CHILLER PLANT AUDIT REPORT

FOR

BDMS

FEBRUARY 2023

Contents

1 INTRODUCTION

Trane Thailand ("Trane") was engaged by BDMS Phuket to conduct a chiller plant audit on 21 FEB 2023 to 28 FEB 2023.

The main objectives for the chiller plant audit were:

1. To determine the cooling load profile and operating system efficiency for the chiller plant as a baseline.
2. To utilize the audit findings and baseline for establishing energy savings measures.

1.1 Plant location

1.2 Chiller Plant Equipment

The central air-conditioning system at the ground floor of the chiller plant is served by the following equipment.

1.2.1 Water Cooled Centrifugal Chiller

	CH-1	**CH-2**	**CH-3**	
Maker	Trane	Trane	Trane	
Model	RTHD3G3G3	RTHDD3G3G3	RTHDD3G3G3	
Serial Number	U05H03317	U05H03318	U08J01271	
Capacity (RT)	378.1	378.1	378.1	
Power (kW)	221	221	221	
Efficiency (kW/RT)	0.585	0.585	0.585	
Evap LWT (°F)	45	45	45	
Evap Flow Rate (gpm)	903.4	903.4	903.4	
Evap EWT (°F)	55	55	55	
Cond EWT (°F)	90	90	90	
Cond Flow Rate(gpm)	1200	1200	1200	
Cond LWT (°F)	98.9	98.9	98.9	
Year Installed	2005	2005	2008	

1.2.2 Primary Chilled Water Pump (End Suction Type)

	PCHP-1	**PCHP-2**	**PCHP-3**	
Maker	EBARA	WILO	WILO	
Model	150x125FS4HA	ASP150A	ASP150A	
Capacity (gpm)	912	912	912	
Power (kW)	11	11	11	
Efficiency (kW/RT)	0.029	0.029	0.029	
VSD	YES	YES	YES	
Motor Efficiency	-	-	-	
Pump Efficiency	-	-	-	
Pump Head (ft)	40	40	40	
Year Installed	N/A	N/A	N/A	

1.2.3 Secondary Chilled water Pump (End Suction Type)

Equipment	**SCHP-1**	**SCHP-2**	**SCHP-3**	
Maker	EBARA	EBARA	EBARA	
Model	150x125FS4XA	150x125FS4XA	150x125FS4XA	
Capacity (gpm)	912	912	912	
Power (kW)	37	37	37	
Efficiency (kW/RT)	0.097	0.097	0.097	
VSD	YES	YES	YES	
Motor Efficiency	-	-	-	
Pump Efficiency	-	-	-	
Pump Head (ft)	120	120	120	
Year Installed	N/A	N/A	N/A	

1.2.3 Condenser Water Pump (End suction type)

	CDP-1	CDP-2	CDP-3	
Maker	EBARA	EBARA	EBARA	
Model	150x125FS4JA	150x125FS4JA	150x125FS4JA	
Capacity (gpm)	1140	1140	1140	
Power (kW)	18.5	18.5	18.5	
Efficiency (kW/RT)	0.048	0.048	0.048	
VSD	YES	YES	YES	
Motor Efficiency	-	-	-	
Pump Efficiency	-	-	-	
Pump Head (ft)	60	60	60	
Year Installed	N/A	N/A	N/A	

1.2.4 Cooling Tower Water (Cross Flow)

Equipment	**CT-1**	**CT-2**		
Make	Cooling Man	Liang Chi		
Model				
Capacity (gpm)	1140	1140		
Power (kW)	3x5.5	2x7.5		
Efficiency (kW/RT)	0.044	0.05		
Dry Bulb Temp (°F)	-	-		
Wet Bulb Temp (°F)	84	84		
Heat Rejection (RT)	300	300		
Year Installed	2020	2020		

The chiller plant is currently operated manually.

2 AUDIT METHODOLOGY

Measurements were done at the headers of the chilled water and condenser water circuits. Chilled water temperatures and flow rates were measured to determine the cooling tonnage. Power consumption for each chiller and total chilled water pumps, condenser pumps with some of cooling towers were trend-logged to establish the baseline energy consumption. Power consumption for each chilled water pump, condenser pump and cooling tower were spot measured.

Pumps and cooling towers are equipped with VSDs. Chilled water pump, condenser water pump and cooling tower motor operation were reported as a fixed speed. They were adjusted manually. Hence, the power consumption profiles of chilled and condenser pumps and cooling tower are expected to be stable or a step shape.

2.1 Instrumentation

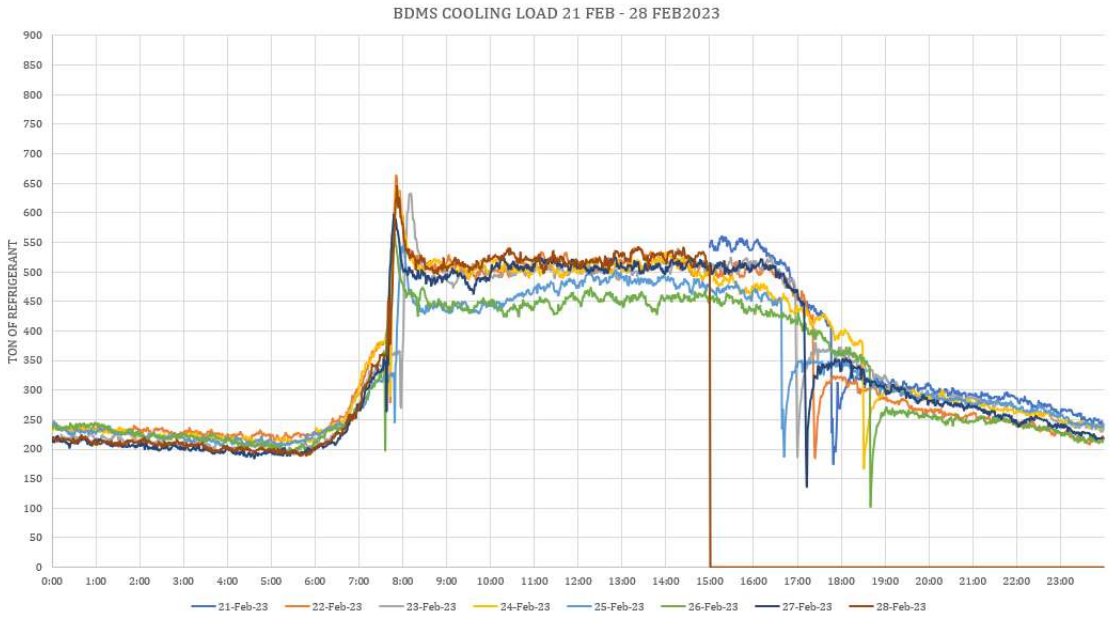
The table below summarizes the instruments that were deployed for Chiller Plant.

Data Description	Instrument Type	Installed Location	Accuracy
Chilled Water Loop			
CHWS Temp	10k Thermistor	CHWS Header	± 0.054°F
CHWR Temp	10k Thermistor	CHWR Header	± 0.054°F
CHW Flow	Ultrasonic	CHWS Header	± 2.0%
Condenser Water Loop			
CDWS Temp	10k Thermistor	CDWS Header	± 0.054°F
CDWR Temp	10k Thermistor	CDWR Header	± 0.054°F
CDW Flow	Ultrasonic	CDWS Header	± 2.0%
Power			
Main Incoming	Power Meter	Power Panel	± 1.5%

The instrumentation layout can be referred to under Appendix A.

3 DATA ANALYSIS

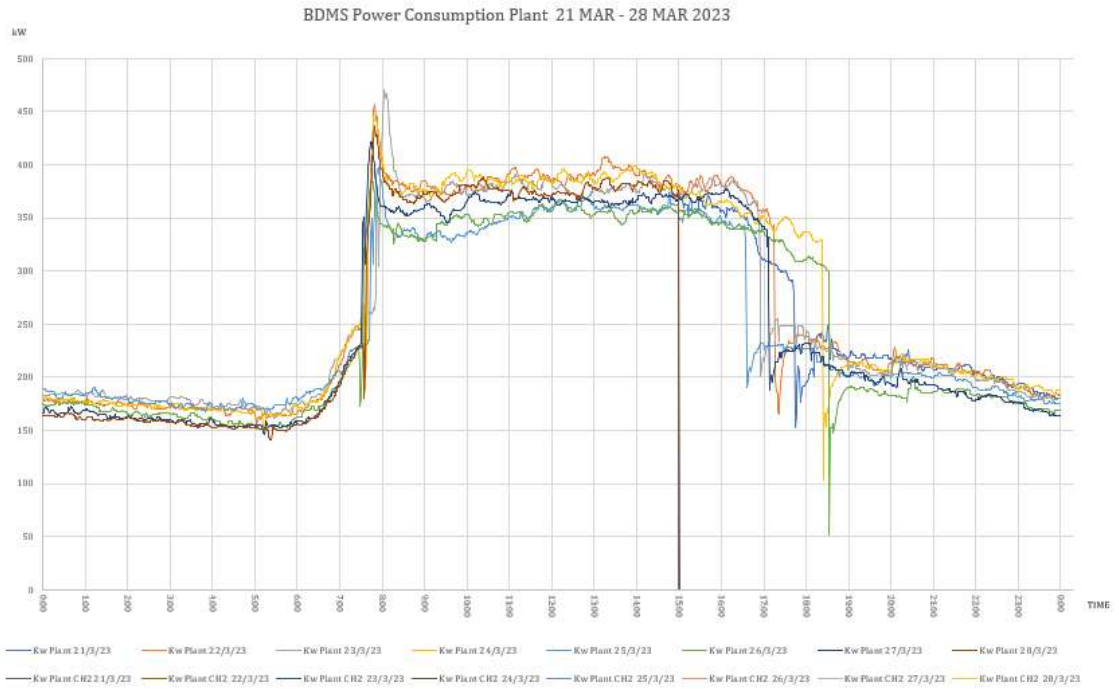
3.1 Cooling Load



- Graph shows that the cooling load profile of chiller plant was fluctuated during the measurement period. The graph shape is a upward U curve.
- The morning cooling load averaged at 216 RT before 6:00. The peak cooling load averaged at 442 RT, slightly decreasing to 264 RT during 19:00-23:59.
- The chiller plant operates 24 hours a day. It is observed that chiller plant is operating with a chiller capacity of 378 RTx2 during daytime and 378x1 during nighttime.

