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Executive Summary

Spectrum Engineers conducted a thorough analysis of the existing Wahlen VAMC campus chilled water system. Using existing design documentation, site surveys, and trending data a holistic overview of the entire campus was compiled. The following report shall discuss, in detail, the findings of this analysis.

Every effort was made to use the most up to date and accurate information, however due to the fragmented nature of the information available some engineering judgment had to be used in the determination of deficiencies and recommendations.

Campus level deficiencies can be broken into three levels: 1) Building Level, 2) Loop Level, and 3) Plant Level.

Building level deficiencies include maintenance items, design and operational issues, equipment beyond useful life, and testing/balancing issues.

Secondary chilled water loop deficiencies include piping distribution limitations, isolation and redundancy items, and building level supply branch control.

Chilled water plant level deficiencies include condenser water capacity limits, redundancy and future capacity limits, as well as operational degradation due to low temperature differentials.

The report subdivides each of these categories and discusses the causes and corrective recommendations required. Using this approach should allow for the VAMC engineering personnel to select those items, deemed most urgent, to be completed without the need to undertake a full campus wide overhaul during one project.

It is not the opinion of Spectrum Engineers that a complete new system be installed to supplement the existing plant, but instead a five year phased renovation of the existing system. Following a segmented scheme should allow for much needed upgrades and repairs while still allowing for budget concerns in regards to other capital needs.

It is the opinion of Spectrum Engineers that all recommendations in the report be undertaken, but completion of any number of the items will serve to enhance the function and reliability of the existing system.

Using the current operating conditions, the expected reduction in operating energy consumption can summarized by the following:

1. Air Handler Cleaning/Maintenance: 10%-25% reduction in fan brake horse power consumption for every half inch of pressure drop reduction. This is a conservative estimate based on an operating AHU with four inch total pressure drop.
2. Correction of Low Delta Temperature: 5%-10% reduction in total chilled water plant operating power.
 - a. This includes a 25%-50% reduction in secondary pumping power alone by removing all three way control valves and installing two way control valves.
3. If all recommendations are completed the entire chilled water plant should see, at a minimum, 10%-15% reduction in operating power. That reduction would equal ~450,000 kW-HR per year. (Using 2012 totals)



Introduction

In August 2012, Spectrum Engineers was contracted to perform a chilled water system analysis of the existing campus system. The project scope was to review the existing systems, identify operational deficiencies, estimate current connected load (with future expansion), review historical trending data and suggest corrective actions.

Currently the George E. Wahlen VAMC campus operates three centrifugal water cooled chillers. These chillers form the backbone of the campus system which supplies cooling water to numerous buildings. This system has been operating in its current state since the early nineteen nineties (~20 years) with the original system infrastructure being much older. Significant campus additions, modifications, obsolete technology and operational degradation have caused this system to cease being able to perform its intended mission. That mission being to supply cooling water to meet the campus needs with the best operational efficiency possible, while providing mission critical redundancy in case of component failure.

This report shall attempt to outline Spectrum Engineer's findings of the campus system and make common sense recommendations to allow the VAMC to continue to meet its current and future needs. This report in no way attempts to be an absolute statement of fact. Due to the complex nature of the systems being analyzed and the fragmented data available some engineering judgment and approximation had to be used. However, by comparing all known information (as-builts, site survey and trending data) a macro level picture was developed which will allow for future capital investment determination.



Overview of Existing Conditions

Chilled Water Plant

Building 27 currently houses three existing water cooled chillers (2-900 ton, 1-450 ton). These chillers operate in a traditional primary-secondary system. This type of system was first developed in the mid-fifties (1954) as a way to allow for the constant flow requirement of centrifugal chillers (typical till the 90's) while providing for varying flow at the system level (see Figure 1 next page). As a chiller becomes operational the primary loop water increases proportionally based on its capacity. Secondary loop water flow varies based on the load requirements and the pressure reading at some predetermined system point. This mismatch in flow results in water mixing at either the supply leg or the return leg, depending on which loop has the greater flow.

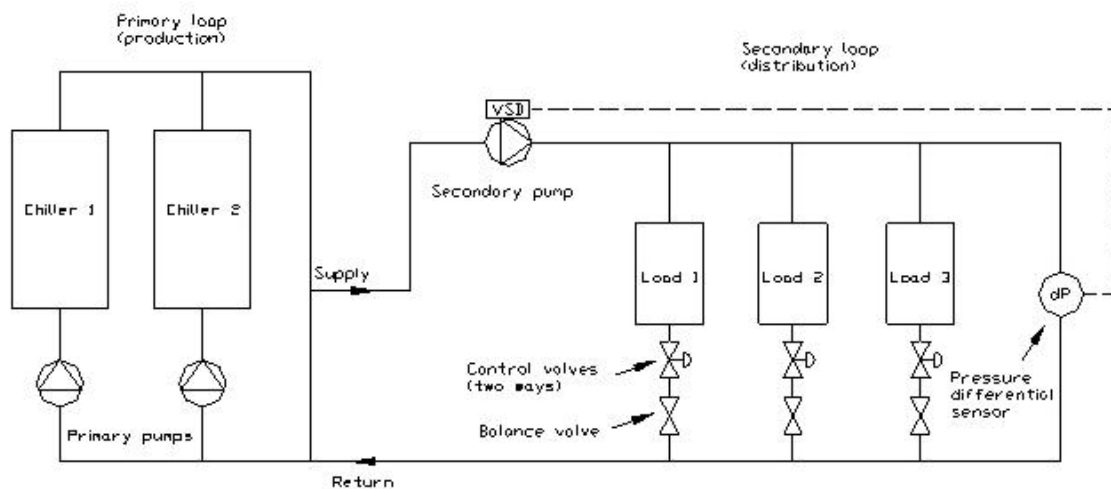


Figure 1: Typical Primary-Secondary Chilled Water System

An example of this can be seen in the following table (Table 1).

NUMBER OF CHILLERS OPERATING	PRIMARY GPM	SECONDARY GPM	CHWS (P) °F	CHWR (P) °F	CHWS (S) °F	CHWR (S) °F
1	1000	1500	45	55	48.3	55
2	2000	1500	45	52.5	45	55

Table 1: A Typical P-S System with 10° Delta T

As shown above, either the supply water temperature of the secondary system rises or the return water temperature of the primary falls depending on how many chillers are in operation. Either condition always results in degraded delta temperature of one of the loops.

Figure 1 isn't completely accurate for the campus system as the secondary loop has a mix of three-way, two-way, and no control valves serving the loads. This existing condition adds another factor into the equation. That factor is low delta temperature syndrome. When three-way mixing valves, in combination with no control valves, are scattered throughout the secondary loop a condition will exist that insures cold supply water is always bypassing around coils. This causes the return water temperature to drop which in turn causes both the primary and secondary loop delta temperature to fall. The overall effect of this is to limit the ability of a running chiller to load fully. An example of this can be seen in Table 2.

NUMBER OF CHILLERS OPERATING	RATED CAPACITY TONS	OUTPUT CAPACITY	PRIMARY FLOW GPM	DELTA T (P)	SECONDARY FLOW GPM	DELTA T (S)	SECONDARY LOAD TONS
1	500	500	1000	12	1000	12	500
2	500	250	2000	6	2000	6	500
Therefore two chillers must operate at 50% load. Any flow mismatch between primary and secondary will also cause mixing at the return leg of the primary. This will cause the return temperature to continue to drop, further limiting the chiller's ability to load fully.							

Table 2: A Typical Low Delta T System

The overall effect of this condition is to require multiple chiller operation when one chiller could have satisfied the load had it been operating at its design temperature differential or been capable of increased water flow. Since the campus primary chilled water loop is a constant flow system the only option available is to start another chiller when loop delta temperatures drop and secondary loop flow is greater than primary flow. If a second chiller isn't started the supply water temperature will start to increase (due to mixing in the supply leg) and building air handlers will lose control of the leaving air temperature resulting in loss of climate control.

During the review of the existing conditions it was determined that the chilled water system is suffering from a low delta temperature syndrome of between 6 and 8 degrees (Design = 10). This shall be discussed further in the trend data review portion of the report (see below).

Chilled Water Plant Condenser Water System

The current chilled water plant has three machines for a combined theoretical capacity of 2250 tons. However, the operational capacity of the condenser water system serving these machines does not allow for all three to operate at the same time. At this time only two of the 900 ton machines or one 900 ton and the 450 ton can be operated at the same time. The original design intent was for this to not be the case, but operational experience has shown the cooling towers and/or associated pumps cannot fully meet the requirements as originally designed. Therefore the system capacity is only a nominal 1800 tons (max). However, to achieve this nominal 1800 tons all three cooling towers (CT-1, 2, & 4) must be in operation. The result of this is no system redundancy on or near a design cooling day. The loss of any cooling tower and/or either 900 ton machine would cripple the chilled water plant.



Campus Building Systems

The Wahlen VAMC campus has a mix of constant volume, variable volume, dual duct, and multi-zone air handlers throughout its buildings. Just as the type of air handlers are varying so are the chilled water control schemes employed. Most consist of three-way mixing, two-way variable, chilled water coil pumps, or some combination thereof. A few AHU's are isolated with plate and frame heat exchangers. However, none of the heat exchangers viewed had any means of control on the campus side of the system. This means there is no way to ensure a constant temperature differential as the load varies, which contributes to lower delta temperatures and wasted chilled water capacity.

A good portion of the air handlers surveyed are in dire need of repair and/or replacement. The survey team noted the following conditions on a regular basis:

1. Dirty and clogged coils and/or filters
2. Broken and damaged cases with air bypassing coils
3. Insulation removed, missing, or damaged
4. Some units are 40 plus years old and well beyond expected life
5. Oversized control valves and/or cooling coils

All of these conditions lead to inefficiency, wasted energy, and comfort complaints.

Just as the interior systems vary, so do the building level chilled water systems. The campus has a mix of tertiary pumps (with or without decoupling loop), some constant flow and some variable; building plate and frame heat exchangers.

Because no standard scheme has been employed over the years it has become increasing difficult to optimize the chilled water plant for efficient operation. The result is the system must operate to serve whatever building or load is the limiting factor. This generates inefficiencies and wasted operating costs.



As-Built Review

In an attempt to determine the major connected chilled water campus load Spectrum Engineers reviewed all available campus documents. These included most paper drawings located in building six (including a trailer near building 38), all electronic as-builts (cad and scans) provided by Casey Ryan, and any documents located in mechanical rooms. This report in no way claims to have found or reviewed all documentation generated in the sixty plus years the site has been in operation. However, a good faith effort was attempted and most information was located. All used design documents have been compiled, by building, for future use. (See accompanying DVD)

The appendix contains the compiled data collected in full table format, organized by building. (See Table 3) Each building has all the major air handling units currently connected to the campus system. It was not feasible to account for all devices, such as, fan coil units in every building. Very little information was found for these units and survey to verify their existence would have been nearly possible; as well as caused major disruption to the hospital activities.

The design information (Airflow, Temperature, and Design Conditions) was input into Table 3 and calculated values were generated using standard psychometric equations. As part of the report a copy of the excel file will be included for any future analysis. Also part of Table 3 is a comparison of the design chilled water flow rate to each device verses the calculated. Using this information one can see numerous units which appear to be short on water flow. This is only an estimate, as every chilled water coil will have different heat transfer characteristics. Any deviation above ten percent should be field tested and corrected if needed.

When original design information could not be found the following approximation procedure was used:

1. Measure coil face area (fin area see Table 3)
2. Determine if 100% outside air or a mixed air unit
 - a. Mixed air units shall use 20% outside air flow
3. Multiply the coil face area (square feet) by 500 feet per minute to determine maximum supply air flow (cubic feet per minute)
4. Use the following design temperatures:
 - a. Outside Conditions = 98° / 63° (DB/WB)
 - b. Inside Conditions = 75° / 55° (DB/WB)
 - c. Coil Leaving Conditions = 53° / 51° (DB/WB)
5. Use ten degree chilled water entering-leaving temperature for flow calculation
6. Some newer units had air flow data printed on the unit
7. All calculated data at 5000 feet elevation.
 - a. Design elevation used over the years varies between 4220 and 4800 feet

Included in Table 3 is a verification of the type of control valve employed at each air handling unit.



