Mechanical Technical Report 3

Mechanical Systems Existing Conditions Evaluation

Miller Children's Hospital Pediatric Inpatient Addition

Long Beach, CA

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1.0 Executive Summary

The Miller Children's Hospital Pediatric Inpatient Addition is a 4-story, 127,000 sq. ft. facility housing operating rooms, ICUs, patient rooms, as well as administrative offices and conference rooms. The mechanical system for the building uses a constant volume air system with air handling units located on the roof. The on-site central plant houses the chillers, cooling towers, and pumps as well as other electrical equipment for the building. This report summarizes the findings of Technical Reports 1 and 2, researches the main mechanical equipment, and explores the mechanical control systems.

The Pediatric Inpatient Addition mechanical system was designed by JBA Consulting Engineers with two 500-ton centrifugal water cooled chillers, two induced draft cooling towers, seven air handling units, two 2000 MBH hot water boilers, as well as condenser water pumps, chilled water pumps, and hot water pumps. The mechanical system is operated using direct digital controls which monitor and adjust system components to maintain proper set points and conditions of operation. The schematic flow diagrams included in this report outline condenser water flow, chilled water flow, and hot water flow with proper control components.

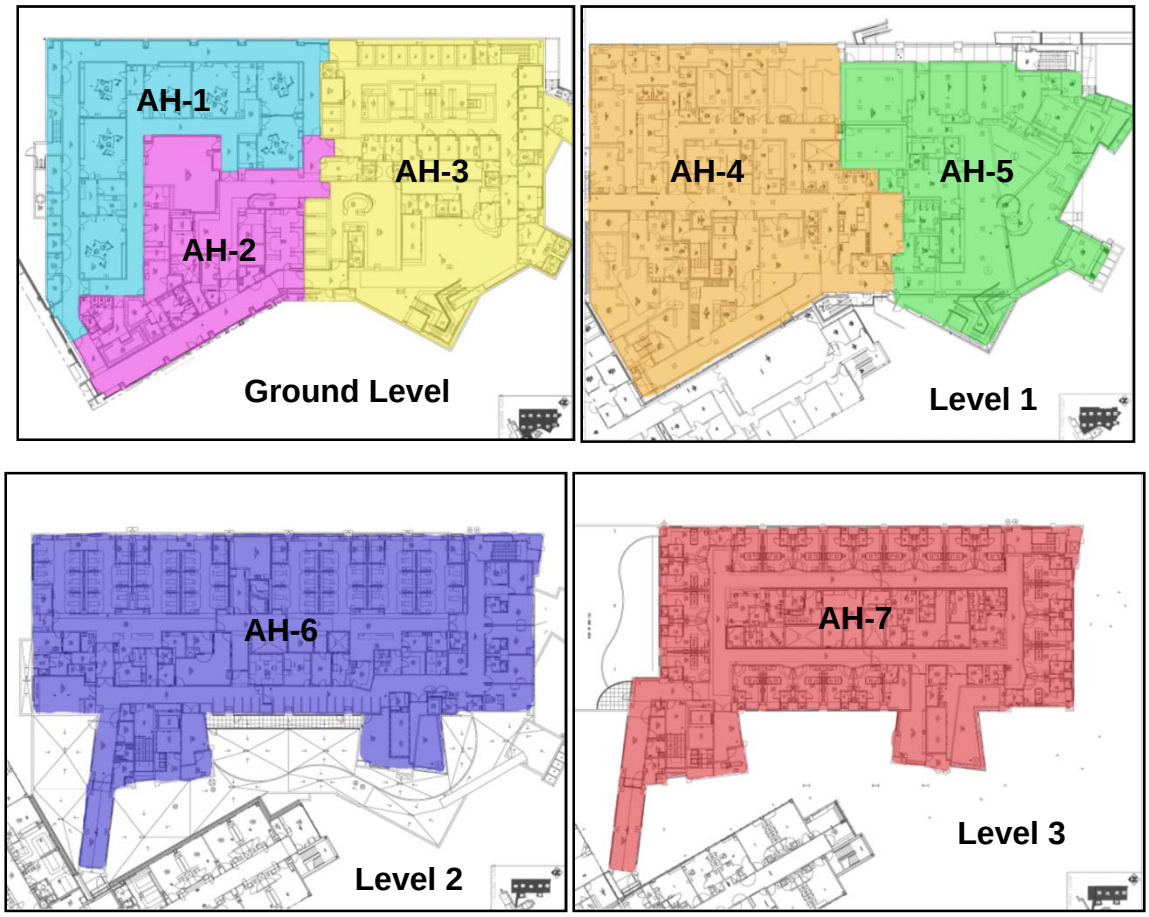
Finally, a critique of the design was done to identify possible areas of improvement or redesign. JBA Consulting Engineers designed the Pediatric Inpatient Addition with the primary objective being patient health and occupant safety. The Tech 2 energy analysis revealed that the building consumes a large amount of energy through mechanical systems operation and may have the potential for reducing some operating costs, warranting further research into energy saving techniques. Another possible option for further research is in the field of indoor air quality, particularly in a medical facility such as this. It is determined that a more in-depth analysis must be done in this area before any conclusion on redesign can be made.

