THE UNIVERSITY OF QUEENSLAND

Bachelor of Engineering Thesis

Energy Efficiency in Commercial Building Air Conditioning: To Monitor the Improvement of New Chilled Water Air Separation and Filtering system.

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Course Code: MECH4500

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UQ Engineering

Faculty of Engineering, Architecture and Information Technology

Abstract

The University of Queensland cooperated with OaseTECH, a Chinese leading manufactory company in fluid technology to study the effect of twin separator on HVAC Chilled water system. The new twin separators are installed on the top of the Colin Clark building (69) plant room. The Colin Clark HVAC chilled water system supplies cooling for these three buildings, Sir Edwards Building (14), Duhig North (12) and Duhig Link (12A). Three UQ buildings were also analysed and put into the simulation software eQUEST. eQUEST simulates the heat gain for three UQ buildings. Twin separators are installed in beginning of July. Two months of post installation HVAC performance data were studied and analysed. The post installation data is compared with pre-installation data and the results from eQUEST simulation. The results show that Colin Clark plant room has a higher cooling load with lower coefficient of performance in 2016 which in contrast with the previous research. After justifying, there are several possibilities why results might be erroneous, such as not enough of data. The data cannot present the normal monthly heat gain. The dirt samples from separators were studied and analysis. The twin separators can remove the dirt from the water system. The noise study on twin separators was also done. All the research and experiment results show that twin separators can improve the quality of chilled and condenser water system with no potential noise problem. Hence, from the work of this thesis, it is recommended to install twin separators on HVAC chilled water cooling system in commercial buildings.

Keywords

Energy Efficiency, Energy performance, Dirt, Air – dirt separator, Coefficient of Performance, Heat Gain, OaseTECH, Cooling energy, Commercial Building

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Table of Content

Chapter I: Introduction

Chapter Summary:

The introduction of this thesis briefly explains the purpose of this project. The energy saving of HVAC system is critically needed. The aim of this thesis is to monitor and quantify the improvement of OaseTECH chilled water air separation and filtering system at UQ Colin Clark building. OaseTECH is a leading manufacture company in fluid technology from China. Twin separators can remove the micro-bubbles and dirt particles within the pipeline. The research shows that weather in July and August 2016 is warmer than July and August in 2015.

1.1 Motivation

Energy efficiency has recently become a significant issue in modern society. There are quite a number of measures being taken against global warming as building energy consumption takes almost 40% of global consumption (Hasan, 2013). Thus, sustainable commercial design and building energy efficiency have to be considered for building construction. Furthermore, energy consumption of buildings is responsible for approximately 20% of Australia greenhouse emission. This includes approximately half house building and half commercial building. The commercial building plays a vital role because the difficulty for business firms to improve building efficiency for a commercial building is lower than populace houses.

Among all of the building efficiency factors for commercial building, HVAC (heating, ventilation, and air condition) system plays an important role because it generally covers about 40% of total building electricity consumption. Therefore, it is a momentous topic to learn how to decrease HVAC energy consumption for energy efficiency of a commercial building and implement it. (Hasan, 2013)

In order to better approach the study of HVAC energy consumption of commercial buildings, the University of Queensland and company OaseTECH collaborate a project one OaseTECH's chilled water air separation and filtering system. The University of Queensland policy aims to continuously improve HVAC efficiency for a building. Therefore, the university provides a large commercial building, Colin Clark Building 39, and cooperates with OaseTECH for this project with the aim to increase the chiller system efficiency of the building.

1.2 Aim

The aim of this thesis is to monitor and quantify the improvement of this new chilled water air separation and filtering system at Colin Clark Building.

1.2.1 Sub-goals

- Estimate the cooling load of the building
- Compare the estimated load against the HVAC performance as metered in 2015
- Estimate the improvement achieved by the new air separation technology
- Remove the air and dust trapped in chilled water pipe
- Noise and corrosion control

1.3 OaseTECH

FIGURE 1-0-1: OASETECH

OaseTECH is a leading manufactory and designer company in fluid technology. OaseTECH produces advanced pressure control, air and dirt separator and provides a flow balancing solution for water circulation system problem. The company is based in Shanghai, China, and has their own R&D department and factories. From Shanghai Disneyland Energy Centre, Mercedes factory, aviation pharmaceutical industries and different scale of commercial/ residential buildings, all of the customer facilities can prove its quality and performance. OaseTECH's automatic micro-bubble and micron-scale dirt air separators, twin separators, are going to be installed for this project. (AIRAH, 2016)

1.3.1 Separators

Dirt Separator: Micron Decontamination

Micron Decontamination separates the minimum particle from operating fluid. Air conditioning system can prevent dirt accumulation, tear and wear within the pipeline by removing particles with a minimum size of 5µm. Efficiency also increases when to lessen increases pressure loss when removing the dirt in the pipeline. The lifetime of the pipeline system and equipment can be prolonged and reach the efficiency of its original design.

Air Separator: Micro-bubbles deaeration

Problem's like gas jam and gas whistling can be solved by separating micro-bubbles and dissolved gas from the fluid of air-conditioning system.

Twin separator

Dirt-air separators are installed in this project. Twin separator combines the advantage of both micron decontamination device and micro-bubbles deaeration device and makes them into one.

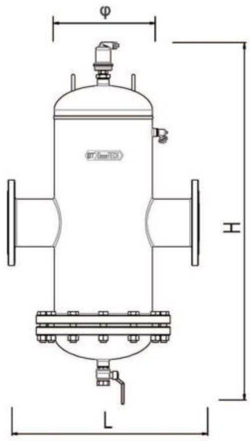


FIGURE 1-0-2: OASETECH SEPARATOR

OaseTECH states twin separator has 80% discharging rate of the primary gas. 50% of gas are going to be removed from the system after 4 to 6 operating hours and reach about 0.4% gas contain in the final state, and up to minimum 10 μm bubble can be removed. About 96% of dirt content is going to be removed, and particle's size can be small as 5 μm.Model TSR200 and TSR250 are installed in this project. The further calculation for pressure head loss is presented in section 2.3 "the location and pressure drop of the OaseTECH filter". (OaseTECH, 2016)

Twin Separator Flange with Overhaul and Automatic Separators

The diameter of Installing Separators						
Model	DN	L(mm)	ϕ (mm)	H (mm)	Flow (m^3/h)	Weight (kg)
TSR200	200	755	400	1650	180	204
TSR250	250	890	500	1900	288	350

FIGURE 1-0-3:THE DIAMETER OF INSTALLING SEPARATORS(OASETECH, 2016)

1.4 Weather in Brisbane

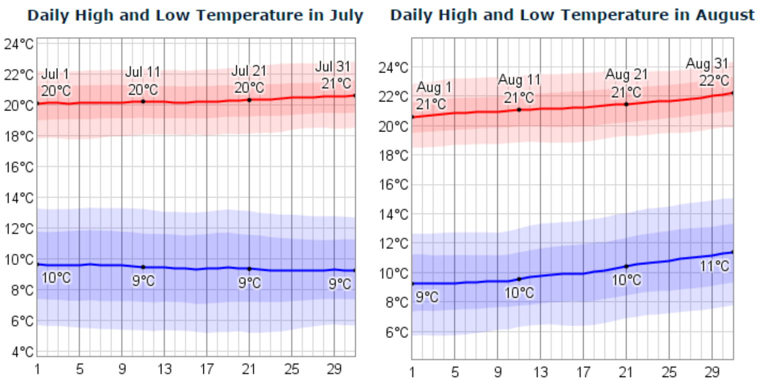


FIGURE 1-4:DAILY HIGH AND LOW TEMP. IN JULY&AUGUST (WEATHERSPARK, 2016)

In order to correctly analysis the building heat load, the weather in Brisbane has to be taken into consideration. Brisbane climate is generally warm and humid. Brisbane has a hot summer with no dry season. The warm season generally starts from early December to the end of March. The cold weather generally starts from the end of May to end of August. This thesis report generally focuses on July and August weathers, because the HVAC measurement data from these two months would be analysed in the result section.

July in Brisbane generally have around 20°C high temperature with low temperature sounding 10°C. The figure 1-4 shows the July's daily high and low temperature in history. On the other hand, figure 1-4 shows that August has generally risen high and low temperature in history. (WeatherSpark, 2016)

1.4.1 Global July and August weather in 2015&2016

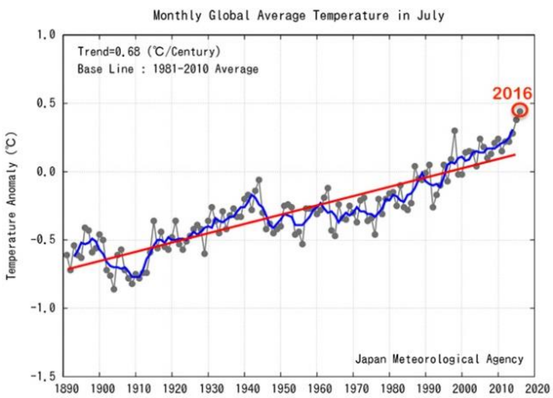
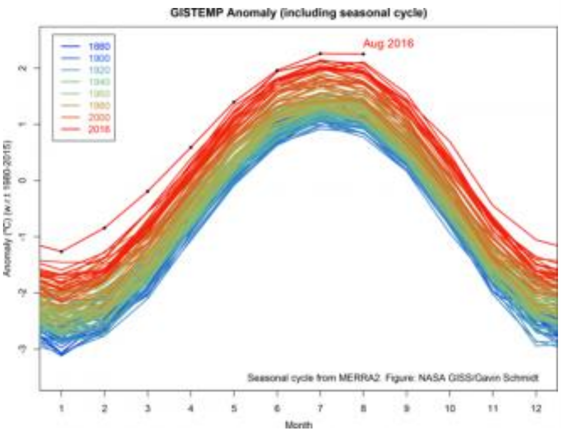


FIGURE 1-5: MONTHLY GLOBAL AVERAGE TEMPERATURE IN JULY (WEATHER.COM, 2016)

The global mean temperatures in July and August 2016 are the hottest mean temperature in the history. Indeed, July 2016 has been the hottest year ever recorded. According to Japan Meteorological Agency and NASA's record in figure 1-5, July 2015 reached the highest average temperature, however, July 2016 global average temperature broke the record again.

Brisbane 2016 July reaches the hottest July day in 70 years according to Brisbane time. (Cooper, 2016) 2016 August temperature also reaches the hottest winter night on record. NASA states 2016 August also broke the hottest record in the history. Figure 1-7 from NOAA's National centre shows Brisbane experienced the record warmest temperature in Jan to August 2016. (weather.com, 2016)



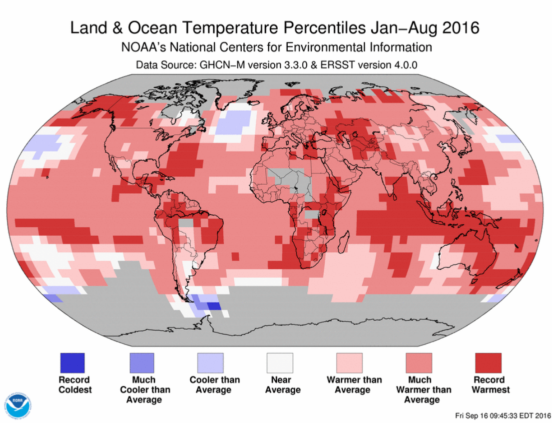


FIGURE 1-6:TEMP. JAN-AUG 2016(THE GUARDIANT, 2016) FIGURE 1-7: ANOMALY OAUG 2016(THE GUARDIANT, 2016)

The Brisbane 2016 is the hottest year according to the research. Therefore, if building cooling load is only based on the effect of weather, 2016 building cooling load supposed to be higher than 2015 building cooling load. The further discussion on the weather affects on building cooling load is presented in the result section. (Sanchez-Lugo, 2016) (Thompson and The Guardiant, 2016)

Chapter II: Building information

Chapter Summary:

The air-conditioning system in Colin Clark plant room supplies cooling of three buildings which are the Sir Edwards Building (14), Duhig North (12) and Duhig link (12A). The structures and materials of the buildings were studied. The plant room on the top of Colin Clark building was also studied.

2.1 Three buildings served and sources of heat gain

There are three building is going to be analyzed in this thesis project. Sir Edwards building (14), Duhig North(12) and Duhig link(12A). The geography location is listed in figure 2-1. Building 12A is a connection between Fryer library and building 12. Between building 12 and building 12, there are only around 9 meters distance. On the west side of the building, group is a flat grassland forecourt, which makes building group is fully exposed under the sunset and west side sun light. On the north, east and south side of building group are surrounding by buildings. The detailed analysis is going to be present in section later sections.

FIGURE 2-0-1:3 BUILDINGS

There are some common sources of heat gain for buildings. The sensible heat gains include the heat from building structure; infiltration; internal heat; the heat from solar radiation through door or windows. Internal heat can come from electrical equipment, indoor lighting and people. Latent heat gains, moisture in the space by people, electrical equipment and air infiltration. The balance between sensible heat gain, latent heat gain and air absorbing capability results the space temperature and humidity.

2.1.1 Sir Edwards Building (14)

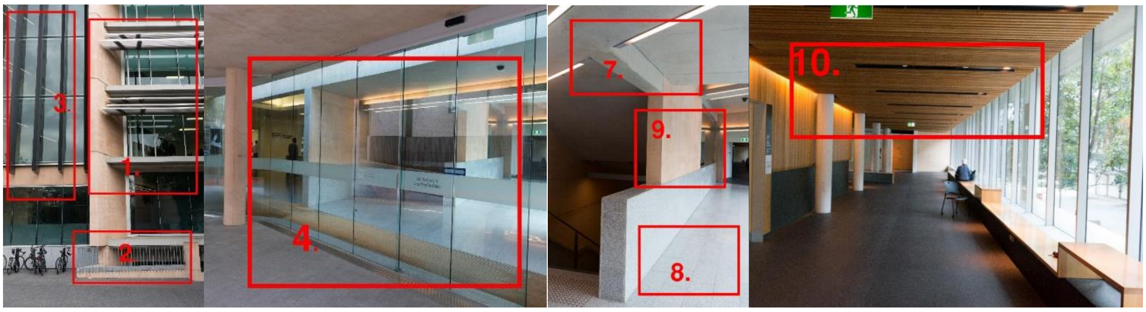
FIGURE 2-0-2:IMAGES OF SIR EDWARDS BUILDING 14

Sir Edwards Building is also known as General Purpose North Building 4. It's an award winning six level teaching building, It has a wide range of advanced teaching spaces, including seminar room, office, function room, student resource area and an auditorium. The two lower floor has a combination of training space with AV equipment for teaching and teaming methodology.The building is also specially designed for ESD principle, so it has advanced design technology on natural daylight, strategic shading, photovoltaic solar panels system, rainwater harvesting and sensor monitoring. The western side of the window is also designed to reflect heat. Sun shade screen also specially design against sun heat. The air-conditioning and lighting system are all sensor-controlled.

2.1.2 Details Analysis for building 14

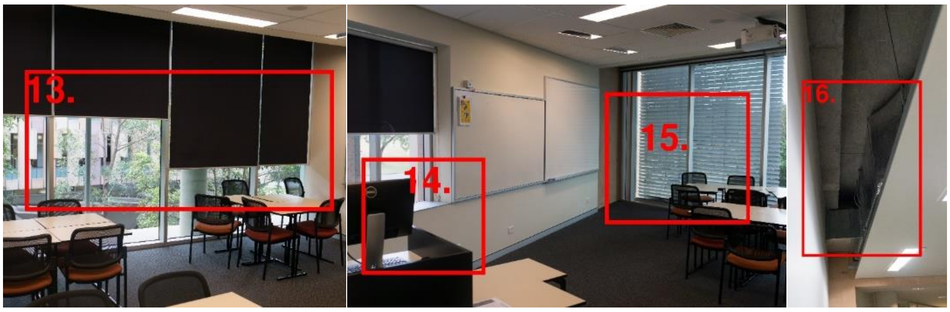
Details are used in ChapterIII. Chapter III :Building Heat Load Simulation

FIGURE 2-0-3: FIGURES FOR BUILDING 14



• 1. From the exterior window, shades normally place to prevent extra heat gain. • 2. Although the building has 6 level, there is a floor is half underground. The simulation within eQUEST assumes its underground grade. • 3. At the east south side building, glass wall has many vertical shades. • 4. Automatic glass doors are located at southeast side and west north side. There are also other entrances at the east side. • 7. The majority of ceiling materials are made out of concretes and have “Drywall Finish” and the lights are also set on into the ceiling. • 8&10. The building floors mainly are “Vinyl Tile”, however the underground floor use the different material. Wood is used as ceiling and a black bouncy Vinyl Tile is used for the floor. • 9. Wall type is “Mass”.

• 11. Building 14 have different sitting area. This is going to affect the calculation for perimeter zone depth. • 12.There are different ceiling height and different lightening system.