Estimation of Current Peak Connected Load

In an attempt to determine the actual peak campus chilled water load three estimation methods were used:

1. Summation of Design Connected Load from As-Built Documents
 - a. Using 75% Diversity Factor
2. Square Footage Estimation by Building Type
 - a. Using 75% Diversity Factor
3. BAS Trending Data during Design Conditions (7/14/13 – 7/20/13)
 - a. See Appendix for NOAA Weather Data for the Month of July 2013
 - b. Average Daily high 99°F

The following table (Table 4) summarizes the three methods used. See appendix for full summary tables. All three methods are in agreement with a mean value of 1454 tons.

	As-Built (75%)	SQFT Estimation (75%)	Trend Data
Chilled Water Load (TONS)	1523	1409	1430

Table 4: Campus Load Estimates

Due to the complexity of the entire chilled water system the first two estimation methods are only good for an order of magnitude (“ballpark”) guess. The only real concrete data with which future capital investment projects can be planned is through the use of trending data.

2013 BAS Trend Data

The existing JCI Metasys control system has the ability to collect trending data and output that data into a standard spreadsheet file format. Spectrum Engineers had the chilled water operators setup a trending log for the week of July 14th through the 20th. The selected data parameters were:

1. Campus Chilled Water Load (Tons)
2. Loop Supply Water Temperature (CHWS T)
3. Loop Return Water Temperature (CHWR T)
4. Loop Total Flow (GPM)
5. CH-1 Water Flow (GPM)
6. CH-2 Water Flow (GPM)
7. CH-3 Water Flow (GPM)

Using the above seven parameters a reasonable picture of the campus system was determined. The following discussion will refer to Chart 1 & 2 in the appendix.



Looking at Chart 1, one can see the operational period of the campus (6am-6pm) outlined in a red hatch for the trending period. The first day, Sunday, does not include an operational period as it started trending at 12 PM. However the noon peak is still listed.

Two trends emerge from a review of the data. The first trend is a weekend cycle. On Sunday and Saturday the campus load ramps up from about 1000 tons at noon to the peak load of approximately 1300 tons in late afternoon. This is consistent with afterhour operation of air handlers and setback zone temperatures. The building internal load is at a minimum which causes a peak building load to occur in the evening, around 6 PM, due to the building structure heating up throughout the day from the exterior heat load. The second and more important trend is the weekday cycle. Each weekday the campus load increases from 800 tons (6 AM) to a peak cooling load of approximately 1430 tons (1 PM), this is consistent with startup load from buildings becoming occupied and peaking in early afternoon due to maximum exterior heat gain.

Chart 1 has two outliers in the data that must be accounted for. Tuesday (7/16) and Wednesday (7/17) both show a peak tonnage of over 1800 tons. These two maximum peaks occur at 8:30 AM. Looking at the loop supply and return water temperatures explains the reason. Thirty minutes prior to the peak, only chiller three was operational and the supply water temperature had risen to 70° (7/16) and 52° (7/17). Well above the set point of 45 degrees. Then chiller one and two started which caused them both to be fully loaded (delta T was above 10). This pull down load to return the supply water temperature to 45 degrees is the cause of the peak. If the loop had not been allowed to rise to such a high supply temperature the peak would have been as the other days show. The proof is in the speed with which the tonnage returns to a nominal 1400 tons (~1 Hour).

Referring to Chart 2, which has load tons plotted verses loop delta temperature, one can see a classic example low delta temperature syndrome. As previously stated, low delta temperature is primarily caused by three-way mixing of chilled water at the load source. When a load source is at minimum demand the control device bypasses supply water around the cooling coil causing return water temperature to drop. When a load source is at a maximum the control device limits bypass and maintains a higher return water temperature. The real world result of this manifests in a tracking of delta temperature with cooling load, therefore as load increases so does delta temperature and vice versa. Looking at Chart 2, it is clear delta temperature is tracking campus load.

The average loop delta temperature for the 6AM-6PM weekday operational period is typically between 6 and 8 degrees. Only once is the delta temperature at the design temperature of 10 degrees and that is during the previously discussed outlier on Wednesday (7/17). This response is consistent with a fully loaded chiller receiving at or above design return water temperature.



Deficiencies

Deficiencies shall be discussed in the following three groups:

1. Building Level
2. Loop Level
3. Plant Level

Building Level

As stated above, no consistent design scheme has been implemented throughout the campus building systems. The varying mix of designs over the years has made it nearly impossible for the chilled water plant to function at its original design intent. The following is a list, in order of magnitude, of known deficiencies:

1. Outdated Air Handling units and accompanying components
 - a. Numerous units are in the thirty plus years age range. The unit casing is visibly damaged and allowing air to bypass the coiling coil.
 - b. Unit insulation is damaged or missing.
 - c. Interior coil surfaces are filled with years of dust and dirt impeding heat transfer and reducing rated airflow capacity.
 - d. Water side fouling of coils resulting in reduced heat transfer (e.g. loss of delta temperature).
 - i. One AHU cooling coil in BLDG 3 (3-AH-1) is so underperforming that the steam coil was piped with chilled water in an attempt to gain more cooling. (the steam is isolated)
 - e. No verifiable control of design outside air flow, resulting in increased entering air temperatures and underperformance of cooling coils.
2. Building Chilled Water Supply systems have been reconfigured so many times over the years there is no complete understanding of where water is flowing or how much.
 - a. Each building, starting with number 1, needs a complete system flow balance in order to determine exactly how much water is needed at each device.
 - b. Building one is a prime example. The building supply piping has three pumps distributing chilled water to all the AHU's. These pumps are controlled via a differential pressure sensor at the main supply and return pipe. As the reading drops or rises above the set point, the VFD's speed up or down to match. However, the problem is a full system balance needs to be performed in order to determine the correct set point. Without a full system balance there is no way to know what value will result in all AHU's receiving the design water flow at any given point in time. The result is either hydraulically remote coils starve for water and/or the pumps waste energy by flowing more water than is needed.
3. Mixing the use of three-way control valves, two-way control valves, no control heat exchangers and dedicated coil pumps.
 - a. Each building needs to be converted to one scheme to ensure correct water flow under all load conditions. This will also ensure consistent temperature differentials.



4. No verification of flow at every AHU. Each air handling unit coil should have a means to measure water flow for verification. See VA detail SD238216-01 in appendix
5. Improperly selected control valve size (Cv). (Most control valves appeared to be piped line size) Over sizing of control valves result in poor performance and hunting.
6. Oversized cooling coils. Most designers select coils at peak design conditions with little regard to part load conditions. As peak design conditions generally only occur 1% of the year (~90 hours) the result is grossly oversized coils that may lose heat transfer performance during reduced load. AHRI Standard 410-2001 requires a minimum tube velocity of 1 feet per second for all coils to be rated. This is to prevent excessive fouling, air entrapment, and reduced heat transfer coefficient.
 - a. An extreme example of this is AHU 3-AC1 in building 3. The original design was for 15,440 cfm however the coil was stated to be selected at 40,000 cfm (future). Until this unit is at or near the future stated flow it will be grossly oversized.

Loop Level

The following secondary chilled water loop deficiencies were noted.

1. The Campus chilled water system is currently configured in a distribution network verses a true loop. This means there is only one path for water to flow to a building. In a true loop system there are two paths for water to flow. This provides redundancy.
 - a. A project is underway to correct this issue.
2. Each building tie-in isn't provided with complete valve isolation. Three valves are required at each tap for full isolation. (A valve before and after the tie-in and one on the branch pipe).
 - a. If this is provided at every tie-in to the loop, no loss of any one section of pipe will cause the loss of a whole building branch. The section of underground pipe can be isolated between vaults and the loop will flow the other direction.
3. Every building is not provided with a properly designed and controlled decoupling loop.
 - a. This will be discussed further in the recommendations
4. There are no differential pressure (DP) sensors installed throughout the campus loop. Each building should be fitted with a DP sensor which would be sampled by the BAS and be used to reset the secondary plant supply pump set point. This would ensure that only the minimum required water is flowing at any given time.
5. The following table summarizes the building branch pipe size and connected flow. Also listed are the maximum gallons per minute allowed by ASHRAE 90.1-2010.
 - a. These flows are based on the totals determined from the as-built review. See Table 3 in the Appendix.
 - b. Only one branch is above the maximum flow limit imposed by ASHRAE 90.1-2010. (BLDG 6&7).
 - c. However, another issue is more concerning and that is building 20 (Valor House). The total connected flow is less than half of the maximum. This would normally not be an issue if the branch piping had a means to control the flow to the building. As it stands now, there is no flow control on that branch and water flow will increase/decrease in response to the pressure at that node. Looking at Table 5, the pressure drop in that section of pipe is only 0.5 ft/100ft at rated flow. Without a flow limiting device the campus chilled water will increase in that



section to match system pressure drop. All pressure systems are self-correcting and will rebalance water flow to equalize the pressure drop to all points on the system. Assuming the campus system developed enough pressure at building 20 to achieve a 2ft/100ft pressure drop, the water flow would increase to 550 gallons per minute. This would be a loss of 72.5 tons of capacity (6°F ΔT) because water was flowing to a branch that didn't need it.

- i. This condition starves other buildings of needed water flow resulting in the secondary pumps increasing water flow to the loop causing the cycle to repeat.
- ii. This condition also exacerbates the low delta temperature cycle causing reduced return water temperature to the plant.

BLDG #	Size (in)	Connected Flow (GPM)	Velocity (FPS)	Pressure Drop (ft/100ft)	Maximum Allowed GPM based on ASHRAE 90.1-2010 (Table 6.5.4.5)
1	8	1300	8.3	2.6	1400
2	5	120	1.9	0.3	470
2a/45	8	560	3.6	0.5	1400
3	5	410	6.6	2.9	470
47	3	60	2.6	0.95	210
4	5	120	1.9	0.3	470
5	4	100	2.5	0.64	400
6&7	5	510	8.2	4.3	470
8	3	60	2.7	1.0	210
9	3	145	6.3	4.8	210
13	2	60	5.4	5.9	130
14	8	810	5.2	1.1	1400
16	4	125	3.1	0.95	400
20	6	260	2.8	0.5	860
A	6	330	3.7	0.8	860

Table 5: Building Branch Piping

Plant Level

The following chilled water plant deficiencies were noted.

1. No N+1 redundancy. The loss of either 900 ton machine would cripple the plant capacity to less than the required 1430 nominal tons needed on a design cooling day.
 - a. Future campus expansion must also be taken into consideration when discussing this issue.
2. The existing condenser water system cannot meet the cooling capacity of the chilled water plant.
 - a. Chiller 1 (900 ton) and Chiller 2 (900 ton) were originally designed to have a dedicated cooling tower (CT-1 & 2 respectively). However, if both chillers are in operation a third tower is need (CT-4). When this occurs all three cooling towers are piped in parallel and the total condenser water flow is distributed across all three fill sections.



3. Secondary Chiller water pump control
 - a. There is only one differential pressure sensor (DPS) located across the main supply and return header in building 27. The set point for this sensor is determined by outside air temperature.
 - b. A more efficient control logic would be to install a remote DPS at each building and have the plant set point be determined by the worst case reading. The BAS would poll every building sensor at 15 minute intervals and reset the plant set point according. This would ensure only the minimum water flow was produced at any given time.
 - i. For every one gallon per minute change in flow the power required goes up or down by the cube
 - ii. E.g. : $GPM_1 = 500$, $HP_1 = 20$; $GPM_2 = 250$
 - iii. $New\ HP_2 = 20 * (250/500)^3 = 2.5$
 - iv. For this example the power required would decrease by a factor of 8
4. The single largest consumer of power in the plant is an operating chiller. Because the campus is suffering from a reduced temperature differential during 90% of its operation multiple chillers must be in operation to satisfy the demand. This is solely caused by the use of constant flow chillers (as discussed in the existing conditions section above).
 - a. A better solution would be newer variable flow centrifugal chillers with VFDs for capacity control and unloading.
5. No graphical user interface (GUI) is provided at the control system operator's station. Plant monitoring and system operation would be greatly increased if the chilled water operators had a system map showing all devices, the set points, current status, and any alarm conditions.
 - a. A typical system would be similar to the boiler operators control station.