2.0 Building Design Background

The Pediatric Inpatient Addition to Miller Children's Hospital is a 4-story, 127,000 sq. ft. facility. Operating rooms are located on the ground floor, which is actually below grade. The first floor consists of the main lobby with gift shop and sanctuary, conference and office spaces, and physicians' rooms. The second floor houses the neonatal intensive care unit. Finally, the patient rooms are located on the third floor with mechanical penthouse on the roof above.

The building utilizes a constant air volume with reheat system. Seven AHUs located on the roof of the tower supply air to the 4 levels of the building through two centrally-located mechanical shafts. Figure 1 below shows the areas for each AHU.

Figure 1: AHU Areas



The central plant for the Pediatric Inpatient Addition is located on the site but was part of a separate drawing package. The central plant houses the chillers, cooling towers, and pumps as well as other electrical equipment. Two 500-ton centrifugal water chillers supply chilled water to the AHUs and fan coil units for the building. Two induced draft cooling towers, located on the roof of the central plant, cool condenser water from 95˚F to 85˚F. Hot water is supplied to the reheat coils throughout the building with two gas-fired boilers housed in the rooftop mechanical room of the tower.

2.1 Objectives and Requirements

An important design objective when designing a hospital or other medical facility is to ensure the safety of the patients, staff, and other occupants. Therefore, strict standards and codes are used for design, primarily those set forth by the Office of Statewide Health Planning and Development (OSHPD) for California. These must be followed very closely throughout the design process and are stricter than ASHRAE standards to ensure patient health and safety, but tend to be more lenient in regards to energy consumption. An example of this is the constant air volume system designed for the Pediatric Inpatient Addition. Although a CAV system consumes more energy to operate than a VAV system, code requires that sensitive pressure differences be maintained between certain spaces for safety to prevent the spread of hazardous air contaminants.

Also, another design requirement is the addition of the central plant. The existing Miller Children's Hospital is considered a non-conforming building by California code. This means that all utilities serving the new Pediatric Inpatient Addition have to be completely separate from the existing hospital. Essentially, the two buildings need to be completely disconnected from one another as far as mechanical and electrical systems are concerned. Consequently, a new central plant was included in the project, although the existing central plant for the hospital had enough capacity to serve the addition.

2.2 Site Energy Sources and Rates

There is no energy source located on the site of the Pediatric Inpatient Addition. All energy is obtained from local utilities. The electricity supplier for Long Beach, CA is Southern California Edison. The rate used for analysis is $0.07/kWh. Most of the

mechanical equipment runs on electricity, with the exception of the boilers, which are gas-fired. The gas rate used for analysis is $0.24/therm through the Long Beach Gas and Oil Department.

2.3 Site Factors

Because the Pediatric Inpatient Addition is connected to the Miller Children's Hospital, existing conditions require demolition and renovation of portions of the hospital. An existing AHU located on the ground floor of the hospital serves the redesigned areas of the hospital. The Addition itself and central plant are located just east of the hospital and replaces an existing parking lot.

2.4 Outdoor and Indoor Design Conditions

The outdoor design conditions for the Pediatric Inpatient Addition were used for Long Beach, CA and are summarized in Table 1 below. The indoor design conditions are also listed in Table 1.

