Building and Construction Authority

CODE ON
PERIODIC ENERGY AUDIT
OF
BUILDING COOLING SYSTEM

2.00 Edition

History of amendments

S/N	Brief description of changes	Revision date
1	Edition 1.0 –first issue	1st July 2013
2	Edition 1.01 –first revision Revision to Section 6.1 Minimum OSE Standards for Energy Audit Submission New paragraph 6.1.2.1 added, to include the minimum OSE compliance standards for buildings that is on land within areas stipulated under the 1st and 2nd schedules to the BC (Environmental Sustainability) Regulations 2008	1st April 2014
3	Edition 2.00 - second revision Revision to Introduction - Updated Building Control (Environmental Sustainability Measures for Existing Buildings) (Amended) Regulations 2016. Revision to Section 1 Scope - Added in the list of buildings excluded: Data centres, Religious buildings, Utility buildings; and removed service apartments from the list. Revision to Section 4.1 - Paragraph 4.1.3 changed sentence: “It is only applicable for water-cooled condensers.” to “It is only applicable for water-cooled chiller system.” Revision to Section 5.4 - Combined paragraph 5.4.1 and 5.4.2, to include as supporting documents to be submitted via e-corenet and included Chiller(s) part load performance (at 10% interval from 100% to minimum value) from equipment supplier at operating conditions. Revision to Section 6.1 - Paragraph 6.1.3 changed from taking the largest aggregate cooling capacity of a combination of water cooled and air cooled chilled water plant to the weighted average of the air conditioning systems; and Table 6.1.4 added hospital’s operating hours Revision to Section 6.2 - Footnote 1 under 6.2.7 included VSD and harmonic filter losses where applicable; and Revision to Annex A – Included harmonic filter losses (where applicable) for Plant A/B/C under Note. The key changes to Annex B include:	1st July 2016

	a) Added Building Address and Image; and PE/Energy Auditor signature on front cover b) New Section on Executive Summary & Recommendation c) Under building information, included paragraph for number of guest rooms for hotel/service apartment d) Under Chilled Water Plant Design information, added EWT to Table column heading "Chilled water LWT/EWT" e) New Paragraph on Description of Plant Control Strategy f) Updated table of instrumentations to include brand and calibration laboratory g) Chiller Plant Performance Analysis to show 1 week data and added various figures h) Updated Summary of Chilled Water Plant Operating Performance table to include operating condition of chilled water plant i) New Section on Schedule of space operating conditions j) New Appendix on Checklist of Plant Operating Condition (for best practices)		

Contents

INTRODUCTION

The requirements governing the Periodic Energy Audit of Building cooling systems are stipulated in Part IIIB of the Building Control Act and the Building Control (Environmental Sustainability Measures for Existing Buildings) (Amended) Regulations 2016.

The intent of the Code on Periodic Energy Audit of Building Cooling Systems (referred to as “Energy Audit Code’’) is to ensure that building cooling systems are audited to meet minimum system efficiency and continue to be operated efficiently throughout its life cycles.

The Energy Audit Code is not intended to abridge safety, health, environmental or related requirements contained in other applicable laws, codes or policies administered by relevant authorities. Where there is a conflict between the requirements of the Energy Audit Code and other requirements affecting the design, construction or operation of the Chilled Water Plant in the building cooling systems, precedence shall be determined by the relevant authorities, where required.

The contents of the Energy Audit Code are protected by copyright and other forms of proprietary rights. All rights, title and interest in the contents are owned by, licensed to or controlled by BCA and shall not be reproduced, republished, uploaded, posted, transmitted or otherwise distributed in any way, without the prior written permission of BCA. Modification of any of the contents or use of the contents for any other purpose will be a violation of BCA's copyright and other intellectual property rights.

1. SCOPE

The Energy Audit Code sets out the requirements relating to the submission of Energy Audits. The Code also specifies the qualification and experience requirements for registration and renewal as an Energy Auditor with BCA.

The provisions of the Energy Audit Code shall apply to:-

(a) Existing buildings that have undergone Major Energy Use Change; and

(b) New buildings that have applied for planning permission on or after 1 December 2010.

The following building types shall not be covered under the Energy Audit Code:

a) Data centres;

b) Religious buildings;

c) Residential buildings (other than service apartments);

d) Utility buildings;

e) Industrial buildings;

f) Railway premises;

g) Port services and facilities; and

h) Airport services and facilities.

The reference codes, standards and other documents referred in the Energy Audit Code shall be considered part of the requirements of the Energy Audit Code to the extent as prescribed.

2. DEFINITIONS

For the purpose of the Energy Audit Code, the following definitions shall apply:

BC Act	Building Control Act (Chapter 29)
BCA	Building and Construction Authority
Chilled Water Plant	centralised air conditioning system which makes use of chilled water as the medium for removing the heat from the building. This includes the chillers and its ancillary equipment, including pumps and cooling towers where applicable.

Energy Audit	An audit on the Operating System Efficiency of a Chilled Water Plant.
Energy Audit Report	The report of the Energy Audit in the format prescribed in Annex B to the Energy Audit Code.
Energy Auditor	A competent person registered with BCA to conduct the Energy Audit.
Minimum Green Mark Score	The minimum standard of environmental sustainability applicable to that building, expressed in terms of a Green Mark score.
Major Energy Use Change	The installation, substantial alteration or replacement of a/the Water-Cooled/Air-cooled Chiller(s).
Notice	The notice served on the building owner by the Commissioner of Building Control requiring an Energy Audit to be carried out.
Operating System Efficiency (OSE)	The measured system efficiency of the building's Chilled Water Plant during its normal operating hours.
PE(Mech)	a person who is registered under the Professional Engineers Act (Cap. 253) in the mechanical engineering discipline and who has in force a practising certificate issued under that Act authorising him to engage in mechanical engineering work.
Regulations	The Building Control (Environmental Sustainability Measures for Existing Buildings) Regulations 2013
2008 Regulations	Building Control (Environmental Sustainability) Regulations 2008

In instances where terms are not expressly stated in the Energy Audit Code and are defined in other referenced documents, such terms shall have the meanings as determined in those documents.

3. STATUTORY REQUIREMENTS

3.1 Act and Regulations

The following Act and Regulations have relevance:

a. BC Act; and

b. Regulations.

3.2 Referenced Codes and Standards

The following codes and standards have relevance:

a. Code for Environmental Sustainability for Buildings (2nd Edition); and

b. Code on Environmental Sustainability Measures for Existing Buildings (1st Edition)

3.3 Responsibility

Upon receiving the Notice, the building owner shall engage a PE(Mech) or a Energy Auditor registered with BCA, to ensure that the periodic Energy Audit is carried out in accordance with the BC Act, the Regulations and the requirements set out in the Energy Audit Code. The building owner shall ensure that the OSE meets the minimum energy efficiency standard (referred to as “Minimum OSE”) stipulated in section 6 of the Energy Audit Code and he/she shall undertake further measures within the time frame specified in the Notice to meet the Minimum OSE if the Energy Audit reveals otherwise.

The building owner shall submit the Energy Audit Report prepared by the PE(Mech)/ Energy Auditor in the format prescribed in the Energy Audit Code.

4. COMPLIANCE METHOD

4.1 Operating System Efficiency

4.1.1 The OSE of the Chilled Water Plant shall be determined by the energy audit methodology specified in section 6 of the Energy Audit Code.

4.1.2 The data required for the determination of the OSE shall be obtained from the permanent instrumentations installed in compliance with the Code for Environmental Sustainability of Buildings (2nd Edition and onwards) or the Code on Environmental Sustainability Measures for Existing Buildings that is prevailing at the time of installation.

4.1.3 The heat balance substantiating test is used to determine the quality of the measurements i.e. the uncertainty, installation and position of the instruments is within the prescribed tolerance and requirements of the instrumentations as specified in the Energy Audit Code. It is only applicable for water-cooled chiller system.

5. SUBMISSION PROCEDURES

5.1. General

Building owners will receive a Notice from BCA notifying them that the submission of the Energy Audit is required. Upon receiving the Notice, the building owner shall appoint PE(Mech)/Energy Auditor to submit the Energy Audit Report within the timeframe specified in the Notice. BCA will issue Notice of Approval if the submission of Energy Audit Report is in order.

5.2 For buildings complying with the Code on Environmental Sustainability Measures for Existing Buildings

5.2.1 BCA may serve the 1st Notice to the building owner to submit the Energy Audit Report not less than 36 months from the date of the Notice of Approval of the as-built score.

5.2.2 PE(Mech)/Energy Auditor shall complete and submit the Form BCA-EB-OSE01 (Application for Approval of Operating System Efficiency of Building Cooling Systems) with supporting documents electronically via CORENET e-submission system.

5.2.3 The building owner may be served each subsequent Notice not less than 36 months from the date of the last Notice, for subsequent Energy Audit submissions.

5.3 For buildings complying with the Code for Environmental Sustainability for Buildings (from 2nd Edition)

5.3.1 BCA may serve the 1st Notice to the building owner to submit the Energy Audit Report any time after issuance of Temporary Occupation Permit (referred to as ''TOP'') or Certificate of Statutory Completion (referred to as ''CSC''), if no TOP is issued. PE(Mech)/Energy Auditor shall complete and submit the Form BCA-EB-OSE01 with supporting documents electronically via CORENET e-submission system.

5.3.2 The building owner may be served each subsequent Notice not less than 36 months from the date of the last Notice, for subsequent Energy Audit submissions.

5.4 Documentary Evidence

5.4.1 The building owner and the PE(Mech)/Energy Auditor shall submit the following supporting documents electronically via CORENET e-submission system:-

- Scanned copy of BCA's notice for the submission of the Energy Audit in pdf format
- As-built drawings of chiller plant room plan layout indicating details of instruments locations
- As-built schematic drawings of the chiller plant
- 1 week raw data of the following data points in excel format (xls.) with date and time stamp: chilled water supply temperature (°C); chilled water return temperature (°C); condenser water supply temperature (°C); condenser water return temperature (°C); chilled water flow rate (l/s); condenser water flow rate (l/s); electrical power of chiller(s), chilled water pump(s), condenser water pump(s) & cooling tower(s) (kW). The excel file should include all the chart plots specified in Annex B.
- Energy Audit Report in accordance to ANNEX B
- Instruments' calibration certificates from the accredited laboratories and their factory calibration certificates from manufacturers.
- Drawings showing the details of instruments installation
- All input parameters for the permanent instrumentations (e.g. flow meter settings for pipe material, diameter, circumference, thickness, roughness, type of lining etc.)
- Calculation of the overall uncertainty of measurement of the resultant chiller plant in kW/RT to be within ±5% of the true value based on instrumentation specifications and calibration certificates.

1) for central chilled water system; and

2) for individual chillers (if instrumentation are installed at individual chillers and header/risers)

- Chiller(s) part load performance (at 10% interval from 100% to minimum value) from equipment supplier at operating conditions.

5.5 Registration and Renewal of Registration of Energy Auditor – Qualifications and Experience

5.5.1 An individual shall be eligible to be registered as an Energy Auditor with BCA under Section 22FG of the BC Act if he holds the following qualifications:

i. Possess at least an engineering or a building-related undergraduate degree in architecture, building science, facility management, or sustainable building design, or any equivalent professional qualification acceptable by the Commissioner of Building Control; and

ii. Have at least 3 years of relevant practical experience in central air-conditioning design and installation, or operation; and

iii. Completed 2 ASHRAE Level III Energy Audits or 3 Periodic Energy Audits on Building Cooling Systems under the supervision of a PE(Mechanical) or BCA registered Energy Auditor respectively; and

iv. Passed the interview and/or exam by the Energy Auditor Committee.