Corrective Action Recommendations

As with the deficiencies, the recommendations shall be discussed in the following three groups:

1. Building Level
2. Loop Level
3. Plant Level

Building Level

1. Evaluate every air handling unit, by building, and develop a master replacement schedule.
 - a. The following metrics should be considered when developing the replacement schedule
 - i. Age & Condition of Unit
 - ii. Evaluate performance (Satisfying Load or Underperforming)
 - iii. Area served (Critical vs. Noncritical)
 - iv. Total Cost (Budget Cost Installed)
 1. \$7.5/cfm Mixed Air unit
 2. \$15/cfm 100% Outside Air Unit
 - v. Yearly Capital Allocation
 - b. Unit evaluation should include preventative and corrective maintenance
 - i. Coil cleaning
 - ii. Belt adjustment and bearing lubrication
 - iii. Filter replacement
 - iv. Case damage repair (includes insulation)
2. Convert all or most control valves to variable flow two-way control.
 - a. Installing flow verification devices at all AHUs per VA standard detail. (See appendix)
 - b. Identify and replace all existing incorrectly sized control valves.
 - i. Valve Cv shall be based on coil pressure drop and total system pressure drop. 5-15 Psi is typical
 - ii. Line sized control valves are normally too large and require the valve to operate at its lower limits causing erratic control and hunting.
 - iii. Equal Percentage characteristics are recommended.
3. Perform a complete building level test and balance (TAB) of the entire chilled water system.
 - a. This will identify problem branches with low flow and allow a replacement plan to be developed.
4. Using TAB data, install a decoupling loop, with properly sized pumps at every building.
 - a. See Chilled Water Decoupling Loop Diagram in Appendix
5. Mandate all future AHU replacements or additions design around a minimum 16 °F delta temperature. (45° - 61°)

Loop Level

1. Complete new secondary chilled water distribution piping.



2. Install new building distribution piping vault, with isolation valves, from new loop piping.
3. Install flow control devices at all building branches (Valor House) that have free flowing water.
 - a. See appendix for control diagram example
4. Use new differential pressure sensor, installed as part of decoupling loop, to minimize secondary loop pump flow.
5. Perform monthly trending using new flow meter and temperature sensors at each building to determine largest users of chilled water. This data will help with future capacity determination and whether expansion is needed.

Plant Level

1. As discussed previously, the current connected peak chilled water load is 1430 tons (via Trend Data). Referring to Table 6 in the appendix, the estimated future load (2020 Projection) is an additional 470 tons. This assumes all projects are approved and completed. Therefore, the nominal connected peak load of the chilled water plant will be 2000 tons (rounded up). All future discussions will be based off of this number.
2. The chilled water plant recommendations will follow a three goal staged approach.
 - a. Correct N+1 redundancy
 - b. Correct condenser water shortage
 - c. Allow for future capacity increase
3. Stage 1
 - a. Construct three new brick cooling towers in the outlined space shown in Figure 2 below.
 - i. These can be phased into three, as only one will be required at the start.
 - ii. The first tower installed shall be for the new 1000 ton chiller #3.
4. Stage 2
 - a. Demolish the 450 ton chiller #3 and replace with a new 1000 ton machine. This work shall start after completion of associated cooling tower.
5. Stage 3
 - a. Demolish the 900 ton chiller #1 and install a new 1000 ton machine with associated cooling tower.
6. Stage 4
 - a. Demolish the 900 ton chiller #2 and install a new 1000 ton machine with associated cooling tower.
7. Once all three chilled water machines and their associated cooling towers are completed, demolish the existing four cooling towers and use yard space for maintenance activities (or anything else funds allow).
 - a. All parts of construction can be phased to occur in spring, fall, and winter. This would allow for no loss of capacity and redundancy would be the same as it is now. Final system tie-in would cause minimal outage time.
8. After stage 4 the chilled water plant would meet the three recommendation goals stated above.
9. The new plant would be controlled as shown on the New Chilled Water Plant Diagram (See Appendix)



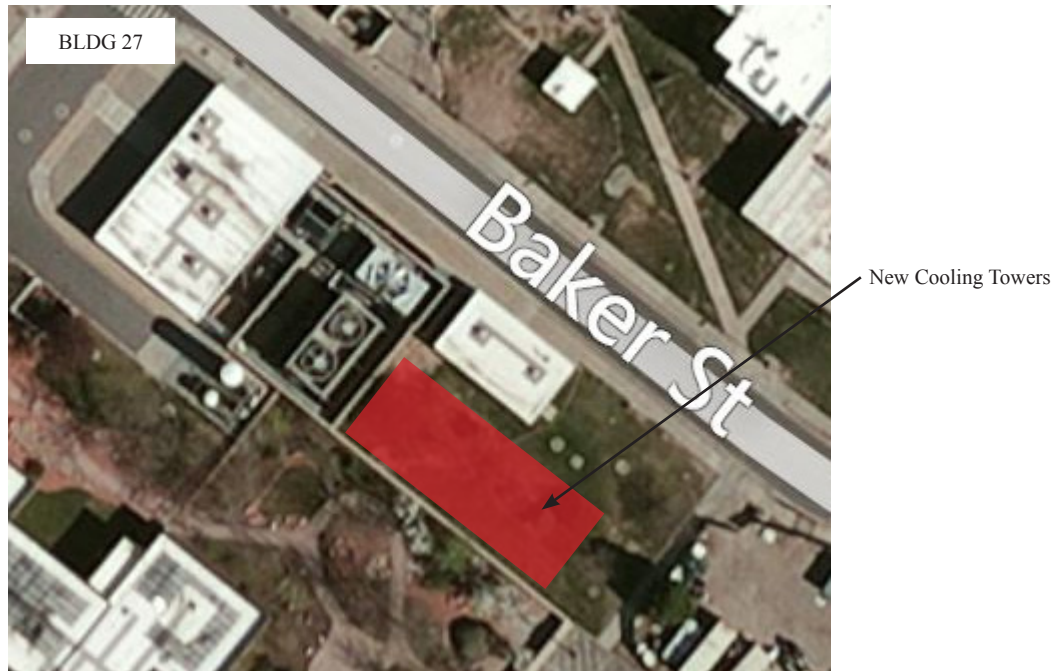


Figure 2

Conclusion

After review of all known data, Spectrum Engineers believes the existing VAMC chiller water plant is typical for the type, age, and size of system. It is our expert opinion that most of the underlying issues start at the building level and culminate with the plant. By performing much needed building level maintenance and upgrades, the existing system can continue to function as is for some time. However, failure of equipment is inevitable and the plant capacity issues associated with the condenser water system deficiencies, the lack of redundancy, and future capacity needs all indicate it is time for the VAMC to start planning future capital investment for much needed upgrades to the campus plant.

Following the above staged corrective action approach should allow for much needed upgrades as well as provide a timeline for budget allocation. In no way must all recommendations be completed as stated or in that order. Each subsection (Building, Loop, Plant) can be completed independently as needed, based on the availability of funds or severity of issue. Any of the recommendations undertaken will greatly improve the campus system function.



Appendices

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**CHILLED WATER DISTRIBUTION / CHILLED WATER ANALYSIS /
UPGRADE B.14 CHILLED WATER FEED**

VA Project: 660-11-87S

26 September 2013



ABBREVIATION LIST	
BLDG	BUILDING
Alt	ALTITUDE (FEET)
SA	SUPPLY AIR (CFM)
OA	OUTSIDE AIR (CFM)
RA	RETURN AIR (CFM)
T_{db}	DRY BULB TEMPERATURE (F)
T_{wb}	WET BULB TEMPERATURE (F)
Hmix	MIX AIR ENTHALPY (BTU/LB.)
Patm	ATMOSPHERIC PRESSURE (In. Hg)
Hlvg	LEAVING AIR ENTHALPY (BTU/LB.)
Qtotal	TOTAL COOLING CAPACITY (BTUH)
Tons	TOTAL COOLING CAPACITY (TONS)
Qsens	SENSIBLE COOLING CAPACITY (BTUH)
ΔT	DELTA TEMPERATURE (F)
GPM	GALLONS PER MINUTE
VLV	VALVE