AVG RT	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	228	210	223	221	220	202	206	216
6:00-18:59	442	455	446	455	414	411	447	475	442
19:00-23:59	284	248	273	270	273	243	261	N/A	264

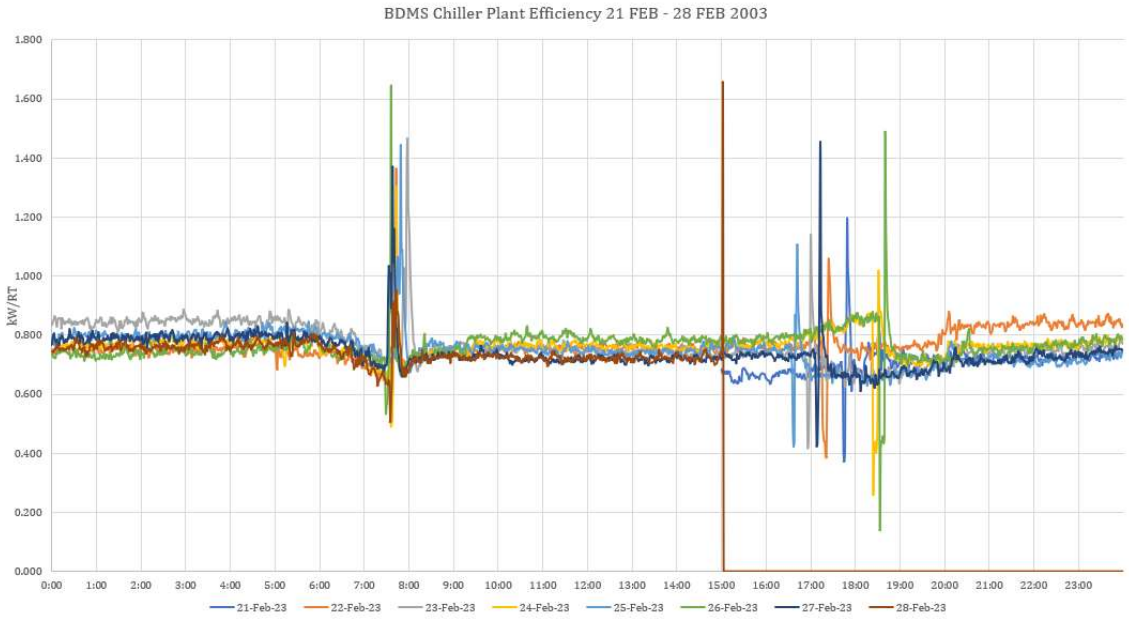
3.2 Power Consumption



- Graph shows the power consumptions were fluctuated every day during the measurement period.
- Peak power consumption averaged at 328 kW during 6:00-18:59, slightly reducing to 196 kW during 19:00-23:59. In the morning, the average power consumption was 169 kW during 0:00-5:59.

AVG kW	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	172	177	172	177	164	160	157	169
6:00-18:59	301	340	332	346	307	320	323	343	328
19:00-23:59	205	204	200	204	194	182	186	N/A	196

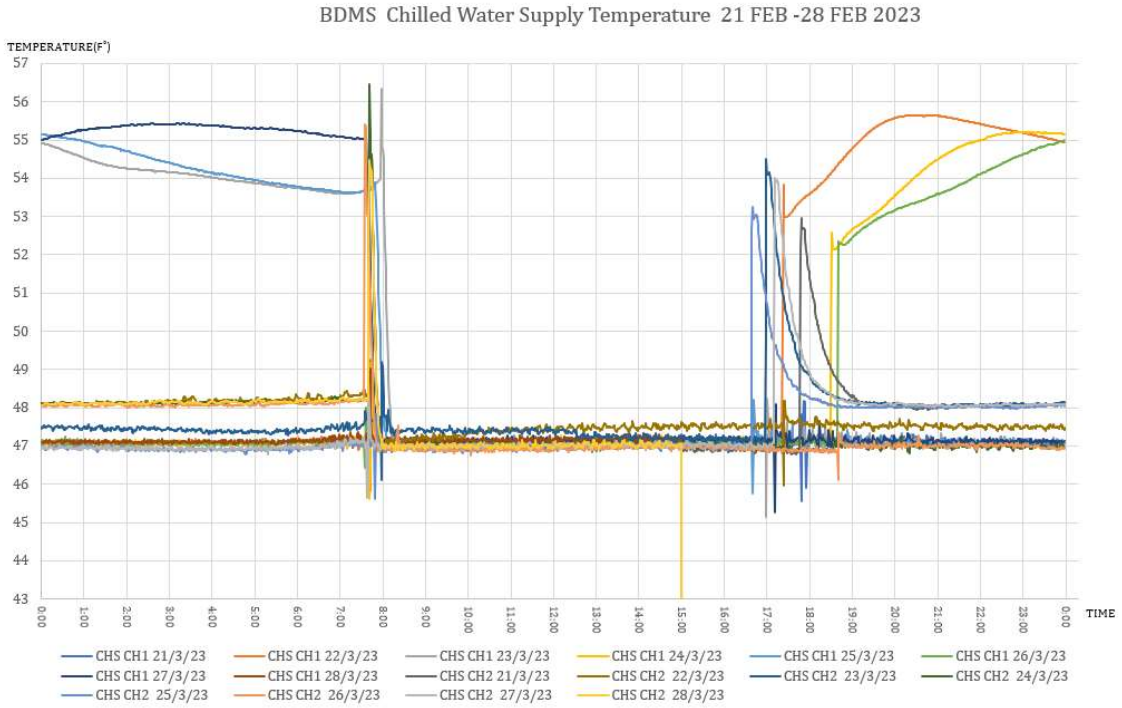
3.3 System Efficiency



- The chiller plant efficiency profiles were not fluctuated when compared to the system cooling load and power consumption profiles.
- Based on the calculated cooling load and measured power, the average system efficiency during peak hours averaged at 0.744 kW/RT. After 19:00, the system efficiency slightly increased to 0.745 kW/RT. Then the system efficiency elevated to 0.782 kW/RT 0:00-5:59.

AVG kW/RT	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	0.751	0.846	0.774	0.803	0.747	0.793	0.764	0.782
6:00-18:59	0.69	0.748	0.746	0.760	0.742	0.780	0.723	0.723	0.744
19:00-23:59	0.72	0.823	0.734	0.756	0.711	0.753	0.716	N/A	0.745

3.4 Chilled Water Supply Temperature

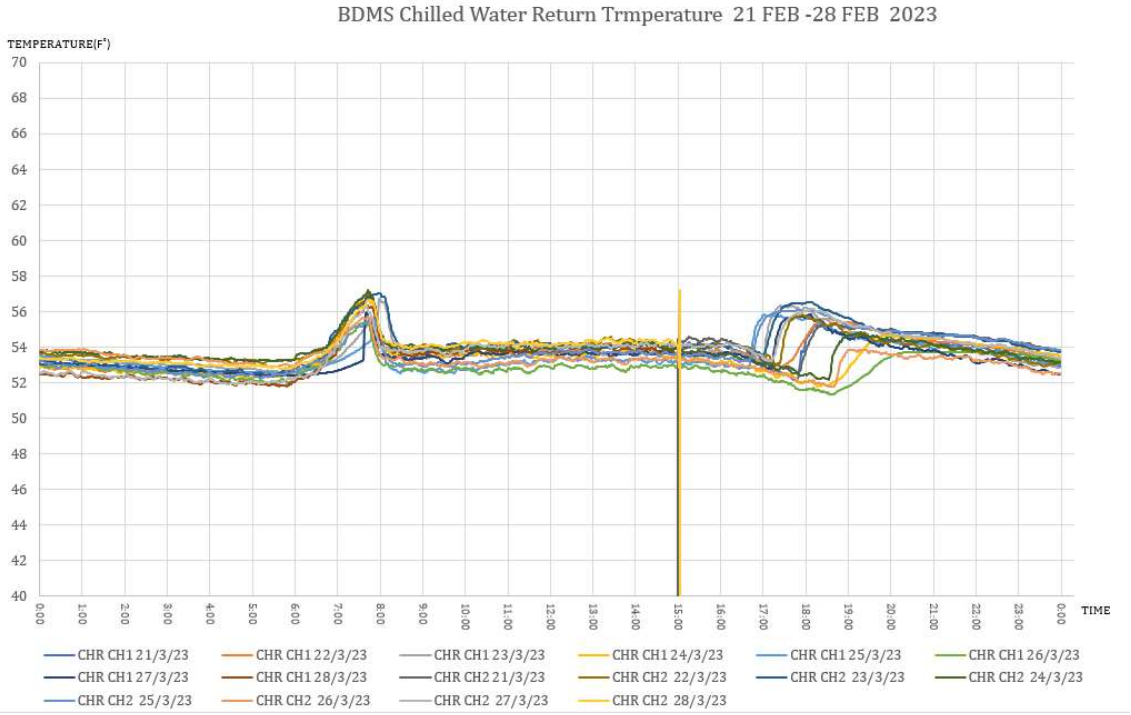


- Based on the chart above, it is shown that the temperature profile of CH-1was steady during daytime at 48.5 °F but nighttime at 49.7 °F.
- Based on the chart above, it is shown that the temperature profile of CH-2 was steady both daytime and nighttime at 47.6 °F.

AVG TEMP CH1	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	47.1	54.4	47.1	54.8	47.1	55.3	47.1	50.4
6:00-18:59	47.1	48.0	50.1	47.1	50.1	47.1	50.5	47.2	48.5
19:00-23:59	47.1	55.4	47.1	49.3	47.1	49.0	47.2	N/A	48.9

AVG TEMP CH2	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	48.2	47.4	48.1	46.9	48.1	46.9	48.1	47.7
6:00-18:59	47.8	47.6	47.7	47.2	47.4	47.2	47.4	47.4	47.4
19:00-23:59	48.0	47.5	48.1	47.0	48.0	47.0	48.1	N/A	47.7