5.5.2 For the purpose of ascertaining whether an individual is capable of carrying out the duties of an Energy Auditor, the Commissioner of Building Control shall decide based on the recommendations provided by the Energy Auditor Registration Committee appointed by him. An application to be registered as an Energy Auditor can be made using the Application Form BCA-EAS-APL which can be either obtained in hardcopy forms or downloaded from http://www.bca.gov.sg. All applications must be accompanied with a fully completed form, supporting certificates and evidence of related work experiences as specified in the form.

5.5.3 The registration as an Energy Auditor shall be valid for 3 years, and each renewal of the registration shall also be valid for 3 years. Application for renewal of registration can be made using the Application Form BCA-EAS-RAPL which can either be obtained in hardcopy forms or downloaded from http://www.bca.sg. All applications must be accompanied with a fully completed form, supporting certificates and evidence of related work experiences as specified in the form and renewal fee.

6. ENERGY AUDIT METHODOLOGY FOR CHILLERS

6.1 Minimum OSE Standards for Energy Audit Submission

6.1.1 This section is for buildings that have undergone major energy-use change under Part IIIB of the BC Act and are required to comply with the Code on Environmental Sustainability Measures for Existing Buildings.

Water Cooled Chilled-Water Plant

Baseline	Building Cooling Load	
	< 500RT	≥500RT
Minimum OSE (kW/RT)	0.85	0.75

Air Cooled Chilled-Water Plant/ Unitary Air conditioners

Baseline	Building Cooling Load	
	< 500RT	≥500RT
Minimum OSE(kW/RT)	1.1	1.0

6.1.2 This section is for buildings subject to the 2008 Regulations and where the applications for planning permission were submitted to the competent authority under the Planning Act (Cap. 232) on or after 1st December 2010.

6.1.2.1 This subsection shall apply to the whole or part of any building that is on land within areas stipulated under the First and Second Schedules to the 2008 Regulations (and such other schedules to the 2008 Regulations as gazetted from time to time). The minimum OSE standard is as listed below and is based on requirements listed in the First and Second Schedules to the 2008 Regulations (and such other schedules to the 2008 Regulations as gazetted from time to time).

Water Cooled Chilled-Water Plant

Baseline	Building Cooling Load	
	< 500RT	≥500RT
Minimum OSE(kW/RT) - Gold^{plus} - Platinum	 0.7 0.7	 0.65 0.65

Air Cooled Chilled-Water Plant

Baseline	Building Cooling Load	
	< 500RT	≥500RT
Minimum OSE(kW/RT) - Gold^{plus} - Platinum	0.85 0.78	Not applicable

6.1.2.2 This subsection shall apply to all other buildings. The minimum OSE standard is as listed below.

Water Cooled Chilled-Water Plant

Baseline	Building Cooling Load	
	< 500RT	≥500RT
Minimum OSE(kW/RT)	0.8	0.7

Air Cooled Chilled-Water Plant

Baseline	Building Cooling Load	
	< 500RT	≥500RT
Minimum OSE(kW/RT)	0.9	0.8

6.1.3 Where there is a combination of water cooled and air cooled Chilled Water Plant, the minimum OSE shall be based on the weighted average of the air conditioning system.

6.1.4 The Energy Audit shall be carried out over the normal operating hours for the various categories of buildings as defined below. The data required to establish the OSE shall be sampled and acquired simultaneously and continuously for a minimum of one (1) week at one (1) minute interval.

Office Buildings:	Hotels/Hospitals:
▪ Monday to Friday: 9am to 6pm **Retail Malls:** ▪ Monday to Sunday: 10am to 9pm	▪ Monday to Sunday: 24 hours **Other building types:** ▪ To be determined based on the operating hours

6.2 Heat Balance Substantiating Test

6.2.1 Verification of the OSE shall be by computing the system heat balance of the water-cooled Chilled Water Plant in accordance with AHRI 550/590 to the extent as prescribed.

Note: For air-cooled Chilled Water Plant, heat balance requirements will not be applicable.

6.2.2 The heat balance shall be computed over the entire normal operating hours as defined in clause 6.1.4 with more than 80% of the computed heat balance within 5% over a one (1) week period.

6.2.3 For a perfectly balanced chiller system, the heat balance can be represented by,

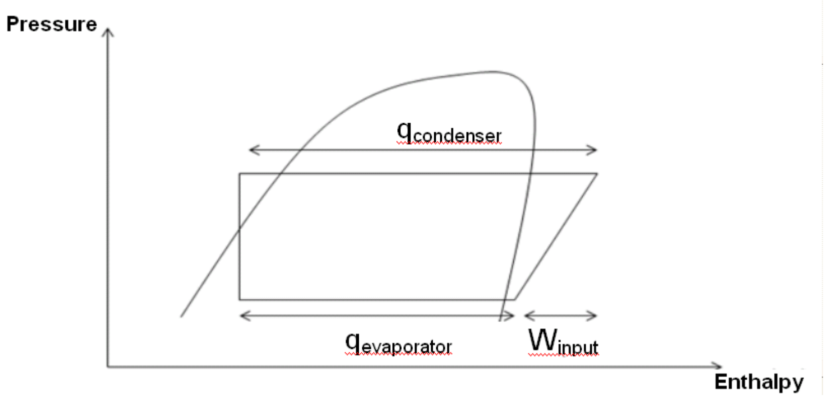
$$q_{condenser} = q_{evaporator} + W_{input}.$$

where $q_{condenser}$ = heat rejected by condenser, kW

$q_{evaporator}$ = heat gain in evaporator, kW

W_{input} = power input to compressor, kW

6.2.4 The pressure enthalpy diagram below shows the concept of a heat balance equation in a vapour compression cycle.



Pressure Enthalpy Chart

6.2.5 The system heat balance of the Chilled Water Plant shall be computed using the formula stated below over the normal operating hours,

$$\text{Percent Heat Balance} = \left| \frac{(q_{evaporator} + W_{input}) - q_{condenser}}{q_{condenser}} \right| \times 100\% \le 5\%$$

6.2.6 For open drive chillers, the W_{input} shall take into account the motor efficiency provided by the manufacturer. An example is provided as follows:

Input power to motor (measured)	= 100 kW
Motor rated efficiency (η)	= 90%
Adjusted power input to compressor W_{input}	= 100 kW x 90%
	= 90 kW

6.2.7 Where hydraulic losses of pumps constitute a substantial heat gain, these losses could be accounted for. The values shall be determined from motor efficiency and pump efficiency values provided by the manufacturer. Examples are illustrated as follows:

(a) **For chilled water pump(s) adjustment,**

Motor input power (measured)	= 30 kW	(A)
Motor rated efficiency (η)	= 90%	(B)
Pump rated efficiency (η)	= 80%	(C)
Hydraulic losses[1]	= (A) x (B) x [(100% – (C)]	
	= 30kW x 90% x (100% - 80%)	
	= 5.4 kW	
Adjusted total input power W_{input}	= kW_i (chillers) + 5.4kW	

Where kW_i (chillers) = adjusted power input to compressor, kW

(b) **For condenser water pump(s) adjustment,**

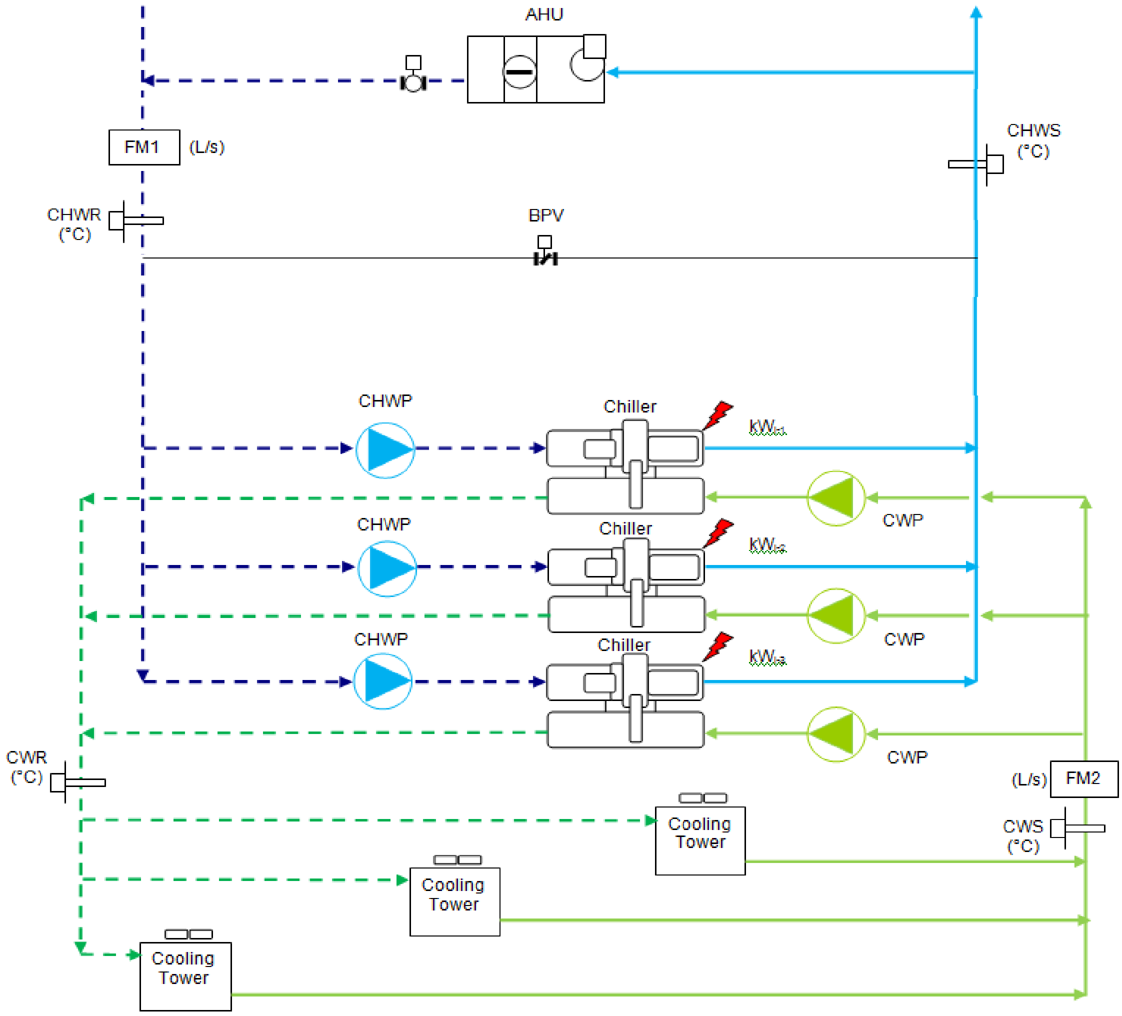
Motor input power (measured)	= 20 kW	(A)
Motor rated efficiency (η)	= 90%	(B)
Pump rated efficiency (η)	= 80%	(C)

Hydraulic losses[1]	= (A) x (B) x [(100% – (C)]
	= 20kW x 90% x (100% - 80%)
	= 3.6 kW
Adjusted $q_{condenser(adj)}$	= $q_{condenser}$ - 3.6kW

[1] For equipment with VSD, the equation shall include variable speed drive losses, harmonic filter losses (where applicable).