• 13. Majority windows in teaching rooms have dark color rolling shade, which can totally cover whole windows. The ceiling materials of teaching rooms are generally “lay-In Acoustic Tile”. • 14. There is always computer and project equipment in the teaching room. • 15.There are also light color horizontal blinds outside of the windows. (Mainly on the west side)

16 & 17. There is an ICTE-UQ Learning on the fourth floor of the building. The building operation time is the base of it’s opening time. The learning center combines auditorium and

multimedia teaching function. • 16 & 17. There is an ICTE-UQ Learning on the fourth floor of the building. The building operation time is the base of it’s opening time. The learning center combines auditorium and multimedia teaching function. Leaning center opening time: Monday to thursay: 8:00 to 5:00, Friday: 8:00 to 4:00 and Saturday Sunday: Closed. • 18, 19 &20. Level 5 and level 6 are mainly offices, which a lot of stuff is doing their daily job here. From picture 19. and 20. a huge size of the shading roof can be identified. The is the part where photovoltaic solar panels system is rain water harvesting are placed. The top view of a building looks like a triangle section mainly covered by solar panels. (Richard Kirk Architect, 2008)

2.3.3 Duhig North (12) and Duhig Link (12A)

FIGURE 2-0-4: FIGURES FOR 12,12A

Duhig North is a 4 level UQ Social Sciences & Humanities Library. There are wide range of library function area, multi-function room, individual study room, study pace and auditorium. Duhig Link is a huge study space, which connects between Fryer library and Duhig north. The operation time for Duhig north on week day is 8.00am - 8.00pm and on weekend is 9.00am - 5.00pm. The building material for both buildings is sandstone. According to the CAD the wall thickness for building 12 is about 152mm which is 6 in (14,12A – 300mm)

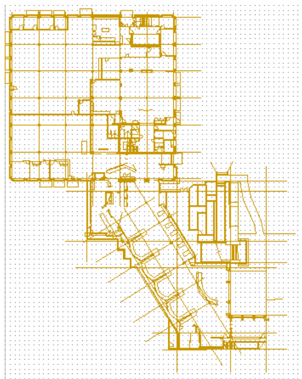
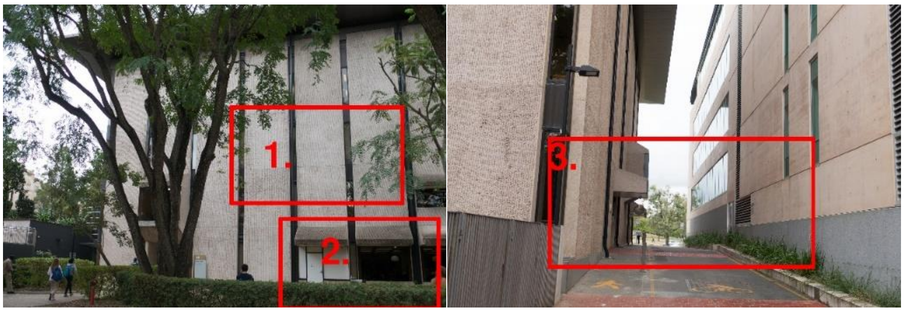
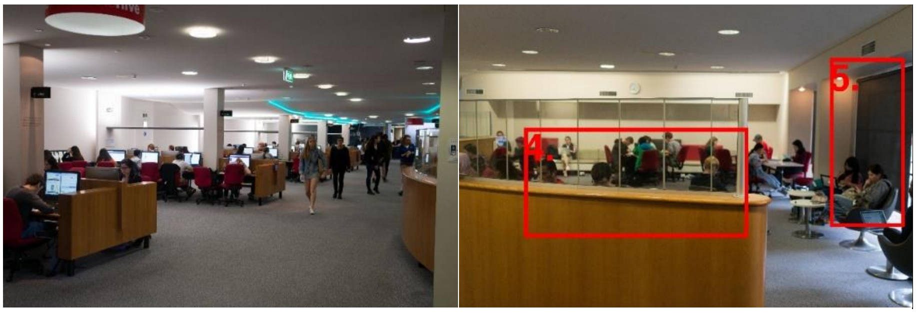


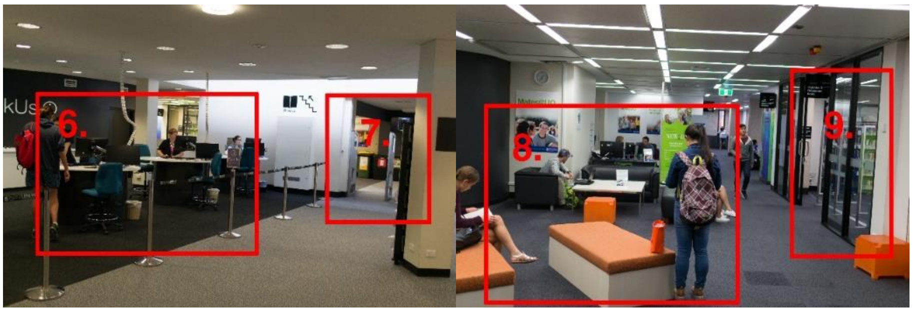
FIGURE 5-0-5:SKETCH OF BUILDING 12 AND 12A



1.2.& 3. From the highlighted areas, building 12 is identified with only small amount of windows, not much light can go pass the windows. There are entries on the east and north side of the building. As figure 2 shows, building 14 and building 12 only have about 9 meters interval. Therefore, this affects the modeling of sun light.

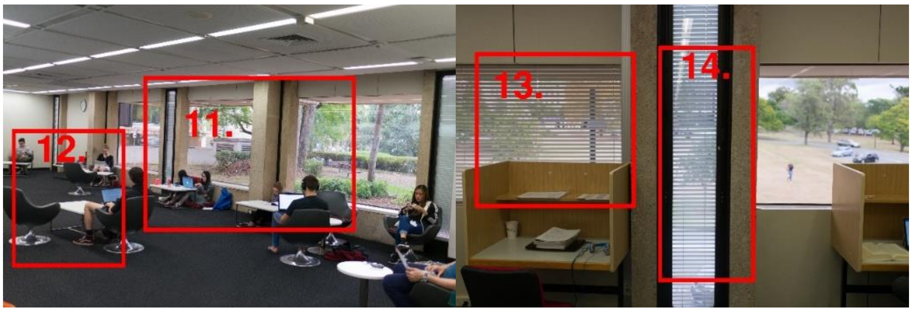


4.&5. Starting analysis from building 12A. As mentioned, building 12A is a 1 level building, connecting between Fryer library and building 12. It has a huge study space and computer area. Many students goes pass or study in this area. The area is also considered only one zone since there is no wall within the area.



6. 7. 8. & 9.The UQ IT section also locates in building 12A(section6.), therefore, there are always an officer and computer equipment. Besides the IT section, it's the entry to the building 12, social sciences& Humanities library.(section.7) 11. 12. 13. &14.In the first floor of social

science library, there is a studying area with several group rooms and multimedia room.(section.9) There is also the reading area for the student to study read.(section.12) There are large windows in study area leads light into studying area. However, the windows in upper floors of building 12 (section.13 and 14) are normally small and it's shade by "medium color horizontal blinds"



2.2 Colin Clark Plant Room and Air conditioning system

Plant room is located on the top of UQ Business School, Colin Clark Building 39 Rooftop. There are three air-dirt twin separator were installed within in this project. HVAC system is assisting cooling for Building 12, 12A and 14. Colin Clark is a six-floor building, and majority functions are offices for the school of economic and school of business.

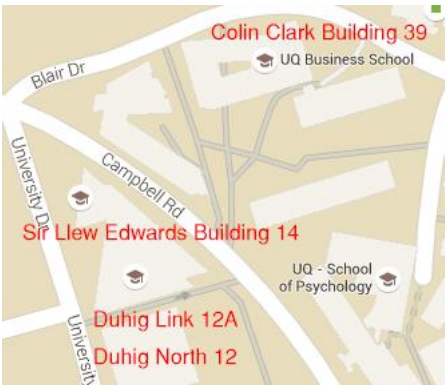


FIGURE 2-6:ARIAL MAP

From the arial photo, the plant room are generally under-covered. Only 4 cooling towers exposed under the air. The structure of the cooling tower is detailed in the 2.2.1 section. The installation of the air-dirt twin separators is also installed according to the figure 7.

2.2.1 Cooling towers

The cooling towers are majority resource for dirt getting into the condenser water.

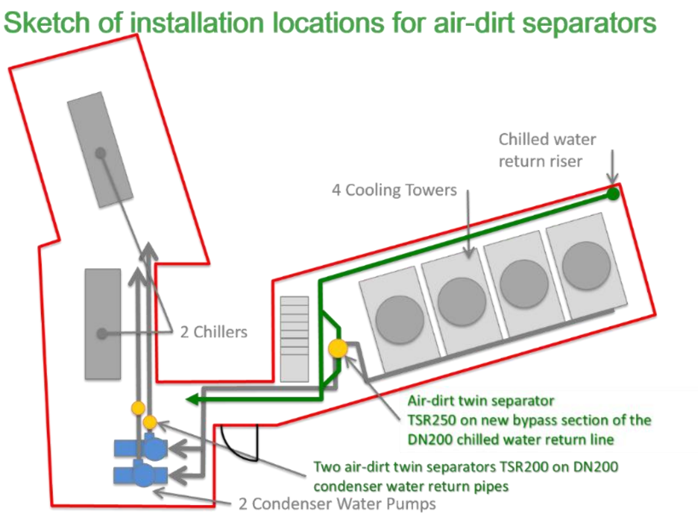


FIGURE 2-7:SKETCH OF INSTALLATION

Which condenser water dropping out of the top of cooling towers and cooling by air coming in from the side of the cooling tower. Dirt and air are mixtures of the water, so the cooling efficiency decrease. There are also other ways that dirt comes into the condenser water, such as the cleaning and sterilizing the cooling water tower, but the majority of dirt are from the cooling tower.

FIGURE 2.8:COOLING TOWER PHOTOS

The cooling tower can draw the air from the bottom section of the cooling tower and then cool the condenser water. In the end, they blow the air out from the top of the cooling tower. This way can prevent them to have a hot air cycle which might decrease the efficiency of cooling. Figure 8 shows the brief operation for cooling tower. The quality of water and functions of cooling tower are also control by the monitors. (Macleod-Smith, 2016)

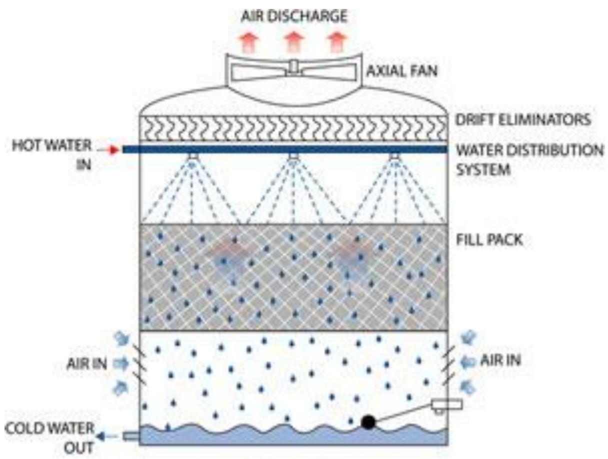


FIGURE 2.9 COOLING TOWER SKETCH(MACLEOD-SMITH, 2016)

2.2.2 Plant room

The pipe system from original Plant room are already well designed and an electrical sensor is also installed. The electrical signal is always collected by the University of Queensland, therefore, plant room can be monitored and analysed.

FIGURE2-10:PLANT ROOM PIPE SYSTEM

There are two water system in the plant room, condenser water system and chilled water system. The simple graph for Colin Clark plant room is shown.

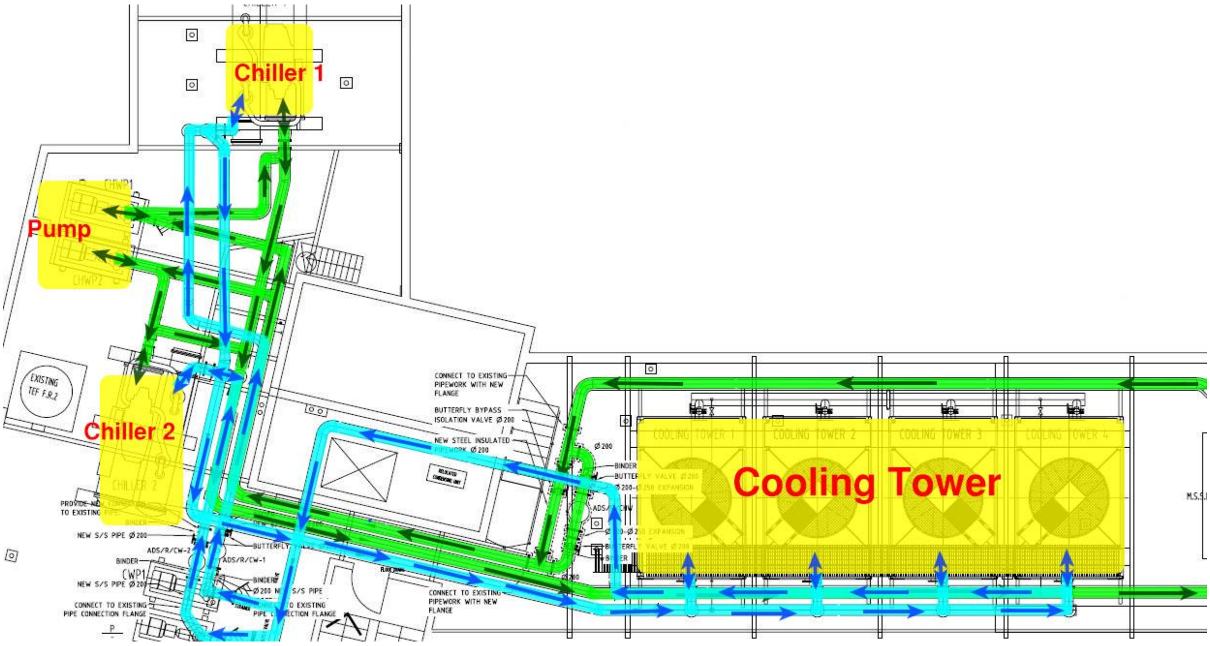


FIGURE 2-11 PLANT ROOM

Green lines are the chilled water system and blue lines are the condenser water system.

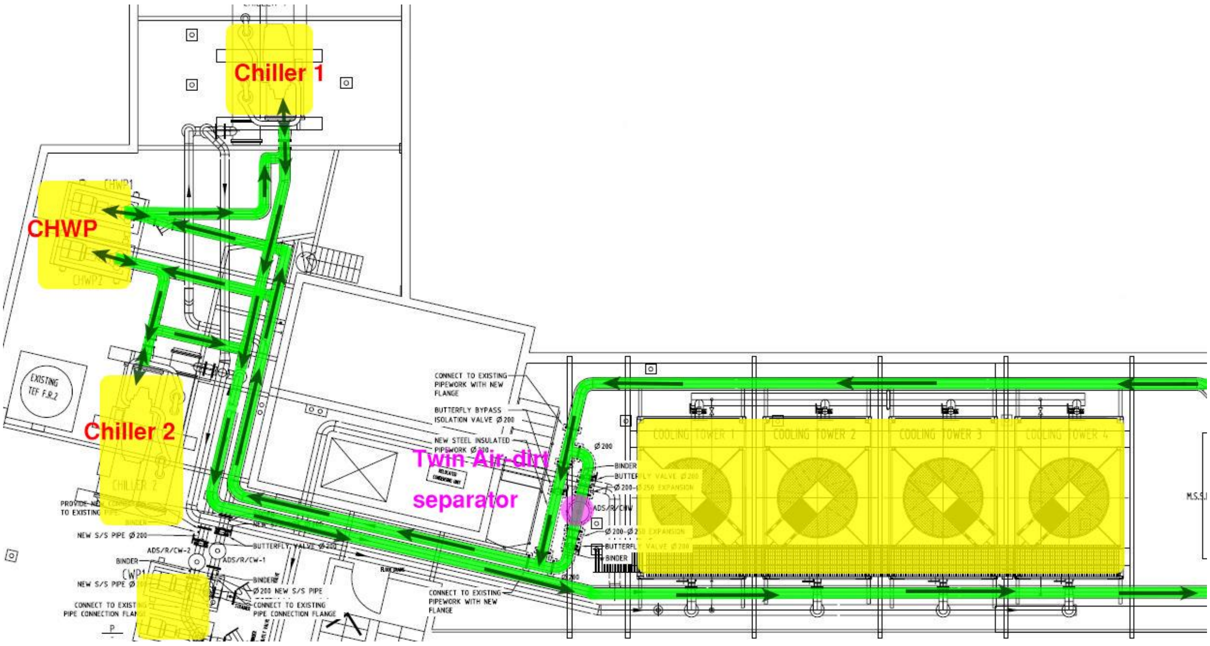


FIGURE 2.12:CHILLED WATER

The chilled water system collects the heat from the building and release the heat in the chillers. The twin separator is also installed on the chilled water system.

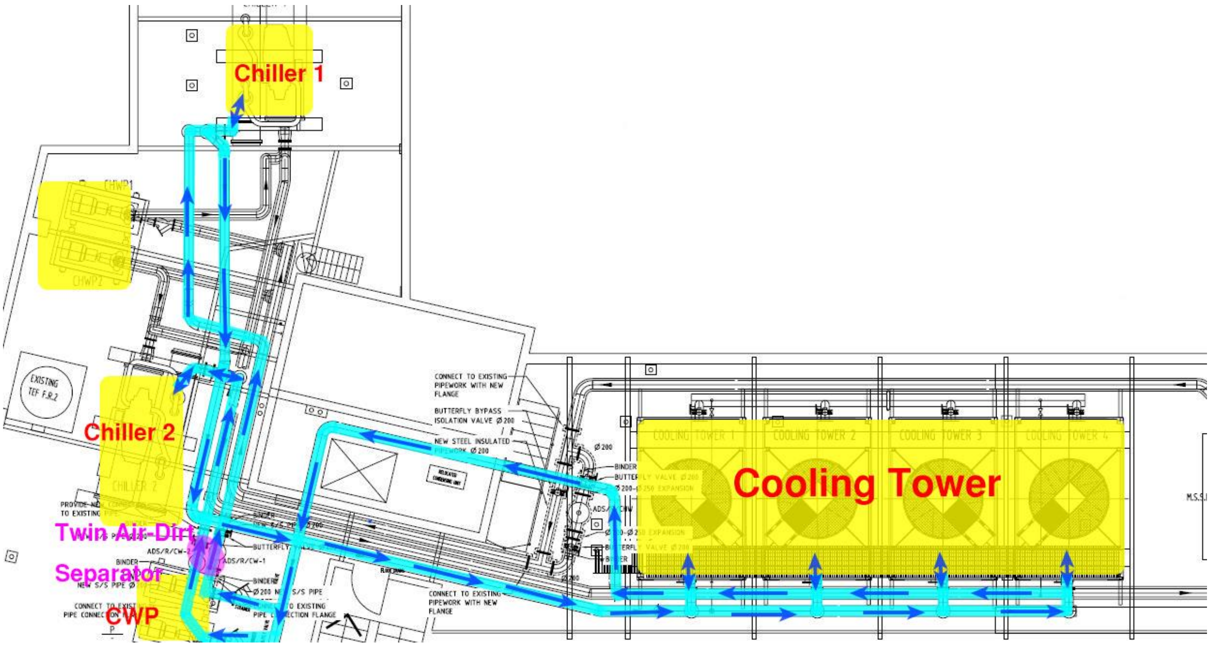


FIGURE 2.13: CONDENSER WATER

Condenser water system collects the heat from the chillers and then release the heat inside the cooling tower. There are two twin separators are installed on the condenser water system.