3.5 Chilled Water Return Temperature

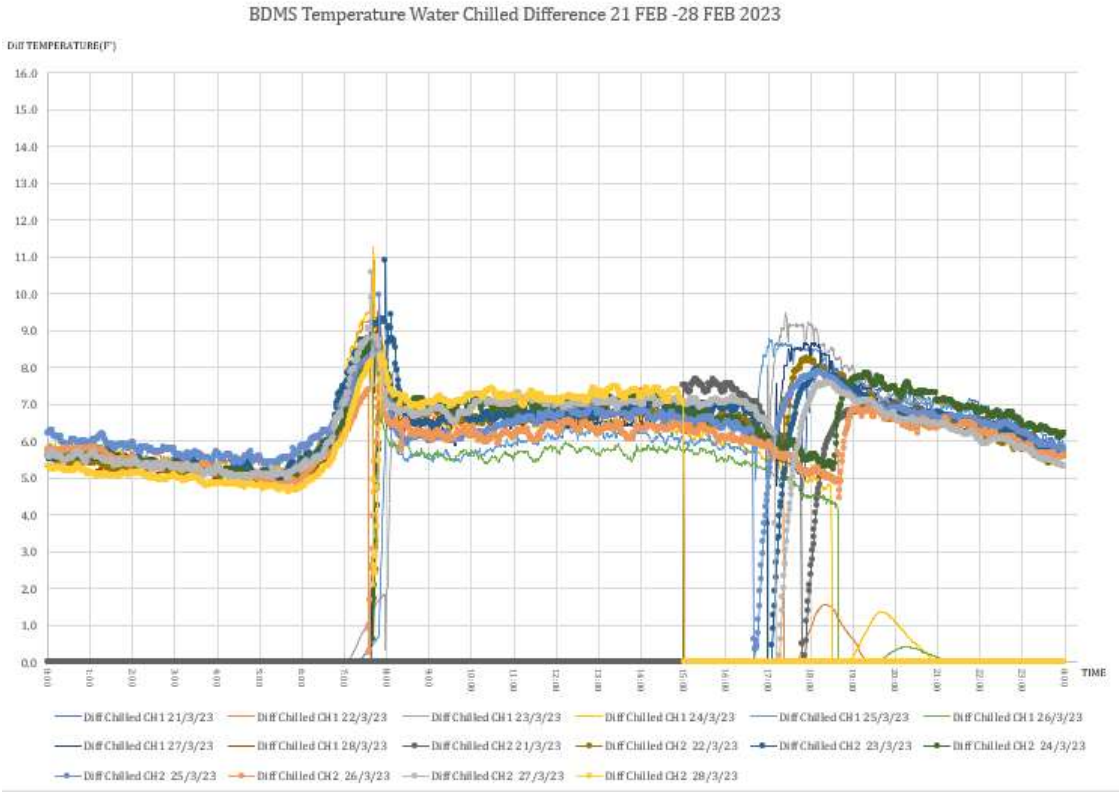


- The above graph shows that the CHWR temperature profile was fluctuated and looked like a sine wave.
- The average temperature of CH-1 was 53.6°F during the peak hours. After that the average CHWR temperature slightly decreased to 53.9°F and 52.7°F during 19:00-23:59 and 0:00-5:59 respectively.
- The average temperature of CH-2 was 54.1°F during the peak hours. After that the average CHWR temperature slightly increased to 54.2°F and 53.0 °F during 19:00-23:59 and 0:00-5:59 respectively.

AVG TEMP (CH-1)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	52.6	53.0	52.6	52.9	52.5	52.8	52.2	52.7
6:00-18:59	53.9	54.0	54.0	53.5	53.5	52.8	53.7	53.9	53.6
19:00-23:59	54.0	54.3	53.9	54.1	53.9	53.4	53.5	N/A	53.9

AVG TEMP(CH-2)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	53.4	52.8	53.5	52.7	53.4	52.2	53.1	53.0
6:00-18:59	54.1	54.4	54.5	53.9	53.9	53.2	54.2	54.3	54.1
19:00-23:59	54.6	53.9	54.6	54.0	54.6	53.3	54.3	N/A	54.2

3.6 Chilled Water Temperature Difference

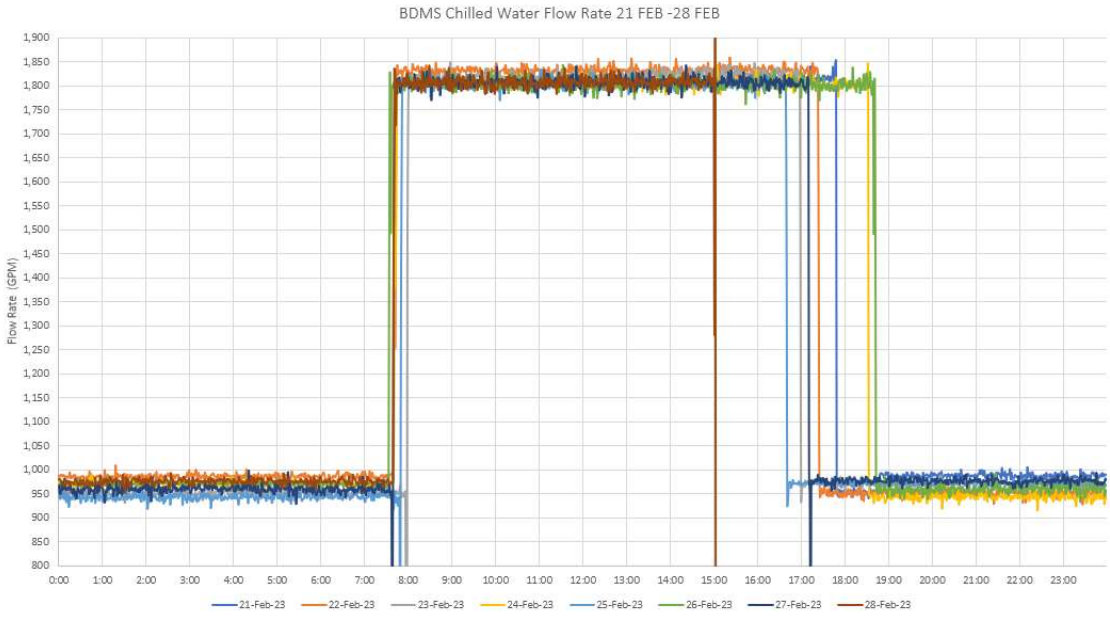


- Based on the above graphical plots, it is shown that the chilled water temperature differences were fluctuated.
- Calculated temperature difference of CH-1 between 6:00 and 18:59 averaged at 6.3°F. Between 19:00 and 23:59, the temperature difference was 5.7°F. In the morning, average temperature difference was 5.4°F during 0:00-5:59.
- Calculated temperature difference of CH-2 between 6:00 and 18:59 averaged at 6.7°F. Between 19:00 and 23:59, the temperature difference was 6.5°F. In the morning, average temperature difference was 5.3°F during 0:00-5:59.
- As the general design temperature difference is 10°F, it shows that the chillers were receiving excessive chilled water flow rate based on the lower temperature difference as detailed earlier.

AVG TEMP (CH-1)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	5.6	N/A	5.5	N/A	5.4	N/A	5.1	5.4
6:00-18:59	6.7	6.1	6.4	6.4	6.1	5.7	6.6	6.7	6.3
19:00-23:59	6.9	0.3	6.7	0.7	6.8	0.2	6.4	N/A	5.7

AVG TEMP(CH-2)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	5.2	5.4	5.3	5.7	5.3	5.3	5.0	5.3
6:00-18:59	6.4	6.7	6.9	6.7	6.6	6.1	6.9	7.0	6.7
19:00-23:59	6.5	6.4	6.5	7.0	6.6	6.3	6.3	N/A	6.5

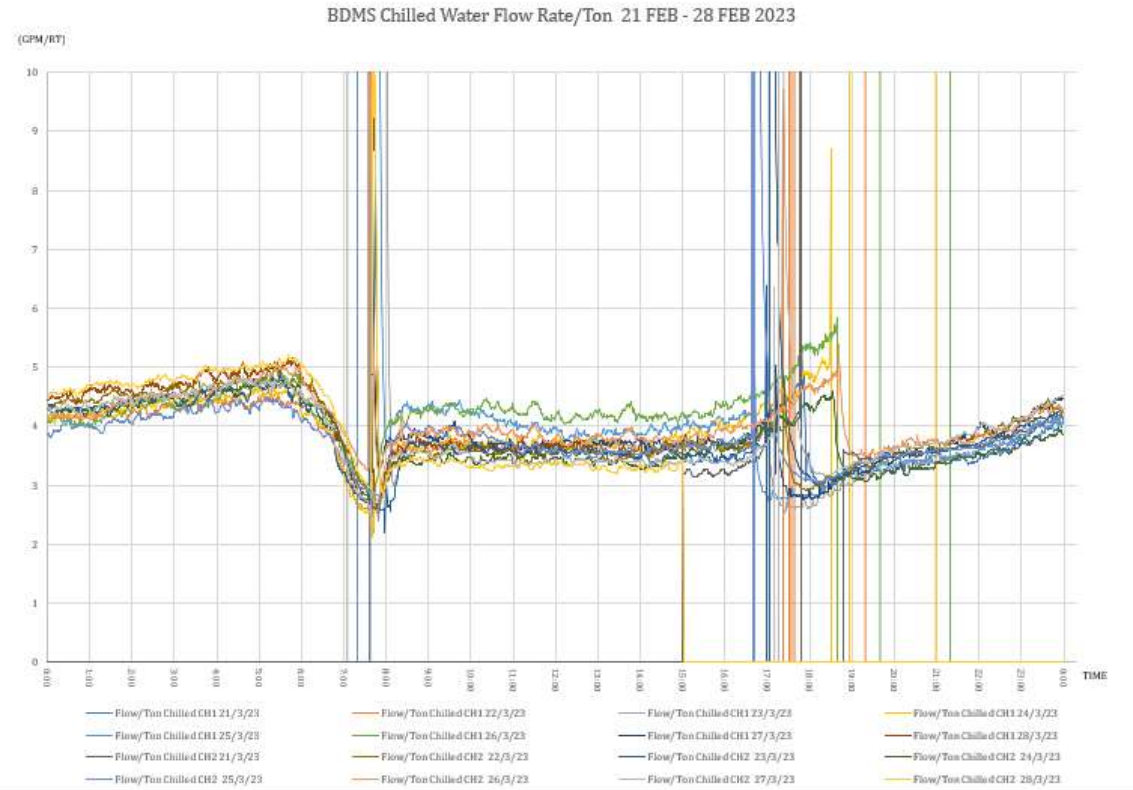
3.7 Chilled Water Flow Rate



- The existing chilled water pumps are equipped with fixed speed VSDs. Then the flow rate is almost constant.
- The graphical plot shows that the highest water flow rate was during daytime across the measurement period each day.
- The average flow rate observed was 966, 1608 and 966 GPM during 0:00-5:59, 6:00-18:59 and 19:00-23:59 respectively, which is close to the general design flow rate of 378 RT at nighttime, but this plant operates below 756 RT during daytime.