ANNEX A - Determining Heat Balance for Different Plant Configuration

Plant A – Constant Primary Chilled-Water System



A: $q_{evaporator}$ = m x Cp x ΔT = FM1 x Cp x (CHWR - CHWS)

B: $q_{condenser}$ = m x Cp x ΔT = FM2 x Cp x (CWR - CWS)

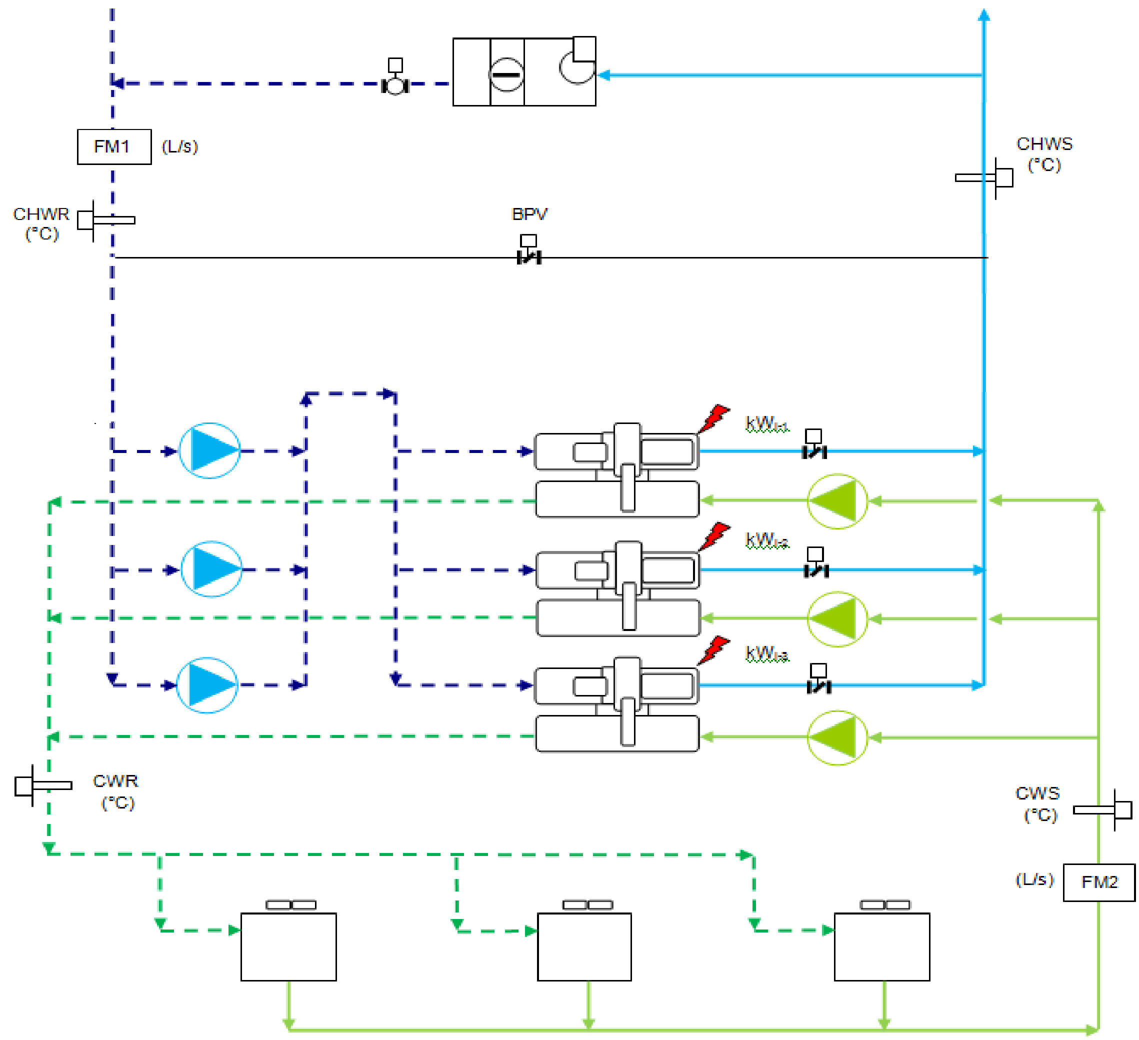
C: W_{input} = $kW_{i\text{-}1}$ + $kWi_{\text{-}2}$ + $kWi_{\text{-}3}$

where Cp = 4.19 kJ/kg °C & density of water is assumed to be 1kg/L

Percent heat balance = [(A + C) – B] / B x 100%

Note : Hydraulic losses of pumps constituting substantial heat gain, $W_{input}/q_{condenser}$ may be adjusted to account for these additional heat gains. The values shall be determined from variable speed drive losses, harmonic filter losses (where applicable), motor efficiency and pump efficiency values certified by the manufacturer.

Plant B – Variable Primary Chilled-Water System



A: $q_{evaporator}$ = FM1 x Cp x (CHWR - CHWS)

B: $q_{condenser}$ = FM2 x Cp x (CWR - CWS)

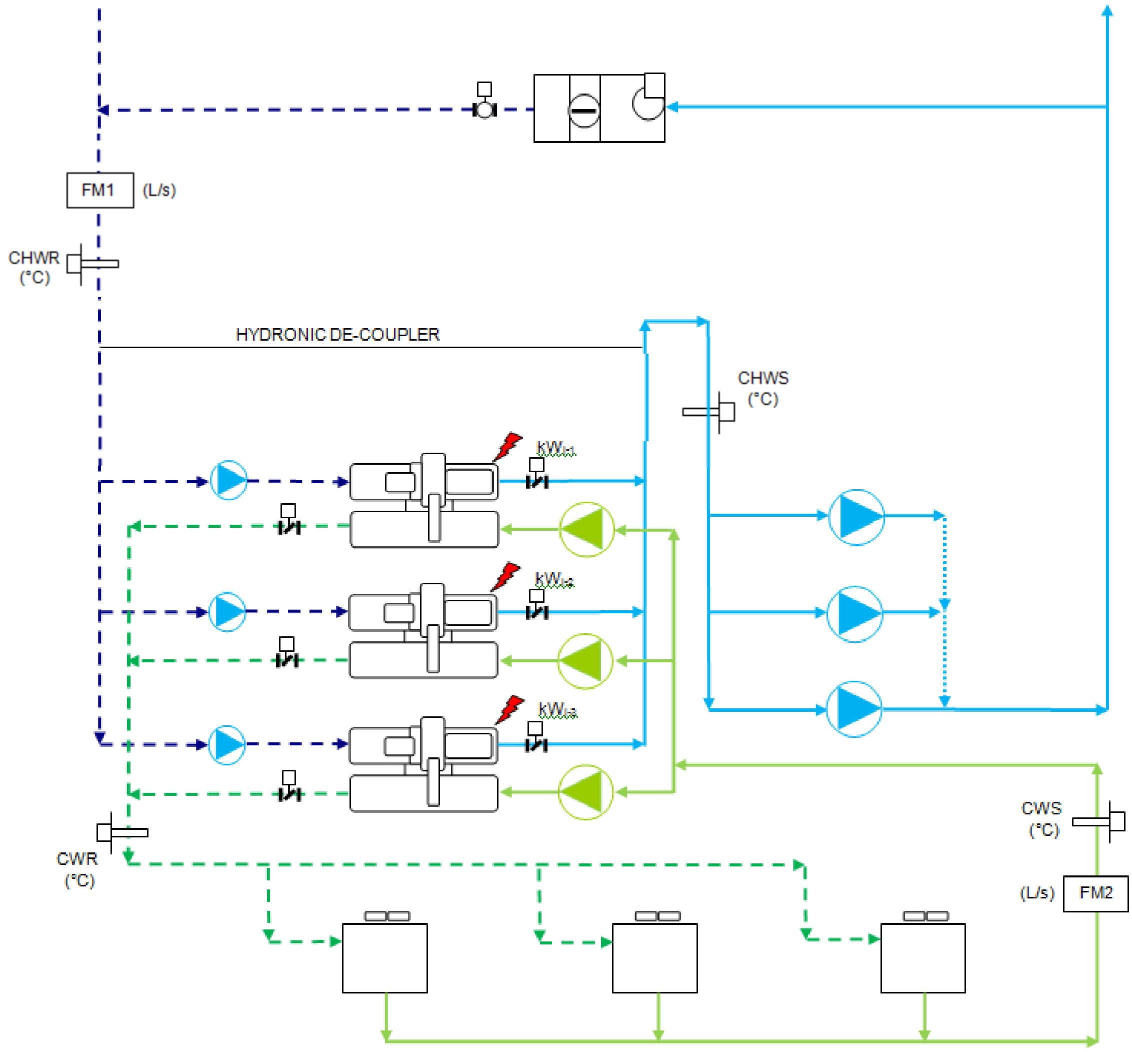
C: W_{input} = $kW_{i\text{-}1} + kW_{i\text{-}2} + kW_{i\text{-}3}$

where Cp = 4.19 kJ/kg °C & density of water is assumed to be 1kg/L

Percent heat balance = [(A + C) – B] / B x 100%

Note: In the event where hydraulic losses of pumps constitute substantial heat gain, $W_{input}/q_{condenser}$ may be adjusted to account for these additional heat gains. The value shall be determined from variable speed drive losses, harmonic filter losses (where applicable), motor efficiency and pump efficiency values certified by the manufacturer.

Plant C – Constant Primary & Variable Secondary Chilled-Water System



A: $q_{evaporator}$ = FM1 x Cp x (CHWR – CHWS)

B: $q_{condenser}$ = FM2 x Cp x (CWR - CWS)

C: W_{input} = kW_{i-1} + kW_{i-2} + kW_{i-3}

where Cp = 4.19 kJ/kg °C & density of water is assumed to be 1kg/L

Percent heat balance = [(A + C) – B] / B x 100%

Note: In the event where hydraulic losses of pumps constitute a substantial heat gain, these losses have to be properly accounted for. The value shall be determined from variable speed drive losses, harmonic filter losses (where applicable) and pump efficiency values certified by the manufacturer.

The following example illustrates a successful heat balance where 80% of the computed heat balance falls within ± 5% as required.