2.2.3 Coefficient of performance

In order to calculate the efficiency of water system, the performance of HVAC system is characterized by a quantity equation. The equation is known as the coefficient of performance (COP). The higher value means the better HVAC system efficiency. COP is a dimensionless ratio and it changes depending on operating condition.

$$COP = \frac{removed\ heat}{input\ work} = \frac{cooling\ load}{Energy\ consumption}$$

2.3 The location and pressure drop of the OaseTECH filter

Pressure drop for twin separators

The pressure (head) losses for separator can be determined according to the chart and equation below. There are two types of OaseTECHseparators, one type with diameter number DN 250 and the other one with diameter number DN 200. DN number indicates the diameter size for pipe. The K_{vs} for TSR200 is 780.6 (m3/h) and for TSR250 is 1185.7(m3/h). The confiscations are calculated based on different flow rate of the section.

Computational formula of pressure drop

$$\triangle P = \left(\frac{\dot{Q}}{K_{VS}}\right)^2 \cdot 100kpa$$

Note:
1. $\dot{Q}$: the flow of system
2. Kvs: The system flow coefficient
3. The flow of system ≤ the maximum flow of the equipment

Look–up table for the system flow coefficient

Interface size	K_{VS} in m³/h	Interface size	K_{VS} in m³/h	Interface size	K_{VS} in m³/h
DN 50	72.2	DN 150	487.9	DN 400	2668.4
DN 65	121.7	DN 200	780.6	DN 450	3148.8
DN 80	158.5	DN 250	1185.7	DN 500	3589.6
DN 100	244.3	DN 300	1696.4	DN 600	4630.6
DN 125	351.3	DN 350	2155.7		

FIGURE 2.14:PRESSURE DROP

The following results are demonstrate from the calculations. The pipe has to withstand certain amount of pressure drop. Furthermore, the pressure drop will constantly monitor by a transducer on the side of the pipe. (if the transducer actually get installed, the write more about transducer)

It's a linear function for pressure drop and flow rate, furthermore the bigger the interface models are the higher pressure drop can be tolerance.

Model	Pressure drop	Flow rate	Pressure drop	Flow rate
TSR250	1.34 kPa	38 L/s	5.4 kPa	76 L/s
TSR200	5.3 kPa	50 L/s	9.0 kPa	65 L/s

2.3.1 TSR200

Two twins air-dirt separator is installed according to the position in the figure below. There will be a space required for chiller servicing. However, it's alright to install the separator according to the graph, since it's not on the way of working flow.

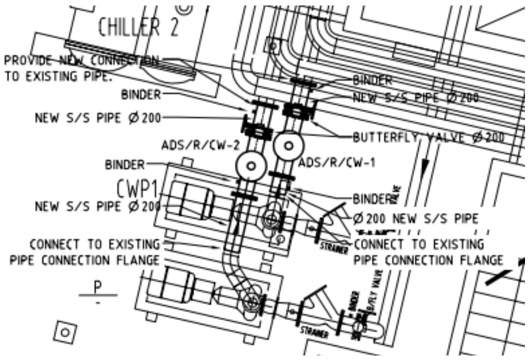


FIGURE 2.15:TSR200 DRAWING

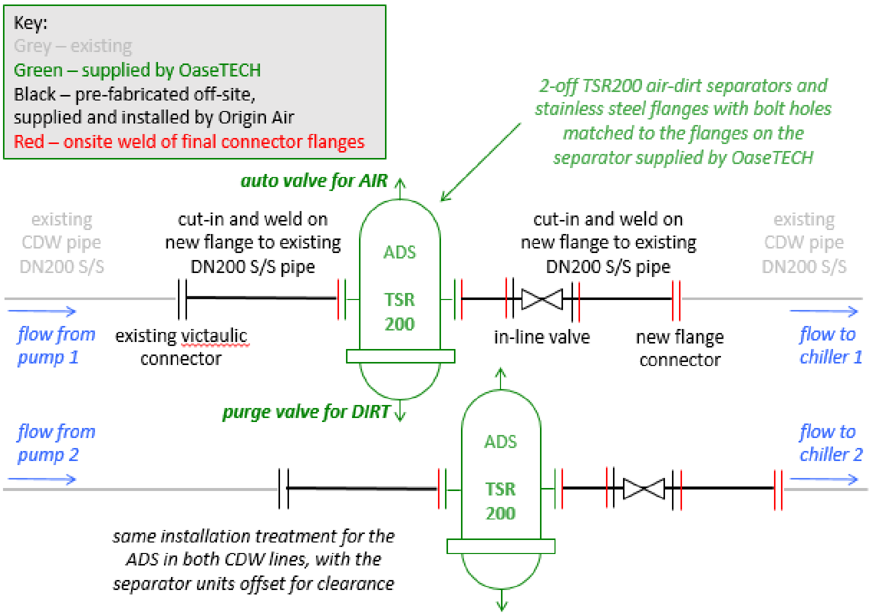


FIGURE 2.16:TSR200 LOCATION AND DEATILS

2.3.2 TSR250

The location is chosen after considering the position of pipe and access ability. This location can also maintenance from the blow and on the landing. The waiting is supported by existing overhead frame. Moreover, the installation is done by unbolting and reconnecting and no welding required on the site.

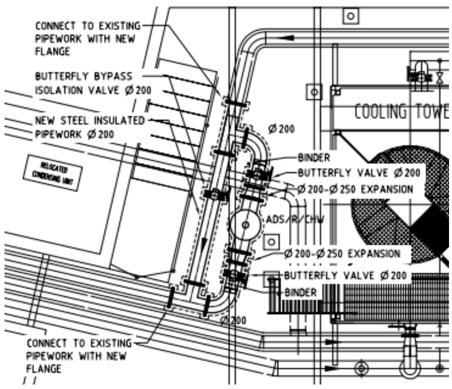


FIGURE 2.17:TSR250 DRAWING

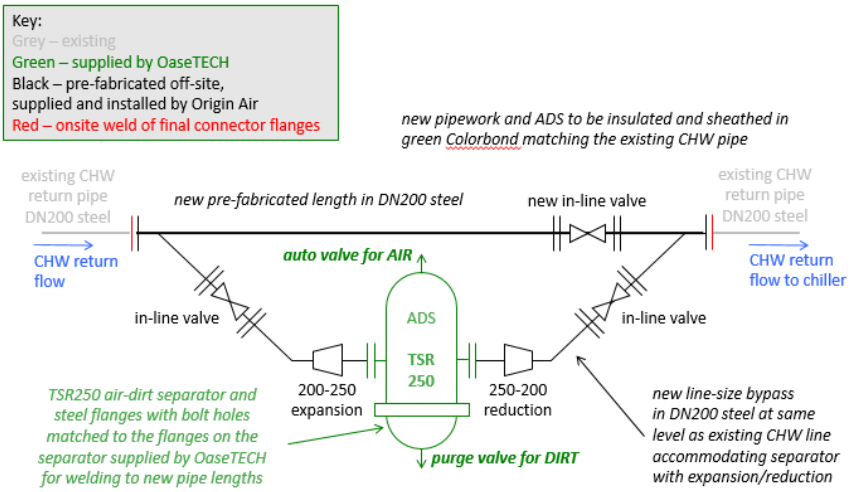


FIGURE 2.18: TSR250 DETAILS

Chapter III: Building Heat Load Simulation

Chapter Summary:

The building simulation software, eQUEST, is developed by one of the America's national labs. It can simulate the heat gain of building. A small testing model is made to validate eQUEST. The result is compared with the results from hand calculation. The results of hand calculation are similar to eQUEST result. The simulation of three buildings were calculated. Building 14 has the highest ratio of heat gain. The simulation results for the three buildings are similar to past cooling loads (Aug 12 to Jul 15).

FIGURE 3-0-1:EQUEST

3.1 eQuest Introduction

eQUEST is a sophisticated energy simulation tool for building analysis which gives professional energy simulation result. eQUEST bases one DOE-2.2 simulation engine, which is developed by a partnership of James J. Hirsch & Associates(JJH) and Lawrence Berkeley National Laboratory(LBNL) supported by The United states Department of Energy(USDOE) and the United States electric and gas utility industry. It combines building creation and energy efficiency measure into detailed graphical results and spreadsheet. (Zhu, 2014) (Hirsch, 2004)

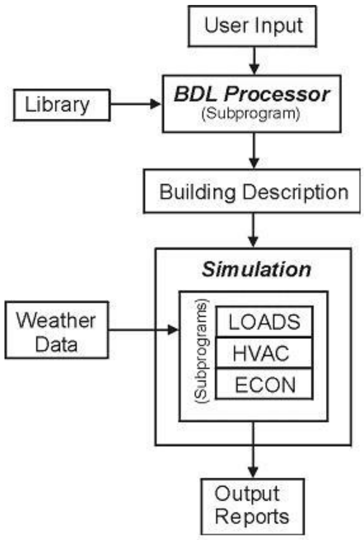
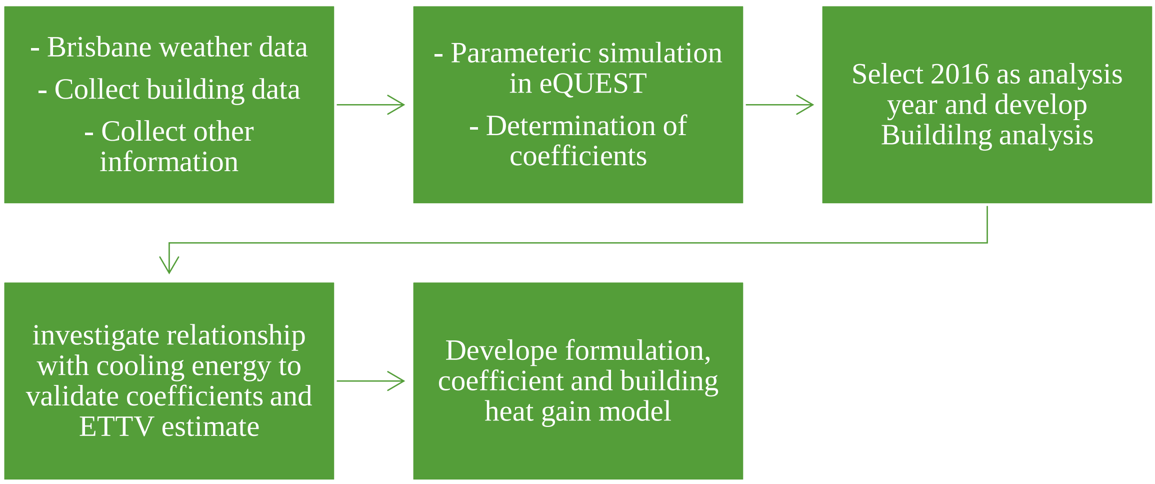


FIGURE 3-2: EQUEST FRAME WORK



3.2 eQuest Validation(Simple Model)

A small scale case is tested in this section, in order to verify eQuest software. A small metal cabin room with three windows on the south, east and west side and one door on the north side is simulated. By comparing simulation results and hand calculation result for cooling load. eQuest software can be verification for calculating more complicated building model.

3.2.1 Assumption and Sketch

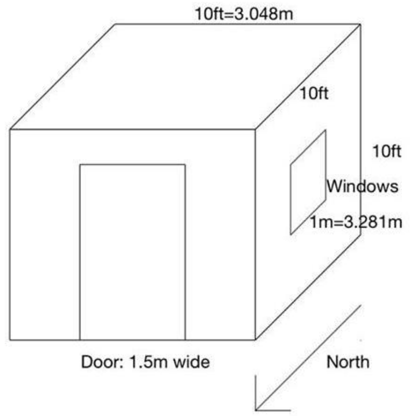


FIGURE3-3:SIMPLE MODEL

Door: 1 (Face north)

Windows: 3 (Face east, west and south)

- Brisbane Area
- Office Building
- No other heat generated
- No Shading
- 1 Person + 1 Computer
- Lighting: 100W

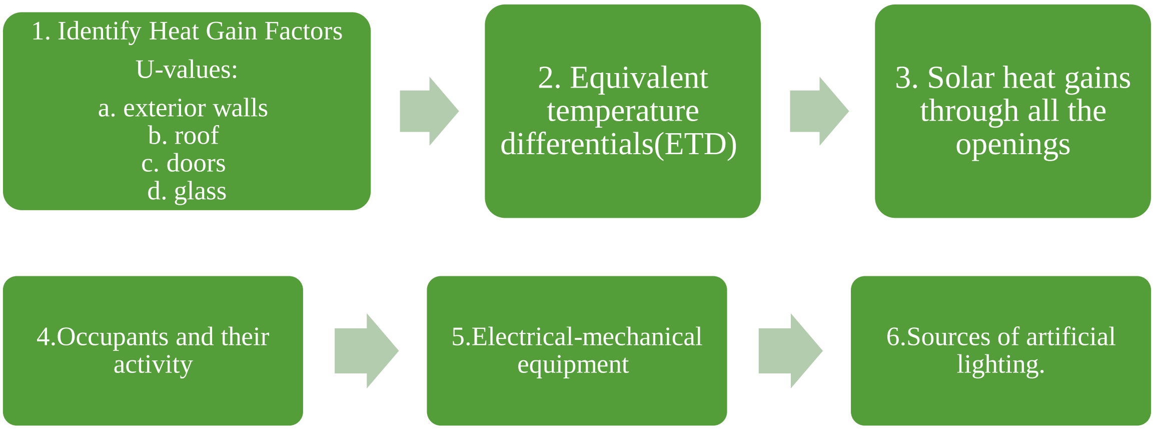
3.2.2 Design Development Wizard:

Project / Site / Utility: This is an official building in Brisbane area. This office operates entire 2015 year. Building Shell: Area is $100\ ft^2(9.29m^2)$ and has 1 about grade. Roof and Walls are 24 in (60cm) Metal Frame. It only has 1 door, which is Air lock entry(glass). Three windows are double Clear/Tint with 10.764% window ratio. 1 fully grew man is using computer inside the office. Lighting and Office equipment are both around $2\frac{w}{ft^2}(21.5278\frac{w}{m^2})$ inside the building.

3.2.3 Hand calculation

The calculation in eQUEST validation is calculate in British units, because eQUEST operates in British units.

There are different ways to calculation heat gain for a building. The following way is the general way of calculation. The first flow chart is heat gain from outside. The second flow chart is internal heat gain. In order to calculate the heat gain of the simplified building, it's very imported to understand how does heat transfer from outside to inside. The basic concept starts with the overall heat-transfer coefficient.