AVG GPM	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	986	951	971	943	971	960	976	966
6:00-18:59	1563	1614	1556	1666	1533	1683	1580	1653	1608
19:00-23:59	987	952	971	944	971	960	977	N/A	966

3.8 Chilled Water Flow Rate per Unit Cooling

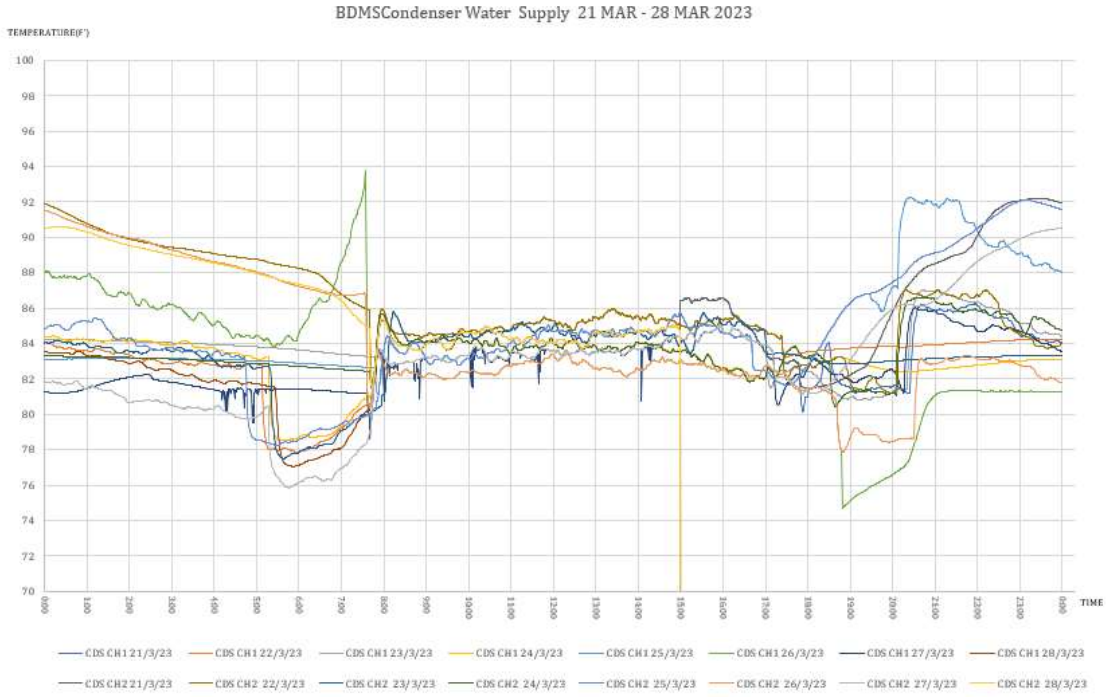


- The CH-1 average chilled water flow rate (GPM/RT) was 4.5, 3.3 and 3.6 during 0:00-5:59, 6:00-18:59 and 19:59-23:59 respectively which were higher than the normal design value of 2.4. Such finding is consistent with the relatively lower chilled water temperature difference.
- The CH-2 average chilled water flow rate (GPM/RT) was 4.5, 4.1 and 3.7 during 0:00-5:59, 6:00-18:59 and 19:59-23:59 respectively which were higher than the normal design value of 2.4. Such finding is consistent with the relatively lower chilled water temperature difference.

GPM/RT (CH-1)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	4.3	N/A	4.4	N/A	4.4	N/A	4.7	4.5
6:00-18:59	3.6	N/A	N/A	4.7	N/A	4.3	3.7	3.6	3.3
19:00-23:59	3.5	N/A	3.6	N/A	3.6	N/A	3.8	N/A	3.6

GPM/RT (CH-2)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	4.6	N/A	4.5	4.2	4.5	4.5	4.8	4.5
6:00-18:59	3.8	3.6	5.9	3.7	4.1	4.2	3.8	3.5	4.1
19:00-23:59	3.7	3.8	3.7	3.4	3.7	3.8	3.9	N/A	3.7

3.9 Condenser Water Supply Temperature

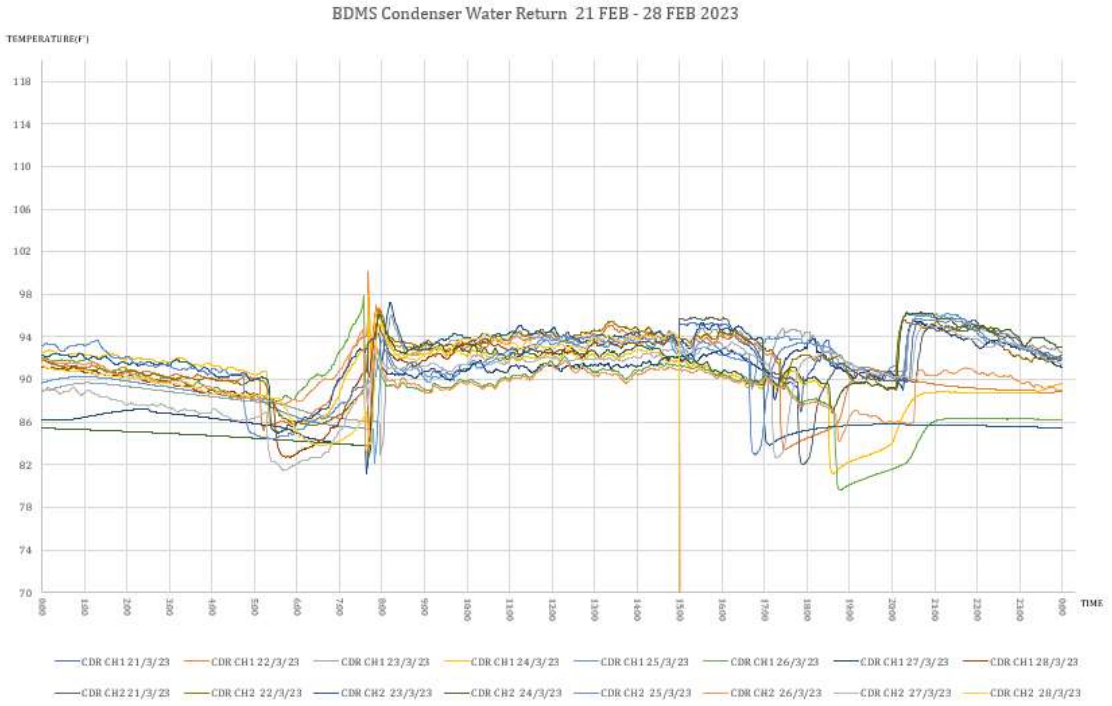


- The condenser water supply temperature ranged between 83.2°F and 85.8°F during the measurement period. The peak temperature of the day was during nighttime.
- Between 6:00 and 18:59, the average reading of CH-1 was 83.5°F. Between 19:00 and 23:59, the average reading was 84.1°F. The average temperature was 83.2°F during 0:00-5:59.
- Between 6:00 and 18:59, the average reading of CH-2 was 83.6°F. Between 19:00 and 23:59, the average reading was 85.8°F. The average temperature was 85.3°F during 0:00-5:59.
- Measurement data shows that the cooling towers could provide lower condenser water supply temperatures is less than the design value of 90.0°F most of the measurement period.

AVERAGE TEMP (CH-1)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	82.5	84.0	83.3	83.1	85.9	81.6	82.1	83.2
6:00-18:59	84.1	84.0	84.0	83.1	83.8	83.0	83.1	83.2	83.5
19:00-23:59	84.2	84.0	84.6	82.8	89.5	79.7	84.2	N/A	84.1

AVERAGE TEMP (CH-2)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	89.7	82.9	83.1	83.0	89.3	80.3	89.1	85.3
6:00-18:59	84.0	85.0	83.5	83.4	83.3	82.9	82.5	84.7	83.6
19:00-23:59	88.7	84.9	83.2	84.7	89.7	81.6	87.6	N/A	85.8

3.10 Condenser Water Return Temperature

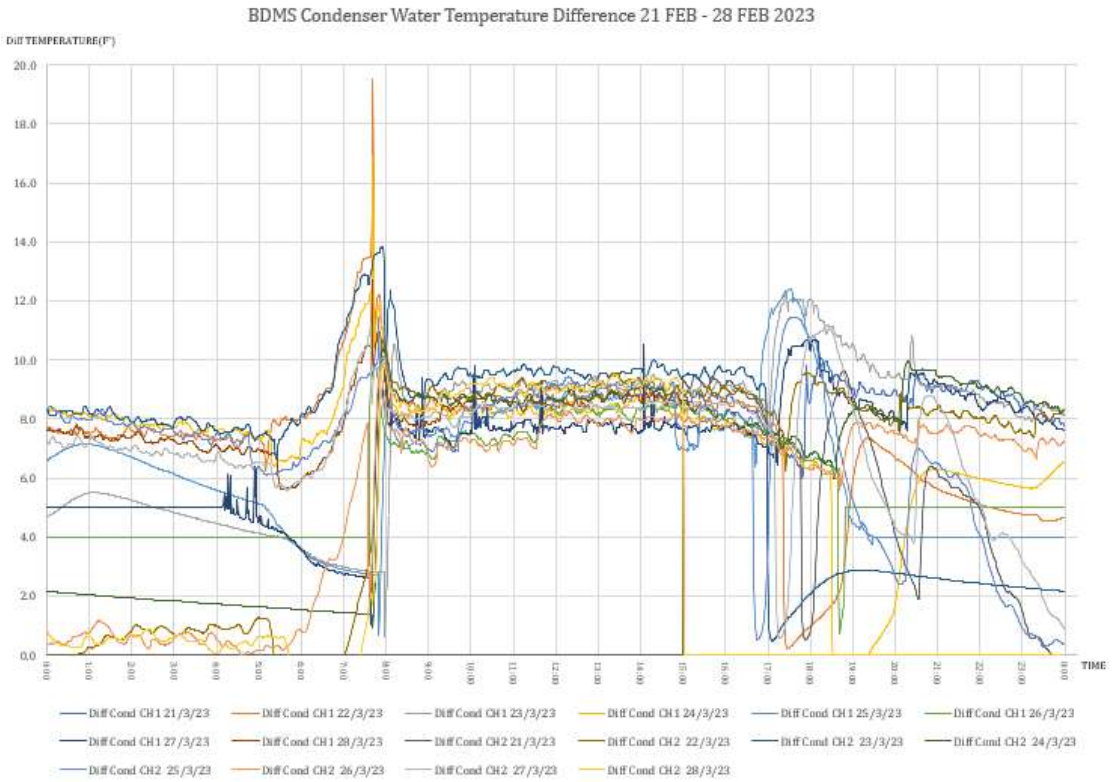


- During the peak hours of 6:00 to 18:59, the return temperature was observed to range between 90.1°F and 93.6°F.
- Average return temperature during the peak operation was 91.3°F. The value slightly decreased to 90.6°F at 19:00 to 23:59, then decreased to 88.9°F at 0:00 to 5:59.