Table 1: Indoor/Outdoor Design Conditions

	Indoor Design			Outdoor Design	
	DB Temp	WB Temp	Relative Humidity	DB Temp	WB Temp
Summer	75˚F	62˚F	50%	90˚F	71˚F
Winter	75˚F	-	-	38˚F	-

Table 1 shows the indoor and outdoor design conditions for Long Beach, CA, 33.8˚ latitude, 25 ft elevation. The values were taken from calculations done by JBA Consulting Engineers and can also be found in ASHRAE Standard 90.1-2004.

3.0 Design Ventilation Requirements

The design ventilation outdoor air requirements for the Pediatric Inpatient Addition were calculated in Technical Report 1 and are summarized in Table 2 on the following page. The designed ventilation requirement is obtained from the design documents and the AHU schedule as the minimum outdoor air required for each unit. As stated in Technical Report 1, although the minimum designed values may be lower than the

estimated design values for several AHUs, the maximum amount of OA that can be supplied by each unit (assuming 100% OA) exceeds the estimated value in all cases.

Table 2: Ventilation Requirements

	Ventilation Requirement (cfm)	
AHU	Designed	Tech 1 Estimate
1	6,000	3,173
2	1,500	2,764
3	15,000	3,837
4	5,000	4,691
5	4,000	9,786
6	6,000	5,862
7	5,000	5,725
Total	42,500	35,838

Table 2 shows the ventilation requirements both designed and estimated from Tech 1. The estimate from Tech 1 used ASHRAE Standard 62.1-2004 to determine OA rates for each space. Overall, the designed OA is higher than the estimated requirement.

4.0 Design Heating and Cooling Loads

The design heating and cooling loads for the Pediatric Inpatient Addition were calculated in Technical Report 2 and are summarized in Table 3 on the following page. Trane's Trace 700 software program was used to estimate the design loads for the HVAC system in the Pediatric Inpatient Addition. No such program was used in the initial design of the building, and instead hand calculations were done to size the HVAC system. The system was designed by JBA Consulting Engineers. The engineer's values for lights and equipment loads, design occupancy, and the design indoor and outdoor air conditions for heating and cooling were inputted into Trace for each space. The schedules for lights, people, and equipment loads were all created according to the use of a typical hospital facility. The HVAC system was then created according to the design documents. The air handling units are constant volume with space reheat, two chillers with cooling towers (located in the central plant) provide chilled water to the cooling coils, and two boilers provide the hot water to the space reheat coils.

The designed supply air values for the Pediatric Inpatient Addition are slightly higher than the Trace calculated values, which is typically the case when comparing Trace output to hand calculations in that the hand calculations tend to be slightly more conservative. The Trace calculations are a closer approximation to the actual building loads than the hand calculations. This trend continues with the heating loads and all but two of the cooling loads.

Table 3: Heating and Cooling Loads

	Tech 2 Estimated Values		JBA Design Values	
	Cooling Load (tons)	Heating Load (MBH)	Cooling Load (tons)	Heating Load (MBH)
AH-1	44	275	66	535
AH-2	12	68	25	187
AH-3	34	164	80	386
AH-4	50	302	58	434
AH-5	63	312	59	480
AH-6	70	407	66	566
AH-7	50	307	57	501

Table 3 summarizes the findings from Tech 2 for the heating and cooling loads. The designed values tend to be slightly more conservative than the calculated TRACE values for both heating and cooling loads.

5.0 Annual Energy Consumption

The annual energy consumption for the Pediatric Inpatient Addition was also calculated as part of the Technical Report 2 using Trace 700. An energy analysis was not performed by the engineer on the project. The reason for this is because the energy consumption of the building was not the primary element driving the design. The importance of patient health and safety exceeds the need to reduce energy consumption. The building was designed in accordance with OSHPD standards, which exempt medical facilities from meeting many energy consumption requirements. The annual electric energy consumption for the Pediatric Inpatient Addition is approximately 4,410,000 kWh, and the gas consumption is 42,000 therms. The percent breakdown can be seen in Figure 2 on the following page.