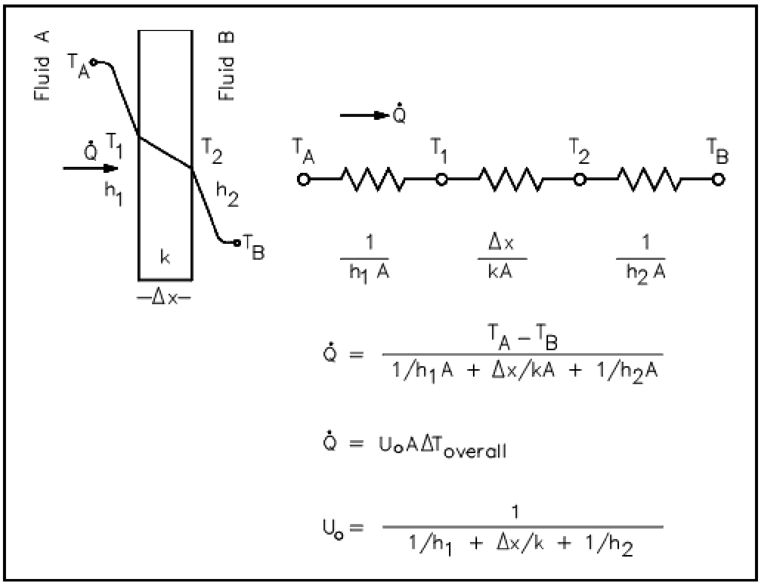


FIGURE: 3-4: HEAT TRANSFER

(ExpertsMind, 2016)

The heat transfer process is demonstrated by resistance network, and the heat transfer is calculated by overall temperature different (temp. A – temp.B) divided by overall resistance. This transfer might combine conduction and convection transfer. The convection transfer also indicated by$\dot{Q} = U_o A \Delta T_{overall}$. (ExpertsMind, 2016) The calculation process is presented in Appendix. The calculation are based on following equations.

$$U\ value = overall\ heat\ transfer\ coef.$$

$$Q_c = AU(equivalent\ temperature\ differentials)$$

$$Q_c = AU(T_{outside} - T_{inside}), Q_r = ASg(shading\ coefficients)$$

To calculate the internal heat gain,

$$Qp = nM$$

$$n = No.of\ occupants, M = activity\ sensible\ heat\ gain\ in\ Btu/hr$$

$$Q_m = 3.4 * wattage\ (electricl - mechanical\ equipment)$$

$$Q_l = 3.4 * wattage\ (artifical\ lighting)$$

$$Fluorescent\ lighting\ =\ 0.8\ watts/ft^2,$$

$$Incandescent\ lighting\ =\ 1.5\ watts/ft^2$$

The average annual outside temperature within a year is about 78 F($25.556°C$)

The most productive temperature for human is about 70 F ($21.11°C$)to 73 F($22.778°C$) (Adams, 2014)

3.2.4 eQuest calculation

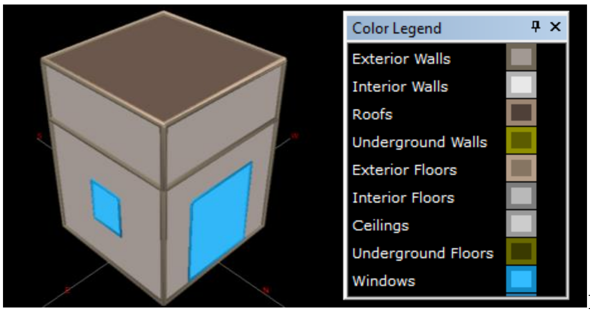
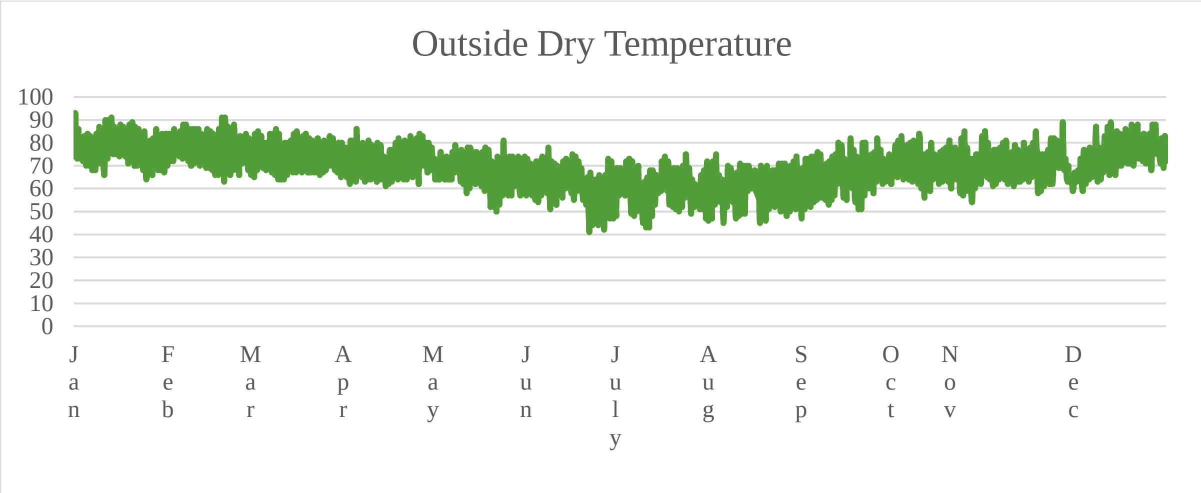
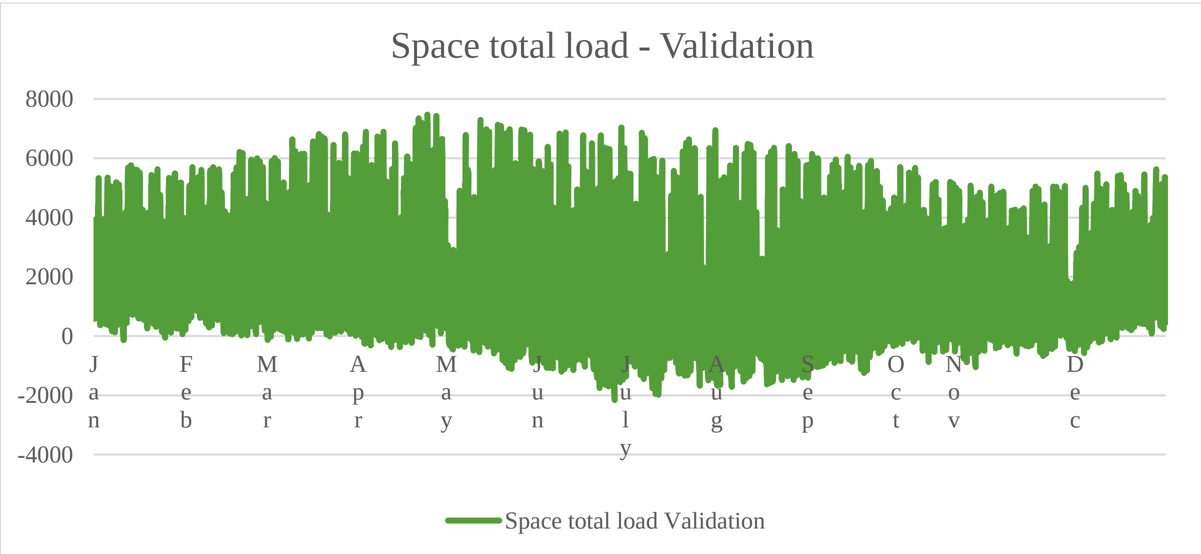


FIGURE 3-5: EQUEST(SIMPLE)

3.2.5 Result and Discussion



Average Outside dry temperature is about 68.8181 F



The space total load presents the heat load need for maintaining the room temperature with in the building.The average result is about 1654.904487 btu/hr(0.485kW)

	Average Temperature(F)	**Total Heat Gain (Btu/hr)**
Hand Calculation	78	1778
eQUEST Results	68.8181	1654.904487

The result shows that total heat gains are very similar. There is only 123.098 Btu/hr in difference, this might due to the average temperature data for eQUEST is 68.8181F and the hand calculation uses 78F. This indicates in the small scale example, eQUEST can generate a correct answer, therefore, the three buildings simulation can provide a general scope of how much heat gain are from the buildings.

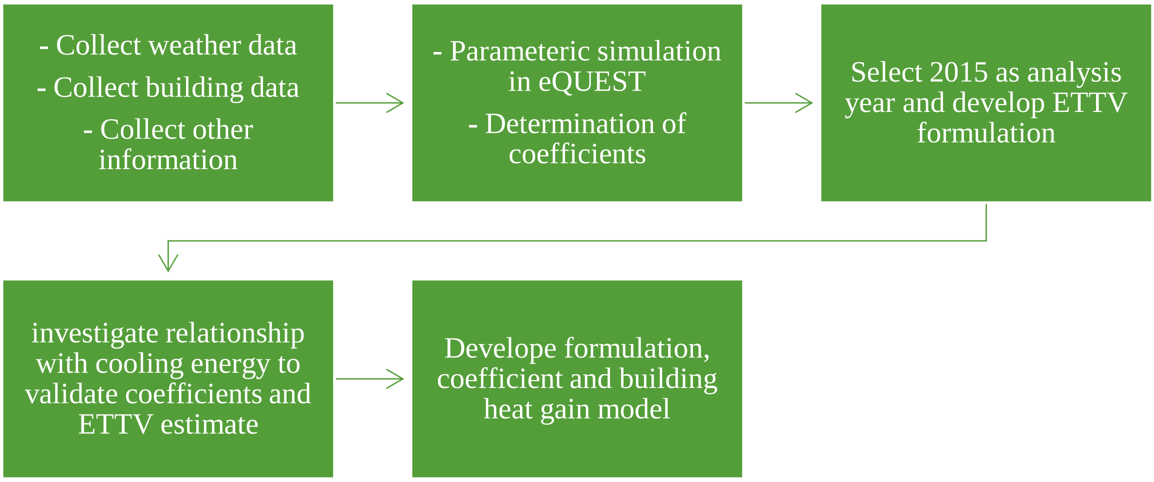
3.3 eQuest Model for three buildings

After validating the simple model in section, eQuest Validation(Simple Model), eQUEST can be assured that it's a proper tool to model the building heat gain. Therefore, within this section, three different model for eQUEST building is going to be modeled. The calculation is based on 2015 academic calender.

3.3.1 Assumptions:

In this three modelling, there are many assumptions are made, in order to give a general scale of modelling. The geometry shape of buildings is drawn according to the imported CAD file. Windows and wall are simplified. Walls and roofs are assumed to be 6-inch concrete.

3.3.2 Process



3.3.3 Sir Llew Edwards Building (14), Duhig North (12) and Duhig Link (12A)

Investigation

BUILDINGS ARE SIMULATED BASE ON THEIR CAD DRAWING. SIR EDWARDS BUILDING IS SIMULATED BASE ON ITS 2ND FLOOR CAD DRAWING. BUILDING 12 AND BUILDING 12A USE THE 1ST FLOOR CAD DRAWING.

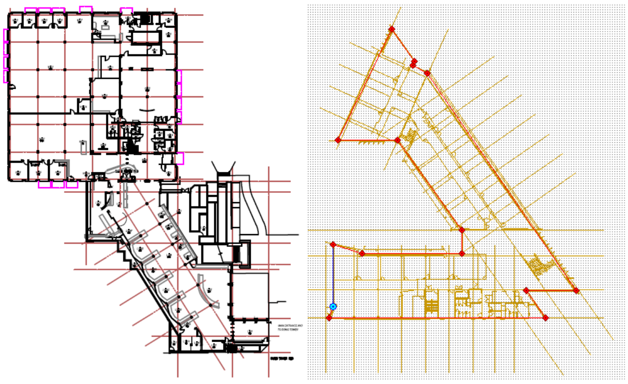


FIGURE 3-6: 3BUILDLINGS

There are two different type of areas

GFA: Gross Floor Area (includes both enclosed and unenclosed areas, such as open door)

UFA: Useful Floor Area (only the enclosed area, which is air-conditioning is)

Normally, average GFA is used to simulation, but eQUEST actually count as all the unenclosed area into the simulation, in order to present a more realistic outcome.

Floor	**GFA**(m^2)
Level 1	1326
Level 2	1828.5
Level 3	1891.7
Level 4	1895.9
Level 5	1861.3
Level 6	1323.6
Average (Building 14)	1687.83 m^2 =18167.65092 f^2

Floor	**GFA**(m^2)
Level 0	338.1
Level 1	1750
Level 2	1788
Level 3	1754
Level 4	1754
Average (Building 14)	1761.5 m^2 =10215 f^2

The building types are chosen to be “school University” in “Brisbane” and as the eQUEST temperature and actual temperature is compared in the validation part. The weather data assume to be correct. There are three different school seasons, “ school”, “school break” and “summer”.

While doing the simulation mid-semester break and exam period count as school time The detail options are presented in the “appendix. 3 buildings simulation”

3.4 Simulation results from eQUEST

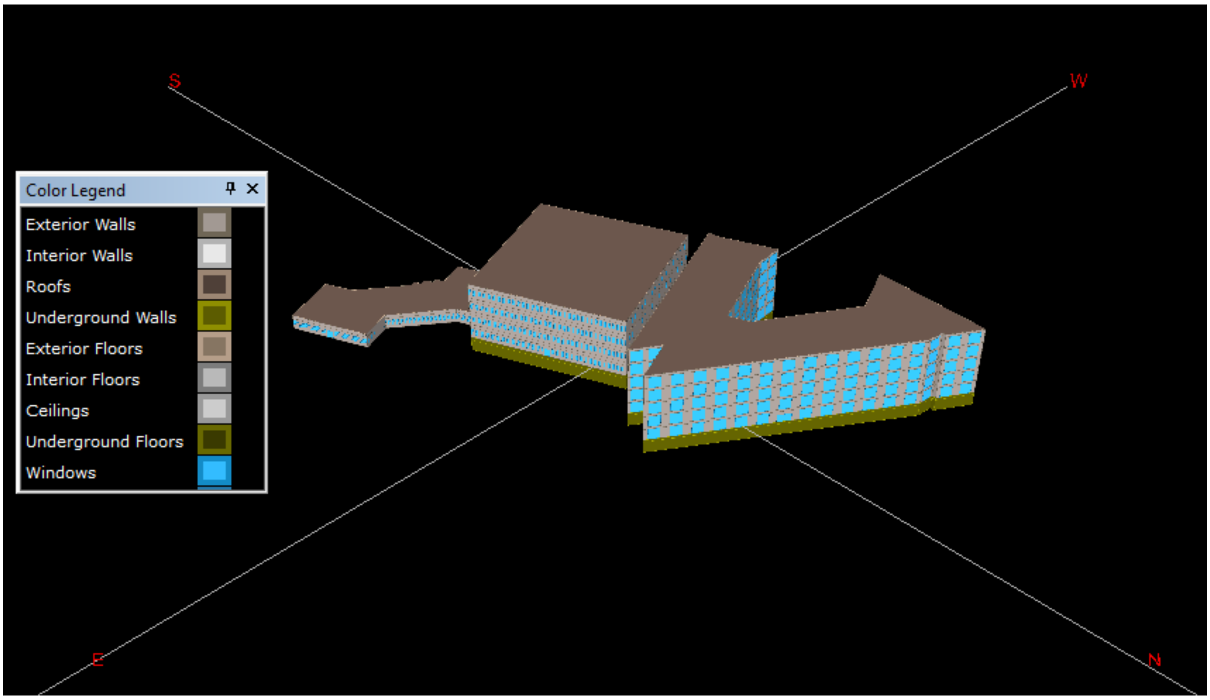


FIGURE 3-7:3D MODEL FROM EQUEST

After simulation, a set of data and a 3D model are created. Figure 3-7 shows that 3D model shape. Data is collected and put into excel sheet in order to calculate the heat gain from simulation result. Figure 3-8 to Figure 3-10 are the heat gain result related to each building.

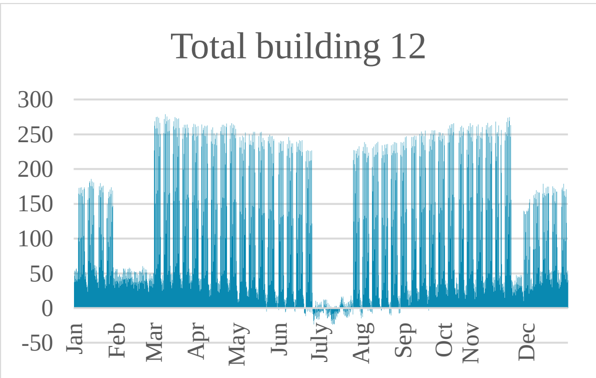


FIGURE 3-8:TOTAL BUILDLING

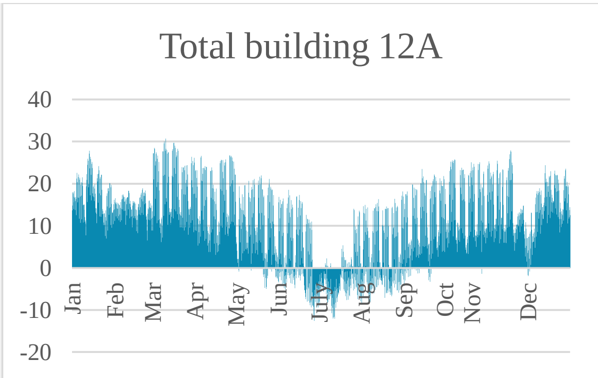


FIGURE 3-9: TOTAL BUILDING 12A

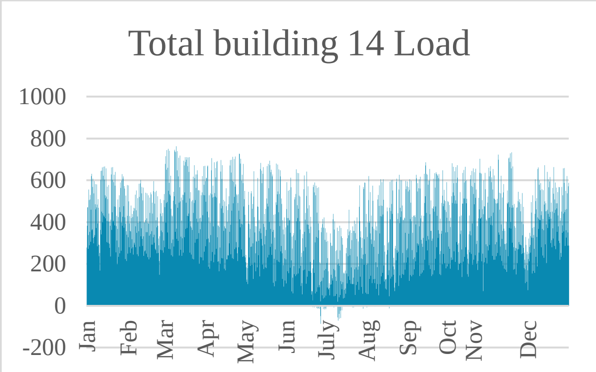


FIGURE 3-10:SIMULATION RESULT FOR BUILDING 14

The results are in line charts and bigger clear figures are in the Appendix section. These three figures show a clear pattern that three buildings rely on different heat sources. Building 12 strongly relies on university schedule because the pattern of the chart of building 12 looks very similar to university schedule. It is obvious that from March to June and August to November, they are semester 1 and 2. Additionally, summer semester takes place from December to January. On the other hand, building 12A has a clear pattern following the weather condition. Although there is still a little effect from university schedule, the pattern of 12A is similar to the trend of weather. Building 14 is a large commercial building and half of the building are school offices. Therefore, its heat gain has much less effect from weather and university schedule.

By comparing these three results, building 14 covers more than half of the heat gain. See figure 3-11. Building 12A has an abnormally high data in March. The reason for this high data in March might due to two reasons. First, the building shape of building 12A is a long shape and the major source of the sun is from the north-east side. Therefore, in particular time of the year, building 12A would be hotter. The second reason might be due to the high IT usage in the beginning of the semester. This can be determined by the higher heat gain in March and August from simulation result for building 12A. The October value is interestingly low and looks like it is out of the curve. This happens in all of the building simulation results. The study on the results does not explain the reason why October value is so low, therefore, the reason might be related to the eQUEST simulating module.