AVERAGE TEMP (CH-1)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	90.0	88.8	91.0	89.1	89.9	86.4	89.2	89.2
6:00-18:59	92.5	92.1	92.4	90.9	91.4	90.1	90.4	91.6	91.3
19:00-23:59	93.0	89.6	93.5	87.4	93.5	84.7	92.7	N/A	90.6

AVERAGE TEMP (CH-2)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	90.1	90.7	84.9	90.4	89.8	87.0	89.5	88.9
6:00-18:59	91.8	92.7	92.1	90.8	91.7	89.9	90.8	91.6	91.4
19:00-23:59	92.7	92.9	85.7	93.6	93.2	89.0	92.6	N/A	91.4

3.11 Condenser Water Temperature Difference

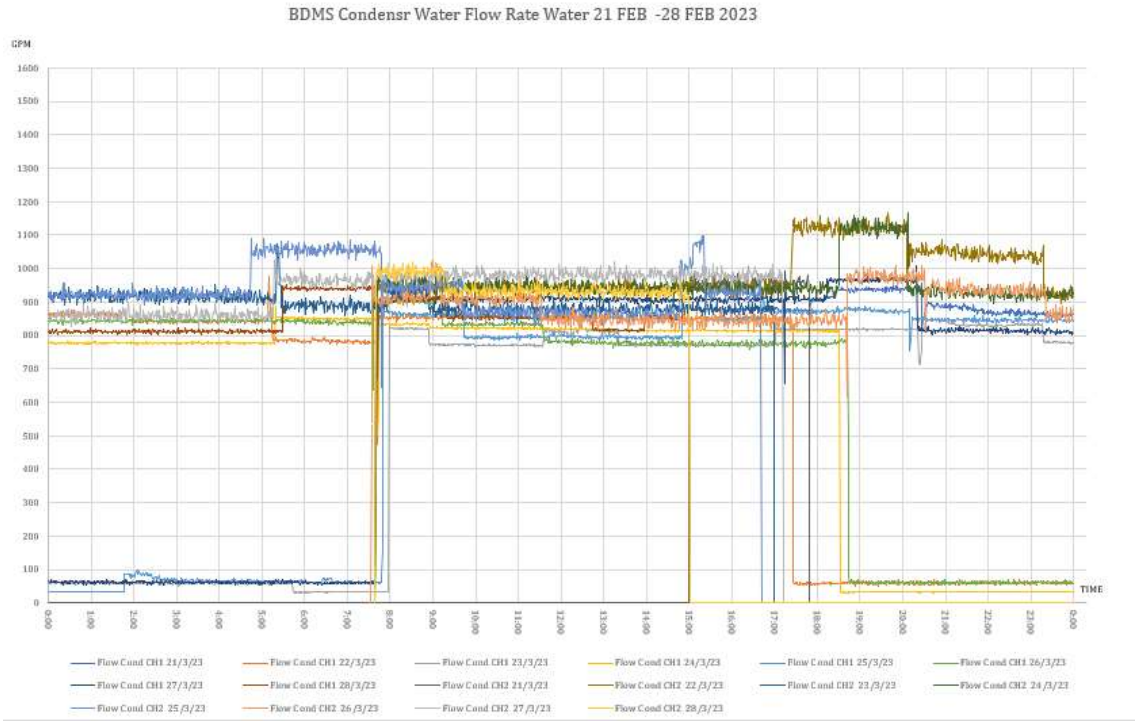


- The graphical plot shows that the condenser water temperature difference was fluctuated during the measurement period.
- Calculated CH-1 temperature difference during 6:00-18:59 and 19:00-23:59 averaged at 7.9°F, 6.6°F, between 0:00 and 5:59, the temperature difference was a little down to 6.0°F.
- Calculated CH-2 temperature difference during 6:00-18:59 and 19:00-23:59 averaged at 8.0°F, 5.7°F, between 0:00 and 5:59, the temperature difference was a little down to 3.8°F.
- As the design temperature difference is 10°F, this shows that there is room for further improvement. An increase in the temperature difference will allow for a lower condenser water flow rate and further improve the system efficiency.

AVERAGE TEMP (CH-1)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	7.5	4.7	7.7	6.0	4.0	4.8	7.1	6.0
6:00-18:59	8.4	8.0	8.4	8.2	7.6	7.1	7.3	8.4	7.9
19:00-23:59	8.8	5.6	9.0	5.1	4.0	5.0	8.5	N/A	6.6

AVERAGE TEMP (CH-2)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	N/A	7.9	N/A	7.4	0.5	6.7	N/A	3.8
6:00-18:59	7.8	8.5	8.6	7.4	8.4	7.0	8.2	8.6	8.0
19:00-23:59	4.2	8.1	2.5	8.9	3.5	7.5	5.1	N/A	5.7

3.12 Condenser Water Flow Rate

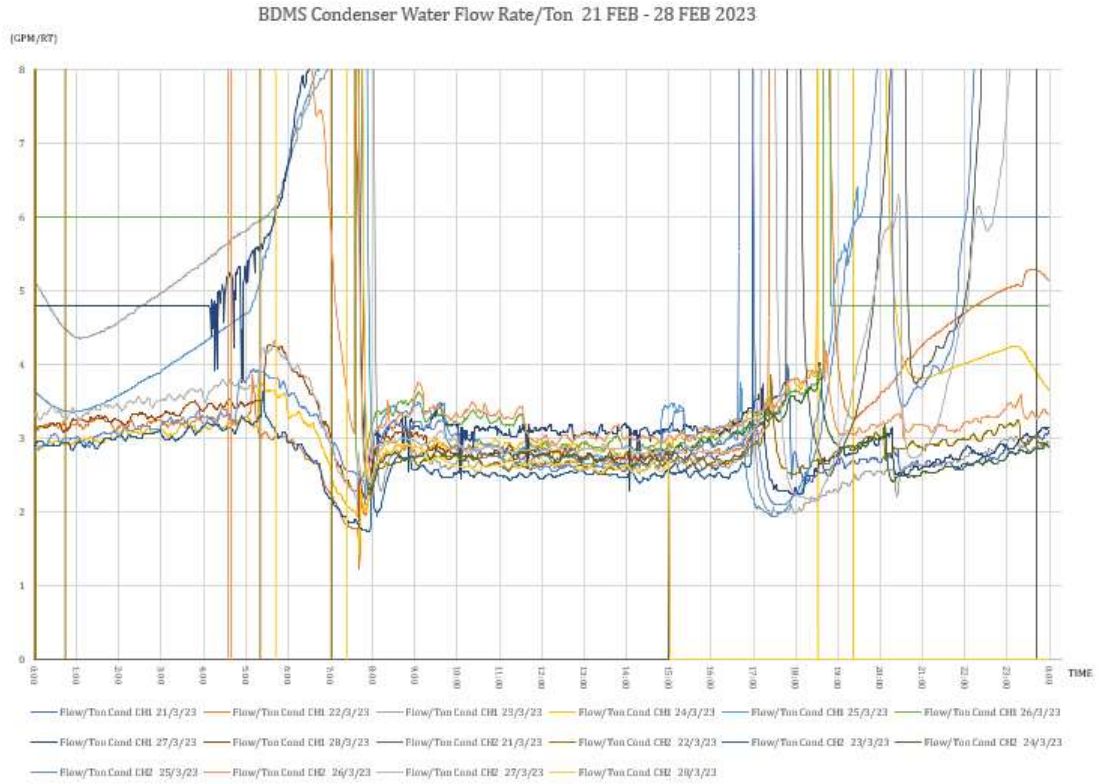


- Similarly, the chilled water pumps, the condenser water pumps are equipped with fixed speed VSDs. Then the flow rate is almost constant.
- As the table below, it shows that the average condenser water flow rates during the measurement period were lower than the design flow rate of 378 RT.

AVE. GPM (CH-1)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	843.2	N/A	785.9	N/A	843.1	N/A	823.0	823.8
6:00-18:59	890.3	747.1	674.5	793.9	727.5	795.3	803.0	874.0	788.2
19:00-23:59	891.3	N/A	819.8	N/A	851.9	N/A	855.0	N/A	854.5

AVE. GPM (CH-2)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	N/A	914.6	N/A	949.1	N/A	873.2	N/A	684.2
6:00-18:59	958.0	965.9	884.2	950.4	927.9	871.8	976.6	944.4	934.9
19:00-23:59	N/A	1044.3	N/A	970.1	N/A	939.0	N/A	N/A	984.4

3.13 Condenser Water Flow Rate per Unit Cooling

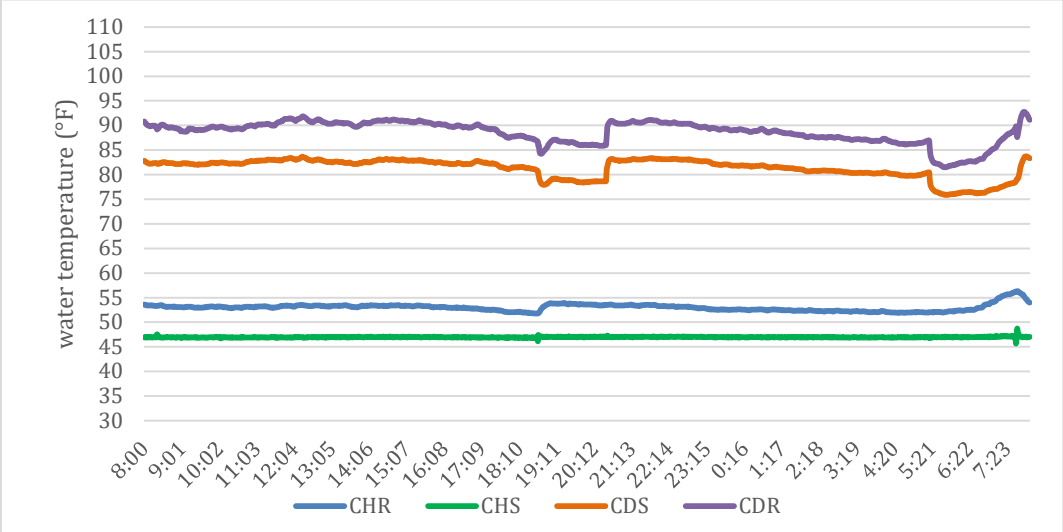


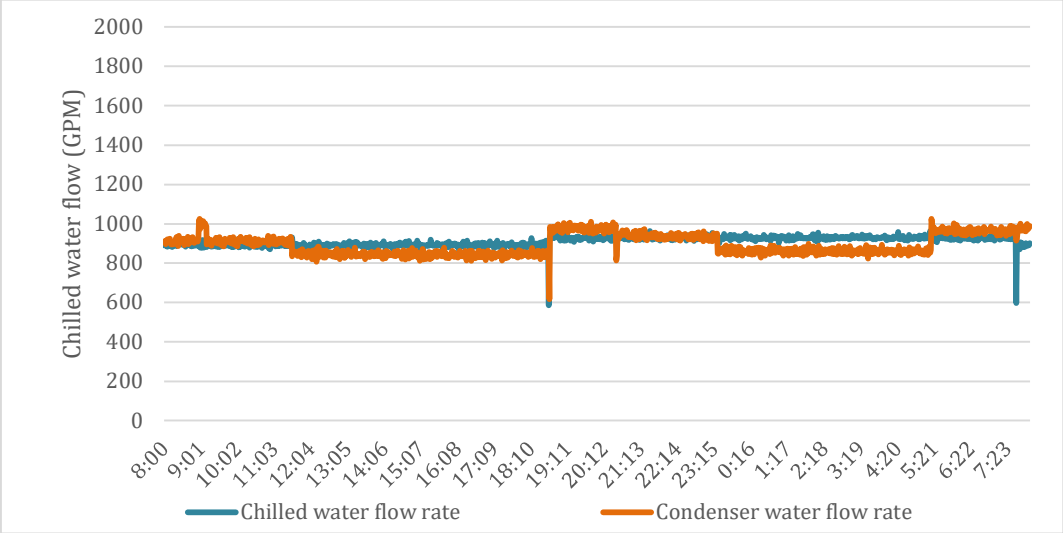
- During peak hours, the average condenser water flow (GPM/RT) was 3.73 for CH-1 and 5 for CH-2 which was higher than the design value of 3.0. the rest of the measurement period, the average flow rates (GPM/RT) were higher than the design value too. When looking the temperature difference value, it was also lower the design value. It shows that the system has an excess flow on condenser water side.