Figure 2: Annual Energy Consumption

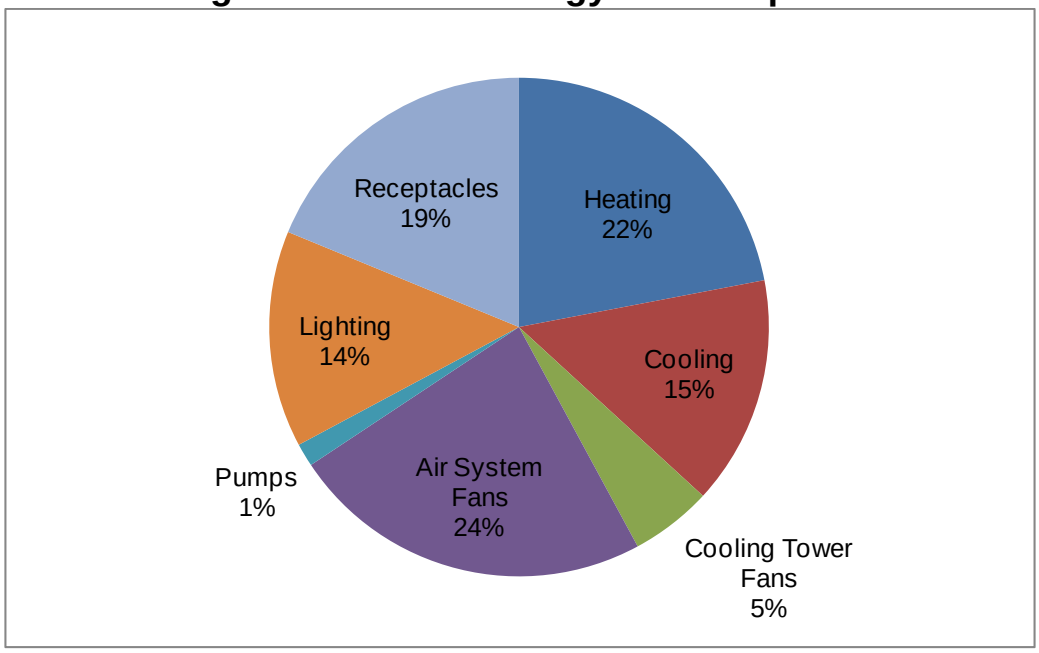


Figure 2 shows the percent breakdown of the annual total energy consumption for the Pediatric Inpatient Addition. The mechanical systems comprise 67% of the entire building energy consumption.

6.0 Major Mechanical Equipment Summary

As stated earlier, the mechanical equipment for the Pediatric Inpatient Addition is primarily located in two areas: the central plant and the tower roof. The central plant houses the chillers, cooling towers, and chilled water pumps. The air handling units, boilers, and hot water pumps are located on the tower roof. This section summarizes the major equipment that comprises the mechanical system for the building.

6.1 Chilled Water System

The chilled water system for the Pediatric Inpatient Addition is located in the central plant. Two centrifugal water cooled chillers supply chilled water to the rooftop AHUs as well as various fan coil units located throughout the building. The chiller data can be found in Table 4 on the following page. The induced draft cooling towers are located on the roof of the central plant and are fitted with variable frequency drives. The cooling tower data can also be found on the following page in Table 5. See the HVAC

Schematic Diagrams section and Appendix to view the chilled water and condenser water flow diagrams.

Table 4: Chiller Data

Centrifugal Water Cooled Chiller												
Quantity	Nominal Size (tons)	Evaporator				Condenser			Full Load Capacity (kW/ton)	NPLV (kW/ton)	Refrigerant Type	VFD
		GPM	EWT	LWT	Max ΔP (ft)	GPM	EWT	Max ΔP (ft)				
2	500	1000	56	44	12	1500	85	16	0.566	0.501	HFC-134A	No

Table 5: Cooling Tower Data

Induced Draft Cooling Tower								
Quantity	GPM	EWT °F	LWT °F	EAT °F WB	Fan Motor			
					HP	Volts	Phase	VFD
2	1500	95	85	78	25	460	3	Yes

6.2 Hot Water System

The hot water system for the Pediatric Inpatient Addition is located in the mechanical room on the tower roof. Two copper finned tube gas-fired hot water boilers supply hot water to 145 reheat coils located throughout the building. The boilers also supply hot water to the heating coil for AH-3. Boiler data can be found in Table 6 below. See the HVAC Schematic Diagrams section and Appendix to view the hot water flow diagram.