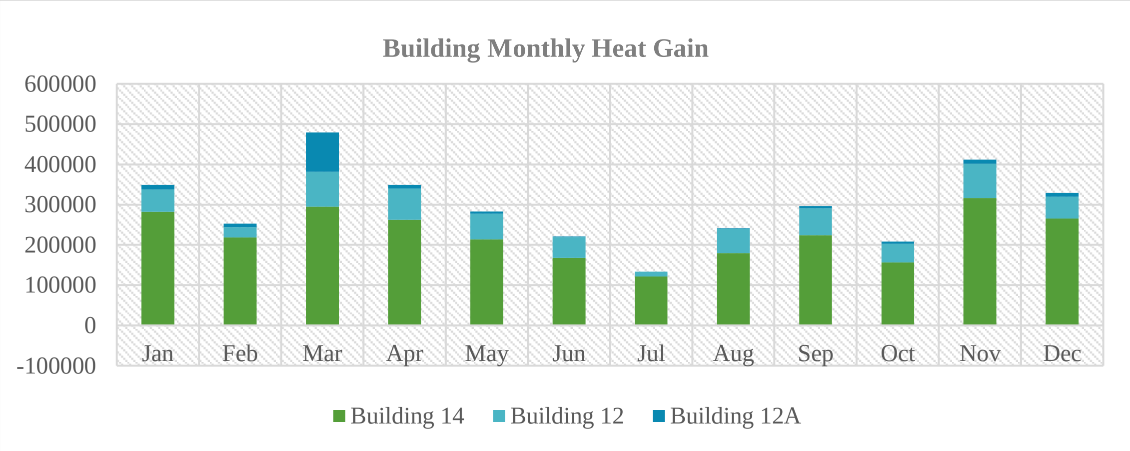


FIGURE 3-11:BUILDING MONTHLY HEAT GAIN

Figure 3-12 is the chilled water data from northern Precinct provided by the University of Queensland. The results are generally equally distributed. Summer has a higher amount of usage. March has the highest percentage (13.5%) and January has second highest percentage (12.6%). The actual monthly kWh cooling load is put into comparison shown in figure 3-12. UQ uses an average 3 COP to calculate the approximate electrical consumption. The Colin Clark building plant room covers about 1.1% of UQ total electrical consumption.

Northern Chilled Water Precinct			
	Monthly kWh Ref	Percentage	
Aug-14	166276	4.2%	
Sep-14	233324	5.8%	
Oct-14	346790	8.7%	
Nov-14	479878	12.0%	
Dec-14	412901	10.3%	
Jan-15	501699	12.6%	
Feb-15	430652	10.8%	
Mar-15	538527	13.5%	
Apr-15	309060	7.7%	
May-15	244064	6.1%	
Jun-15	178221	4.5%	
Jul-15	152120	3.8%	
12 Month Total	3993512	100%	
Electical Consumption	1331171	3	Average COP
Campus Total	125000000	1.1%	

FIGURE 3-12:NORTHERN CHILLED WATER PRECINCT.

Figure 3-13 shows the comparison between total simulation and real monthly record. In January, February and March, the real monthly results are higher than simulation. The simulation value in October is also lower than real monthly measurement. There are several possibilities that building has higher real monthly value. One of the possibilities is that post-graduate students have a different academic calendar. The heat gain amount from post-graduate student adds on the current heat gain. The other possibility is that school facility usage during the holiday cannot be fully simulated. The activities during the holiday are all different in different university. eQuest university module might not able to give the correct estimation. Although some values are different, the eQUEST simulation generally shares similar trend as real monthly result.

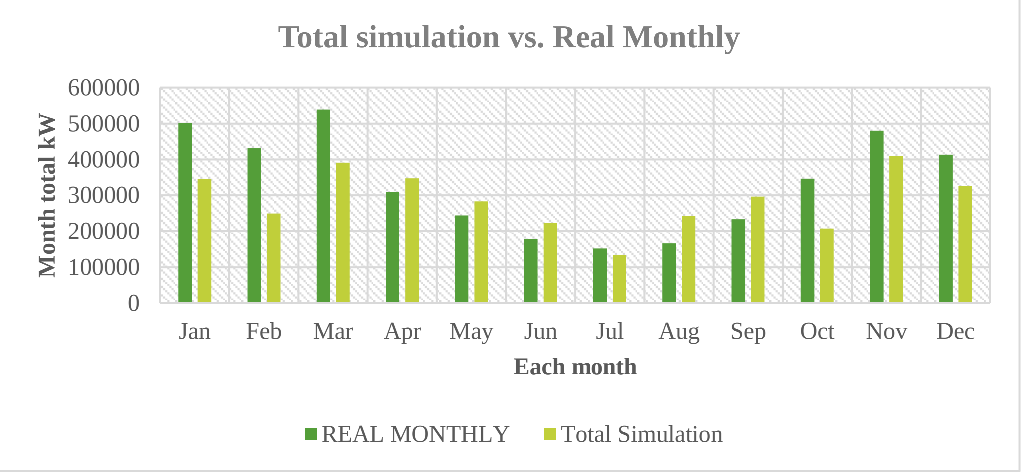


FIGURE 3-13:SIMULATION VS. REAL (AUG 14 TO JUL 15)

The eQUEST should give a reasonable simulation for required heat load of three buildings. By cooling this heat load, three buildings can be maintained at the constant temperature. This heat load is used as a standard in post air conditioning performance in order to justify the correct amount of energy efficiency increased by twin separator.

Chapter IV: Air conditioning performance

Chapter summary

The post-installation performance data were also collected. The results were compared with data in previous year, 2015. Data shows that the cooling load in 2016 is lower than the cooling load in 2015. This contradicts the predicted weather trend. COP also shows that the year of 2015 has a higher cooling load. However, the results might be inaccurate for several reasons. Firstly, the measurements only consisted of two-month data. Secondly, there were more events or activities in 2015 at which the data of these events could not be excluded. Thirdly, the energy consumption from the plant room has no general trend and it is not consistent.

4.1 Post Air conditioning performance

The twin separators are installed in the beginning of July and the change of installation was happened in August. The data analysis of this thesis report focuses on operations in July and August. The data set of September and October were still incomplete while writing this report. Bigger figures are presented in the appendix. Heat capacity of water is set as 4.187 kJ/kgK. The chilled water is operated around 5°C to 10°C. 4.187 kJ/kgK is lower than the average water heat capacity at 5°C to10°C (heat capacity: 5°C: 4.202 kJ/kgK & 10°C: 4.192 kJ/kgK). The reason why UQ uses such number is due to the several chemical treatments done on the chilled water so, heat capacity for chilled water changed. (Engineering - Tool box, 2016)

4.2 Methodology – calculate performance

In order to calculate the performance, the raw data provided by UQ is used.

- 39 CHSEQ Common Chilled Water Supply Temperature
- 39 CHSEQ Common Chilled Water Return Temperature
- 39 CHLR1 Chiller 1 MAG Flow
- 39 CHLR2 Chiller 2 MAG Flow
- 39 Chiller System kW Refrigeration (kWr)

The result of "39 Chiller System kW Refrigeration (kWr)" can be calculated. The temperature difference between supply and return temperature reflects the amount of heat gain on one litre of chilled water. The flow rate of water decides how much water is cooling the building at a set time so, the total heat gain can be calculated.

$$\mathrm{T_s} = \ Chilled\ Water\ Supply\ Temperature\ (°C)$$

$$\mathrm{T_r} = \ Chilled\ Water\ Return\ Temperature(°C)$$

$$\dot{Q}_1 = Chiller\ 1\ water\ flow\ (l/s)\ , \dot{Q}_2 = Chiller\ 2\ water\ flow\ \ (l/s)$$

$$\mathrm{Q} = \ \mathrm{m} * \mathrm{C} * \Delta\mathrm{T}$$

$$\mathrm{C} = \text{Heat Capacity of Water} = 4.187\ kJ/kgK$$

$$\text{System kW Refrigeration} = \ (\mathrm{T_r} - \mathrm{T_s}) * (\dot{Q}_1 + \dot{Q}_2) * 4.187$$

The system kW also equals to the cooling load of the building. This cooling load is used to calculate the coefficient of performance. The coefficient of performance is introduced in previous chapter. The equations are shown below.

$$Coefficient\ of\ Performance(COP) = \frac{Removed\ heat}{Input\ work}$$

$$COP = \frac{Cooling\ load\ for\ chilled\ water}{Electricity\ Consumpted}$$

4.3 Post Air Conditioning Result Analysis

The figures show the post air conditioning result performance for July and August. The simulation result from eQUEST is used to compare the ideal cooling load.

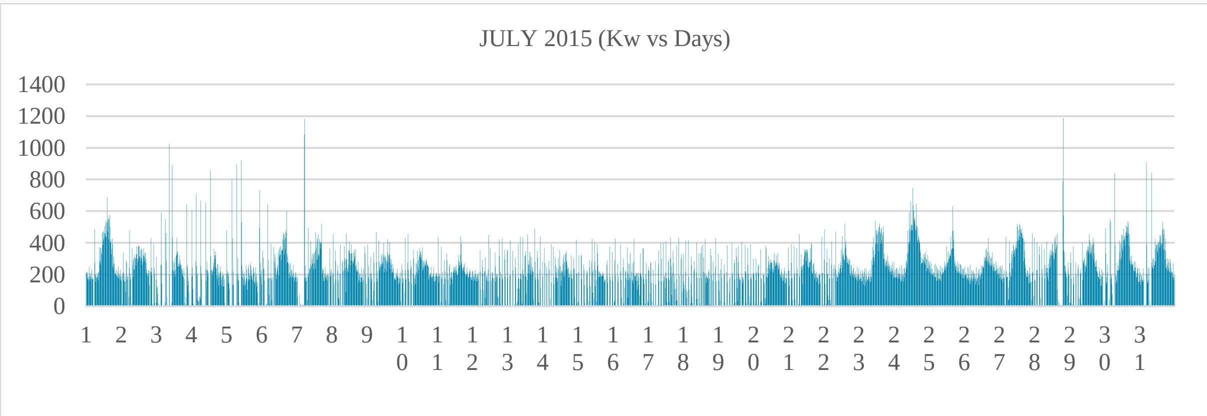


FIGURE 4-1:JULY 2015 KW REFRIGERATION.

There is not much to address on 2015 data except that there are two extra high values which are on the 7th and 28th.

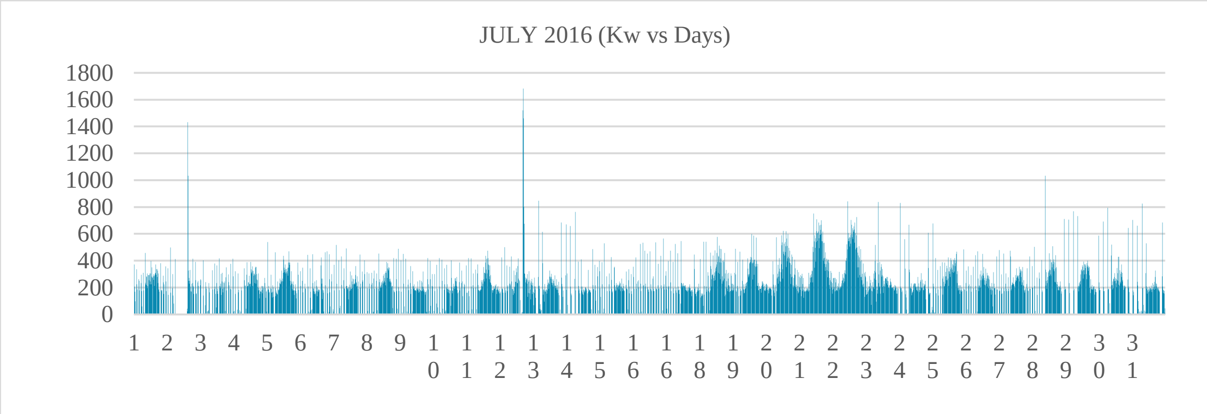


FIGURE 4-2:JULY 2016 KW REFRIGERATION.

The installation took place in 2nd of July which is the beginning of the university holiday. Therefore, there is an empty space on the 2nd of July. There are two extra high values on 2nd and 12th. The extra high value on 2nd of July is believed to be the system testing.

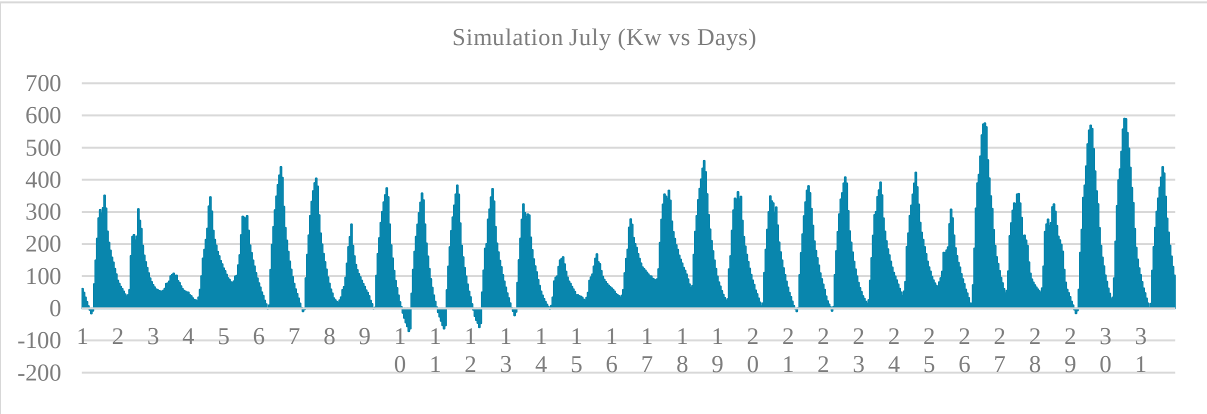


FIGURE 4-3:SIMULATION RESULTS FOR JULY

The simulation results show the ideal situation for expected cooling. The maximum value is only up to 600 kW. The eQUEST simulation can obviously show the continuity of the result. There is even a negative heat gain for this result.

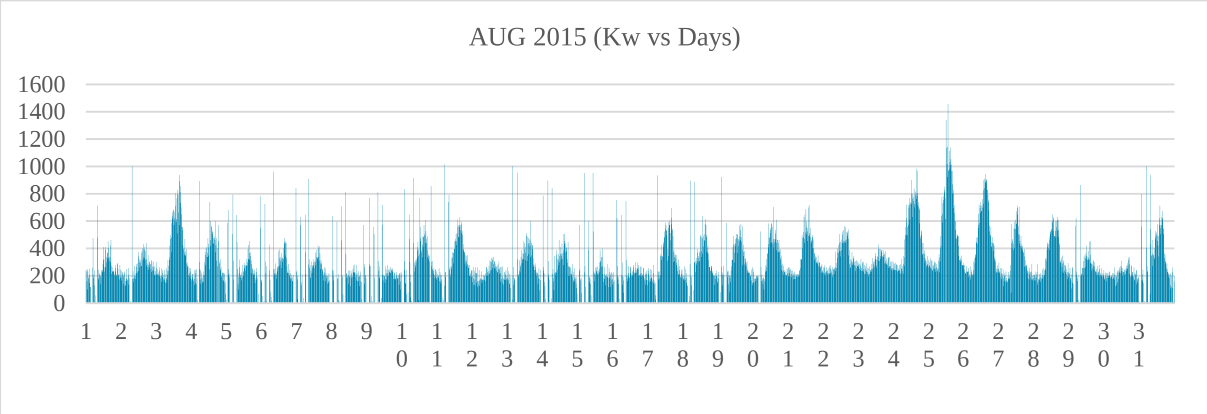


FIGURE 4-4:JULY 2015 KW REFRIGERATION.

The result of August shows that there are very high cooling loads on 24th to 27th. This probably indicates any event that was held on those days.

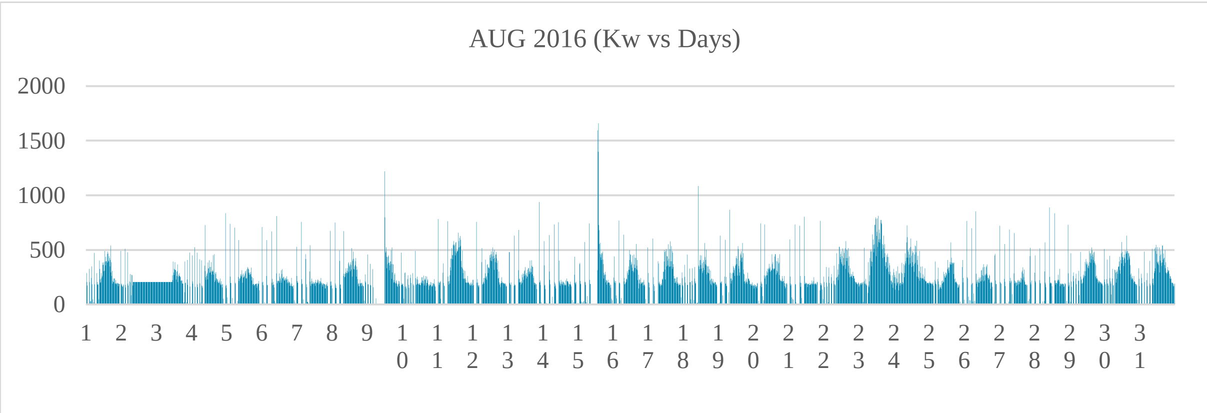


FIGURE 4-5:AUG 2016 (KW VS DAYS)

For the result in August 2016, there are two peak results on 9th and 15th. The change of installation (change the handle) also stopped the HVAC system on 9th of August. A testing section from 2nd to 3rd was taken place so, cooling load shows a straight flat value. The rest of the day is operating normally.