GPM/RT (CH-1)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	3.2	N/A	3.1	N/A	6.0	N/A	3.4	3.9
6:00-18:59	2.9	5.9	3.5	3.0	3.8	3.7	3.7	2.9	3.7
19:00-23:59	2.7	N/A	2.7	N/A	6.0	N/A	2.8	N/A	3.6

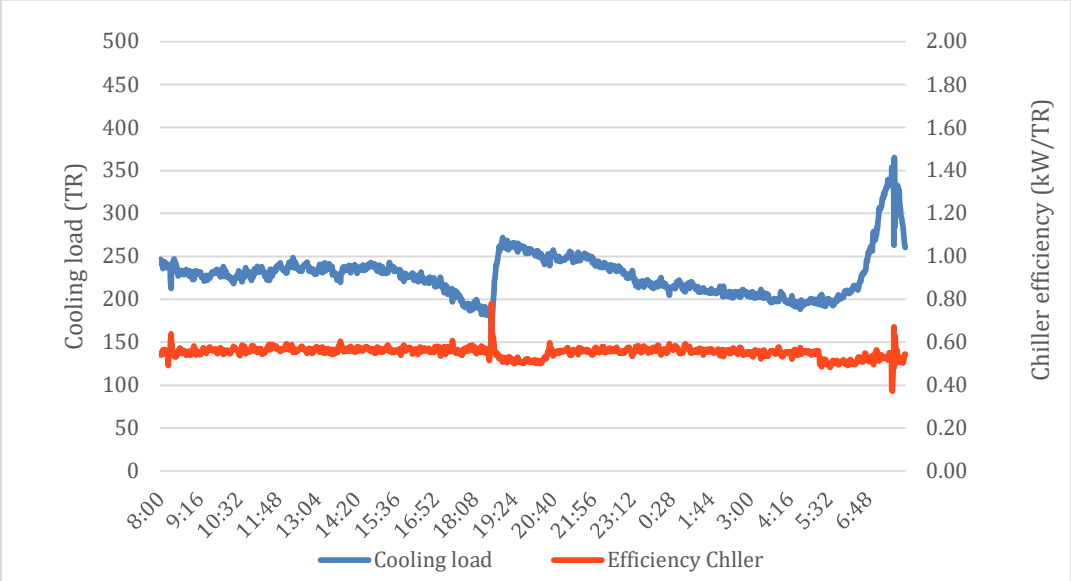
GPM/RT (CH-2)	21-Feb-23	22-Feb-23	23-Feb-23	24-Feb-23	25-Feb-23	26-Feb-23	27-Feb-23	28-Feb-23	OVERALL
0:00-5:59	N/A	N/A	3.1	N/A	4.1	N/A	5.0	N/A	3.0
6:00-18:59	5.1	6.6	4.6	3.0	3.8	3.7	3.7	2.9	4.2
19:00-23:59	N/A	3.0	N/A	15.7	N/A	4.8	N/A	N/A	7.8

3.14 Data Analysis Chiller No.1

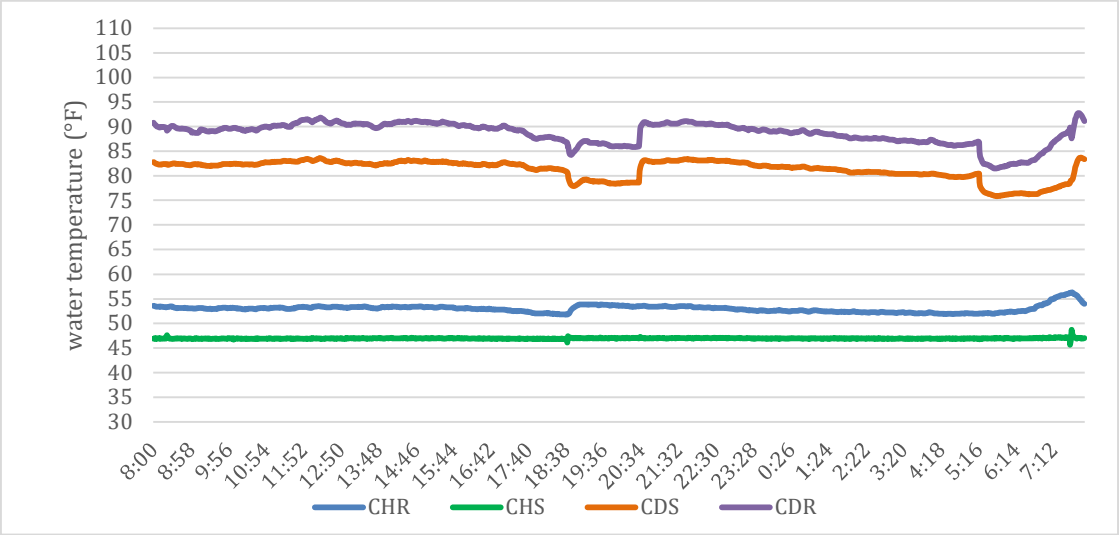


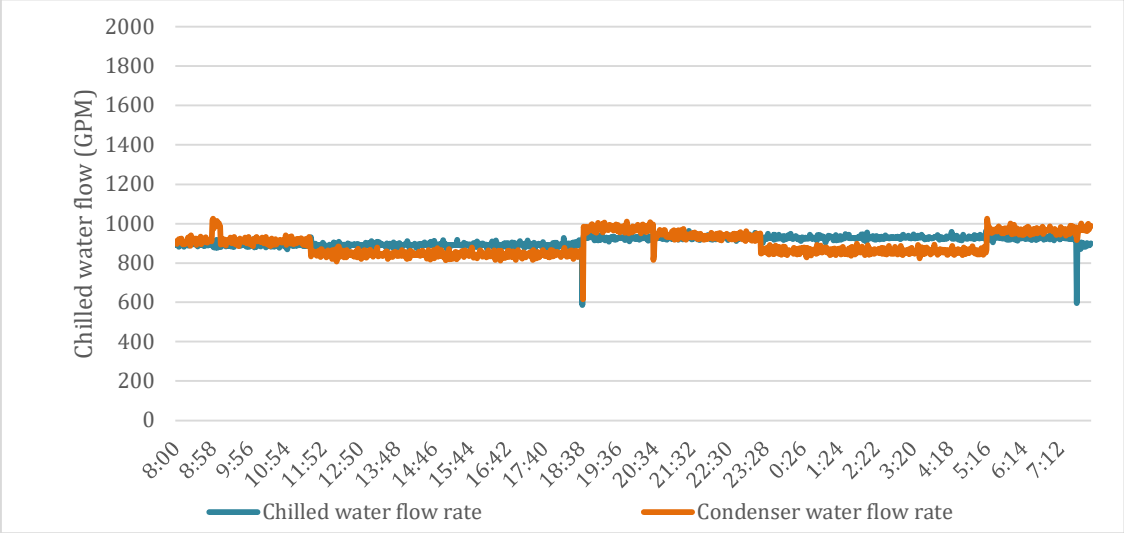


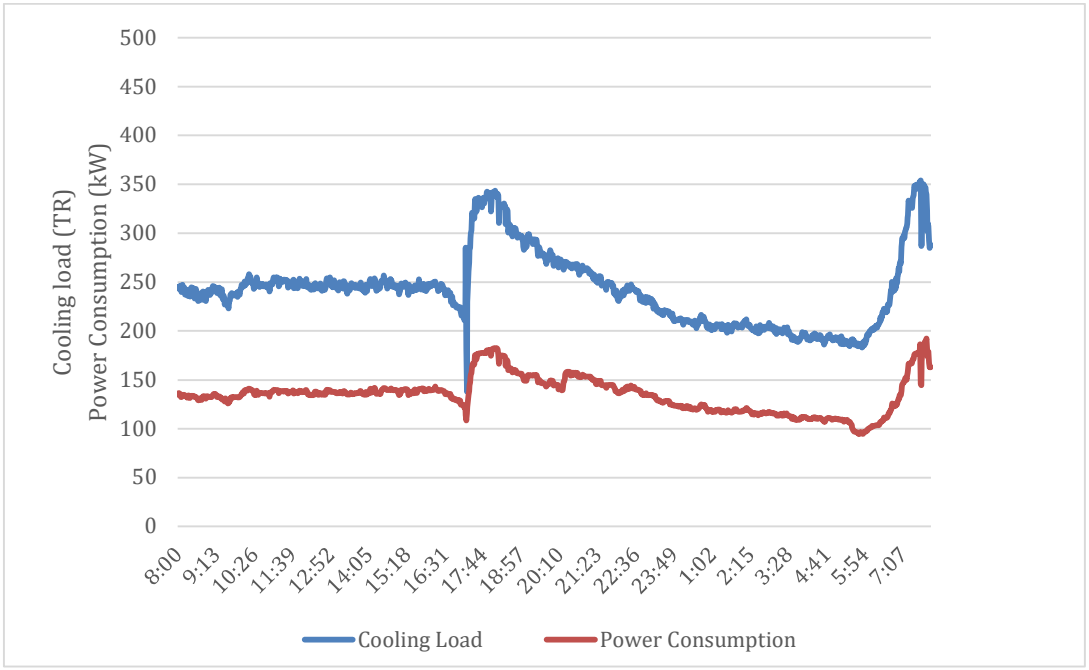

500
450
400
350
300
250
200
150
100
50
0
Cooling load (TR)
Power Consumption (kW)
8:00
9:16
10:32
11:48
13:04
14:20
15:36
16:52
18:08
19:24
20:40
21:56
23:12
0:28
1:44
3:00
4:16
5:32
6:48
Cooling Load
Power Consumption