Table 6: Hot Water Boiler Data

Copper Finned Tube Hot Water Boiler			
Quantity	Input (MBH)	Heat Output (MBH)	Thermal Efficiency
2	2000	1740	0.87

6.3 Air Handling Units

As previously stated, the air handling units for the Pediatric Inpatient Addition are located on the roof of the tower and serve the four levels of the building. The units supply a constant air volume with zone reheat to maintain pressure differences between

spaces. AH-3 supplies 100% OA and the others supply mixed air. Data for each of the 7 AHUs can be found in Tables 7 through 9 on the following page. Fan data for the supply and return fans are located in Table 7, cooling coil data is located in Table 8, and heating coil data is located in Table 9. Note that only one air handling unit has a heating coil, AH-3.

Table 7: AHU Fan Data

Air Handling Unit Fans										
AHU	Supply Fan				Return/Exhaust Fan				Min OA CFM	Volts/ Phase
	CFM	Total Static Pressure (in. WC)	Fan RPM	Motor HP	CFM	Total Static Pressure (in. WC)	Fan RPM	Motor HP		
1	20,000	6.0	1476	40	19,000	1.5	829	10	6,000	460/3
2	7,000	5.0	1852	10	6,000	1.5	1238	5	1,500	460/3
3	15,000	5.0	1258	25	-	-	-	-	15,000	460/3
4	20,000	5.0	1397	30	16,000	1.5	756	7.5	5,000	460/3
5	18,000	5.0	1340	25	16,700	1.5	965	10	4,000	460/3
6	20,000	5.0	1397	30	17,000	1.5	773	10	6,000	460/3
7	18,000	5.0	1340	25	15,000	1.5	900	10	5,000	460/3

Table 8: AHU Cooling Coil Data

Air Handling Unit Cooling Coil										
AHU	Air Side					Water Side				Face Velocity (fpm)
	Entering Temp. (˚F)		Leaving Temp. (˚F)		Max. ΔP (in. WC)	GPM	Entering Temp. (˚F)	Leaving Temp. (˚F)	Max. ΔP (ft. WC)	
	D.B.	W.B.	D.B.	W.B.						
1	79.5	65.5	52.4	52.1	1.0	121.6	45	58	10	430
2	81.4	66.3	52.8	52.5	1.0	44.4	45	58	10	453
3	90	71	53.6	53.4	1.0	130	45	58	10	437
4	78.8	64.8	52.3	52.1	1.0	114.5	45	58	10	424
5	78.3	64.7	52.4	52.2	1.0	101.5	45	58	10	443
6	79.5	65.5	52.5	52.3	1.0	120.4	45	58	10	424
7	79.1	65.1	52.5	52.2	1.0	105	45	58	10	443

Table 9: AHU Heating Coil Data

Air Handling Unit Heating Coil								
AHU	Air Side			Water Side				Face Velocity (fpm)
	Entering Temp. D.B. (˚F)	Leaving Temp. D.B. (˚F)	Max. ΔP (in. WC)	GPM	Entering Temp. (˚F)	Leaving Temp. (˚F)	Max. ΔP (ft. WC)	
3	38	83.5	0.3	61.4	180	156	5	436

6.4 Water Pumps

Water pumps for the chilled water loop and condenser water loop are located in the pump room in the central plant for the Pediatric Inpatient Addition. The condenser water loop has two centrifugal pumps, with one as a standby. The chilled water loop uses two primary pumps and two secondary pumps, with one secondary as a standby. The hot water loop has two primary and two secondary pumps as well. All ten centrifugal pumps are suction frame mounted. The water pump data for these pumps is listed below in Table 10.

Table 10: Water Pump Data

Centrifugal Water Pump								
Pump	Quantity	GPM	Total Head (ft.)	Motor				VFD
				HP	Volts/ Phase	RPM	Min. Efficiency	
Condenser Water	2	1500	60	40	460/3	1750	0.8	No
Primary Chilled Water	2	1000	50	20	460/3	1750	0.81	Yes
Secondary Chilled Water	2	750	70	20	460/3	1750	0.78	Yes
Primary Hot Water	2	90	20	1	460/3	1750	0.67	No
Secondary Hot Water	2	240	60	7	460/3	1750	0.76	Yes