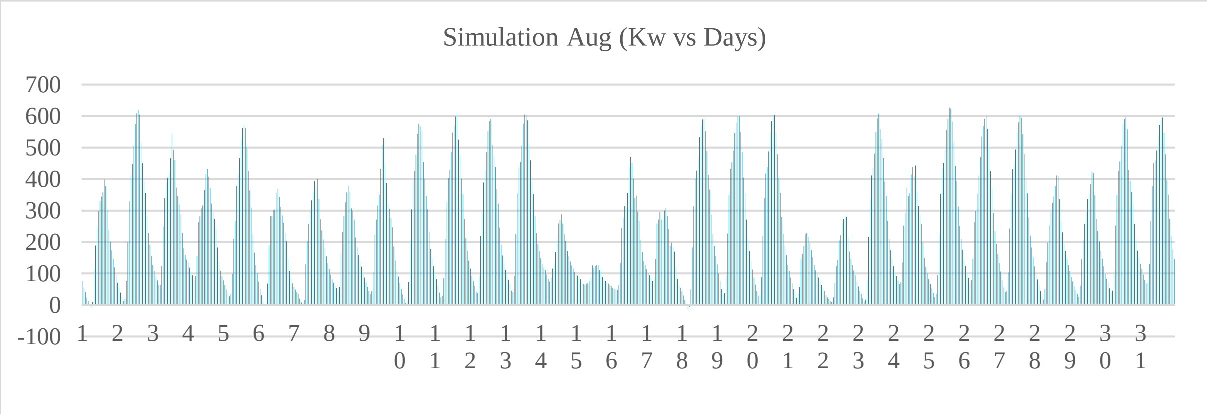


FIGURE 4-6:SIMULATION AUG (KW VS DAYS)

The simulation results are generally smooth. There are not peak values or unexpected values.

4.4 Numerical Result Analysis

There are two analyses done in this section. The first analysis is done on the raw numerical result including all of the abnormal values. The second analysis is done on the modified value. This set of the results is modified according to a reasonable justification. The modified value would be a better approach to a more efficient improvement.

4.4.1Raw Numerical Result Analysis

The raw data includes all of the available data in July and August. This raw data gives a straightforward result. This result might not able to react with the actual increase in energy efficiency.

Raw Numerical Analysis – July				
	July Total (kW)	**July average hr (kW)**	**(%) Based on simulation**	**(%) Based on Before inst.**
eQUEST Simulation	121600.79	163.44	100%	80.38%
2015 (Before installation)	151274.39	203.32	124.4%	100%
2016 (After installation)	142083.24	190.97	116.84%	93.92%
Raw Numerical Analysis – August				
	Aug Total (kW)	**Aug average hr (kW)**	**(%) Based on simulation**	**(%) Based on Before inst.**
eQUEST Simulation	179948.29	241.86	100%	85.51%

2015 (Before installation)	210428.12	282.83	116.94%	100%
2016 (After installation)	159295.10	214.10	88.52%	75.69%

The raw data numerical analysis shows that after installing new twin separator, at least 6.08% of energy has been saved in July. About 24.31% of energy has been saved in August. This result has not taken weather into account. As mentioned in weather section, July 2016 is the warmest month in the history so, the energy saved by twin separator might be higher than these numbers. However, this number includes some of the unexpected events so, modified numerical results are presented.

4.4.2 Numerical Result Analysis (Modified)

There are some events or reasons that cause the cool load to increase. Thus, extra high value in the data should be removed. The events do not happen every year so, it is more correct to calculate the improvement in heat efficiency without those events. If the cooling load (kW) is higher than the maximum cooling load in eQUEST simulation in that month (590 kW for July and 627 kW for August), then numbers are modified by certain scales. If there is any result over this number, the value is definitely from an abnormal state. This state might come from a special event or system testing. The scales are calculated as following.

$$July\ scale: \frac{Average\ value\ for\ eQUEST\ July}{Maximum\ Value\ for\ eQUEST\ July}$$

$$July\ Scale = \frac{163.4419}{589.8296} = 0.2771$$

$$August\ Scale: \frac{Average\ value\ for\ eQUEST\ August}{Maximum\ Value\ for\ eQUEST\ August}$$

$$August\ Scale = \frac{241.866}{626.5746} = 0.386$$

The design of this scaling process is to change the over-valued results back to average month result. This hugely decreases the effect on the particular events or special occasions. The modified data also removes some abnormal values and puts the average value from that month’s simulation. For example, there is a gap at the start of July and this measurement gap is caused by the installation of the separator. Their values in these gaps are all zero. A substitute number fills up this value. The substitute number for July is 163kW which is the average value from eQUEST simulation in July.

Modified Numerical Analysis – July				
Modified	**July Total (kW)**	**July Average hr (kW)**	**(%) Based on simulation**	**(%) Based on Before inst.**
eQUEST Simulation	121600.79	163.44	100%	82.17%
2015 (Before installation)	147982.3	198.901	121.7%	100%
2016 (After installation)	136522.7	183.4982	112.27%	92.25%
Modified Numerical Analysis – August				
Modified	**Aug Total (kW)**	**Aug Average hr (kW)**	**(%) Based on simulation**	**(%) Based on Before inst.**
eQUEST Simulation	179948.29	241.86	100%	93.99%
2015 (Before installation)	191447.2	257.3215	106.39%	100%
2016 (After installation)	157342.5	211.4819	87.44%	82.19%

After the modification of value, a more reasonable result is created. Results show that the cooling load of August 2016 is 7.81% less than the cooling load of August 2015. The results in July also show the cooling load in July 2016 is 7.75% less than July 2015. This indicates that both of these months in 2016 have less cooling load than 2015. August is believed to have a correct value since it is more similar to eQUEST result. The further discussion on cooling load is in the discussion - Performance section.

4.5 COP - Colin Clark Plant Room

The coefficient of performance is calculated by $COP = \frac{work\ out}{work\ in}$. The "work out" value equals to the cooling load from chilled water. The "work in" value equals to energy consumption for plant room. Therefore, the energy consumption data is analysed.

UQ provides the measurements of energy consumption from two ports. The corresponding meters are meter 37.05 and meter 39.03. Both of these meters are measuring the sample load of Colin Clark plant room. The only difference is their location. Meter 37.05 locates at sub 17.

Meter 39.03 locates at MSB of Colin Clark building. However, in 2015, there is a gap in the data due to meter issue. In order to calculate the correct meter, this thesis report only considers meter 39.03. Figure 4-7 shows the comparison of 2016 and 2015 measurements on meter 39.03. The results of meter 37.05/meter 39.03 in 2016/2015 July and August are presented in the appendix.

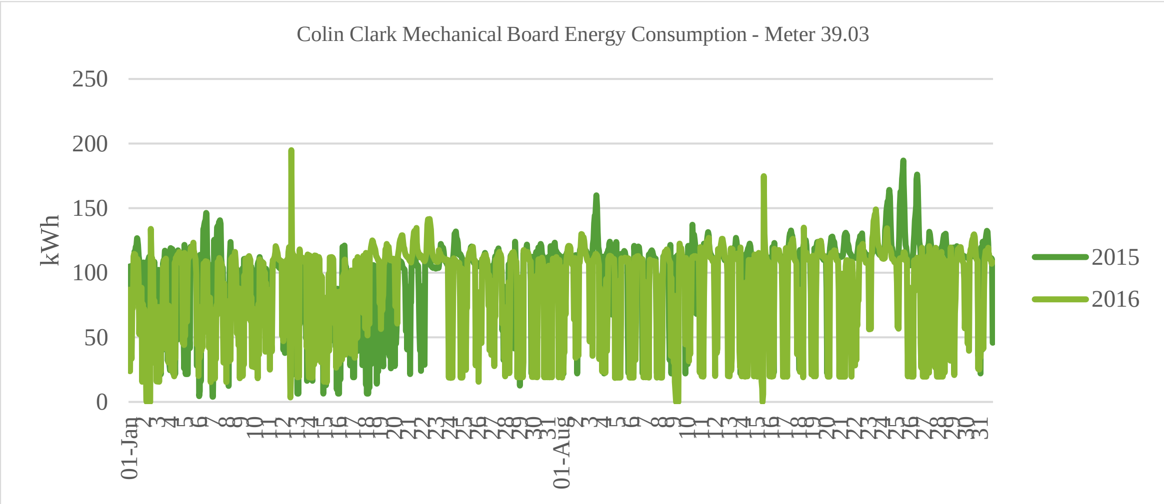


FIGURE 4-7:COLIN CLARK MECHANICAL BOARD ENERGY CONSUMPTION - METER 39.03

4.5.1 Result for COP

July	**Monthly Consumption (kW) – 37.05**	**COP – 37.05**	**Monthly Consumption (kW) – 39.03**	**COP – 39.03**
2015	31570.97333	4.791565791	64216.16668	2.355705792
2016	62990.87	2.25561658	62951	2.257045
August				
2015	39670.29999	5.304424953	79348.05995	2.651963126
2016	66184.47	2.406834976	66033.41	2.412341

4.6 Discussion: Performance

There are two sets of COP calculated from the energy consumption results. The COP of meter 37.05 is obviously wrong because the number for 2015 July/August COP equals to 4.79/5.3. The normal COP chilled water system is around 3 so, COPs are far too high. This is because the meter was not functioning properly in 2015. There is a measurement gap in meter 37.05. One the other hand, meter 39.03 provides more reasonable COP results. The result shows that COPs decrease in 2016. Results for July drops from 2.36 to 2.26 and the results for August drops from 2.65 to 2.41. Although this results are against the prediction, there are further discussions on this result. Result might not be able to indicate that Colin Clark HVAC system has lower efficiency in 2016 This point of view is supported by several phenomena.

The first reason why this COP cannot present the actual improvement after installing twin separators is because the cooling load is against the weather results. Brisbane weather in 2016 is hotter than Brisbane weather in 2015. Therefore, the cooling load in 2016 is supposed to be higher than 2015 cooling load. Interestingly, the cooling load in 2016 is lower than 2015 for the three buildings. Although the post modification has been done to the data, the modified cooling load of 2016 is still lower than 2015.

The second reason why this COP result can not present the actual improvement is because the time for samples is too short. This report only has two-month data. The separator is installed in the beginning of the first month. There are some changes on the system after installation within these two months. Therefore, it is hard to present the actual efficient improvement after installing twin separator.

The third reason why this COP result can not present the actual improvement is because electricity consumption charts in 2015 and 2016 has a totally different pattern. There is no obvious trend for electricity consumption in July and August. Although the electricity consumption generally stays around 0 to 150 kWh. There are always unexpected changes on some dates. This is probably due to events or special occasion for the buildings.

The results are somewhat unpredictable. Although the results of the cooling load have been modified, they still contradict to the measurement of Brisbane’s weather. The cooling load results show that there is a huge gap between August 2015 and August 2016. It is very hard to exclude the effect of particular events for short-term measurement. Two-month samples are not enough, thus, the data are too short to be of great significance. The electricity consumption in 2015 and 2016 only has a very minor relationship. In order to calculate the correct COP, a long measurement time is needed. A full event schedule record for these three buildings are also needed. With all of these information in the future, the appropriate improvement of COP can be presented.

Chapter V: Noise

Chapter Summary:

This thesis report used a noise measuring app called SPLnFFT on iPad 4 to measure the noise generated. The noise within the plant room is in the range between 80dB to 90dB but, the sources of noise are generally from cooling tower and chiller. The twin separators do not have noise problem because the noise from chiller and cooling tower is much higher than the twin separators. Nevertheless, there are some noise absorption or protection that can be done on the plant room. The noise produced from air-dirt separator's daily operation is generally low comparing to surrounding noises in the plant room. Noise is generated when the air-dirt filter operates and hence, it is crucial to not only measure but also control the level of noise production. A noise meter is used while operating the air-dirt filter. Apart from that, a maintenance schedule is also needed so that all of the maintenance works can be done accordingly, for example, once per month.

5.1 Background

Noise exposure in the workplace is one of the most frequent occupational diseases. There are more than 22 million workers at risks of potential noise exposures in the U.S. Hearing loss due to noise exposure is one of the most common injuries. (Roberts, Kardous, and Neitzel, 2016)Therefore, this highlights the significance of preventing noise injuries but controlling the production of noise to the safest level possible. Therefore, sound level meter (SLMs) is designed to measure the noise level. During the separator installation in this project, the whole air conditioning system has been shut down, but the noise made from the installation is lower than the general operating noise. Furthermore, the general operating noise has proves that the air-dirt separator does not affect the general noise.

5.2 Measurement

A noise measuring app, SPLnFFT, on iPad 4 is used to measure the plant room noise. SPLnFFT version 6.1, on iPad 4 with iOS 10.0.1. is used during this measurement. SPLnFFT has been proved by several literature review that it is a validated noise measuring tool. There are several reasons for choosing SPLnFFT app as a noise measuring tool.

Smartphone devices become a common part of our lives. According to Deloitte survey, there are more than 15 million smartphones used in Australia. Almost 80% of surveyed Australian have a smart phone at 2015. This number has increased by 10% from 2014. (Deloitte, 2015) Therefore it is much more common for workers to have a smartphone than the technical noise measurement device. Furthermore, the measuring device requires special training to operate the device, which increases the difficulty of the measuring. Smartphones are used for measurement in this thesis in order to make the noise maintenance job easier, as well as make this measurement as future reference. (Kardous and Shaw, 2015)

SPLnFFT, mobile phone application is selected for this measurement. According to US National Library of Medicine National Institutes of Health department's report, SPLnFFT app from 'Fabien Lefebvre' is one of the best noise measuring app. SPLnFFT only has a 0.07 dB mean difference from the actual reference values in un-weighted sound pressure levels section. The accuracy of iOS device is higher than an android device. Therefore, this thesis uses an iOS device, iPad 4, as a reference. (Kardous and Shaw, 2015)

There are four locations chosen for noise measurements. See figure 5-2. These four locations can cross-analyse the possible noise resource.

FIGURE 5-0-1:NOISE MEASUREMENT

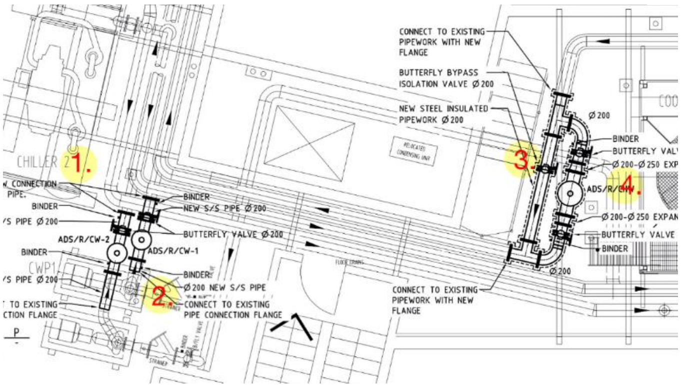


FIGURE 5-0-2:NOISE MEASUREMENT LOCATIONS.

5.3 Noise Results

There are 4 set samples noise meausrements. Measurements are done at the same locations. The results are shown from Figure 5-3 to 5-6. Each vertical gap signifies one minute. The sample generally covers from 7 to 15 minutes. The general results are shown the table 5-1.

FIGURE 5-3:NOISE DATAS

Chiller 2 is operating when measurement is taking. The first test sample is measured in 2016-08-05. The noise sample is rough for location 3 and 4. It's obvious that measurements for 3 and 4 changes around. Location 3 section various from 81dB up to 89 dB, but results majority stay around 82dB. Location 4 section various from 81dB to 90 dB.

FIGURE 5-4:NOISE DATAS

Chiller 1 is operating when measurement is taking. The 2nd test sample is measured in 2016-08-22. This 08-22 sample has much clear trend as measurement tool. There are 4 clear sections for this measurement. There are still some unexpected measurements in the result. Despite the measurement in the beginning of section 2, which is due to setting up, sometime the measurement can be up to 89 dB for section 3 and 4.

FIGURE 5-4:NOISE DATAS

Chiller 1 is operating when measurement is taking. The 3rd test sample is measured in 2016-09-15. 09-15 sample is much stable comparing all the other samples. There are not much unexpected noises.

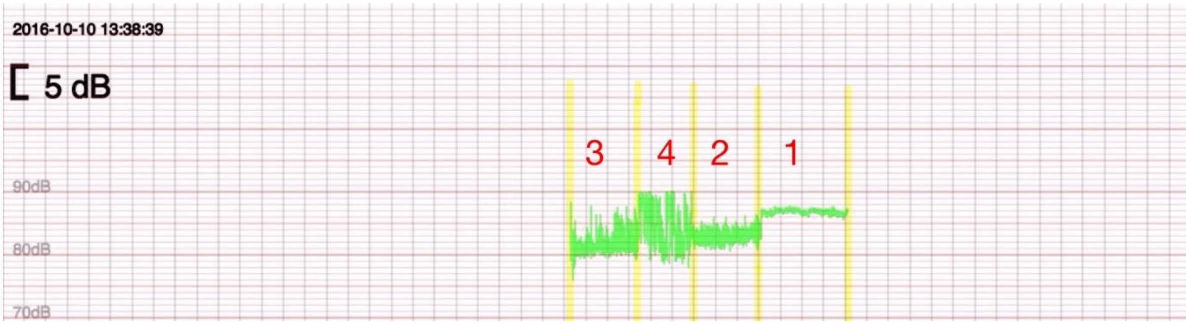


FIGURE 5-5:NOISE DATAS

Chiller 1 is operating when measurement is taking. The last test sample is measured in 2016-10-10. From section 3 and 4, the noise hugely various. The measurement shows the lowest measurement is around 80 dB and maximum measurement is up to 90 dB.