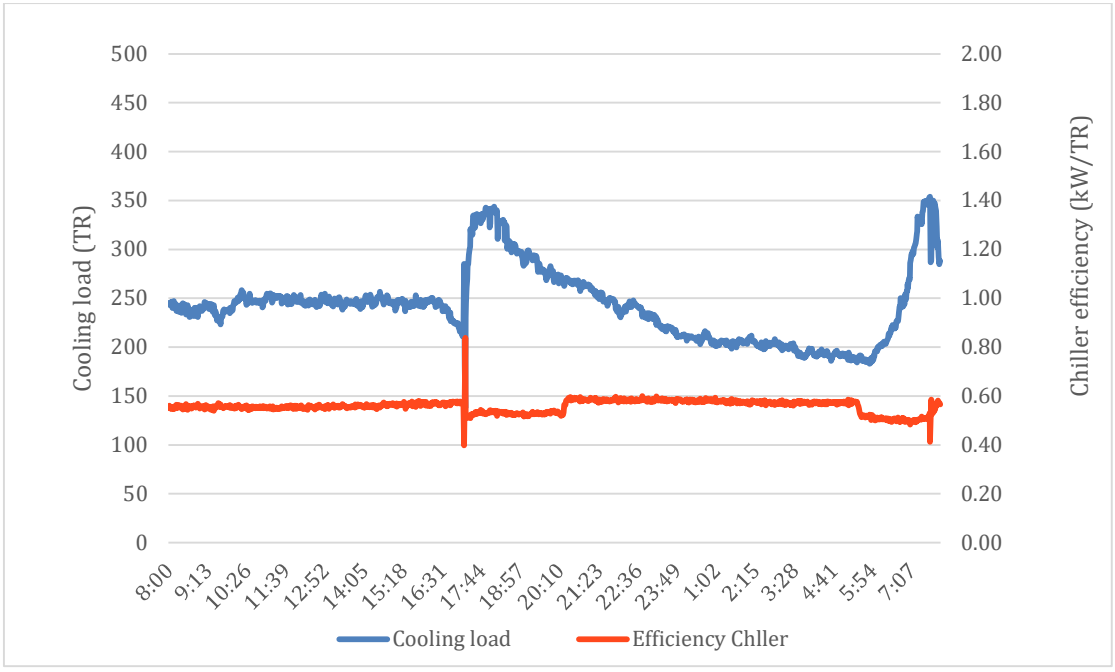

500
450
400
350
300
250
200
150
100
50
0
Cooling load (TR)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Chiller efficiency (kW/TR)
8:00
9:16
10:32
11:48
13:04
14:20
15:36
16:52
18:08
19:24
20:40
21:56
23:12
0:28
1:44
3:00
4:16
5:32
6:48
Cooling load
Efficiency Chller

3.15 Data Analysis Chiller No.2

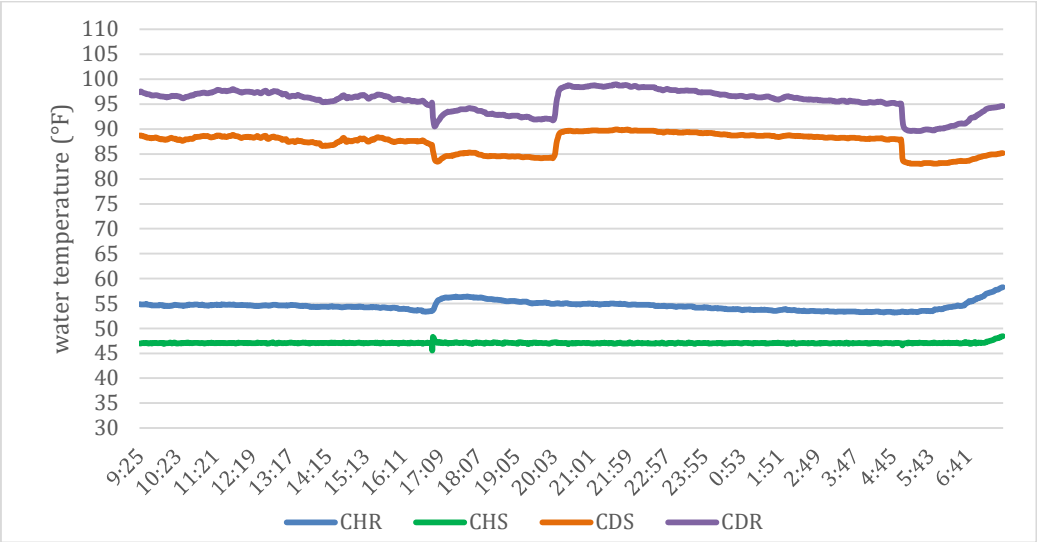


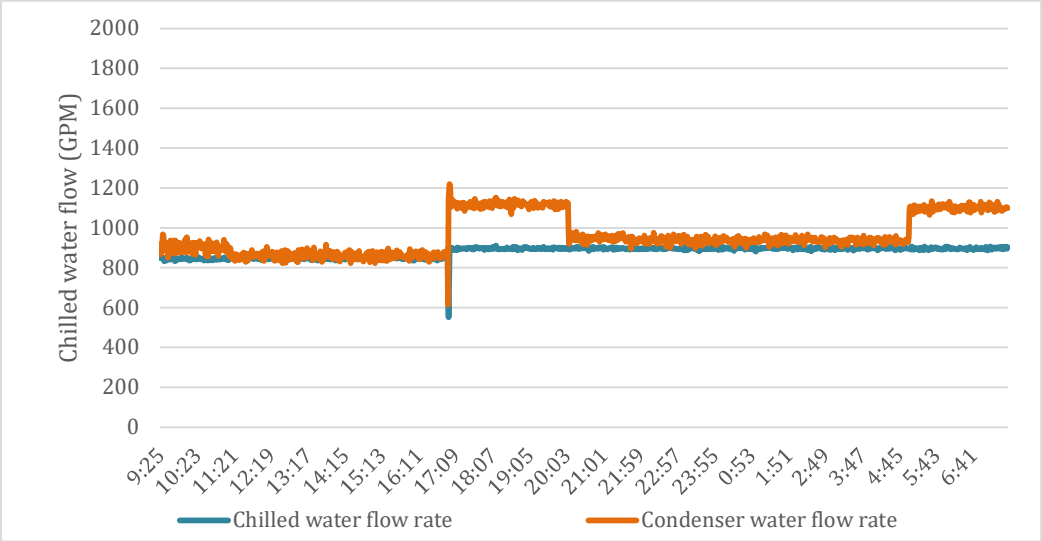


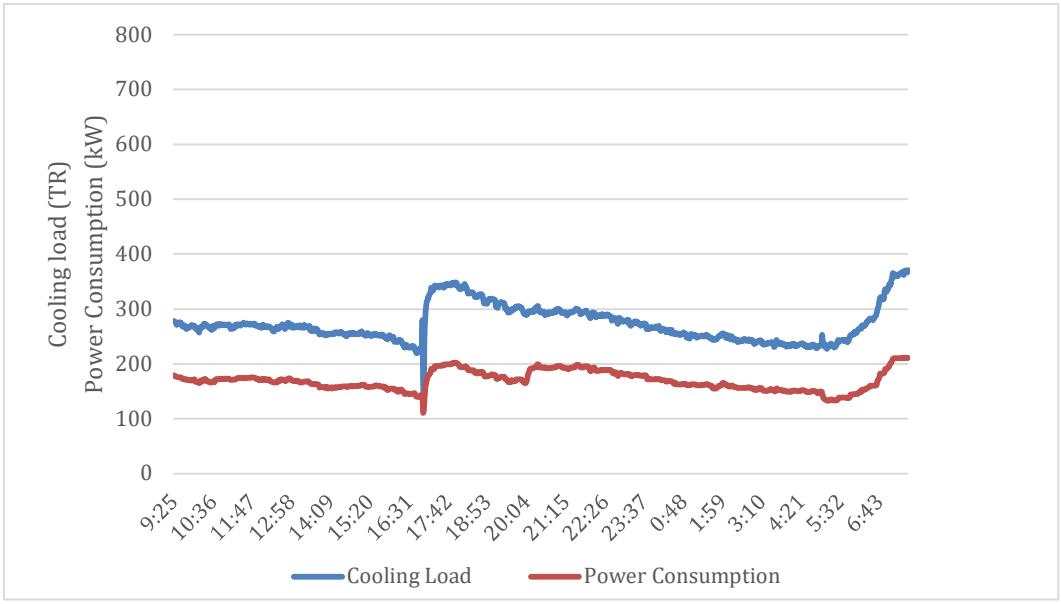

Cooling load (TR)
Power Consumption (kW)
500
450
400
350
300
250
200
150
100
50
0
8:00
9:13
10:26
11:39
12:52
14:05
15:18
16:31
17:44
18:57
20:10
21:23
22:36
23:49
1:02
2:15
3:28
4:41
5:54
7:07
Cooling Load
Power Consumption

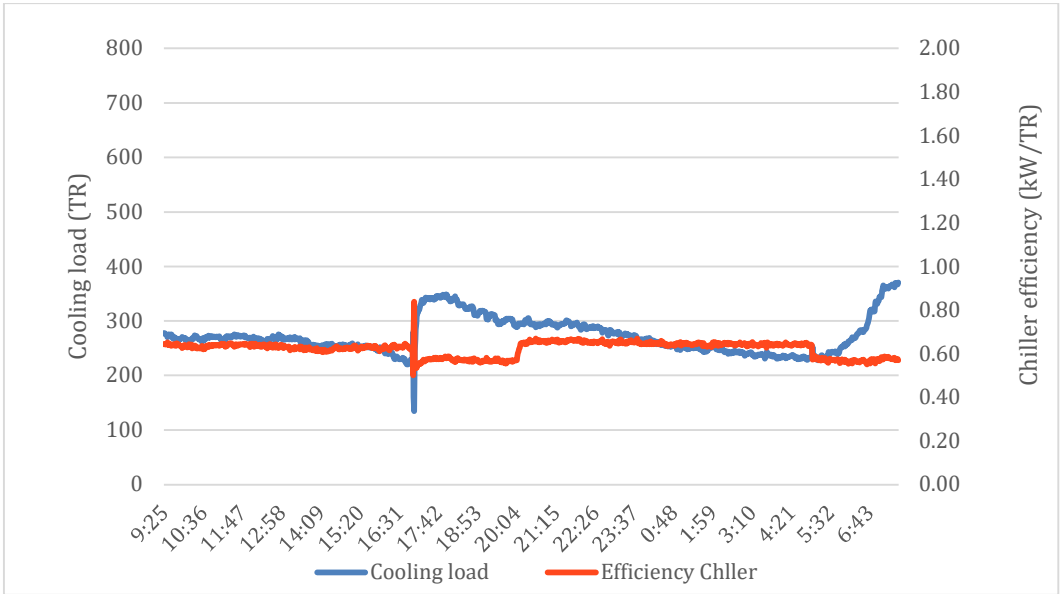

Cooling load (TR)
Chiller efficiency (kW/TR)
500
450
400
350
300
250
200
150
100
50
0
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
8:00
9:13
10:26
11:39
12:52
14:05
15:18
16:31
17:44
18:57
20:10
21:23
22:36
23:49
1:02
2:15
3:28
4:41
5:54
7:07
Cooling load
Efficiency Chller

3.15 Data Analysis Chiller No.3






800
700
600
500
400
300
200
100
0
Cooling load (TR)
Power Consumption (kW)
9:25
10:36
11:47
12:58
14:09
15:20
16:31
17:42
18:53
20:04
21:15
22:26
23:37
0:48
1:59
3:10
4:21
5:32
6:43
Cooling Load
Power Consumption