7.0 HVAC Schematic Diagrams and Controls

The HVAC schematic diagrams for the Pediatric Inpatient Addition include the chilled water flow, condenser water flow, and hot water flow. The diagrams include major mechanical equipment, controllers, sensors, flow directions, etc. and can be found in Appendix A of this report. The control sequences are performed by direct digital controls. This system monitors sensors and then adjusts the mechanical equipment set points and time delays. The variable frequency drives for fans and pumps are monitored by this system, allowing the speed to be adjusted to achieve maximized efficiency of the equipment. In each of the HVAC schematic diagrams, temperature sensors are indicated. These sensors are monitored by the DDC system and the control valves (also indicated) and variable speed pumps are adjusted reach desired set points.

8.0 Critique of System

The Pediatric Inpatient Addition's mechanical systems were designed with great care toward patient health and safety. As this is the number one priority in hospital and medical facility design, they often consume a large amount of energy to operate. Many energy saving techniques are abandoned because achieving both occupant safety requirements and also reduced energy requirements causes the initial cost to rise significantly. Although the system was designed very well in terms of initial cost, maintainability, and space requirements, budget limits caused some energy saving techniques to be dropped as a design option. This is why operational costs for the Pediatric Inpatient Addition are higher than a building where energy saving techniques are more cost feasible. Some of the energy requirements set forth by ASHRAE Standard 90.1 were not met for this very reason. Perhaps upon further analysis, it can be proven that long term savings in mechanical systems operation can outweigh the higher initial cost to implement some of these design approaches.

Another option for further analysis is indoor air quality. As this is a medical facility, many issues arise with patient health and safety in terms of indoor air quality. At this time, no research has been done in that area, aside from proper ventilation requirements researched in Technical Report 1 regarding ASHRAE Standard 62.1. An analysis will have to be done to determine possible problem areas with indoor air quality, and if those problem areas could be addressed logically, and in a cost-effective manner.

9.0 References

JBA Consulting Engineers. 2006, Mechanical Construction Documents. JBA Consulting Engineers, Costa Mesa, CA. 2006.

Center for Energy and Economic Development, “Chart of Electricity Rates in the Largest 100 U.S. Cities.” 2007. Visited 27 Oct. 2007. http://www.ceednet.org/docs/Electric_Rates_top_cities.pdf.

City of Long Beach CA. “Gas Rates: Large Commercial and Industrial.” Effective Nov. 1 2007. Visited 27 Oct. 2007. http://www.longbeach.gov/lbgo/.