	(a) Chilled water supply temperature	(b) Chilled water return temperature	(c) Chilled water flow rate	(d) Condenser water supply temperature	(e) Condenser water return temperature	(f) Condenser water flow rate	(g) Chiller kWe	(h) Heat Gain	(i) Heat Rejected	(j) Percent Heat Balance
dd/mm/yyyy hh:mm	**°C**	**°C**	**L/s**	**°C**	**°C**	**L/s**	**kW**	**RT**	**RT**	**%**
16/6/2012 15:00	6.70	12.60	84.10	29.4	35.5	97.65	308	591.14	709.65	-4.36
16/6/2012 15:01	6.71	12.50	84.20	29.5	35.4	97.60	309	580.81	686.03	-2.53
16/6/2012 15:02	6.72	12.30	84.30	29.6	35.3	97.55	310	560.41	662.44	-2.10
16/6/2012 15:03	6.73	12.10	84.20	29.7	35.2	97.50	311	538.68	638.86	-1.84
16/6/2012 15:04	6.74	12.20	84.10	29.8	35.1	97.55	312	547.05	615.95	3.22
16/6/2012 15:05	6.75	12.00	84.00	29.9	35	97.60	311	525.39	593.01	3.51
16/6/2012 15:06	6.74	12.30	84.10	29.8	35.1	97.65	310	557.07	616.58	4.64
16/6/2012 15:07	6.73	12.10	84.20	29.7	35.2	97.60	309	538.68	639.52	-2.03
16/6/2012 15:08	6.72	12.10	84.30	29.6	35.3	97.55	308	540.32	662.44	-5.21
16/6/2012 15:09	6.71	12.20	84.20	29.5	35.4	97.50	309	550.71	685.33	-6.82
16/6/2012 15:10	6.70	12.40	84.10	29.4	35.2	97.55	310	571.10	674.06	-2.20
16/6/2012 15:11	6.70	12.60	84.10	29.4	35.5	97.65	308	591.14	709.65	-4.36
16/6/2012 15:12	6.71	12.50	84.20	29.5	35.4	97.60	309	580.81	686.03	-2.53
16/6/2012 15:13	6.72	12.30	84.30	29.6	35.3	97.55	310	560.41	662.44	-2.10
16/6/2012 15:14	6.73	12.10	84.20	29.7	35.2	97.50	311	538.68	638.86	-1.84
16/6/2012 15:15	6.74	12.20	84.10	29.8	35.1	97.55	312	547.05	615.95	3.22
16/6/2012 15:16	6.75	12.00	84.00	29.9	35	97.60	311	525.39	593.01	3.51
16/6/2012 15:17	6.74	12.30	84.10	29.8	35.1	97.65	310	557.07	616.58	4.64
16/6/2012 15:18	6.73	12.10	84.20	29.7	35.2	97.60	309	538.68	639.52	-2.03
16/6/2012 15:19	6.72	12.10	84.30	29.6	35.3	97.55	308	540.32	662.44	-5.21
16/6/2012 15:20	6.71	12.20	84.20	29.5	35.4	97.50	309	550.71	685.33	-6.82
16/6/2012 15:21	6.70	12.40	84.10	29.4	35.2	97.55	310	571.10	674.06	-2.20
Total							**6814**	**12,202.71**	**14,367.72**	**32.36**
									Total data count	**22**
									Data Count > +5% error	**0**
									Data Count < -5% error	**4**
									Percentage of heat balance within ± 5%	**82%**

Heat Gain (h) $= m \times Cp \times \Delta T = (c) \times 4.19\text{kJ/kg}\,^{o}\text{C} \times [(b) - (a)] / 3.517$

Heat Rejected (i) $= (f) \times 4.19\ \text{kJ/kg}\,^{o}\text{C} \times [(e) - (d)] / 3.517$

Percent Heat Balance (j) $= 100 \times [(g) / 3.517 + (h) - (i)] / (i)$

Date: DD/MM/YYYY

ENERGY AUDIT REPORT FOR BUILIDNG COOLING SYSTEM

FOR

ENTER BUILDING NAME

At

ENTER BUILDING ADDRESS

(BUILDING IMAGE)

Submitted By

Enter name of PE/Energy Auditor

Signature of PE/Energy Auditor

PE (Mech) Registration No*: Enter No.

Energy Auditor Registration No*: Enter No.

*Delete whichever is not applicable

Contents

*required if using wet bulb temperature as set point

1.0 Executive Summary & Recommendation

(Example)

This report highlights the findings and recommendations obtained from the energy audit performed at Enter Building Name from [Enter Period of Audit] DD/MM/YYYY to DD/MM/YYYY for 24 hrs.

1) *<Description of findings>*
2) *<Description of findings>*
3) *<Description of findings>*

Recommendations for maintenance improvements and low cost energy conservation measures.

1) *<Description of recommendations>*
2) *<Description of recommendations>*
3) *<Description of recommendations>*

Recommendations which would incur capital expenditure.

1) *<Description of recommendations>*
2) *<Description of recommendations>*
3) *<Description of recommendations*

2.0 Building Information

Enter a brief description of the building here.

Project Reference Number	: **Enter project reference indicated in CORENET submission**
Building Name	:
Building Address	:
Postal Code	:
Building Type	:
Building Age	:
Date of last Energy Audit Submission	:
Gross floor area (GFA), m^2	:
Air conditioned area, m^2	:
Number of guest rooms (for hotels/service apartments)	:

3.0 Energy Audit Information For Building Cooling System

Enter PE(Mechanical) / Energy Auditor Name was appointed by **Enter Owner Name/ MCST**, owner of **Enter Building Name** to be the Energy Auditor for the 3 yearly submission of the operating system efficiency (OSE) of the centralized Chilled Water Plant. The report will present the performance of centralized Chilled Water Plant efficiency based on the measurements from the permanent instrumentations installed on site.

Location	:	**Enter location of Chilled Water Plant**
Energy Audit Period	:	**Enter Energy Audit period**
		***Note: Minimum 1 week**
Date of notice served	:	**Enter date of notice served by BCA**
Date of submission in notice	:	**Enter submission deadline stipulated in BCA notice**
Data Logging Interval	:	1 minute sampling
Trend Logged Parameters*	:	Chilled Water Supply main header temperature
		Chilled Water Return main header temperature
		Chilled Water flow rate at chilled water return main header
		Condenser Water Supply main header temperature
		Condenser Water Return main header temperature
		Condenser water flow rate at condenser water return main header
		Power input to Chiller(s)
		Power input to Chilled water pump(s)
		Power input to Condenser water pump(s)
		Power input to Cooling tower(s)

**** Trend logged parameters are not limited to the above and may vary depending on the piping and electrical circuit design.***

3.1 Chilled Water Plant Design information*

ID	Description	Type	Name plate motor (kW)	Total Cooling Capacity (RT)	Chilled water LWT/EWT	Chilled water ΔT	Rated Efficiency kW/RT	Year Installed
CH01	Chiller 1	Centrifugal	239	440	6.7 °C - 12.24 °C	5.54°C	0.543	2014
CH02	Chiller 2	VSD Screw	239	440	6.7 °C - 12.24 °C	5.54°C	0.543	2014
CH02	Chiller3	Screw	239	440	6.7 °C - 12.24 °C	5.54°C	0.543	2014

Table 1: Chiller Information (Example)

ID	Description	Name plate motor (kW)	Pump Head (m)	Flow rate (L/S)	Rated Pump/ Fan efficiency	Rated Motor Efficiency
CHWP 1	Chilled water pump 1	30	25	67.65	81.5%	93.2%
CHWP 2	Chilled water pump 2	30	25	67.65	81.5%	93.2%
CHWP 3	Chilled water pump 3	30	25	67.65	81.5%	93.2%
CWP 1	Condenser water pump 1	18.5	17	84.18	80.5%	92.2%
CWP 2	Condenser water pump 2	18.5	17	84.18	80.5%	92.2%
CWP 3	Condenser water pump 3	18.5	17	84.18	80.5%	92.2%
CT 1	Cooling tower 1	5.5 x 3 Cells	-	82.61	75%	86%
CT 2	Cooling tower 2	5.5 x 3 Cells	-	82.61	75%	86%
CT 3	Cooling tower 3	5.5 x 3 Cells	-	82.61	75%	86%

Table 2: Ancillary equipment Information (Example)

***Based on equipment design specifications and name plate ratings**

3.2 Chilled Water Plant Normal Operating Hours

Monday to Friday	:	1000 – 2100 Hrs
Saturday	:	No operations
Sunday	:	No operations

Note: The operating hours should follow the table in clause 6.1.4

3.3 Description of Plant Control Strategy

Summary of the present plant control strategy adopted for the applicant's building chiller plant systems' operation. You may include but not limited to the following:

1) Chiller sequencing

Describe how the chiller(s) operate to handle the varying building cooling load e.g. chiller cut-in/out sequence varying with building load and addressing peak and off peak load based on (supply water temperature, and/or building load, and/or compressor current running load amps) and time delay.

2) Chilled water pump (if applicable)

Describe the parameters used to control chilled water pumps e.g. pump speed modulate based on ((differential) pressure sensor located at chiller header, or remote AHU cooling coil, or several zones of AHU cooling coil, or optimising pump pressure by critical valve control), set-point(s) and bypass valve controls to ensure chillers operate at minimum flow rate

3) Condenser water pump (if applicable)

Describe the parameters used to control condenser water pumps e.g. modulate to maintain condenser water differential temperature set point or gpm/ton and the set-point(s).

4) Cooling tower (if applicable)

Describe the parameters used to control cooling towers e.g. Modulate base on cooling tower approach temperature (difference between CT leaving water temperature and ambient wet-bulb temperature) set point (adjustable), or scheduled cooling tower leaving temperature set point, or dynamic optimized cooling tower leaving water temperature set point and the set-point(s)

5) Other optimisation (if applicable)

Describe any other optimisation used e.g. Chilled water supply temperature reset. At off-peak period, reset based on outdoor air temperature/humidity, or VPF bypass control, or predefined schedule. (Note: Resetting CHW temperature may incur higher pump power and may compromise on space temperature and relative humidity)

(Example)

Chiller Configuration: <*x*> **unit(s) of** <*x*> **RT chiller &** <*x*> **unit(s) of** <*x*> **RT chiller**

Variable Primary Chilled Water System

Variable Condenser Pump

1) Chiller sequencing

Scenario for Cut-in: *Chilled water supply header temperature is above set point of <x> °C + <deadband> <u>OR</u> total system tonnage is above <x> RT for a period of <x> minutes.*

Scenario for Cut-out: *Chilled water supply header temperature is below set point of <x> °C + <deadband> <u>AND</u> total system tonnage is below <x> RT for a period of <x> minutes.*

Time delay: *Whenever any chiller cuts-in/out, there is <x> minutes delay to allow system to stabilize.*

2) Chilled water pump (CHWP)

Primary CHWP speed is modulated to maintain a differential pressure set point of <x> psi + <deadband>. Differential pressure sensors are installed at chilled water pipe headers. CHWP speed is limited to <x> Hz to ensure chillers running at minimum flow. When CHWP speed ramps down to minimum and differential pressure rises above set point, the bypass valve will open to maintain DP set point and minimum flow rate.

3) Condenser water pump (CWP) <fixed/variable>

Minimum running speed of CWP is <x> Hz. When condenser flow rate is reduced to set point of <x> l/s or <x> gpm/ton, CWP speed would be increased and vice versa.

4) Cooling Tower (CT)

CT fan speed is modulated to maintain leaving condenser water temperature set point of <x> °C which is equal to outdoor air wet-bulb temp plus <x> °C. When chiller(s) is in operation, all CTs would be turn on. When CT leaving water temperature falls below the set point, CT fan speed would be decreased until minimum speed of <x> Hz.

5) Other Optimisation

Chilled water temperature set point is reset to <x> °C during off-peak period from 2000hrs to 0800hrs.

4.0 Instrumentations

Accurate measuring instruments complying with the Code on Environmental Sustainability Measures for Existing Buildings or the Code for Environmental Sustainability of Buildings (2nd edition and onwards) that is prevailing at the time of installation were used during the audit to gather information on the power consumption, temperatures and flow rate.

