecasted Data Center Server Load in watts (W) to the square foot area (sf) of the Data Center Floor if the Data Center Floor were fully occupied. The Data Center Server Load is inflated by the percentage of currently occupied space.
Cooling Load – Tons	A unit used to measure the amount of cooling being done. One ton of cooling is equal to 12,000 British Thermal Units (BTUs) per hour.
Data Center Cooling	Electrical power devoted to cooling equipment for the Data Center Floor space.
Data Center Server/Computer Load	Electrical power devoted to equipment on the Data Center Floor. Typically the power measured upstream of power distribution units or panels. Includes servers, switches, routers, storage equipment, monitors and other equipment.

Data Center Facility	A facility that contains both central communications and equipment, and data storage and processing equipment (servers) associated with a concentration of data cables. Can be used interchangeably with Server Farm Facility.
Data Center Floor/Space	Total footprint area of controlled access space devoted to company/customer equipment. Includes aisle ways, caged space, cooling units electrical panels, fire suppression equipment and other support equipment. Per the Uptime Institute Definitions, this gross floor space is what is typically used by facility engineers in calculating a computer load density (W/sf).
Data Center Occupancy	This is based on a qualitative estimate of how physically loaded the data centers are.
Server Farm Facility	A facility that contains both central communications and equipment, and data storage and processing equipment (servers) associated with a concentration of data cables. Can be used interchangeably with Data Center Facility. Also defined as a common physical space on the Data Center Floor where server equipment is located (i.e. server farm).

8 Appendix B: Facility Diagrams

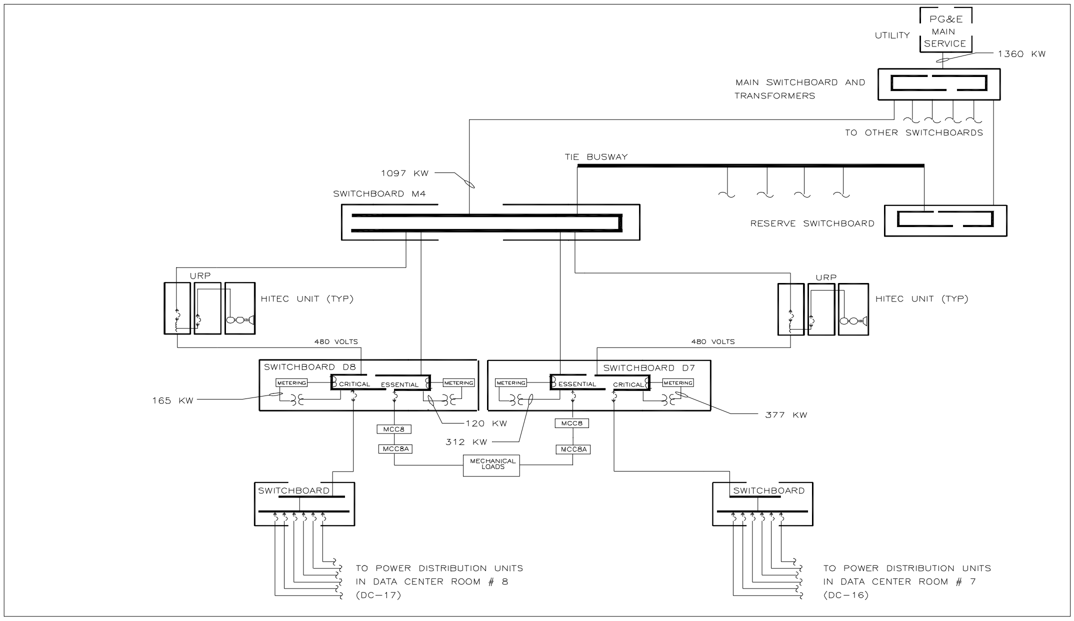

Figure 16. Electrical System Schematic

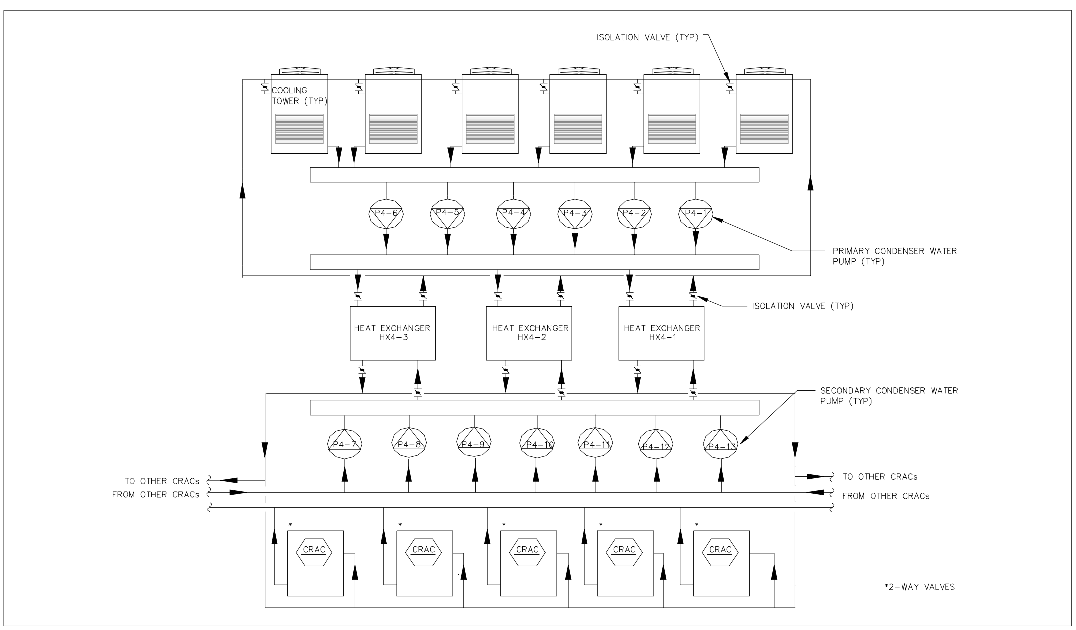

Figure 17. Condenser Water Flow Diagram