Approximated noise level				
	Location 1.	Location 2.	Location 3.	Location 4.
When chiller 1 is operating.	89.5 – 90.5 dB	88.5 – 89.5	81 – 87 dB	85 – 90 dB
When chiller 2 is operating.	84 – 88 dB	82 – 85 dB	79 – 83 dB	80 – 84.5 dB
	Near chiller 2	Near separator (condenser water)	Next to separator (chilled water)	Next to cooling tower

TABLE 5-6

5.4 Noise – Discussion

The results show that majority of the noise sources are from the chiller and cooling tower. There are two different situations. The first situation is when the chiller 2 is operating. The second situation is when the chiller 1 is operating. When the chiller 2 is operating, a noise from location 1 can increase up to 90 dB. The noise from location 2 can also increase up to 89 dB. On the other hand, when chiller 1 is operating, the noise in location 1 and location 2 both dramatically decrease. No matter which chiller is operating, location 1 is always higher than location 2. These results indicate that chiller is the main source of noise.

Location 3 and location 4 shows the noise from cooling tower side. It is obvious that main source of noise is from the cooling tower. Regardless which chiller is operating, the noise from the cooling tower does not alter. However, the results show there would be huge changes for noise from cooling tower and location 3 and location 4 shows simular various pattern. The analysis of these four locations shows that the maximum noise level among the separators is 90 dB and minimum noise level among separators is 83 dB. However, the main noise source is from the chiller and cooling tower. Air-dirt separator does not generate noise that can impact the surrounding.

5.4.1 Sound Pressure Level and noise exposure

This section briefly introduces how harmful it is to be exposed to high volume noise. As mentioned before, there are many workers exposed to high noise in their workplaces. Short-term exposures to high volume noise can cause a temporary change in hearing, which is also known as tinnitus. Tinnitus usually fades away within a short amount of time. However, a prolonged exposure to high noise unfortunately, cause permanent tinnitus or worse, hearing loss.

Another consequence of high noise exposure is that it can increase the level of stress and working fatigue. This can potentially contribute to cardiovascular disorders which can dangerously lead to heart diseases and hypertension.

There are a few direct ways to distinguish whether the workplace is too noisy or not. If a worker hears humming or ringing in their ears after leaving their workplaces, this indicates the noise at the workplace is too high. When workers have to shout to their co-workers around them, this similarly implies that the level of noise is high. Additionally, if workers experience temporary hearing loss after they leave their workplaces, this too signifies that the workplace is too noisy. (Roberts, 2012)

Safe Work Australia has a list on the official Australian specification for noise exposure. Exposure standard for noise is eight hours under average 85 dB(A). The peak noise cannot exist 140 dB(C). dB(A) means the continuous equivalent A-weighted sound for 8 hours, L_(Aeq,8h). dB(C) means the C-weighted peak sound pressure level. If the noise value excess 140 dB(C), it would cause immediate hearing damage on the worker.

5.4.2 Noise sources for buildings

There are three main noise sources of commercial buildings.

1. Building services. (Mainly from HVAC)
2. Noise from outside of the building.
3. Activities inside the building.

HVAC system is the main noise source for high-level floors within the building. Therefore, the noise control of HVAC system hugely affects the learning conditions at high-level floors.

The building material also plays a huge role in sound resistance. There are more and more advanced materials which are sound absorbing. Sound absorbing materials are commonly made up of porous materials, such as rock wool, foam, or material that is porous to air flow. If the non-porous material has good sound transmission loss, it can be a good sound reflector as well. (Bhatia, 2012)

Sound transmission loss means that when the sound wave strikes a barrier, pressure will cause the barrier to vibrate. Then, vibration energy produced from the striking side transfers through the barrier and generates airborne sound on the other side of the barrier. The difference between sound powers of these two sides is known as sound transmission loss (TL) in dB. (Bhatia, 2012)

The other important factor of sound absorbing material is the sound absorption coefficient. Sound absorption coefficient shows the level of how a material can absorb a certain amount of sound over a range of frequency. Figure 5-7. shows common sound absorption coefficients for some materials. The absorption also decreases at a lower frequency of sound. It also has different coefficients for different thicknesses. Figure 5-8 indicates the relationship of absorption coefficient and frequency for the range of thickness from 2.5 cm to 5.0 cm. (Bhatia, 2012)

Material	Sound Absorption Coefficient - α
Plaster walls	0.01 - 0.03
Unpainted brickwork	0.02 - 0.05
Painted brickwork	0.01 - 0.02
3 mm plywood panel	0.01 - 0.02
6 mm cork sheet	0.1 - 0.2
6 mm porous rubber sheet	0.1 - 0.2
12 mm fiberboard on battens	0.3 - 0.4
25 mm wood wool cement on battens	0.6 - 0.07
50 mm slag wool or glass silk	0.8 - 0.9
12 mm acoustic belt	0.5 - 0.5
Hardwood	0.3
25 mm sprayed asbestos	0.6 - 0.7
Persons, each	2.0 - 5.0
Acoustic tiles	0.4 - 0.8

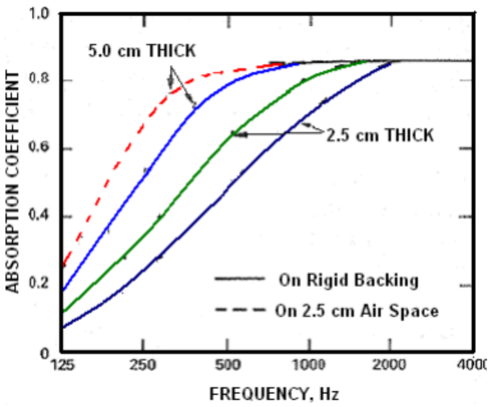


FIGURE 5-7:MATERIAL VS SOUND ABSORPTION FIGURE 5-8:ABSORPTION VS FREQUENCY

5.5 Noise control

According to the measurement, the noise level from Colin Clark plant room is around 80 dB to 90 dB. The Australian standard refers to space in continuous use. The plant room is normally not occupied. However, workers still go to plant room for short time maintenance or inspection, so remedial actions are recommended. A noise assessment can help workers to resolve and analyse the workplace. More information can be found on Australian regulation AS/NZS 1269.1 *Measurement and assessment of noise emission and exposure*. In order to prevent hazardous noise, personal hearing protector and personal protective equipment are claimed to be effective. Personal protective equipment includes ear-muffs or ear-plugs.

There are variable ways to improve HVAC noise situation. Although some of the methods cannot be applied on the chill water system, those methods are still being presented in this paper. (e Noise Control, 2016)

- **Outdoor Sound Blanket/Barrier Wall**

Sound blanket is one of the most flexible ways to reduce unwanted HVAC noise from chiller or compressor. Likewise, sound curtain uses a combination of sound absorption materials. The curtain can be applied in various types of environments. Furthermore, sound curtain is more flexible than barrier wall for it is easy to be installed and removed. The curtain can also be a permanent solution in some geometrically complicated plantrooms at which curtain seems to be the best choice among other options. Outdoor sound barrier wall is one of the best ways to provide permanent noise reduction. The sound barrier wall is an engineered modular panel system and it is commonly used for HVAC systems. Barrier wall can be applied to the chiller, cooling tower or for any outdoor noise sources. Barrier wall can also block any unpleasant views. (e Noise Control, 2016)

- **Sound blanket wrap and duct lagging**

Acoustic wrap is a common way to reduce noise. It is also known as noise covers, or Velcro sealed noise blankets. The effect of wrapping depends on the material. For example, the loaded vinyl or Teflon impregnated cloth sound barrier are the common ways to prevent noise in the duct. Although chiller water system does not have air duct and fan structure, the same principle can be applied on water pipe. Depending on the materials, some blankets are reusable and can hold high temperature. Casting noise can be lagged by barium sulphate lagging material. See figure 5-9. A layer of acoustical cladding can efficiently reduce duck noise. The benefit of acoustical lagging products is that it can suit for any kind of building space.

There are many advantages for sound blankets. It can simply be installed by the personnel of the plantroom. The material is designed as durable, vibration-resistant and insulated material. It is also the best replacement for Asbestos. (e Noise Control, 2016)

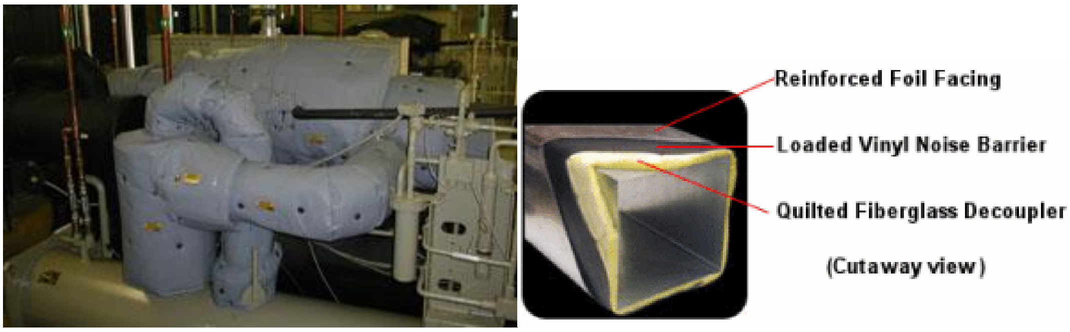


TABLE 5-9:SOUND BLANKET WRAP AND DUCT LAGGING(E NOISE CONTROL, 2016)

- **Silencers**

Silencers and mufflers are normally used for the duct. By using silencers, the noise due to air can be hugely reduced. Although duct silencer can only be applied to some types of air conditioning system, it is an ideal solution for commercial buildings such as hospitals, conference rooms, or office buildings. There are some requirements for installing silencers. Pneumatic pressure drop, space limitation, or fan requirement should all be considered when incorporating the silencer. It would be even better if designer already installs silencers when they are designing the commercial building. (e Noise Control, 2016)

- **Vibration isolation**

Vibration isolation can solve the problem of structure-generated noise. Inadequate vibration isolation is a common reason for vibration noise, so, vibration isolation can solve the principal problem. (e Noise Control, 2016)

5.6 Colin Clark building improvement

The extra air-dirt separator does not increase the noise generated in the Colin Clark plant room. The main noise sources are from cooling towers, pumps and chillers. This section discusses how to decrease noise from HVAC system in the plant room.

There are many ways to improve Colin Clark plant room noise. The most effective way is sound blanket wraps. Colin Clark plant room currently has its own sound barrier wall for cooling towers. Chillers, pumps and air-dirt separators are all under covered. Whole plant room was designed to prevent noise. The space for plant room is also packed with pipeline and machinery, so, there is no space for extra sound barrier wall. Therefore, if further noise reduction is needed, sound blanket wraps would be the best solution.

The sound blanket wrap can also provide further sound protection either temporarily or permanently. Colin Clark building may only require a temporary sound protection. Thus, sound blanket wrap can also be an economical choice for the University of Queensland. Sound blanket wrap is most commonly used for HVAC system, so it can generally be applied to all kinds of HVAC systems around the university. Therefore, it becomes very useful during the exam period. When students are having their exams, the sound blanket wrap can be used on the nearest HVAC system to reduce noise. If there is a conference or office meeting, the sound blanket can also be handy. While university is setting up temporary examination venues, the sound blanket wraps can also prevent high noise production.

In conclusion, the noise control of Colin Clark plant room can still be improved. Although Colin Clark plant room has a nicely designed sound barrier wall, the usage of sound wrap can further improve and control its noise production.

Chapter VI: Water treatment

Chapter Summary:

Four water dirt and impurity samples were collected from 05/08/2016 to 10/10/2016. The benefits of chilled and condenser water system are presented. The possible solutions to deposits control are also outlined. The samples collected show that the amount of dirt within the water system decreases through time. The pH value is consistent with literature review. Apart from the typical dirt and impurities, there are also leaves, seeds and fibres in the water system. The twin separators filter all of the dirt and impurities out.

This section analyses water-related topics to HVAC chilled water system. The HVAC chill water system has two types of water pipelines. One is chilled water line and the other one is condenser water line. Each of them has their own function. Chilled water system collects the heat from the building and exchanges heat inside the chillers. Condenser water collects heat and releases the heat at the cooling tower. This thesis report engages with these two water pipelines because the air-dirt twin separator is installed on both water pipeline systems. One air-dirt separator with 250 mm diameter nominal (DN) is installed on the chiller water pipe system while two air-dirt separators with 200 mm diameter nominal are installed on the condenser water pipeline system.

In this section, two major water systems are analysed based on literature review and experiment results. These sections are going to be divided into several topics. Background knowledge, dirt/impurity elements, methodology, water treatment, pH test and results analysis are presented. (Stanford and Stanford, 2011)

6.1 Methodology

The air-dirt separators can filter condenser water and chilled water. Therefore, impurities are collected on the bottom of twin separators. A dirt collecting schedule is made to collect, study, and clean the dirt, so a clear study of dirt contained in condenser water and chilled water system can understand. The study on removed dirt and impurity can contribute to future water treatment and equipment maintenance. Currently, University of Queensland Property and Facilities Division does not have any twin separators maintenance or dirt cleaning schedule, so it is essential to establish a dirt removal and separator maintenance policy.

The original design plan for dirt/impurity sample extraction is to extract the dirt sample each month. However, the installation for twin separator is delayed from April to July. Therefore, the dirt sample extraction plan was rescheduled. The new schedule is presented in figure 6-1.

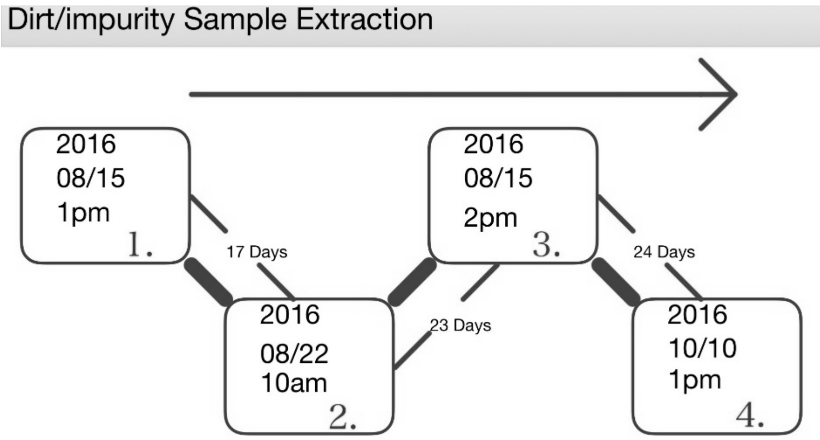


FIGURE 6-1:SAMPLE EXTRACTION

A friendly officer, Dean Lewcock, from UQ Property and Facilities Division, assisted this dirt sample extraction. Therefore, the extraction dates are changed depending on his schedule. The gaps between each extraction dates are expected to be around 20 days but, actual gap depends on student's and Dean's schedule. There are several types of equipment used for extraction.

- Spanner: To remove the threads/plugs for twin separators.
- Teflon Tap: To make sure the pipe threads are sealed and safely installed back.
- Ipad: To measure the noise.
- Sample containers: To collect the dirt sample. (350ml)

The analysis of dirt/impurity samples are presented in later section.

6.2 Background knowledge:

Background knowledge has two general topics: chilled water system and condenser water systems. A literature review of relative water treatments also covers in this section. A certain amount of dust is removed from the cooling system and analysed by the student.

6.2.1 Chilled water system:

Chilled water system is a "closed recirculating water" system. The water treatment for closed loop system is much easier than open loop system. There are several advantages for closed system. (Dave, 2014) (Stanford and Stanford, 2011)

- **No makeup water needed.**

The system for chilled water is closed so, water system does not normally loss water. There are still some water losses such as leakage from pipe, drainage for air separators or tube bundles.

- **Less deposition**

Due to characteristic of closed system, there is much less chance for deposition entering into the pipe.

- **Anaerobic environment**

By removing air content inside the pipeline, the biological fouling problem can be removed.

- **Non-corrosive, non-toxic**

By removing air, oxygen is removed inside the pipeline. Closed system for chilled water is also maintained under low temperature, so corrosion problem can be avoided.

- **Inexpensive**

Water as the secondary refrigerants is cheaper than other secondary refrigerants. There are other secondary refrigerants like sodium chloride brines, glycerine, ethylene or methanol.

- **Better climate control**

Water chiller has better weather control than air cooled chillers. This is because air cooled chiller has to operate outdoor, while water cooled chiller can be indoor. Furthermore, there is no limitation for the length of chilled water pipe.

Although there are many advantages for closed chilled water system, there are still chances for corrosion to happen. Such situations include oxygen pitting, crevice attack and galvanic corrosion. This situation can be prevented using “shot feed” method. “Shot feed” method is introduced in the chemical water treatment section. (Dave, 2014) (Stanford and Stanford, 2011)

6.2.2 Condenser water system:

FIGURE 6-2: REDUCE IN INSIDE DIAMETER

The huge topic of condenser water is to prevent deposition, corrosion and microbiological fouling. The condensed water mainly comes from makeup water, so the water contains a tremendous amount of the dissolved chemical component. Therefore, while replenishment water keeps bringing more dissolved substance, the substance concentration ratio gradually increases. If the water temperature also increases, the water would exceed its solubility and generate scales. The cross-sectional area of the pipe is narrow and sometimes, it might be blocked. The formation of scale directly affects the efficiency of heat transfer and reduces cooling capacity.