The points of measurements are listed in the following table:

ID / Serial No.	Description	Sensor Type	Installation Location	Measurement/ Calibration range	Measurement Uncertainty (%)	Last Calibration Date	Calibration Laboratory
EP80367	Brand X Temperature Sensor	10K Ω Thermistor	CHWS Header	0.01°C – 29.765°C	±0.03 °C	09/05/2014	XX laboratory
EP80364	Brand X Temperature Sensor	10K Ω Thermistor	CHWR Header	0.01°C – 29.765°C	±0.03 °C	09/05/2014	XX laboratory
EP80361	Brand X Temperature Sensor	10K Ω Thermistor	CWS Header	0.01°C – 29.765°C	±0.03 °C	09/05/2014	XX laboratory
EP80363	Brand X Temperature Sensor	10K Ω Thermistor	CWR Header	0.01°C – 29.765°C	±0.03 °C	09/05/2014	XX laboratory
3k672013 43004	Brand X CHW Flow Meter	Magnetic Full Bore	CHWR Header	0 l/s- 288.63 l/s	0.5%	29/10/2013	XX laboratory / factory calibration
3k672014 18063	Brand X CW Flow Meter	Ultrasonic	CWR Header	0 l/s- 483.33 l/s	0.5%	09/05/2014	XX laboratory / factory calibration
38498	Brand X Incoming Power 1	True RMS, 3 phase	MSB Incoming 1	60 – 600 kW	0.5%	08/07/2014	XX laboratory / factory calibration
1402404	Brand X Incoming Power 2	True RMS, 3 phase	MSB Incoming 2	0 – 99999 MW	0.2%	08/07/2014	XX laboratory / factory calibration
38491	Brand X Chiller 1	True RMS, 3 phase	CH/6-1	0 – 99999 MW	0.2%	08/07/2014	-
38487	Brand X Chilled Water Pump 1	True RMS, 3 phase	CHP/6-1	0 – 99999 MW	0.2%	08/07/2014	-
38490	Brand X Condenser Water Pump 1	True RMS, 3 phase	CWP/6-1	0 – 99999 MW	0.2%	08/07/2014	-
38499	Brand X Cooling Tower 1	True RMS, 3 phase	CT/6-1	0 – 99999 MW	0.2%	08/07/2014	-
38497	Brand X Chiller 2	True RMS, 3 phase	CH/6-2	0 – 99999 MW	0.2%	08/07/2014	-
38483	Brand X Chilled Water Pump 2	True RMS, 3 phase	CHP/6-2	0 – 99999 MW	0.2%	08/07/2014	-
1402325	Brand X Condenser Water Pump 2	True RMS, 3 phase	CWP/6-2	0 – 99999 MW	0.2%	08/07/2014	-
38572	Brand X Cooling Tower 2	True RMS, 3 phase	CT/6-2	0 – 99999 MW	0.2%	08/07/2014	-
1402399	Brand X Chiller 3	True RMS, 3 phase	CH/6-3	0 – 99999 MW	0.2%	08/07/2014	-
38574	Brand X Chilled Water Pump 3	True RMS, 3 phase	CHP/6-3	0 – 99999 MW	0.2%	08/07/2014	-
38485	Brand X Condenser Water Pump 3	True RMS, 3 phase	CWP/6-3	0 – 99999 MW	0.2%	08/07/2014	-
38486	Brand X Cooling Tower 3	True RMS, 3 phase	CT/6-3	0 – 99999 MW	0.2%	08/07/2014	-

Table 3: Instrumentation Table (Example)

5.0 Chiller Plant Performance Analysis (1 week data)

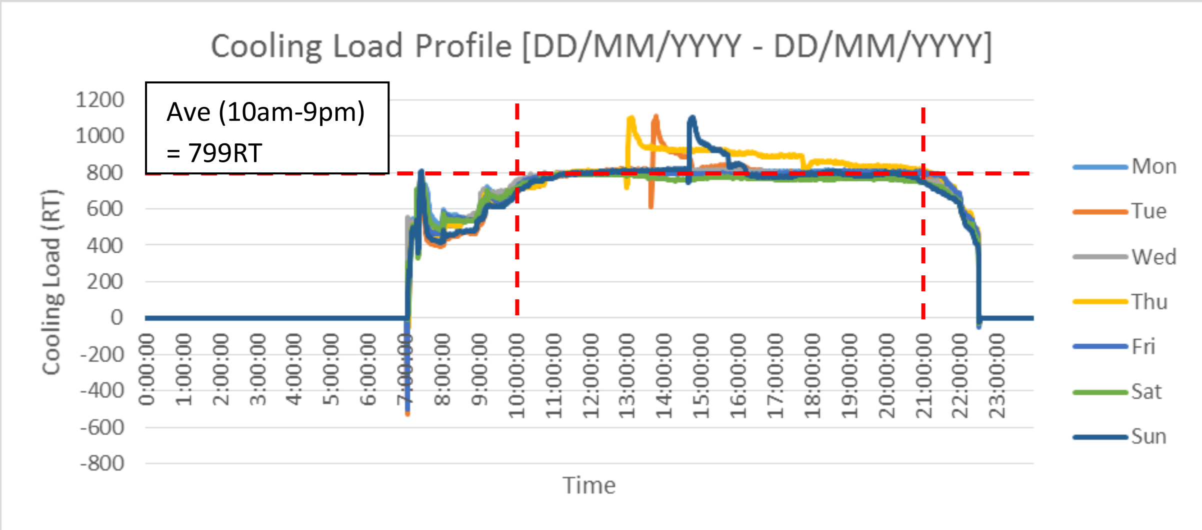


Figure 1: Super-imposed plot of 24 hr Cooling Load Profile RT (Example)

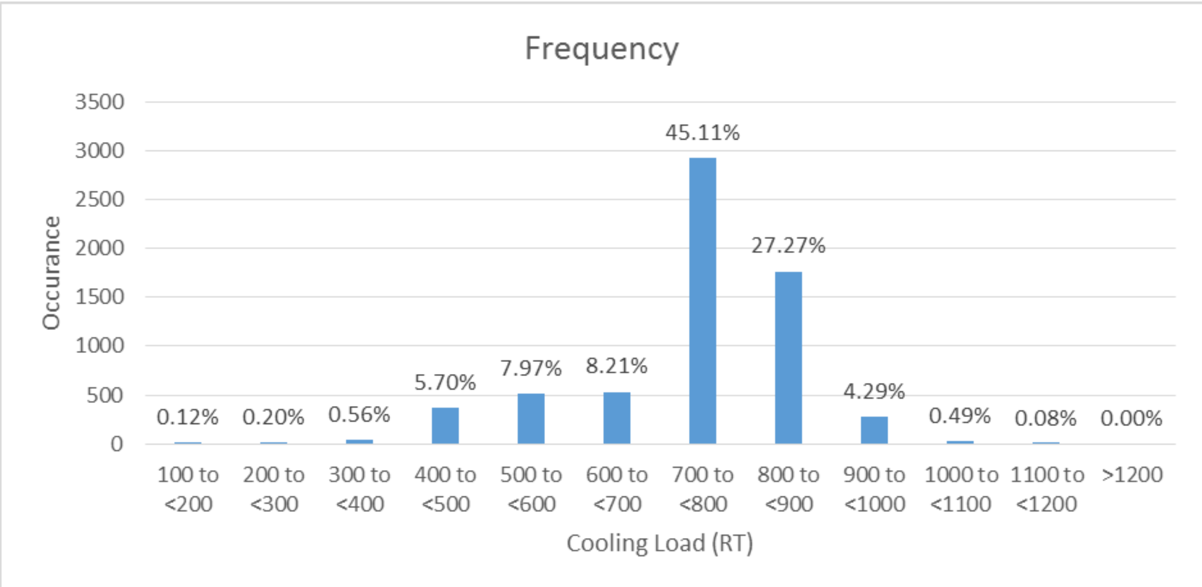


Figure 2: Histogram of Cooling Load Occurrences (Example)

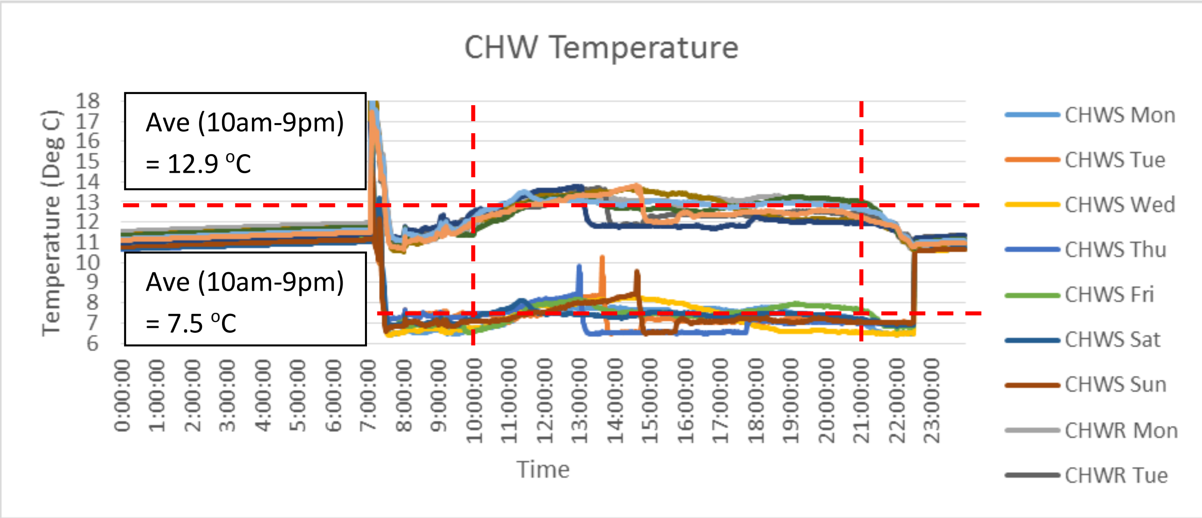


Figure 3: Super-imposed plot of daily chilled water supply/return temperature ^{o}C (Example)

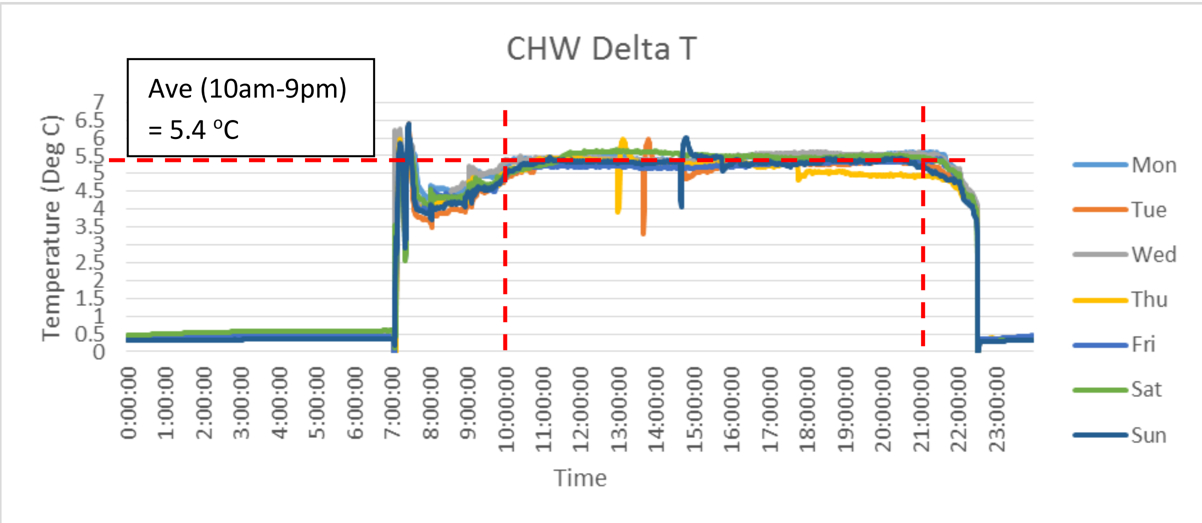


Figure 4: Super-imposed plot of daily chilled water temperature difference ^{o}C (Example)