			Air Quantities			Outdoor Air			Return Air			Mixed Air Calc				Leaving Air			Calc				H ₂ O	Calc	Design	Control	~Coil Size	
BLDG	VA TAG	Alt	SA	OA	RA	T _{db}	/	T _{wb}	T _{db}	/	T _{wb}	T _{db}	/	T _{wb}	Hmix	T _{db}	/	T _{wb}	Hlvg	Qtotal	Tons	Qsens	ΔT	GPM	GPM	VLV	Width	Height
1	AHU-6	5000	10600	2200	8400	97.0	/	66.0	79.3	/	63.5	83.0	/	64.0	32.1	53.7	/	53.6	24.3	316,900	26.4	282,900	10	63.4	59.0	3 WAY		
1	AHU-7	5000	12820	2520	10300	97.0	/	66.0	78.3	/	63.5	82.0	/	64.0	32.1	52.2	/	52.1	23.3	431,800	36.0	349,300	10	86.4	71.0	3 WAY		
1	AHU-8	5000	19990	3230	16760	97.0	/	66.0	79.1	/	63.6	82.0	/	64.0	32.1	54.4	/	54.3	24.7	558,400	46.5	501,700	10	111.7	111.0	2 WAY		
1	AHU-9	5000	6410	1290	5120	97.0	/	66.0	78.2	/	63.5	82.0	/	64.0	32.1	54.4	/	54.3	24.7	179,400	15.0	160,900	10	35.9	37.0	2 WAY		
1	AHU-10	5000	12150	2620	9530	97.0	/	66.0	78.6	/	63.5	82.6	/	64.0	32.2	53.4	/	53.3	24.1	373,500	31.1	323,400	10	74.7	68.0	2 WAY		
1	AHU-11	5000	7200	1880	5320	97.0	/	65.0	74.0	/	56.1	80.0	/	58.5	27.8	51.4	/	45.5	19.3	233,800	19.5	189,600	10	46.8	45.0	2 WAY		
1	AHU-12	5000	4000	4000	0	97.0	/	64.0	75.0	/	63.0	97.0	/	64.0	32.1	54.9	/	47.7	20.6	176,200	14.7	153,900	10	35.2	36.0	3 WAY		
1	MAS	5000	8500	1700	6800	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	124,500	10.4	206,700	10	24.9	No Data Found	2 WAY	68.0	36.0
1	DENT	5000	11460	2292	9168	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	167,800	14.0	278,700	10	33.6	No Data Found	2 WAY	110.0	30.0
1	AHU-5	5000	12000	2900	9100	97.0	/	66.0	77.6	/	63.4	82.3	/	64.0	32.2	55.0	/	50.9	22.5	438,700	36.6	298,600	10	87.7	62.0	3 WAY		
1	1MRI	5000	33000	8250	24750	97.0	/	66.0	76.3	/	58.8	81.5	/	60.7	29.4	55.0	/	51.3	22.8	832,800	69.4	796,700	10	166.6	161.0	2 WAY		
1	INPAT	5000	6150	1230	4920	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	90,000	7.5	149,600	10	18.0	No Data Found	2 WAY	29.5	60.0
1	PET	5000	7000	1400	5600	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	102,500	8.5	170,200	10	20.5	No Data Found	2 WAY		
1	CATH-3	5000	1350		1350				72.0	/	56.0	72.0	/	56.0	25.9	55.0	/	49.0	21.4	23,600	2.0	21,000	10	4.7	4.4	2 WAY		
1	CATH-4	5000	1200		1200				72.0	/	57.5	72.0	/	57.5	27.0	55.0	/	49.0	21.4	25,900	2.2	18,600	10	5.2	4.6	2 WAY		
1	CATH-1	5000	1750	350	1400	97.0	/	65.0	69.5	/	61.2	75.0	/	62.0	30.5	55.0	/	52.0	23.2	48,000	4.0	31,900	7	13.7	10.0	3 WAY		
1	CATH-2	5000	2250		2250				75.0	/	62.0	75.0	/	62.0	30.5	55.0	/	52.0	23.2	61,800	5.2	41,000	7	17.7	10.0	3 WAY		
1	2E5	5000	5380	1080	4300	98.0	/	63.0	75.0	/	55.0	79.6	/	56.6	26.4	53.0	/	53.0	23.9	52,300	4.4	130,700	10	10.5	No Data Found	2 WAY	50.0	31.0
1	2N1	5000	5730	1150	4580	98.0	/	63.0	75.0	/	55.0	79.6	/	56.6	26.4	53.0	/	53.0	23.9	55,700	4.6	139,200	10	11.1	No Data Found	2 WAY	66.0	25.0
1	AHU-13	5000	9200	1840	7360	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	53.0	23.9	89,300	7.4	223,300	10	17.9	No Data Found	2 WAY	50.0	53.0
1	OUTPAT	5000	7200	1880	5320	97.0	/	65.0	74.0	/	56.1	80.0	/	58.5	27.8	51.4	/	45.5	19.3	234,800	19.6	189,600	10	47.0	45.0	2 WAY		
1	BRONCH	5000	980	200	780	98.0	/	63.0	75.0	/	55.0	79.7	/	56.7	26.4	53.0	/	53.0	23.9	9,600	0.8	23,900	10	1.9	No Data Found	2 WAY	21.0	13.5
1	SICU	5000	7355		7355				81.2	/	57.9	81.2	/	57.9	27.3	52.0	/	46.8	20.0	205,000	17.1	197,400	10	41.0	40.0	2 WAY		
1	INP IV	5000	2630		2630				84.0	/	61.0	84.0	/	61.0	29.7	56.0	/	52.0	23.2	64,300	5.4	66,900	10	12.9	11.1	2 WAY		
1	DHCP	5000	3000	600	2400	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	53.0	23.9	29,100	2.4	72,800	10	5.8	No Data Found	3 WAY	36.0	24.0
1	AHU-1	5000	17750	4280	13470	97.0	/	66.0	78.4	/	63.4	82.9	/	64.0	32.1	53.6	/	53.4	24.1	539,100	44.9	473,900	10	107.8	96.0	2 WAY		
1	AHU-2	5000	20000	4800	15200	97.0	/	66.0	78.4	/	63.4	82.9	/	64.0	32.1	54.3	/	54.2	24.7	566,400	47.2	520,200	10	113.3	110.0	3 WAY		
1	AHU-3	5000	8500	8500	0	97.0	/	64.0	78.4	/	63.4	97.0	/	64.0	32.1	47.5	/	46.2	19.7	408,400	34.0	389,700	10	81.7	77.0	3 WAY		
TOTALS																536.6				1297.6								
2	2-1E	5000	8810	8810	0	98.0	/	63.0	75.0	/	55.0	98.0	/	63.0	31.3	53.0	/	51.0	22.6	292,800	24.4	362,400	10	58.6	No Data Found	3 WAY	47.0	54.0
2	2-D	5000	33450	33450	0	97.0	/	66.0				97.0	/	66.0	33.9	55.0	/	48.7	21.2	1,616,100	134.7	1,282,900	10	323.2	241.0	2 WAY		
2	AH-1 (HX)	5000																							206.0	NO VLV		
2	AH-3	5000	35000	7000	28000	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	512,500	42.7	851,100	10	102.5	No Data Found	2 WAY		
2	2-2FL	5000	8630	1730	6900	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	126,500	10.5	209,900	10	25.3	No Data Found	2 WAY	69.0	36.0
2	2-2W	5000	27909	27909	0	95.0	/	67.0				95.0	/	67.0	34.8	77.5	/	61.6	30.2	466,900	38.9	425,200	10	93.4	90.6	3 WAY		
45	1-45	5000	9300	9300	0	97.0	/	66.0				97.0	/	66.0	33.9	55.0	/	52.4	23.5	366,300	30.5	355,500	10	73.3	72.0	2 WAY		
TOTALS																281.8				676.3								

Table 3: As-Built Connected Load





			Air Quantities			Outdoor Air			Return Air			Mixed Air Calc				Leaving Air				Calc				H ₂ O	Calc	Design	Control	~Coil Size		
BLDG	VA TAG	Alt	SA	OA	RA	T _{db}	/	T _{wb}		T _{db}	/	T _{wb}	Hmix	T _{db}	/	T _{wb}	Hlvg	Qtotal	Tons	Qsens	ΔT	GPM	GPM	VLV	Width	Height				
3	3AC-1	5000	40000	6000	34000	97.0	/	66.0		76.3	/	60.6		79.4	/	61.4	30.0	55.0	/	52.0	23.2	1,030,300	85.9	888,600	10	206.1	192.0	3 WAY		
3	3-AHU	5000	2500	500	2000	98.0	/	63.0		75.0	/	55.0		79.6	/	56.7	26.4	53.0	/	51.0	22.6	36,600	3.1	60,800	10	7.3	No Data Found	3 WAY	40	18
3	3-2W-19	5000	4040	4040	0	95.0	/	67.0						95.0	/	67.0	34.8	59.5	/	55.0	25.2	144,600	12.1	129,300	10	28.9	27.2	3 WAY		
3	3-2W1	5000	10260	2050	8210	98.0	/	63.0		75.0	/	55.0		79.6	/	56.7	26.4	53.0	/	51.0	22.6	150,200	12.5	249,500	10	30.0	No Data Found	3 WAY	98.5	30
3	3-AH-1	5000	10260	2050	8210	98.0	/	63.0		75.0	/	55.0		79.6	/	56.7	26.4	53.0	/	51.0	22.6	150,200	12.5	249,500	10	30.0	No Data Found	3 WAY	98.5	30
3	3-2E1																							APPEAR NONOPERATIONAL						
3	3-3-1																													
3	AHU-1-SUB-R1	5000	8500		8500					80.0	/	62.0		80.0	/	62.0	30.5	54.7	/	52.0	23.2	233,900	19.5	195,900	10	46.8	44.4	3 WAY		
														TOTALS				145.5				349.1								
4	4-WST	5000	13800		13800					83.0	/	64.0		83.0	/	64.0	32.1	56.0	/	54.0	24.5	395,700	33.0	338,000	10	79.1	80.0	3 WAY		
4	4-EST	5000	16500	1700	14800	98.0	/	63.0		75.0	/	55.0		77.4	/	55.9	25.9	53.0	/	51.0	22.6	205,800	17.2	367,600	10	41.2	No Data Found	3 WAY	AIR MONITORS	
														TOTALS				50.1				120.3								
5	DCM-1	5000	30000		30000					80.0	/	60.0		80.0	/	60.0	28.9	62.0	/	54.0	24.6	488,100	40.7	485,300	10	97.6	100.0	3 WAY		
														TOTALS				40.7				97.6								
6	OFFICES	5000	10800		10800					79.0	/	58.0		79.0	/	58.0	27.4	53.0	/	48.0	20.7	274,100	22.8	257,400	12	45.7	45.0	3 WAY		
														TOTALS				22.8				45.7								
7	AHU-201	5000	7550	7550	0	97.0	/	62.0						97.0	/	62.0	30.5	57.5	/	48.0	20.8	278,600	23.2	271,400	10	55.7	19.0	2 WAY		
7	AHU-301	5000	12600	12600	0	97.0	/	62.0						97.0	/	62.0	30.5	57.5	/	48.0	20.8	465,000	38.8	453,000	10	93.0	68.0	2 WAY		
7	AHU-401	5000	4600	4600	0	97.0	/	62.0						97.0	/	62.0	30.5	57.5	/	48.0	20.8	169,800	14.2	165,400	10	34.0	33.2	2 WAY		
7	AHU-501	5000	5500	5500	0	97.0	/	62.0						97.0	/	62.0	30.5	57.5	/	48.0	20.8	203,000	16.9	197,700	10	40.6	40.0	2 WAY		
7	AHU-601	5000	2400	2400	0	97.0	/	62.0						97.0	/	62.0	30.5	57.5	/	48.0	20.8	88,600	7.4	86,300	10	17.7	18.0	2 WAY		
7	AHU-701	5000	4300	4300	0	97.0	/	62.0						97.0	/	62.0	30.5	57.5	/	48.0	20.8	158,700	13.2	154,600	10	31.7	31.0	2 WAY		
7	LAUNDRY	5000	40655	13555	27100	97.0	/	65.0		81.2	/	60.5		86.5	/	62.0	30.5	65.0	/	55.0	25.2	794,700	66.2	781,100	10	158.9	170.0	3 WAY		
7	AHU MICE	5000	5150	5150	0	98.0	/	63.0						98.0	/	63.0	31.3	53.0	/	51.0	22.6	171,200	14.3	211,900	10	34.2	No Data Found	3 WAY	FLOOR PLAN SUM	
														TOTALS				194.1				465.8								