800
700
600
500
400
300
200
100
0
Cooling load (TR)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Chiller efficiency (kW/TR)
9:25
10:36
11:47
12:58
14:09
15:20
16:31
17:42
18:53
20:04
21:15
22:26
23:37
0:48
1:59
3:10
4:21
5:32
6:43
Cooling load
Efficiency Chller

4 PERFORMANCE BREAKDOWN

Based on the component's efficiency, the chillers, pumps cooling tower and plant efficiency can be calculated as below:

DESCRIPTION	**SEPARATE-MEASURED EFFICIENCY** (kW/RT)	**HIGH PERFORMANCE BUILDING BENCHMARK** (kW/RT)
SYSTEM	0.757[1]	≤ 0.750[2]
CHs	0.562	0.55 or better
CHWP	0.195	≤ 0.10 @ Max 50ft Head
CDWP		≤ 0.10 @ Max 50ft Head
CTs		0.015

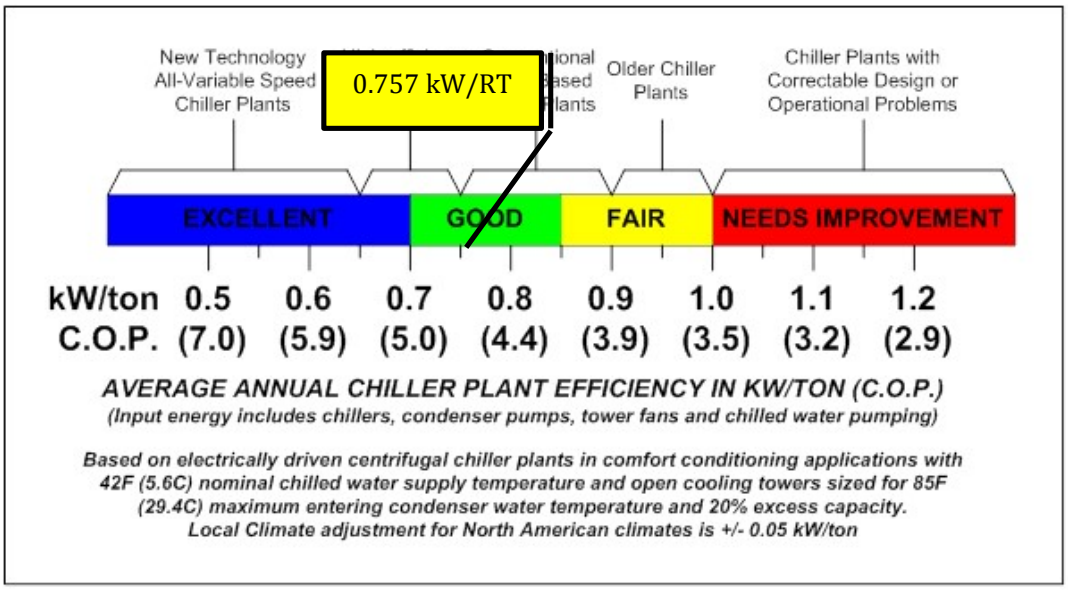
[1] System efficiency during chillers in operation approximately 00:00 – 23:59
[2] Minimum requirement for a Singapore Green Mark-certified project

5 Measurement Summary

5.1 BASELINE ESTABLISHMENT

With the audit result, the energy consumption for Chiller Plant is established as below:

The existing chiller plant is operating with an overall system efficiency of 0.757 kW/RT,
This is 8.14% worse than the minimum “Excellent” ASHRAE rating.



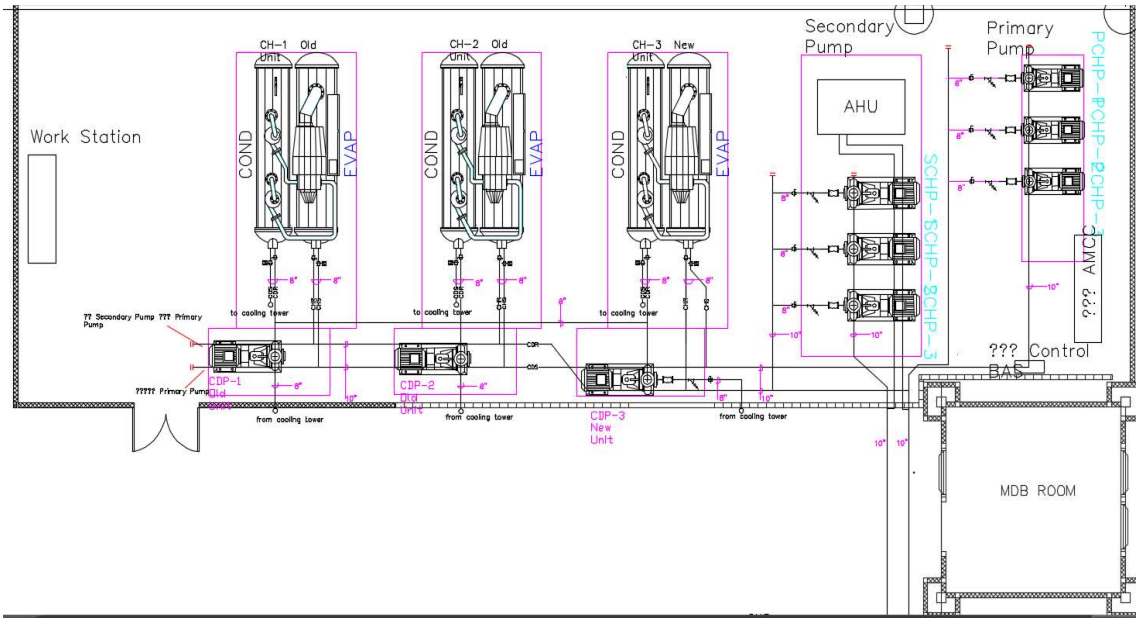
6 Conclusion

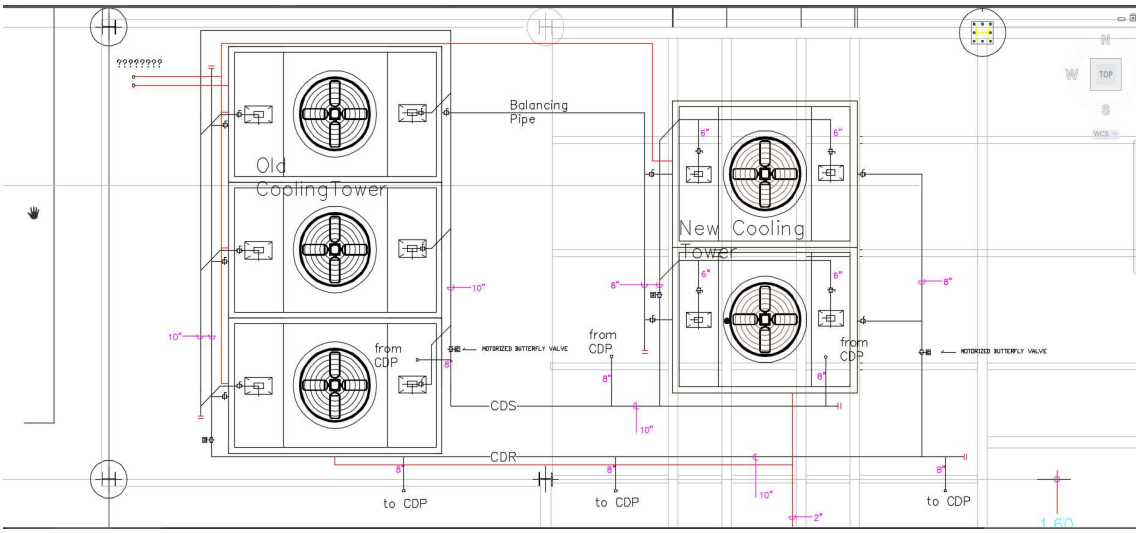
- The existing chiller plant is operating at a fair system efficiency of 0.757 kW/RT.

(**Chiller plant is still good due to higher than 45 °F (7.22 °C) chilled water supply setting)

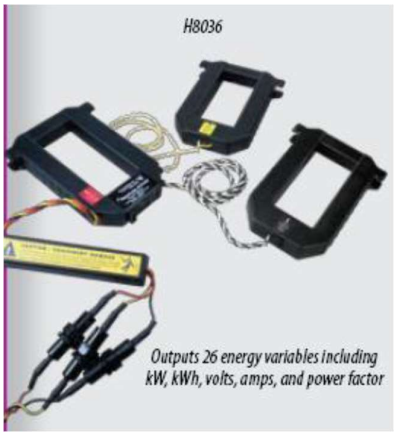
- The plant was observed to be operated manually. All pumps have VSDs with fixed speed and cooling tower have no VSDs.
- Recommend undertaking a detailed chilled and condenser water hydronic study to better understand how to best optimize the pumping system.
- To improve plant efficiency, Convert from constant flow arrangement to variable flow arrangement.
- Equipped VSD for pump & Cooling tower.
- Pressure differential at remoted FCU/AHU to variable speed of CHWP
- Operate 5 cooling tower fans with low speed to save energy.
- Installing a permanent measurement and verification system and a feedback-based controls to optimize the chiller plant system efficiency (CPMS).

APPENDIX A:
INSTRUMENTATION LAYOUT


Work Station
CH-1 Old Unit
CH-2 Old Unit
CH-3 New Unit
COND
EVAP
Secondary Pump
Primary Pump
AHU
SCHP-1
SCHP-2
SCHP-3
PCHP-1
PCHP-2
PCHP-3
??? AMCC
??? Control BAS
MDB ROOM
?? Secondary Pump ??? Primary Pump
????? Primary Pump
CDP-1
CDP-2
CDP-3
from cooling tower

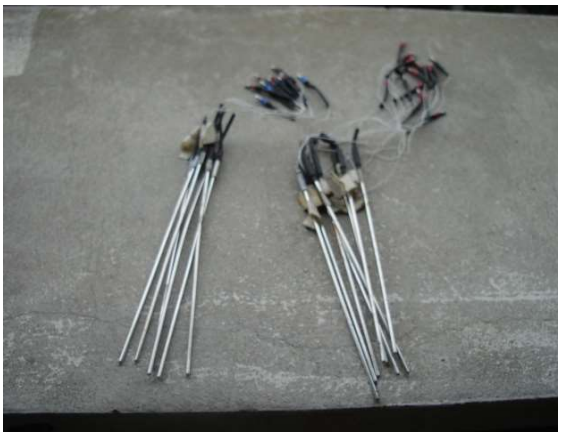

Old Cooling Tower
New Cooling Tower
Balancing Pipe
from CDP
MOTORIZED BUTTERFLY VALVE
CDS
CDR
to CDP

Agilent Data Logger



H8036 Series Power Meter

GE Ultrasonic Flow Meter



Betatherm Thermistor