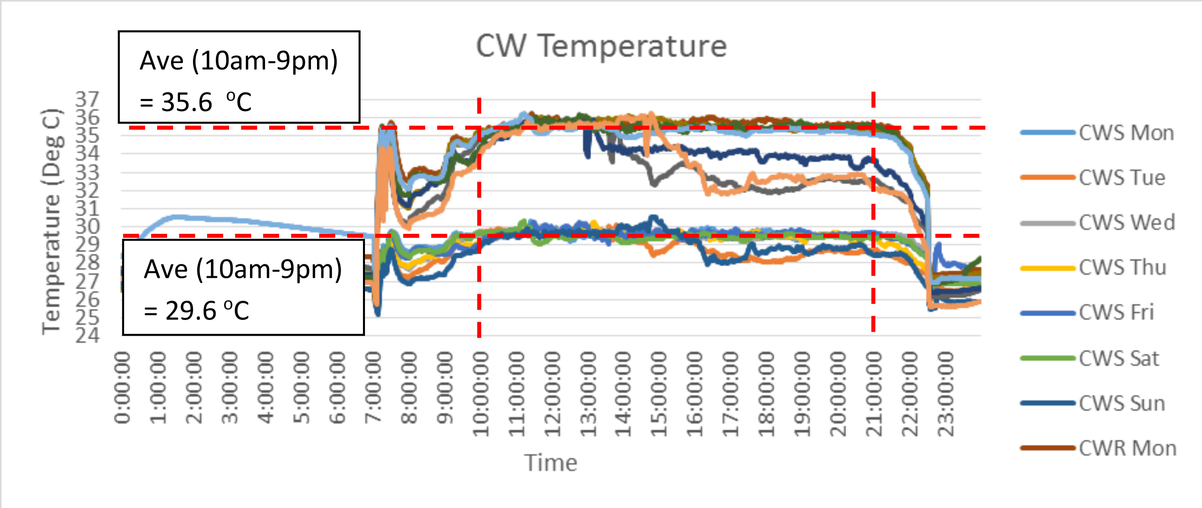


Figure 5: Super-imposed plot of daily condenser water supply/return temperature °C (Example)

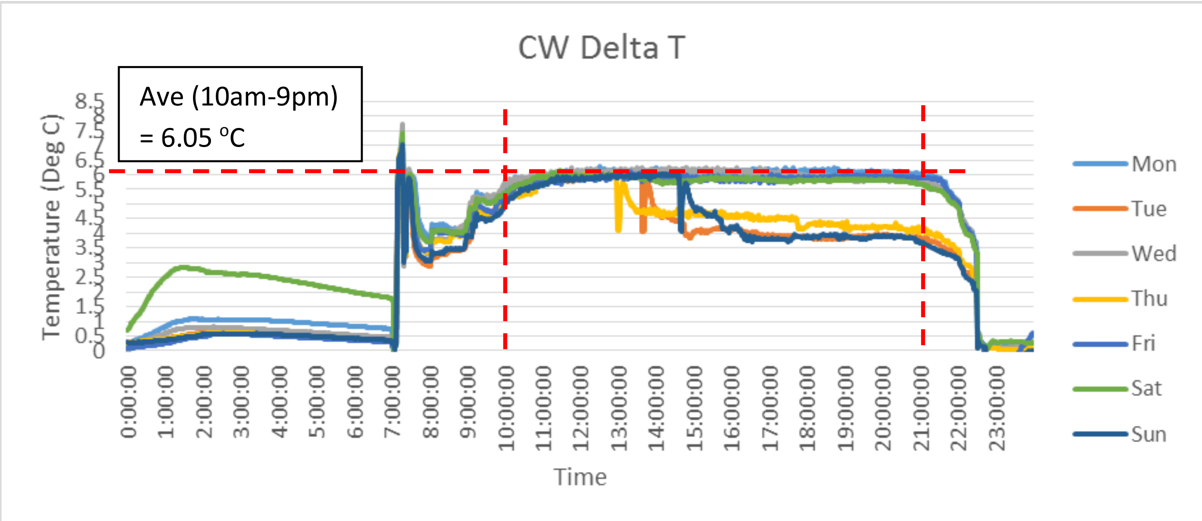


Figure 6: Super-imposed plot of daily condenser water temperature difference °C (Example)

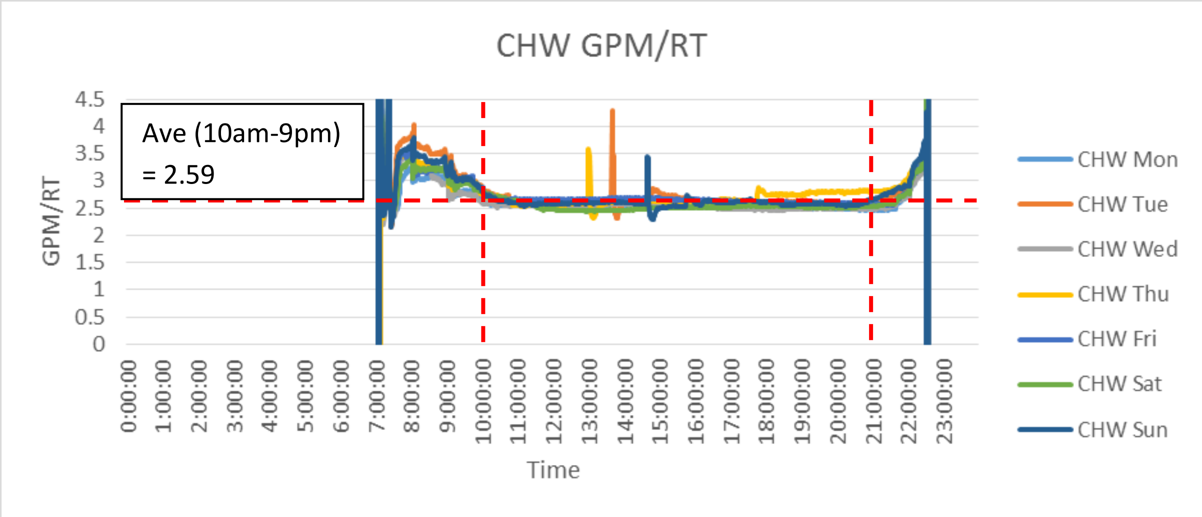


Figure 7: Super-imposed plot of daily chilled water GPM/RT (Example)

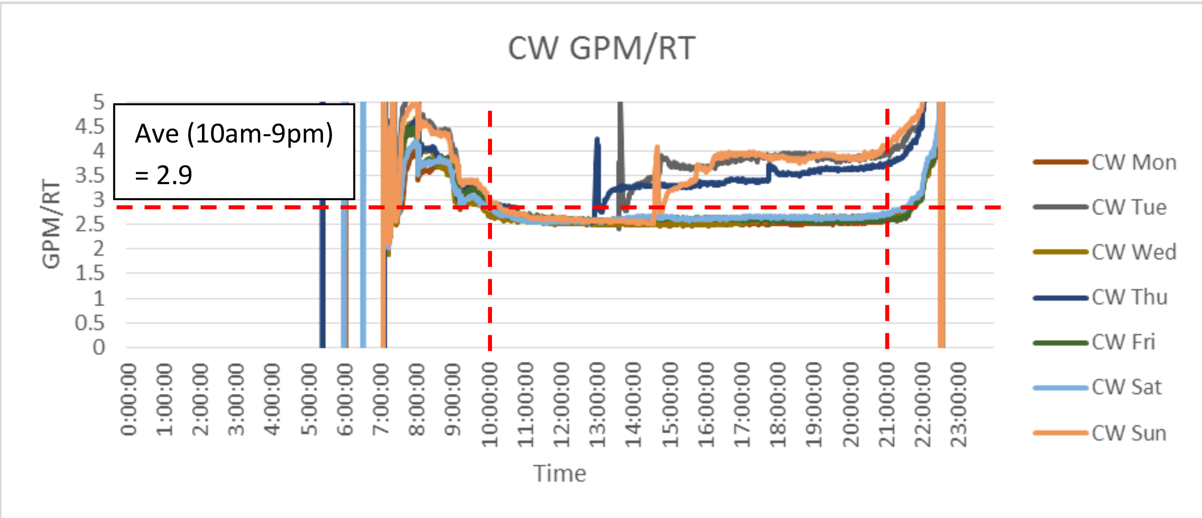


Figure 8: Super-imposed plot of daily condenser water GPM/RT (Example)

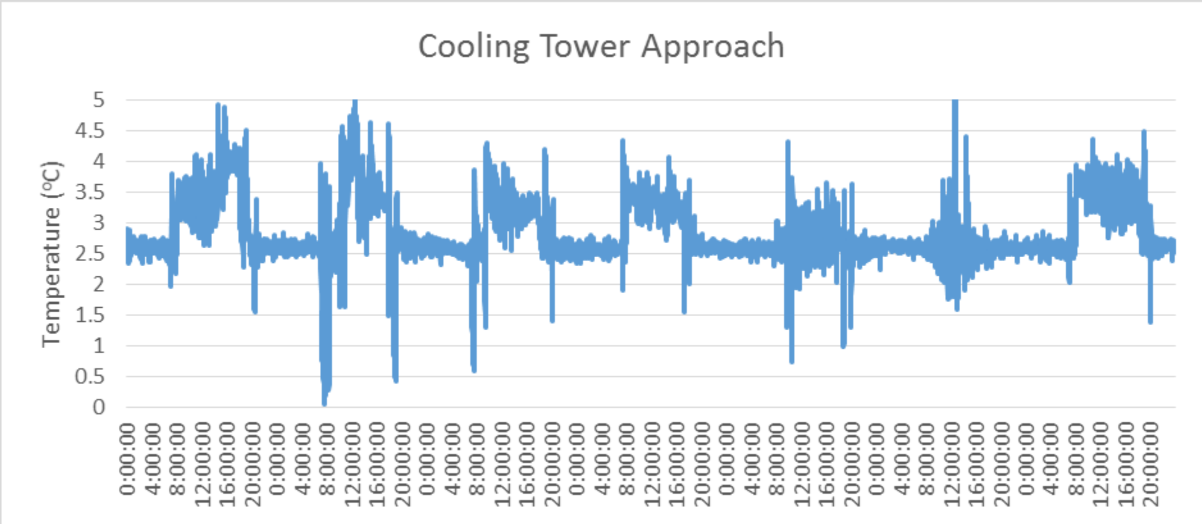


***Figure 9: Cooling Tower Approach Temperature (Example)**

*required if using wet bulb temperature as set point

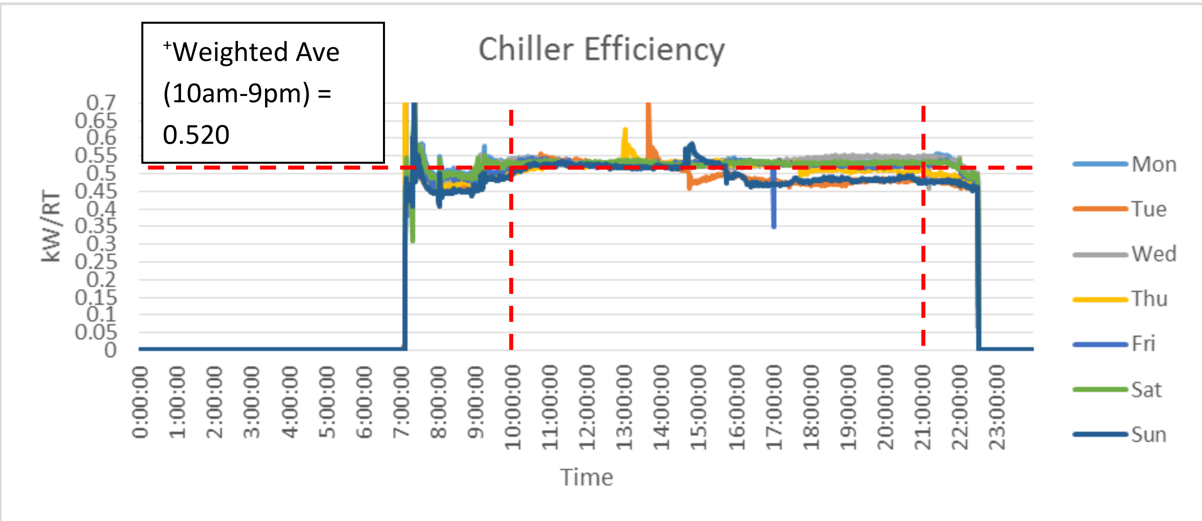


Figure 10: Super-imposed plot of daily chiller efficiency kW/RT (Example)