Table 3: As-Built Connected Load





			Air Quantities			Outdoor Air		Return Air		Mixed Air Calc				Leaving Air			Calc				H ₂ O	Calc	Design	Control	~Coil Size					
BLDG	VA TAG	Alt	SA	OA	RA	T _{db}	/	T _{wb}		T _{db}	/	T _{wb}	Hmix	T _{db}	/	T _{wb}	Hlvg	Qtotal	Tons	Qsens	ΔT	GPM	GPM	VLV	Width	Height				
8	CAFÉ/KITCHEN	5000	6670	6670	0	98.0	/	63.0		75.0	/	55.0		98.0	/	63.0	31.3	53.0	/	51.0	22.6	221,700	18.5	274,400	10	44.3	No Data Found	3 WAY	60	32
8	MULTI PURPOSE	5000	5830	1170	4660	98.0	/	63.0		75.0	/	55.0		79.6	/	56.6	26.4	53.0	/	51.0	22.6	85,500	7.1	141,900	10	17.1	No Data Found	3 WAY	60	28
														TOTALS			25.6				61.4									
9	AH-1	5000	3530		3530					80.0		/	64.0	80.0	/	64.0	32.1	50.6	/	50.5	22.3	133,200	11.1	95,300	10	26.6	28.3	3WAY		
9	AH-2	5000	4530		4530					80.0		/	64.0	80.0	/	64.0	32.1	50.6	/	50.5	22.3	170,900	14.2	122,300	10	34.2	36.4	3WAY		
9	AH-3	5000	3125		3125					80.0		/	64.0	80.0	/	64.0	32.1	50.6	/	50.5	22.3	117,900	9.8	84,400	10	23.6	25.2	3WAY		
9	AH-4	5000	1940		1940					80.0		/	64.0	80.0	/	64.0	32.1	50.7	/	50.5	22.3	73,200	6.1	52,200	10	14.6	15.5	3WAY		
9	RT-1	5000	5000	5000	0	95.0		/	65.0					95.0	/	65.0	33.0	60.0	/	54.0	24.6	158,600	13.2	157,800	10	31.7	37.8	NONE		
9	RT-2	5000	2100	2100	0	95.0		/	65.0					95.0	/	65.0	33.0	60.0	/	54.0	24.6	66,600	5.6	66,300	10	13.3	15.9	NONE		
														TOTALS			60.0				144.0									
13	FCU's	5000			0															280,700	23.4		10	56.1	62.6	2 WAY				
														TOTALS			23.4				56.1									
14	AC-2	5000	15090	8700	6390	92.0		/	61.0	84.7		/	58.6	88.9	/	60.0	28.9	55.0	/	46.0	19.6	535,500	44.6	468,200	11.3	94.8	91.0	2 WAY		
14	AC-3	5000	19330	9000	10330	92.0		/	61.0	83.4		/	58.1	87.4	/	59.5	28.5	55.0	/	46.0	19.6	656,400	54.7	573,200	11	119.3	115.0	2 WAY		
14	AC-1	5000	13550	6000	7550	92.0		/	61.0	83.2		/	58.1	87.1	/	59.4	28.4	55.0	/	45.8	19.5	462,800	38.6	398,200	11	84.1	80.0	2 WAY		
14	AC-4	5000	17990	4400	13590	92.0		/	61.0	82.1		/	57.4	84.5	/	58.3	27.6	55.0	/	46.0	19.6	549,900	45.8	485,700	10.4	105.8	103.0	2 WAY		
14	MORGUE	5000	5400	5400	0	95.0		/	65.0	75.0		/	63.0	95.0	/	65.0	33.0	63.0	/	54.5	24.9	163,400	13.6	155,000	10	32.7	31.0	2 WAY		
14	AC-5	5000	18510	11610	6900	92.0		/	61.0	84.5		/	59.4	89.2	/	60.4	29.2	55.0	/	46.0	19.6	680,700	56.7	579,400	11.7	116.4	113.0	2 WAY		
14	AC-6	5000	14460	6200	8260	92.0		/	61.0	83.1		/	57.7	86.9	/	59.1	28.2	55.0	/	46.0	19.6	476,100	39.7	422,200	11	86.6	85.0	2 WAY		
14	AC-9	5000	10200	10200	0	95.0		/	65.0	68.0		/	57.3	95.0	/	65.0	33.0	52.0	/	50.0	22.0	429,900	35.8	402,000	20	43.0	43.0	3 WAY		
14	AC-10	5000	11830	3870	7960	92.0		/	61.0	69.7		/	59.5	77.0	/	60.0	28.9	52.0	/	51.0	22.6	284,200	23.7	270,800	10	56.8	55.0	3 WAY		
14	AC-11	5000	5650	1480	4170	92.0		/	61.0	69.0		/	58.5	75.0	/	59.2	28.3	52.0	/	51.0	22.6	122,500	10.2	119,000	10	24.5	25.0	2 WAY		
14	AH-2	5000	13500	2700	10800	98.0		/	63.0	75.0		/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	197,700	16.5	328,300	10	39.5	No Data Found	2 WAY	108	36
14	MAS	5000	1800	360	1440	98.0		/	63.0	75.0		/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	26,400	2.2	43,800	10	5.3	No Data Found	2 WAY	AIRFLOW TAG	
														TOTALS			382.1				808.8									
20	HX	5000																		1,200,000	100.0		10	240.0	256.0	NONE				
														TOTALS			100.0				240.0									
A	AHU-1	5000	44000		44000					85.0		/	59.0	85.0	/	59.0	28.1	50.0	/	46.0	19.6	1,448,500	120.7	1,420,800	10	289.7	330.0	3 WAY		
														TOTALS			120.7				289.7									
47	FCU's	5000																		273,912	22.8		9.3	58.9	58.7	3 WAY				
														TOTALS			22.8				58.9									
16	AHU-1	5000	29665		29665					78.0		/	62.0	78.0	/	62.0	30.5	56.0	/	55.0	25.2	588,000	49.0	591,500	10	117.6	124.0	2 WAY		
														TOTALS			49.0				117.6									
														GRAND TOTALS			2031				4770									

Table 3: As-Built Connected Load





EXISTING CONNECTED LOAD ESTIMATION				Air Quantities			Outdoor Air			Return Air			Mixed Air Calc			Leaving Air			Load Calc				H ₂ O	Calc	
BLDG	SQFT	CFM/SQFT	Alt	SA	OA	RA	T _{db}	/	T _{wb}	T _{db}	/	T _{wb}	T _{db}	/	T _{wb}	Hmix	T _{db}	/	T _{wb}	Hlvg	Qtotal	Tons	Qsens	ΔT	GPM
B-1	343320	1.50	5000	514980	103000	411980	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	7,540,500	628.4	12,523,000	10	1508.1
B-2	114100	1.25	5000	142630	28530	114100	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	2,088,500	174.0	3,468,500	10	417.7
B-2A	36000	1.50	5000	54000	10800	43200	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	790,700	65.9	1,313,100	10	158.1
B-3	87065	1.35	5000	117540	23510	94030	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	1,721,100	143.4	2,858,300	10	344.2
B-4	35000	1.00	5000	35000	7000	28000	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	512,500	42.7	851,100	10	102.5
B-5	30590	1.60	5000	48940	9790	39150	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	716,600	59.7	1,190,100	10	143.3
B-6	22300	0.45	5000	10040	2010	8030	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	147,100	12.3	244,200	10	29.4
B-7	50100	1.50	5000	75150	15030	60120	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	1,100,400	91.7	1,827,400	10	220.1
B-8	36275	0.60	5000	21770	4350	17420	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	318,700	26.6	529,300	10	63.7
B-9	13500	1.50	5000	20250	4050	16200	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	296,500	24.7	492,400	10	59.3
B-13	5600	1.25	5000	7000	1400	5600	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	102,500	8.5	170,200	10	20.5
B-14	218000	1.35	5000	294300	58860	235440	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	4,309,200	359.1	7,156,600	10	861.8
B-16	30000	1.00	5000	30000	6000	24000	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	439,300	36.6	729,500	10	87.9
VASNH	60000	1.00	5000	60000	12000	48000	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	878,500	73.2	1,459,000	10	175.7
VALOR HOUSE	108000	1.00	5000	108000	21600	86400	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	1,581,300	131.8	2,626,300	10	316.3

TOTAL TONS	TOTAL TONS	TOTAL GPM	TREND DATA TONS
SQFT 100%	SQFT 75%	100%	AVG WEEKDAY
1879	1409	4509	1430

TONS DIVERSITY SQFT/TREND	76%	GPM	3432
		USING TONS DIVERSITY	

GPM DIVERSITY TREND/SQFT	96%	GPM (TREND)	4315
		WITH 8.2 °F ΔT	

Table 4a: Square Foot Load Estimate





09/21/2013

U.S. Department of Commerce
National Oceanic & Atmospheric Administration
National Environmental Satellite, Data, and Information Service

Record of Climatological Observations
These data are quality controlled and may not be identical to the original observations.

National Climatic Data Center
Federal Building
151 Patton Avenue
Asheville, North Carolina 28801
www.ncdc.noaa.gov

Station: SALT LAKE CITY INTERNATIONAL AIRPORT, UT US

GHCND:USW00024127

Observation Time Temperature: Unknown Observation Time Precipitation: 2400

Elev: 4226 ft. Lat: 40.778° N Lon: 111.969° W

P r e l i m i n a r y	Y e a r	M o n t h	D a y	Temperature (°F)		at O b s e r v a t i o n	Precipitation(see **)				At Obs Time	Evaporation		Soil Temperature (°F)					
				24 hrs. ending at observation time			24 Hour Amounts ending at observation time					24 Hour Wind Movement (mi)	Amount of Evap. (in)	4 in depth			8 in depth		
				Max.	Min.		Rain, melted snow, etc. (in)	F l a g	Snow, ice pellets, hail (in)	F l a g				Snow, ice pellets, hail, ice on ground (in)	Ground Cover (see *)	Max.	Min.	Ground Cover (see *)	Max.
	2013	7	1	104	71		0.00		0.0		0								
	2013	7	2	102	74		0.00		0.0		0								
	2013	7	3	100	73		0.00		0.0		0								
	2013	7	4	93	68		0.53		0.0		0								
	2013	7	5	93	68		0.18		0.0		0								
	2013	7	6	94	70		0.11		0.0		0								
	2013	7	7	95	71		T		0.0		0								
	2013	7	8	95	69		T		0.0		0								
	2013	7	9	99	73		0.00		0.0		0								
	2013	7	10	104	71		0.00		0.0		0								
	2013	7	11	94	71		T		0.0		0								
	2013	7	12	89	71		T		0.0		0								
	2013	7	13	92	71		0.10		0.0		0								
	2013	7	14	97	66		0.00		0.0		0								
	2013	7	15	100	70		0.02		0.0		0								
	2013	7	16	98	70		0.21		0.0		0								
	2013	7	17	97	71		0.00		0.0		0								
	2013	7	18	100	74		0.00		0.0		0								
	2013	7	19	102	71		0.00		0.0		0								
	2013	7	20	102	71		0.00		0.0		0								
	2013	7	21	101	71		0.00		0.0		0								
	2013	7	22	102	73		0.00		0.0		0								
	2013	7	23	100	72		0.00		0.0		0								
	2013	7	24	97	73		0.00		0.0		0								
	2013	7	25	98	75		0.00		0.0		0								
	2013	7	26	101	71		0.00		0.0		0								
	2013	7	27	86	71		T		0.0		0								
	2013	7	28	89	69		T		0.0		0								
	2013	7	29	89	71		T		0.0		0								
	2013	7	30	95	71		0.01		0.0		0								
	2013	7	31	101	75		0.00		0.0		0								
	Summary			97.1	71.2		1.16		0.0										

The '*' flags in Preliminary indicate the data have not completed processing and quality control and may not be identical to the original observation
Empty, or blank, cells indicate that a data observation was not reported.
* Ground Cover: 1=Grass; 2=Fallow; 3=Bare Ground; 4=Brome grass; 5=Sod; 6=Straw mulch; 7=Grass muck; 8=Bare muck; 0=Unknown
"s" This data value failed one of NCDC's quality control tests.
"T" values in the Precipitation category above indicate a TRACE value was recorded.
"A" values in the Precipitation Flag or the Snow Flag column indicate a multiday total, accumulated since last measurement, is being used.
Data value inconsistency may be present due to rounding calculations during the conversion process from SI metric units to standard imperial units.





BAS TREND 7/14/13-7/20/13 (CHW TONS)