Appendix – HVAC Schematic Diagrams

Figure 3: Condenser Water Flow Diagram

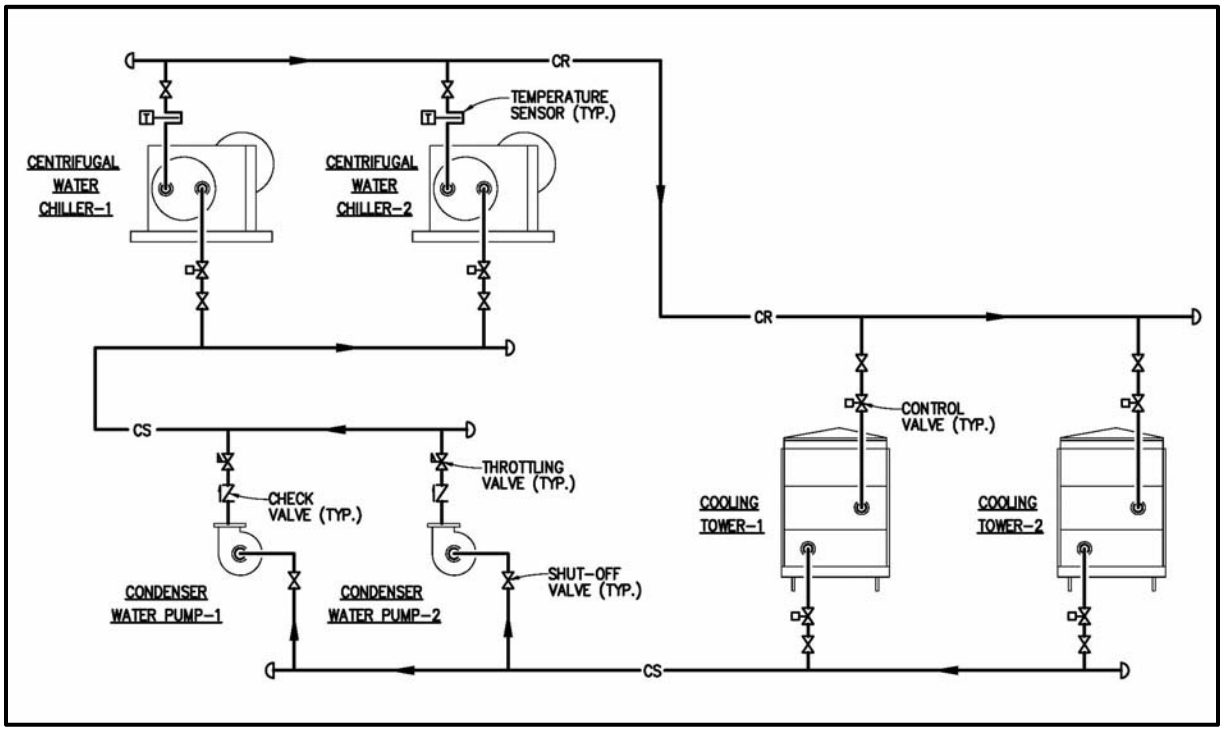


Figure 4: Chilled Water Flow Diagram

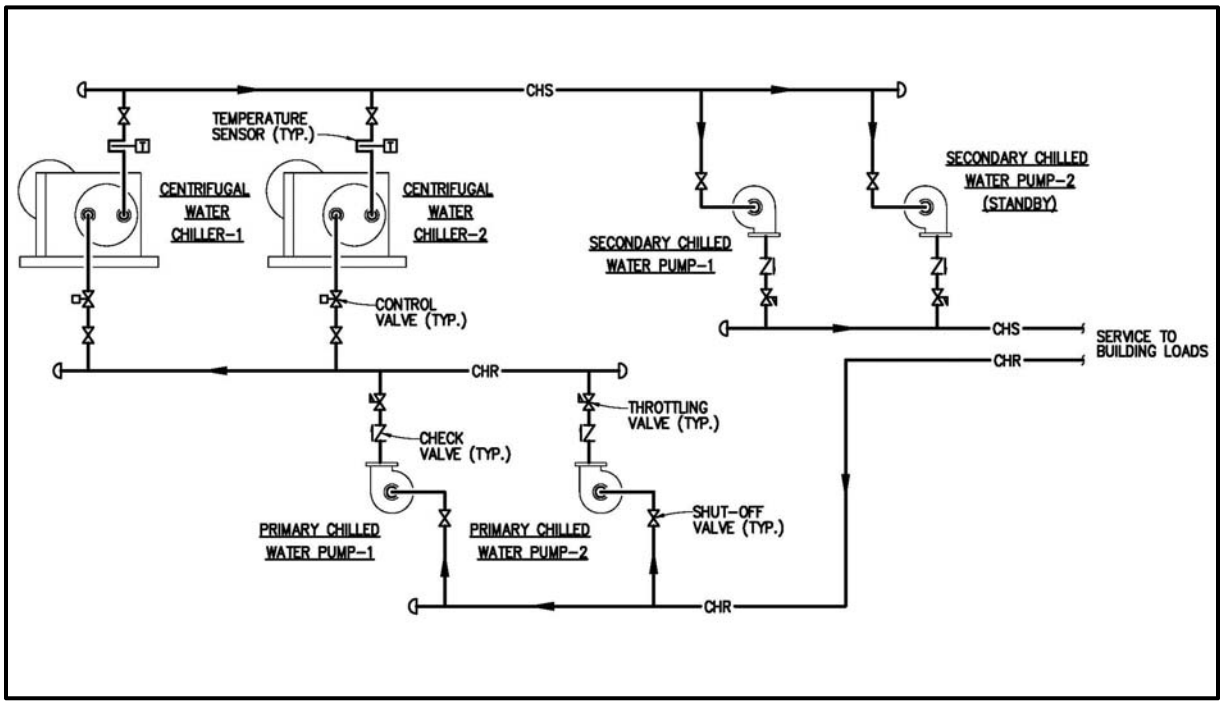


Figure 5: Hot Water Flow Diagram