+Weighted average: ∑ kW-hr / ∑ RT-hr

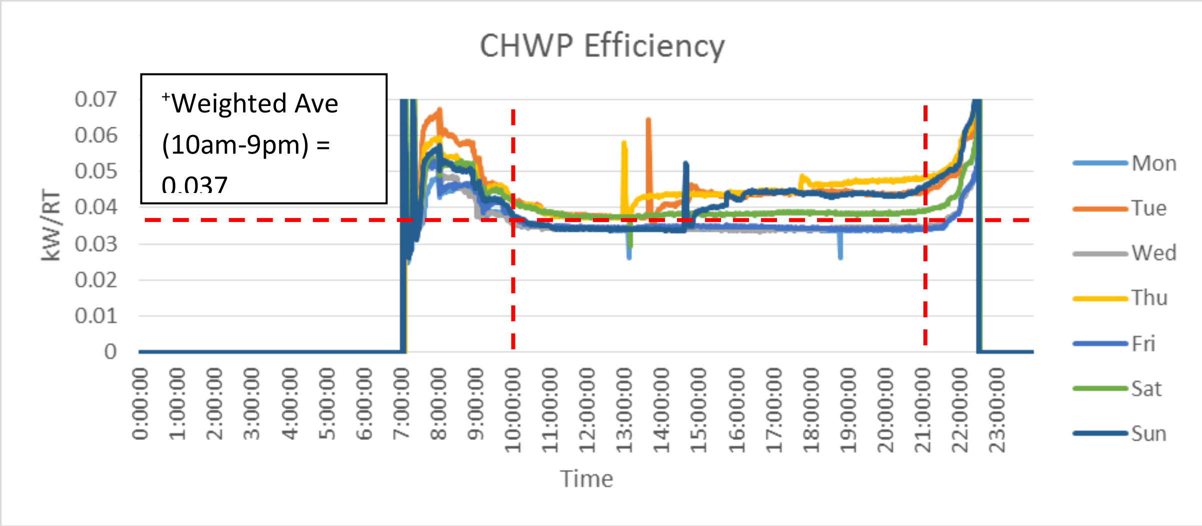


Figure 11: Super-imposed plot of daily chilled water pump efficiency kW/RT (Example)

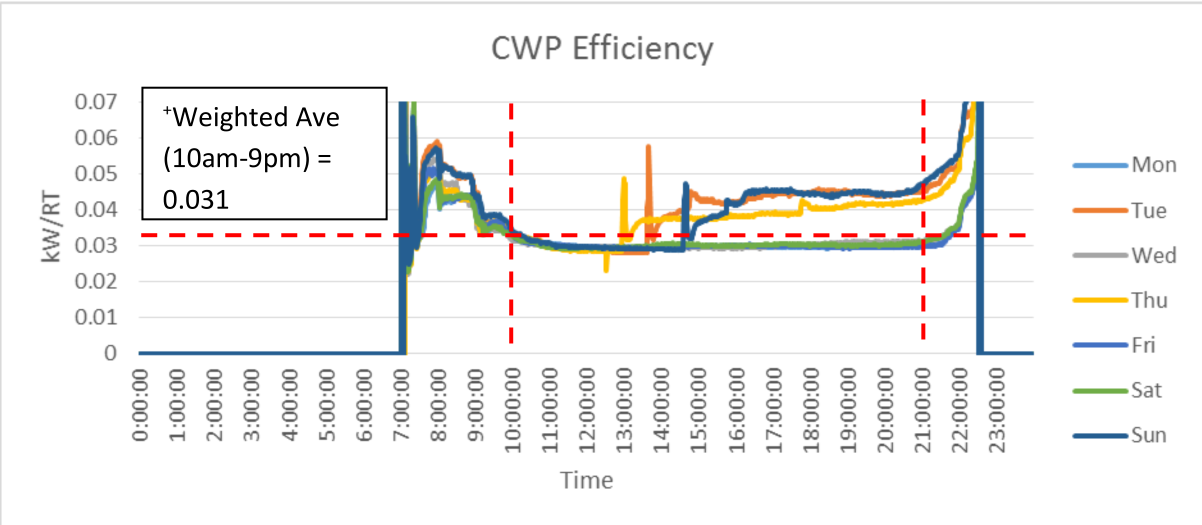


Figure 12: Super-imposed plot of daily condenser water pump efficiency kW/RT (Example)

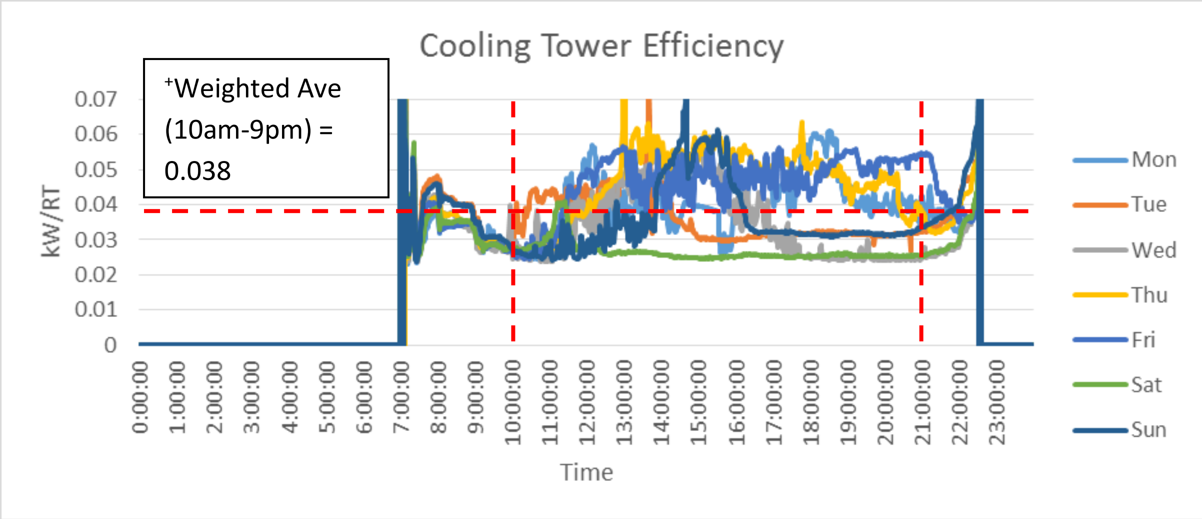


Figure 13: Super-imposed plot of daily cooling tower efficiency kW/RT (Example)

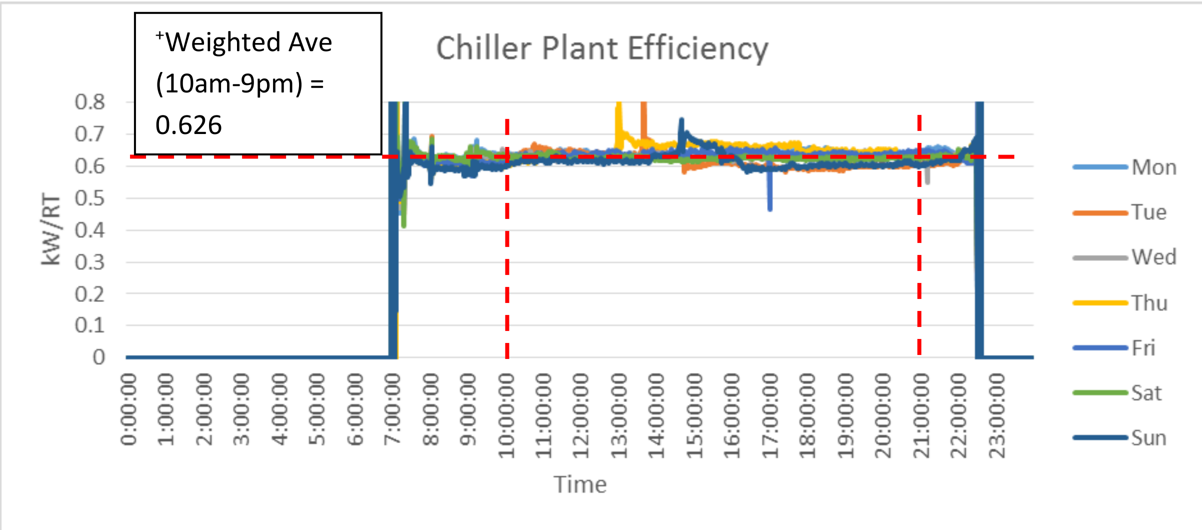


Figure 14:Super-imposed plot of daily chiller plant system efficiency kW/RT (Example)

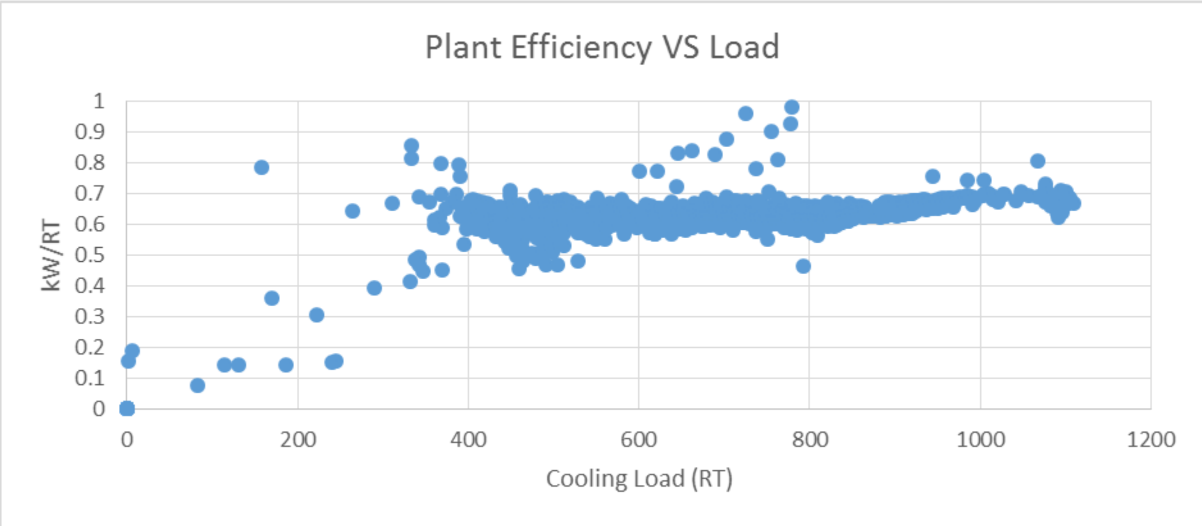


Figure 15: Scatter plot of chiller plant efficiency over cooling load (Example)