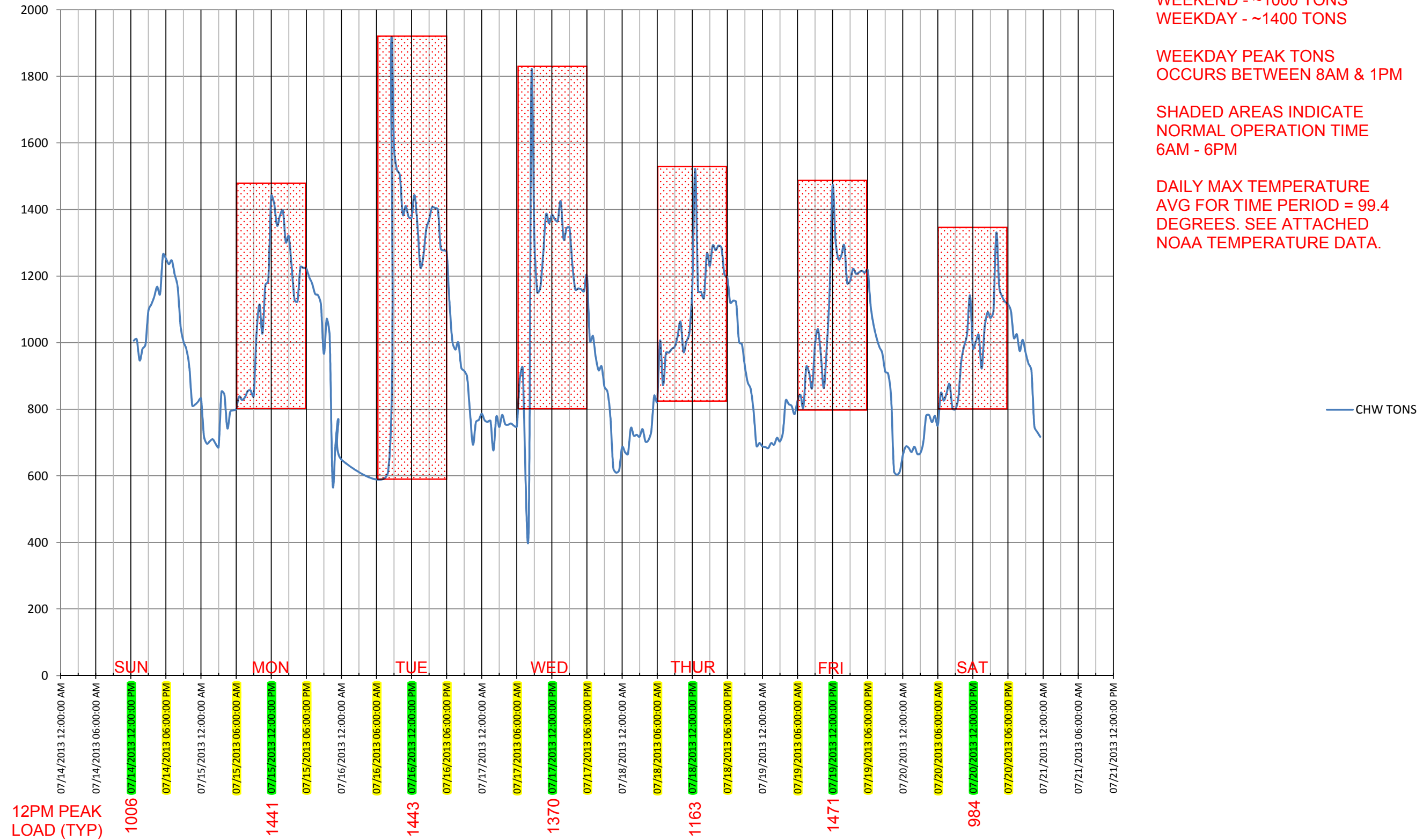


Chart 1: Campus Chilled Water Tons



BAS TREND 7/14/13-7/20/13

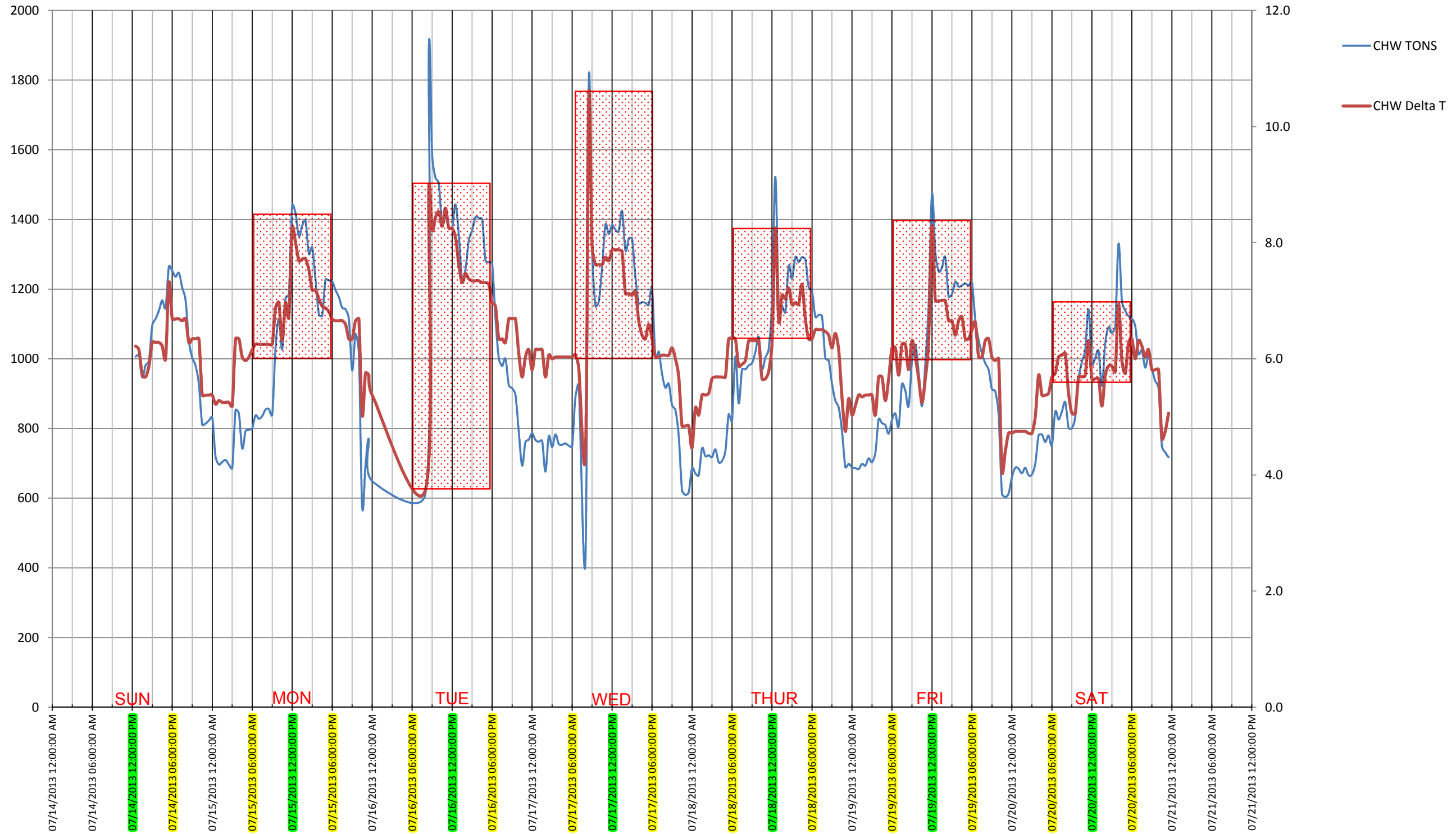
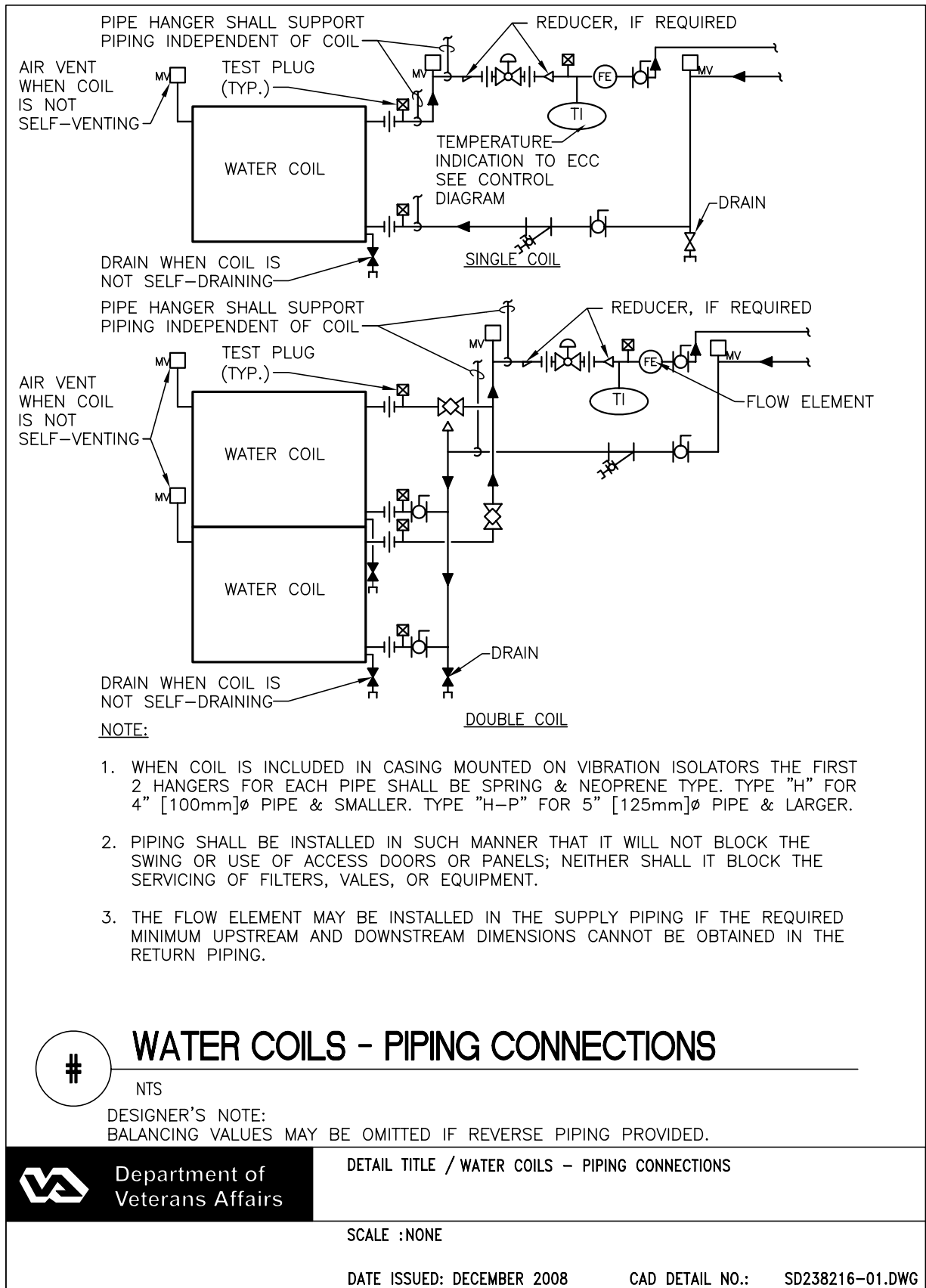
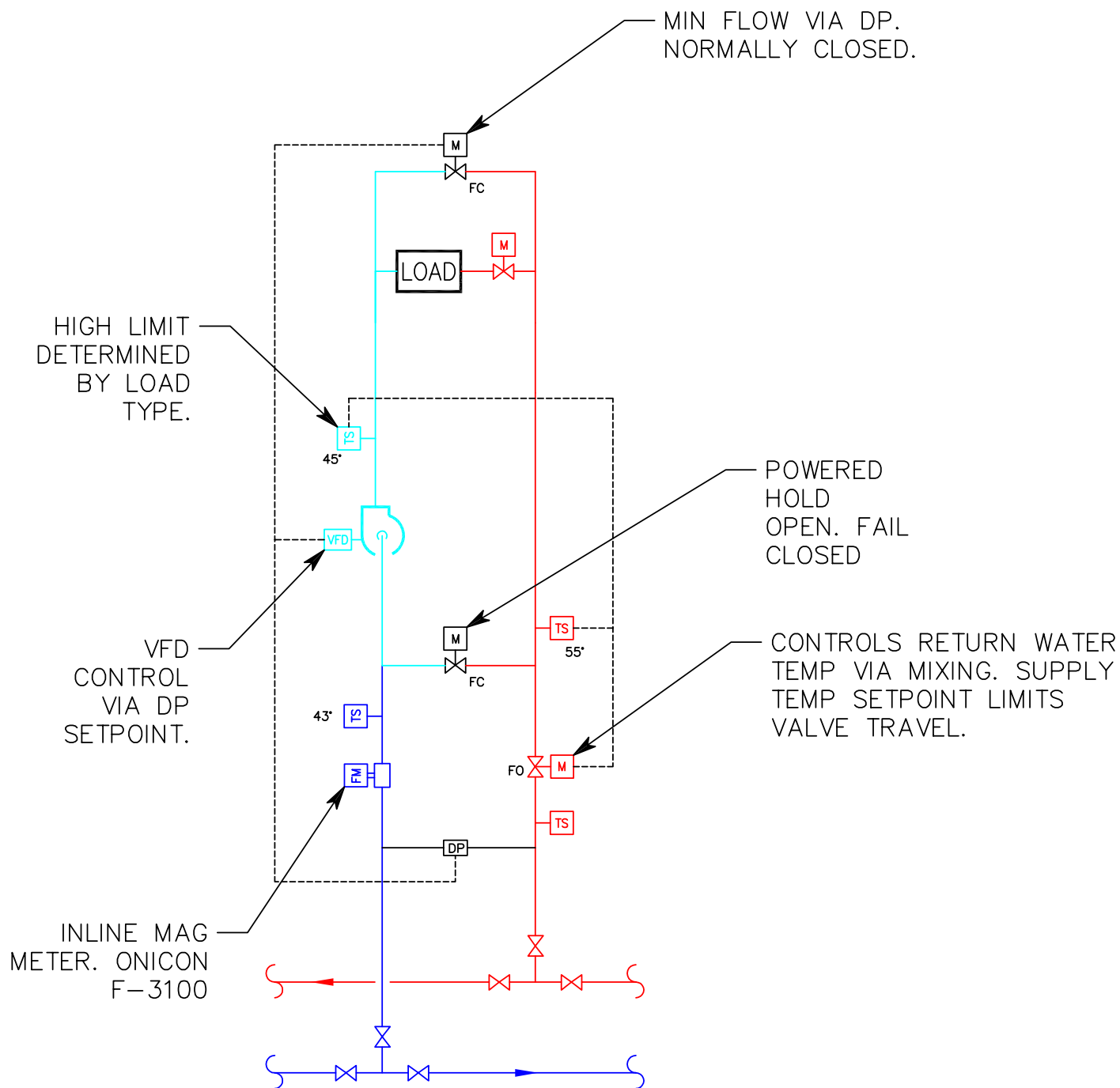
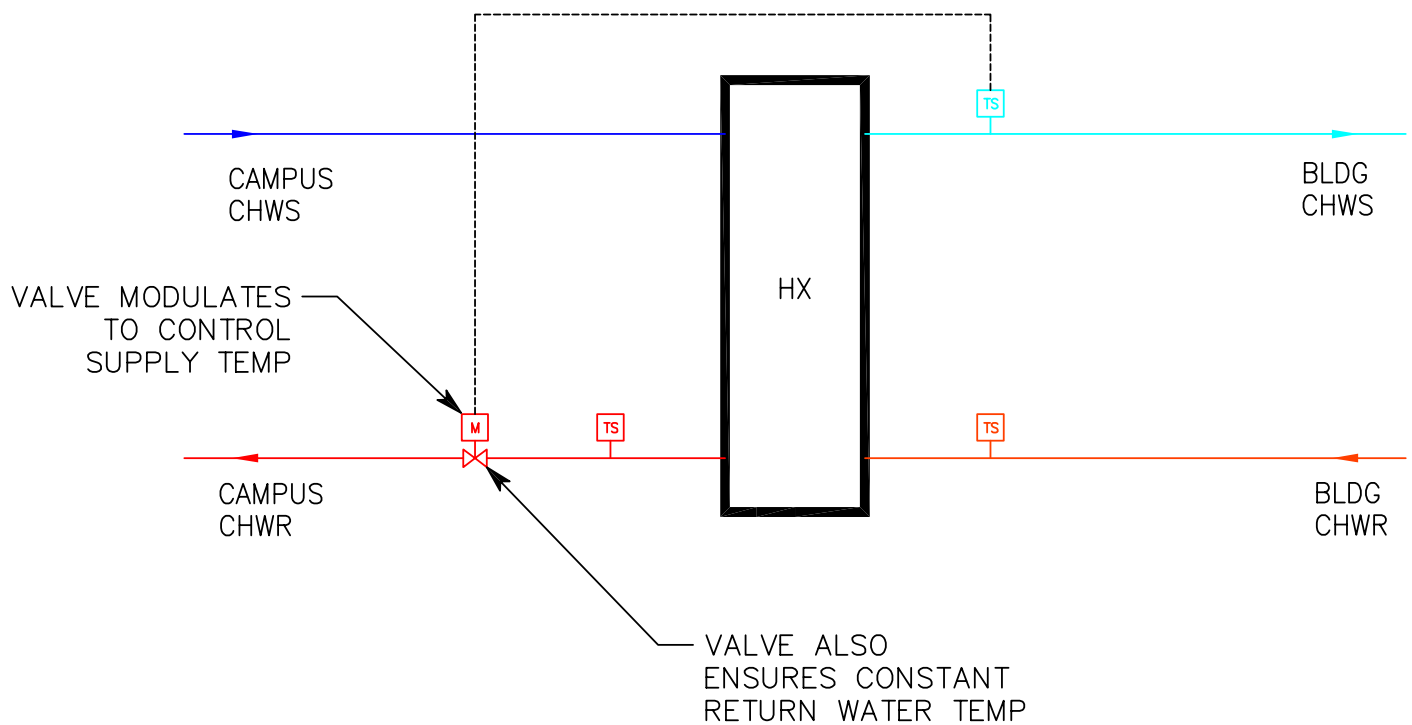


Chart 2: CHW Delta T vs Tonnage





Chilled Water Decoupling Loop Diagram



HX Control Diagram



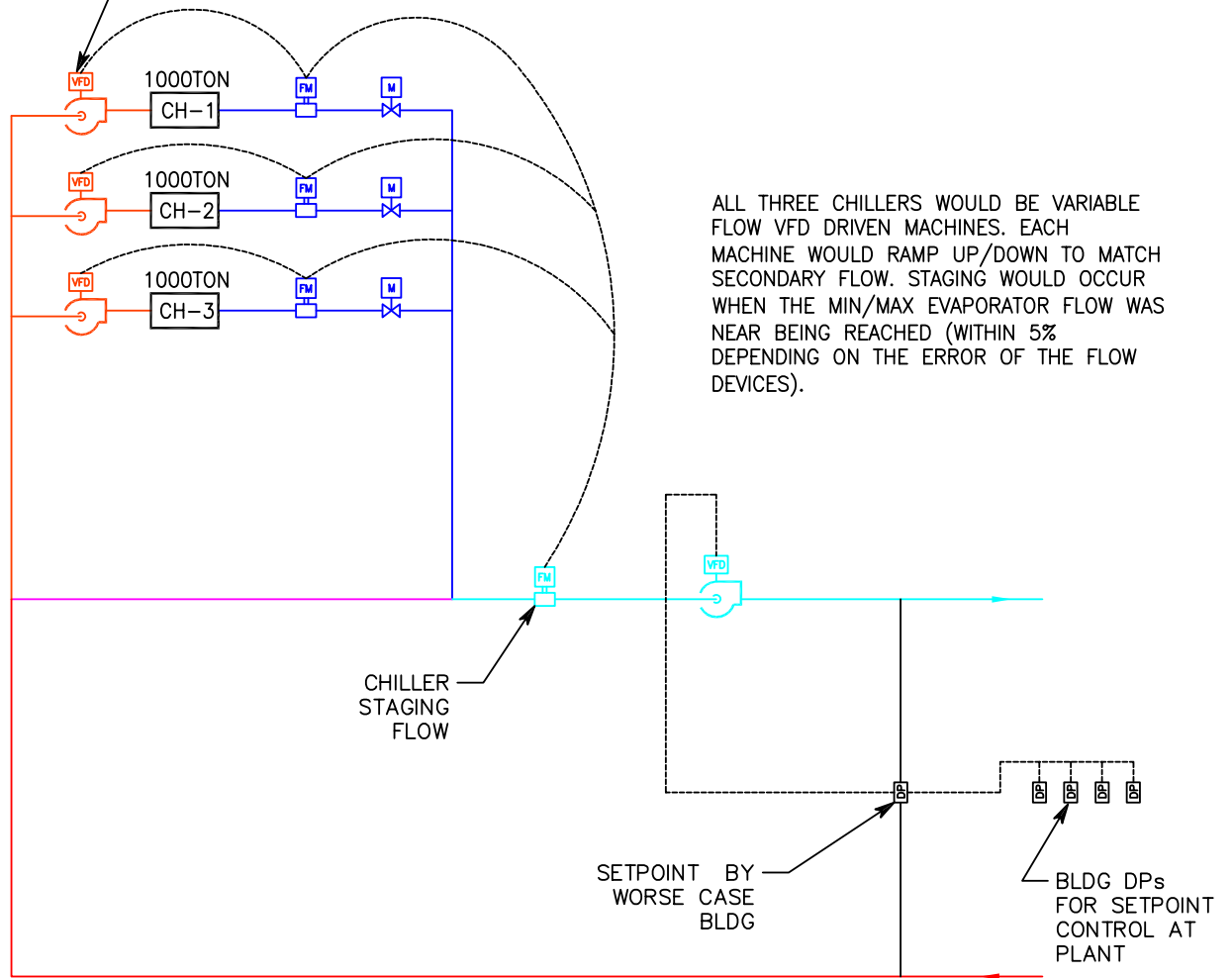
FUTURE CONNECTED LOAD ESTIMATION				Air Quantities			Outdoor Air		Return Air		Mixed Air Calc			Leaving Air			Load Calc				H ₂ O	Calc			
BLDG	SQFT	CFM/SQFT	Alt	SA	OA	RA	T _{db}	/	T _{wb}	T _{db}	/	T _{wb}	T _{db}	/	T _{wb}	Hmix	T _{db}	/	T _{wb}	Hlvg	Qtotal	Tons	Qsens	ΔT	GPM
B-51 New Specialty Clinic Building	66000	1.20	5000	79200	15840	63360	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	1,159,700	96.6	1,925,900	16	145.0
Rehab & Prosthetics Expansion	5600	1.25	5000	7000	1400	5600	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	102,500	8.5	170,200	16	12.8
B-2 Biobank Research Addition	36000	1.20	5000	43200	8640	34560	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	632,500	52.7	1,050,500	16	79.1
B-1 New Emergency Department	30000	1.50	5000	45000	9000	36000	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	658,900	54.9	1,094,300	16	82.4
Audiology / Eye Clinic Building	45000	1.40	5000	63000	12600	50400	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	922,500	76.9	1,532,000	16	115.3
3MW Combustion Turbine with 300 Ton Absorption Chiller	15000	1.05	5000	15750	3150	12600	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	230,600	19.2	383,000	16	28.8
B-1 Emergency Department Expansion	30000	1.50	5000	45000	9000	36000	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	658,900	54.9	1,094,300	16	82.4
B-14 Pharmacy & Canteen Expansion	45000	1.20	5000	54000	10800	43200	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	790,700	65.9	1,313,100	16	98.8
B-3 Acute Pshyc Addition	45000	1.20	5000	54000	10800	43200	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	790,700	65.9	1,313,100	16	98.8
B-1 Expand Cardiology	10000	1.20	5000	12000	2400	9600	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	175,700	14.6	291,800	16	22.0
B-90 1st Floor Dental Expansion	15000	1.20	5000	18000	3600	14400	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	263,600	22.0	437,700	16	33.0
Community Living Center	45000	1.20	5000	54000	10800	43200	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	790,700	65.9	1,313,100	16	98.8
B-8 HBPC / Education	7000	1.20	5000	8400	1680	6720	98.0	/	63.0	75.0	/	55.0	79.6	/	56.7	26.4	53.0	/	51.0	22.6	123,000	10.3	204,300	16	15.4

DIVERSITY	100%	75%
TOTAL TONS	630	470
TOTAL GPM	913	680

Table 6: Future Connected Load Estimation



RAMPS BETWEEN MIN
AND MAX CHILLER FLOW
TO FULLY LOAD CHILLER



New Chilled Water Plant Diagram

COST ESTIMATE

BUILDING LEVEL (SEE DETAIL NEXT PAGE)