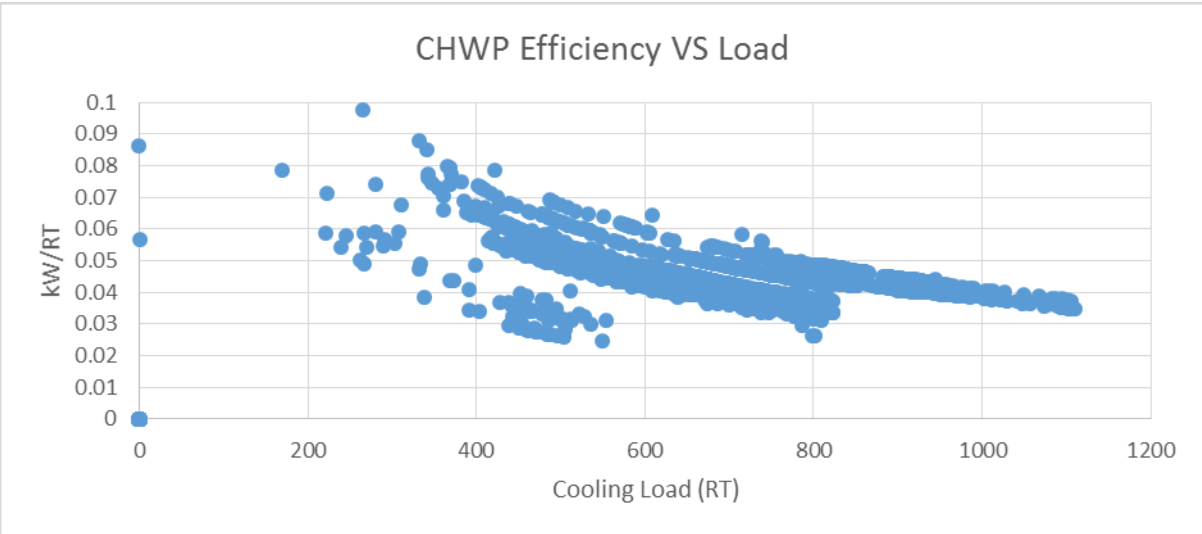


Figure 16: Scatter plot of chilled water pump efficiency over cooling load (Example)

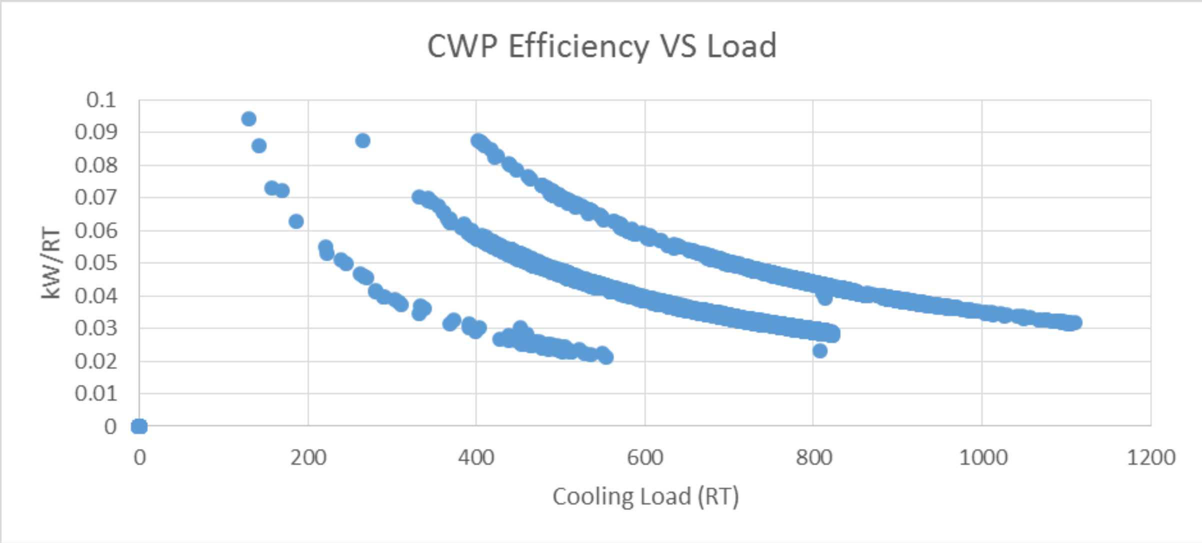


Figure 17: Scatter plot of condenser water pump efficiency over cooling load (Example)

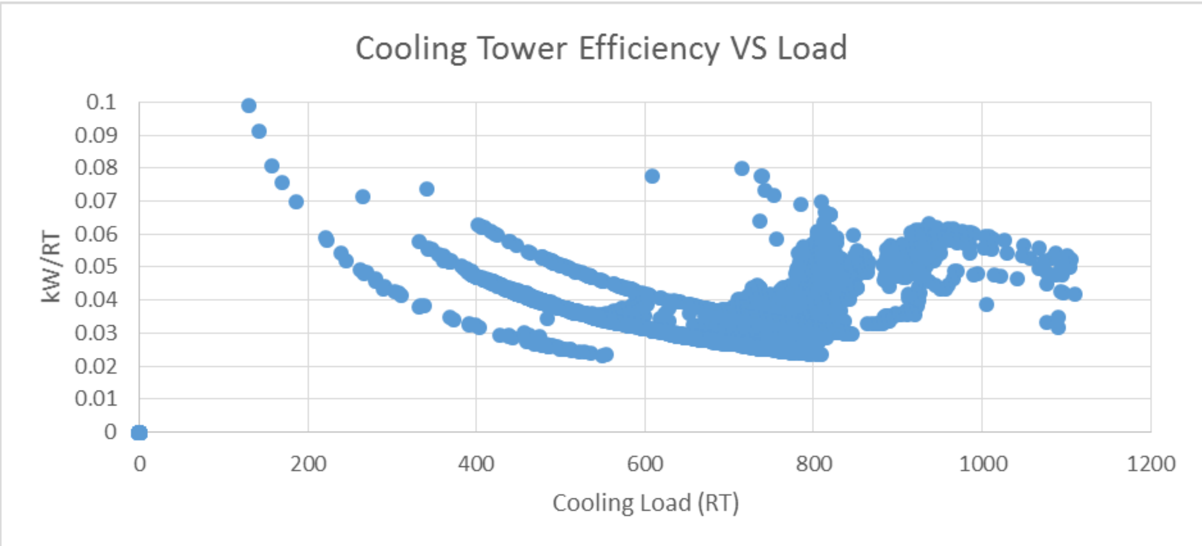


Figure 18: Scatter plot of cooling tower efficiency over cooling load (Example)

5.1 Summary of Chilled Water Plant Operating Performance

Daily Average Reading	Period		Unit
	Daytime^	Night-time~	
Cooling Load			RT
Cooling Load Density (Air-con area)			m2/RT
Power Consumption			kW
Chilled water supply temperature			°C
Chilled water return temperature			°C
Chilled water delta T			°C
Chilled water flow rate			l/s
Chilled water flow rate vs cooling load			USgpm/RT
***Condenser heat rejection**			HRT
***Condenser water supply temperature**			°C
***Condenser water return temperature**			°C
***Condenser water delta T**			°C
***Condenser water flow rate**			l/s
***Condenser water flow rate vs cooling load**			USgpm/RT
Chiller(s) efficiency			kW/RT
Chilled water pump(s) efficiency			kW/RT
***Condenser water pump(s) efficiency**			kW/RT
***Cooling tower(s) efficiency**			kW/RT
Overall chiller plant efficiency			kW/RT

Table 4: Chilled Water Plant Performance Summary

*Not applicable to air-cooled Chilled Water Plant

~For hotels and other developments with 24-hour operations only; Night-time shall refer to the period from 11pm – 7am;

^ For hotels and other developments with 24-hour operations, day-time shall refer to the period from 7am – 11pm; for all other developments, daytime shall refer to the normal operating hours stipulated in clause 6.1.4

6.0 Summary of Heat Balance

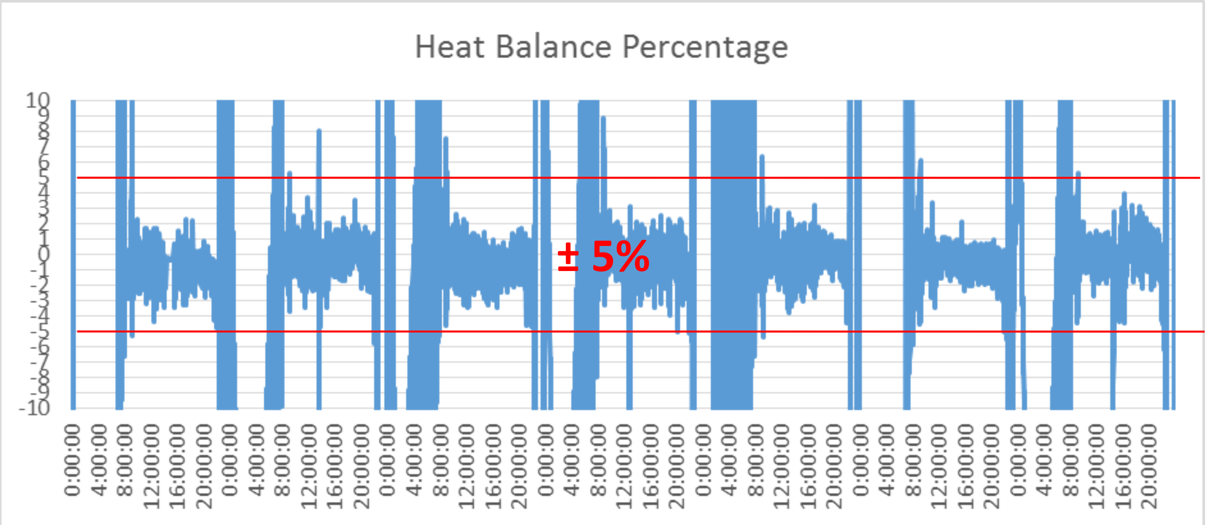


Figure 19: System Level Heat Balance Plot (Example)

	Quantity	Unit	Formula
Sum of total electrical energy used		kWh	(A)
Sum of total cooling produced		RTh	(B)
Sum of total heat rejected		RTh	(C)
Chiller Plant Efficiency		kW/RT	(A) / (B)
Total Heat Balance Data Count		-	(D)
Data Count > + 5% error		-	(E)
Data Count < - 5% error		-	(F)
Data Count within ±5% error		-	(G) = (D) – (E) – (F)
% Heat Balance within ±5% error		%	100 x (G) / (D)

Table 5: Heat Balance Summary

7.0 Schedule of space operating conditions

(10 points Spot measurements)

	*Room name (ie Air conditioned Habitable Spaces)	Dry Bulb Temperature (°C)	Relative Humidity (%)	CO2 Concentration (ppm)
1	Ie Office 1			
2	Ie Office 2			
3	Ie Meeting Room 1			
4	Ie Meeting Room 2			
5				
6				
7				
8				
9				
10				

Table 6: Space Condition Schedule (Example)

APPENDIX

Checklist of Plant Operating Condition (for best practices)

	Yes	No	Actual value
Is Chilled water delta T lower than 5.5 or design?			
Is the cooling tower approach temperature 1.5 °C higher than outdoor wet bulb temperature?			
Is the Chilled water pump efficiency higher than 0.03 kW/RT?			
Is the Condenser water pump efficiency higher than 0.035 kW/RT?			
Is the Cooling Tower efficiency higher than 0.03 kW/RT?			
Are all Chilled water pumps installed with VSD?			
Are all Condenser water pumps installed with VSD?			
Is the Cooling Tower installed with VSD?			
Does Refrigerant Condenser approach exceed range of 0.5 °C to 1.5 °C?			
Does Refrigerant Evaporator approach exceed range of 0.5 °C to 1.5 °C?			

Table 7: Checklist of Plant Operating Condition (for best practices)