- | | |
|--------------------------------------|---------------|
| 1. CLEANING & MAINTENANCE OF AHUs = | \$2,500/EA |
| 2. NEW CONTROL VALVE = | \$2,500/EA |
| 3. TEST & BALANCE (ASSUMES 1 WEEK) = | \$8,000/BLDG |
| 4. AHU REPLACEMENT | |
| a. MIXED AIR UNIT (INSTALLED) = | \$7.5/CFM |
| b. OUTSIDE AIR UNIT (INSTALLED) = | \$15/CFM |
| 5. DECOUPLING LOOP = | \$30,000/BLDG |

LOOP LEVEL (SEE DETAIL NEXT PAGE)

- | | |
|------------------|-------------|
| 1. VALVE VAULT = | \$30,000/EA |
| 2. DP SENSOR = | \$4,000/EA |

PLANT LEVEL

STAGE 1

- | | |
|-------------------------------|--------------|
| 1. 1000 TON COOLING TOWER | |
| a. INCLUDES PUMP, PIPE, ETC = | \$272,500/EA |

STAGE 2

- | | |
|-------------------------------|--------------|
| 1. 1000 TON CHILLER | |
| a. INCLUDES PUMP, PIPE, ETC = | \$609,700/EA |

STAGE 3

- | | |
|-------------------------------|--------------|
| 1. 1000 TON CHILLER | |
| a. INCLUDES PUMP, PIPE, ETC = | \$609,700/EA |
| 2. 1000 TON COOLING TOWER | |
| a. INCLUDES PUMP, PIPE, ETC = | \$272,500/EA |

STAGE 4

- | | |
|--|--------------|
| 1. 1000 TON CHILLER | |
| a. INCLUDES PUMP, PIPE, ETC = | \$609,700/EA |
| 2. 1000 TON COOLING TOWER | |
| a. INCLUDES PUMP, PIPE, ETC = | \$272,500/EA |
| 3. CONTROLS UPGRADE (USER INTERFACE) = | \$25,000 |



COST ESTIMATE BY BUILDING										
			AHU REPLACE COST		MAINTENANCE COST	CONTROL VALVE COST	BLDG DECOUPLER	VALVE VAULT	BALANCE (TAB) COST	BLDG DP SENSOR
BLDG	VA TAG	SA	MIN	MAX						
1	AHU-6	10600	\$79,500	\$159,000	\$2,500	\$2,500				
1	AHU-7	12820	\$96,150	\$192,300	\$2,500	\$2,500				
1	AHU-8	19990	\$149,925	\$299,850	\$2,500	\$2,500				
1	AHU-9	6410	\$48,075	\$96,150	\$2,500	\$2,500				
1	AHU-10	12150	\$91,125	\$182,250	\$2,500	\$2,500				
1	AHU-11	7200	\$54,000	\$108,000	\$2,500	\$2,500				
1	AHU-12	4000	\$30,000	\$60,000	\$2,500	\$2,500				
1	MAS	8500	\$63,750	\$127,500	\$2,500	\$2,500				
1	DENT	11460	\$85,950	\$171,900	\$2,500	\$2,500				
1	AHU-5	12000	\$90,000	\$180,000	\$2,500	\$2,500				
1	1MRI	33000	\$247,500	\$495,000	\$2,500	\$2,500				
1	INPAT	6150	\$46,125	\$92,250	\$2,500	\$2,500				
1	PET	7000	\$52,500	\$105,000	\$2,500	\$2,500				
1	CATH-3	1350	\$10,125	\$20,250	\$2,500	\$2,500				
1	CATH-4	1200	\$9,000	\$18,000	\$2,500	\$2,500				
1	CATH-1	1750	\$13,125	\$26,250	\$2,500	\$2,500				
1	CATH-2	2250	\$16,875	\$33,750	\$2,500	\$2,500				
1	2E5	5380	\$40,350	\$80,700	\$2,500	\$2,500				
1	2N1	5730	\$42,975	\$85,950	\$2,500	\$2,500				
1	AHU-13	9200	\$69,000	\$138,000	\$2,500	\$2,500				
1	OUTPAT	7200	\$54,000	\$108,000	\$2,500	\$2,500				
1	BRONCH	980	\$7,350	\$14,700	\$2,500	\$2,500				
1	SICU	7355	\$55,163	\$110,325	\$2,500	\$2,500				
1	INP IV	2630	\$19,725	\$39,450	\$2,500	\$2,500				
1	DHCP	3000	\$22,500	\$45,000	\$2,500	\$2,500				
1	AHU-1	17750	\$133,125	\$266,250	\$2,500	\$2,500				
1	AHU-2	20000	\$150,000	\$300,000	\$2,500	\$2,500				
1	AHU-3	8500	\$63,750	\$127,500	\$2,500	\$2,500				
BLDG TOTAL		245555	\$1,841,663	\$3,683,325	\$70,000	\$70,000	\$30,000	\$30,000	\$8,000	\$4,000





COST ESTIMATE BY BUILDING										
			AHU REPLACE COST		MAINTENANCE COST	CONTROL VALVE COST	BLDG DECOUPLER	VALVE VAULT	BALANCE (TAB) COST	BLDG DP SENSOR
BLDG	VA TAG	SA	MIN	MAX						
2	2-1E	8810	\$66,075	\$132,150	\$2,500	\$2,500				
2	2-D	33450	\$250,875	\$501,750	\$2,500	\$2,500				
2	AH-1 (HX)					\$2,500				
2	AH-3	35000	\$262,500	\$525,000	\$2,500	\$2,500				
2	2-2FL	8630	\$64,725	\$129,450	\$2,500	\$2,500				
2	2-2W	27909	\$209,318	\$418,635	\$2,500	\$2,500				
45	1-45	9300	\$69,750	\$139,500	\$2,500	\$2,500				
BLDG TOTAL		123099	\$923,243	\$1,846,485	\$15,000	\$17,500	\$30,000	\$30,000	\$8,000	\$4,000
3	3AC-1	40000	\$300,000	\$600,000	\$2,500	\$2,500				
3	3-AHU	2500	\$18,750	\$37,500	\$2,500	\$2,500				
3	3-2W-19	4040	\$30,300	\$60,600	\$2,500	\$2,500				
3	3-2W1	10260	\$76,950	\$153,900	\$2,500	\$2,500				
3	3-AH-1	10260	\$76,950	\$153,900	\$2,500	\$2,500				
3	3-2E1									
3	3-3-1									
3	AHU-1-SUB-R1	8500	\$63,750	\$127,500	\$2,500	\$2,500				
BLDG TOTAL		75560	\$566,700	\$1,133,400	\$15,000	\$15,000	\$30,000	\$30,000	\$8,000	\$4,000
4	4-WST	13800	\$103,500	\$207,000	\$2,500	\$2,500				
4	4-EST	16500	\$123,750	\$247,500	\$2,500	\$2,500				
BLDG TOTAL		30300	\$227,250	\$454,500	\$5,000	\$5,000	\$30,000	\$30,000	\$8,000	\$4,000





COST ESTIMATE BY BUILDING										
			AHU REPLACE COST		MAINTENANCE COST	CONTROL VALVE COST	BLDG DECOUPLER	VALVE VAULT	BALANCE (TAB) COST	BLDG DP SENSOR
BLDG	VA TAG	SA	MIN	MAX						
5	DCM-1	30000	\$225,000	\$450,000	\$2,500	\$2,500				
BLDG TOTAL		30000	\$225,000	\$450,000	\$2,500	\$2,500	\$30,000	\$30,000	\$8,000	\$4,000
6	OFFICES	10800	\$81,000	\$162,000	\$2,500	\$2,500				
BLDG TOTAL		10800	\$81,000	\$162,000	\$2,500	\$2,500	\$30,000	\$30,000	\$8,000	\$4,000
7	AHU-201	7550	\$56,625	\$113,250	\$2,500	\$2,500				
7	AHU-301	12600	\$94,500	\$189,000	\$2,500	\$2,500				
7	AHU-401	4600	\$34,500	\$69,000	\$2,500	\$2,500				
7	AHU-501	5500	\$41,250	\$82,500	\$2,500	\$2,500				
7	AHU-601	2400	\$18,000	\$36,000	\$2,500	\$2,500				
7	AHU-701	4300	\$32,250	\$64,500	\$2,500	\$2,500				
7	LAUNDRY	40655	\$304,913	\$609,825	\$2,500	\$2,500				
7	AHU MICE	5150	\$38,625	\$77,250	\$2,500	\$2,500				
BLDG TOTAL		82755	\$620,663	\$1,241,325	\$20,000	\$20,000	\$30,000	\$30,000	\$8,000	\$4,000
8	CAFÉ/KITCHEN	6670	\$50,025	\$100,050	\$2,500	\$2,500				
8	MULTI PURPOSE	5830	\$43,725	\$87,450	\$2,500	\$2,500				
BLDG TOTAL		12500	\$93,750	\$187,500	\$5,000	\$5,000	\$30,000	\$30,000	\$8,000	\$4,000
9	AH-1	3530	\$26,475	\$52,950	\$2,500	\$2,500				
9	AH-2	4530	\$33,975	\$67,950	\$2,500	\$2,500				
9	AH-3	3125	\$23,438	\$46,875	\$2,500	\$2,500				
9	AH-4	1940	\$14,550	\$29,100	\$2,500	\$2,500				
9	RT-1	5000	\$37,500	\$75,000	\$2,500	\$2,500				
9	RT-2	2100	\$15,750	\$31,500	\$2,500	\$2,500				
BLDG TOTAL		20225	\$151,688	\$303,375	\$15,000	\$15,000	\$30,000	\$30,000	\$8,000	\$4,000





COST ESTIMATE BY BUILDING										
BLDG	VA TAG	SA	AHU REPLACE COST		MAINTENANCE COST	CONTROL VALVE COST	BLDG DECOUPLER	VALVE VAULT	BALANCE (TAB) COST	BLDG DP SENSOR
			MIN	MAX						
13	FCU's									
BLDG TOTAL							\$30,000	\$30,000	\$8,000	\$4,000
14	AC-2	15090	\$113,175	\$226,350	\$2,500	\$2,500				
14	AC-3	19330	\$144,975	\$289,950	\$2,500	\$2,500				
14	AC-1	13550	\$101,625	\$203,250	\$2,500	\$2,500				
14	AC-4	17990	\$134,925	\$269,850	\$2,500	\$2,500				
14	MORGUE	5400	\$40,500	\$81,000	\$2,500	\$2,500				
14	AC-5	18510	\$138,825	\$277,650	\$2,500	\$2,500				
14	AC-6	14460	\$108,450	\$216,900	\$2,500	\$2,500				
14	AC-9	10200	\$76,500	\$153,000	\$2,500	\$2,500				
14	AC-10	11830	\$88,725	\$177,450	\$2,500	\$2,500				
14	AC-11	5650	\$42,375	\$84,750	\$2,500	\$2,500				
14	AH-2	13500	\$101,250	\$202,500	\$2,500	\$2,500				
14	MAS	1800	\$13,500	\$27,000	\$2,500	\$2,500				
BLDG TOTAL		147310	\$1,104,825	\$2,209,650	\$30,000	\$30,000	\$30,000	\$30,000	\$8,000	\$4,000
20	HX					\$10,000				
BLDG TOTAL						\$10,000	\$30,000	\$30,000	\$8,000	\$4,000
A	AHU-1	44000	\$330,000	\$660,000	\$2,500	\$2,500				
BLDG TOTAL		44000	\$330,000	\$660,000	\$2,500	\$2,500	\$30,000	\$30,000	\$8,000	\$4,000
47	FCU's									
BLDG TOTAL									\$8,000	\$4,000
16	AHU-1	29665	\$222,488	\$444,975	\$2,500	\$2,500				
BLDG TOTAL		29665	\$222,488	\$444,975	\$2,500	\$2,500	\$30,000	\$30,000	\$8,000	\$4,000



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CHILLED WATER DISTRIBUTION / CHILLED WATER ANALYSIS /
UPGRADE B.14 CHILLED WATER FEED
VA Project: 660-11-87S
26 September 2013