The maintenance and post processing are expensive and capital consuming, especially the huge commercial building HVAC system like Colin Clark building plant room can be very troublesome. The most common problem of HVAC system is deposition problem. The scale or dirt adheres to the surface of the heat exchanger. The dirt adherence can reduce efficiency, increase maintenance cost, and cause early equipment replacement. The scale might also cause other side effects such as algae and bacteria growth and consolidation of the loose particle. The twin separators can help prevent these problems by removing scales and loose particles. Research has shown that if there is a ¼ inch of limescale, 40% of extra energy is needed to heat the water. (De Baat Doelman, 2013)

6.3 Deposition control

One of the greatest features of air-dirt twin separator is to remove deposition from the water system. Deposition includes impurity, scale, dirt from the environment, and mineral solids from makeup water. Water is one of the greatest solvents to contain all kinds of depositions. The purpose of deposition control is to prevent the deposition to accumulate on the wet surface of the pipe line.

There are many sources for deposition. As mentioned before, one of the sources for dissolved solids is from makeup water. The types of dissolved solids depend on the source of water and the geology. However, the common solid includes sedimentary rocks and the most common sedimentary rock is limestone. Limestone is produced from from calcium and magnesium carbonate when dissolved in water.

This also makes water become "harder". The level of hardness indicates the amount of calcium carbonate dissolved in the water. Refer to table 6-1. When the water is too hard, the deposits of calcium carbonate accumulate on the wet surfaces and eventually, decrease the efficiency of heat transfer significantly. The Brisbane City Council also reports that Brisbane water generally has hardness around 68 to 210 mg/L $CaCO_3$, which is in the range of good quality according to Australian drinking water guidelines.

Water Hardness ($\mathbf{CaCO_3}$		
From calcium and magnesium salts. Hard water is difficult to lather.		
	< 60 mg/L CaCO3	Soft but possibly corrosive
	60-200 mg/L CaCO3	Good quality.
	200-500 mg/L CaCO3	Increasing scaling problems.
	> 500 mg/L CaCO3	Severe scaling.

TABLE 6-1: WATER HARDNESS (NHMRC, 2006)

In order to solve the water hardness problem, the concentrative control solids are added during chemical water treatment to decrease the hardness level. The makeup water with low solid concentration can also help to solve the hardness problem.Some of the factors of calcium carbonate deposition (scale) are outlined below. (NHMRC, 2006) (Vesley, 2008)

- ***Temperature***

The HVAC water supply is normally from 21.1$°C$ to 30$°C$ under light load and web bulb. Most of dissolved solids are generated at higher temperature.

- ***pH***

pH is also an important issue for water scale. The brief knowledge of pH is introduced in the later section.

- ***Calcium hardness***

The amount of calcium hardness in water directly affects the amount of the scale.

- ***Alkalinity***

Alkalinity means the total amount of negative ions such as hydroxide, carbonate and bicarbonate within the water. Alkalinity also indicates the ability for water to dissolve acid.

- ***Dissolved solid***

The amount of solids such as iron and magnesium also affects the amount of scale in the water.

Besides calcium carbonate, there are also other common impurities. (Yaoxian, 2011) (Vesley, 2008)

- Calcium carbonate $CaCO_3$, such as limestone
- Calcium phosphate $Ca_3(PO_4)_2$
- Calcium silicate Ca_2O_4Si

- Calcium sulfate $CaSO_4$
- Magnesium silicate
- Gravel
- Dust
- Algae, moss and microorganism
- Silt

6.3.1 Chemical water treatment

Moving on to water treatment, shot feed method is a type of chemical treatment that senses chemical feeder. This involves adding treatment chemicals in a one-time shot after the system is filled with water. See figure 6-3. Treatment is recommended to be 200 to 300 ppm molybdite while the water in initially filled in. The University of Queensland has a contract company to maintain the quality of chemical water. (Vesley, 2008)

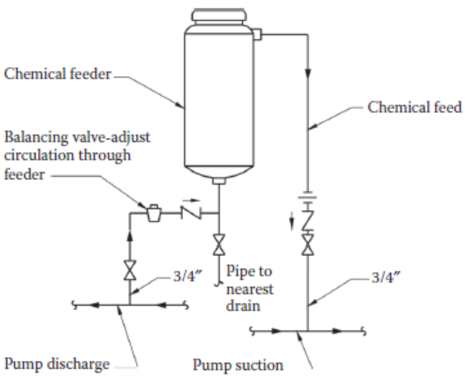


FIGURE 6-3 THE CHEMICAL TREATMENT FOR PLANT ROOM FIGURE 6-4 BYPASS CHEMICAL SHOT FEEDER TO PREVENT CORROSION IN CHILLED WATER

6.3.2 Makeup water.

Makeup water is an important factor to keep water volume constant for condenser water. There are many possible ways to lose water. Three of the most common ways are “evaporation loss”, “drift loss” and “blowdown loss”.

- ***Evaporation loss***

The evaporation loss relates to weather condition. To calculate evaporation loss, the heat rejection rate, flow rate and range are needed. Evaporation rate is normally ~1% of water flow for 10 degrees range.

$$Heat\ of\ vaporization\ of\ water$$

$$Heat\ load = Flow\ rate\ x\ Range$$

$$Evaporation\ rate{:}\ E = \frac{Heat\ load}{Heat\ of\ vaporization}$$

- ***Drift Loss***

Drift loss is normally provided by cooling tower manufacturer because cooling tower causes the drift loss. The modern HVAC system has about 0.0001% to 0.005% of drift loss, so it is commonly ignored during calculation.

- ***Blowdown loss***

Water treatment for deposition control is built based on the intentional wasting of water. The relationship between solid and system's cycles of concentration is shown. Cycles of concentration are normally around 5 to 10 cycles depending on expecting deposition control.

$$BD(blowdown\ flow) = \frac{E(evaporation\ rate)}{(Cycles - 1)}$$

The final calculation of makeup water concludes:

$$Evaporation = 0.01 * \ N_{water} = \ 0.01N$$

$$Blowdown = \frac{0.01N}{5 - 1} = 0.0025N$$

$$Total\ make\ up = 0.0125N$$

6.3.3 The cycle of concentration

The cycle of concentration is the relationship between dissolved solid in blowdown and makeup water.

$$Cycle\ of\ concentration = \frac{Dissolved\ solids(ppm) in\ blowdown}{Dissolved\ solid(ppm) in\ makeup\ water}$$

$$Cycle = \frac{MU(total\ makeup\ flow)}{BD(total\ blowdown\ flow)}$$

6.3.4 Galvanic corrosion

Galvanic corrosion is one of the most common metal corrosions. This process involves the transfer of electron flow between anode and cathode. Figure 6-5, clearly introduces the principle of galvanic corrosion. The anode is iron which transfers two electrons away. The positively charged iron reacts with two hydroxyl radicals and then form ferrous hydroxide. Ferrous hydroxide reacts with water and consequently forms ferric hydroxide. The rust is generated. (Commons, 2015)

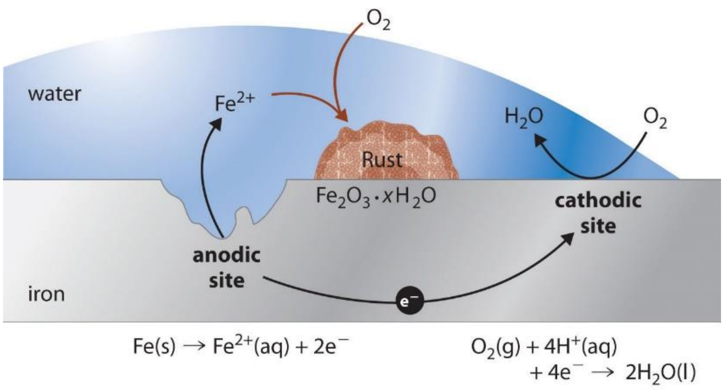


FIGURE 6-5:CORROSION (COMMONS, 2015)

The corrosion is usually caused by impurities in the metal or water. Therefore, twin separator can decrease the possibility of corrosion by removing the impurities from the water. By removing the impurities, this can also decrease the possibility of metal surface scratches which can also cause the corrosion.

Another efficient way to prevent metal corrosion is to choose the proper material. Stainless steel is the best choice. Although the initial cost increases by 20% to 40 %, it is a worthy investment in the long term. Adding inhibitors is also a good option to prevent corrosion. The treatment programs generally require water pH from pH 7.5 to 8.5 or 9.5.

6.3.4.1 White rust

White rust can cause the loss of galvanised coating. In order to prevent this, a secondary coating is used on all wet surfaces. Set the water treatment pH between pH 7.0 to 8.0.

6.3.5 Biological fouling

Biological fouling is caused by bacteria, phytoplankton, algae, zooplankton and fungi. This results from the open system with water full of oxygen and the slime inside the tower, pipe, and system surface. Slime is insulated and this decreases the heat transfer efficiency. Slime also accelerates corrosion because slime usually contains oxygen. The twin separator can remove the potential slime within the water and decrease the amount of oxygen in the water.

Besides filtering out the slime and oxygen, the primary method to prevent biological fouling is to fully clean the cooling tower twice during the cooling season. The fully cleaning includes drain, scrub and dry the cooling tower before refilling. The chemical treatment such as nonoxidizing antimicrobial and oxidising chemicals are also a common way to prevent biological fouling.

6.3.6 pH

pH is one of the most important factors to measure water quality. pH value depends on H^+ and OH^+ (hydroxide) within the water. ($H_2 0 \rightarrow H^+ + OH^-$) The concentration of H^+ depends on the pH value from 0 to 14. See figure 6-6.

pH Scale

pH	H^+ Concentration (g mol/L)	Relative Acid	Relative Base
14	10^{-14}		10,000,000
13	10^{-13}		1,000,000
12	10^{-12}		100,000
11	10^{-11}		10,000
10	10^{-10}		1000
9	10^{-9}		100
8	10^{-8}		10
7	10^{-7}	Neutral	
6	10^{-6}	10	
5	10^{-5}	100	
4	10^{-4}	1000	
3	10^{-3}	10,000	
2	10^{-2}	100,000	
1	10^{-1}	1,000,000	
0	10^{0}	10,000,000	

FIGURE 6-6:PH SCALE

pH value also relates to alkalinity and acidity. When pH value increases by 1, it will increase the nature of the solution 100-fold. Many methods use pH value to predict the potential of deposition from the Langelier saturation index (LSI), Ryzner stability index(RSI) to Puckorius Scaling index(PSI). The PSI is the newest prediction basing on the actual pH and total alkalinity.

$$PSI = 2(pH_s) - pH_{eq}$$

$$pH_{eq} = 1.465 \log_{10}(total\ alkalinity) + 4.54$$

The corrosion control of water should be within pH 4 to pH 10. See figure 6-7. The corrosion rate decreases when pH increases. The most desirable range of cooling tower is from 8.0 to 9.0 with alkalinity level less than 400ppm. If it is in the metal tower, pH 7.0 to 8.0 can prevent the corrosion of white rust. Therefore, pH 7.5 to 8.5 is ideal pH for metal cooling tower (condenser water). The pH value for closed chilled water system is expected to be pH 8.8 to 9.5. The pH analysis on collected samples are presented in later section. (The Construction Sciences Research Foundation, 2015)

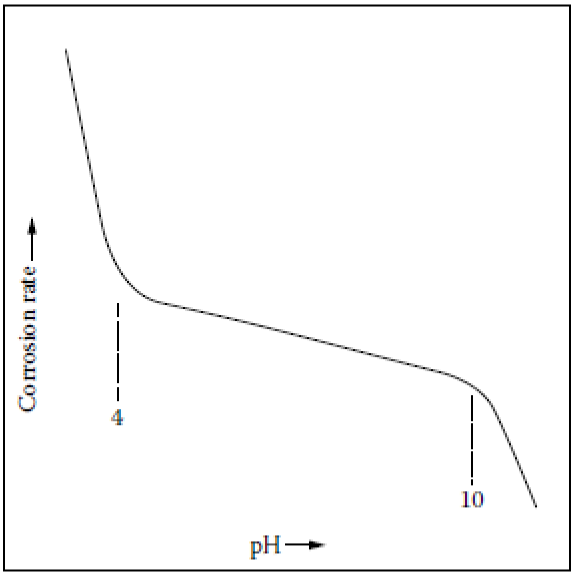


FIGURE 6-7:CORROSION RATE VS PH

6.4 Dirt/impurity samples analysis

Samples were collected. The separators are number coded into 1 to 3. See figure 6-8. The testing schedule and separators information are listed. About 350ml of water/dirt sample are collected each time.

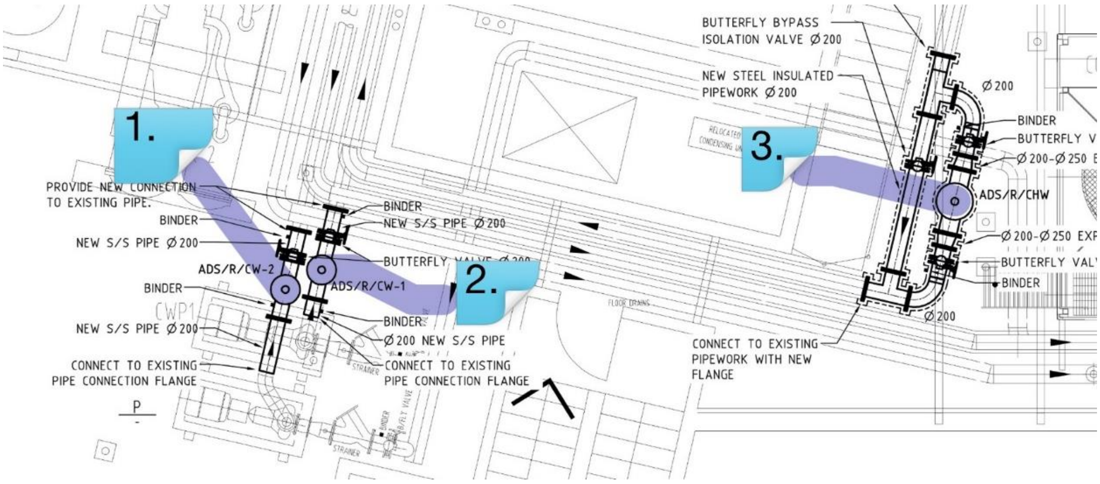


FIGURE 6-8:SEPARATOR NUMBERS

Schedule for taking dirt samples			
	Separator 1.	Separator 2.	Separator 3.
05/08/2016	-	Operating	Operating
22/08/2016	Operating	-	Operating
15/09/2016	Operating	-	Operating
10/10/2016	-	Operating	Operating

There are 16 samples were taken in the end. See figure 6-9. A pH test using macherey-nagel pH-Fix test strips is done for each of them. The pH test results are in the pH test result section. A dirt/impurity analysis is also done. The dirt results are presented in impurity analysis section.

FIGURE 6-9: WATER SAMPLES AND PH

The photos of three types of samples are taken and shown in figure 6-10. The sample of the left side is in plastic bottle container. The middle sample is in a glass bowl with water. While the sample on the right side is without any water. These photos help students judge what is inside the dirt sample.

FIGURE 6-10:THREE TYPES OF SAMPLES.

6.4.1 Dirt Amounts and Appearance – results and discussions

The samples are lined up as shown in condenser water results pictures. On the left-hand side is the newest sample while on the right-hand side is the oldest sample. The first set of photos are photos from the water bottles. The second sets of photos are dirts under water inside a glass bowl. The visual judgement is used to compare the dirt amount. There are a few reasons to choose visual judgement.

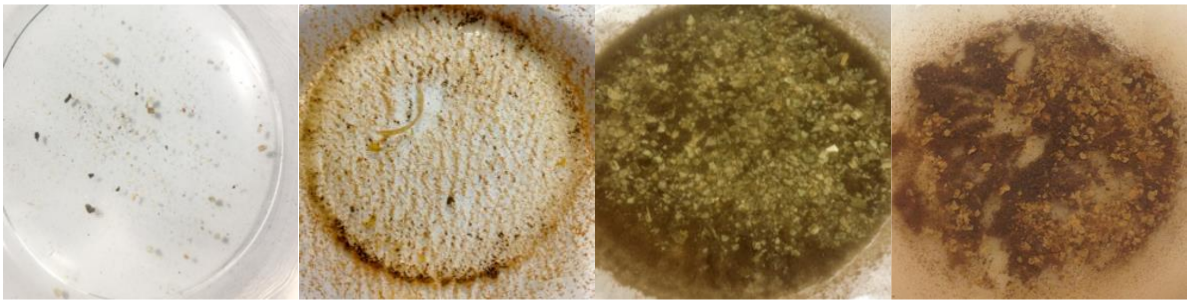
- Impurities in each period are different so, the measurement of the weight weight cannot clearly identify the change.
- The amount of dirt for chilled water is markedly little so, any sample tranfer between containers causes some losses of dirt. Hence, visual judgement is the best.
- Visual judgement can also identify the colour of water.

It is also obvious that when the separator is operating, the dirt amount is less than non-operating separator's dirt amount. This might due to the effect of water turbulence. After impurities are separated from the water pipe system, it deposits down to the very bottom of the separator. When the dirt valve at the bottom of the separator is opened, the deposited impurities usually flow out from the bottom. However, when the separator is operating, impurities in dirt separating area are still in the fluxional state. Therefore, the amount of dirt flowing out from fluxional state is not as much as flowing out from deposited state.

Condenser water, Separator 1. (New → Old)

Not operating	Operating	Operating	Not operating

Condenser water, Separator 2. (New Old)



From the visual analysis of dirt sample sets, the amount of dirt obviously decreases. However, in some cases like “separator 2 08/05 08/22” and “separator 1 09/15 10/10”, the newer dirt amount is higher than the older dirt amount. This is because when separators are operating, the amount of dirt is much more than the non-operating one. In order to give a fair analysis, all of the non-operating samples are put together in figure 6-11. Although two different separators have two chillers, the main sources of impurities are the same. The cooling tower is the major source of impurity. Therefore, the dirt contents should be quite similar. Figure 6-11 clearly shows the dirt content decreases over time.

None Operating Samples (New Old)

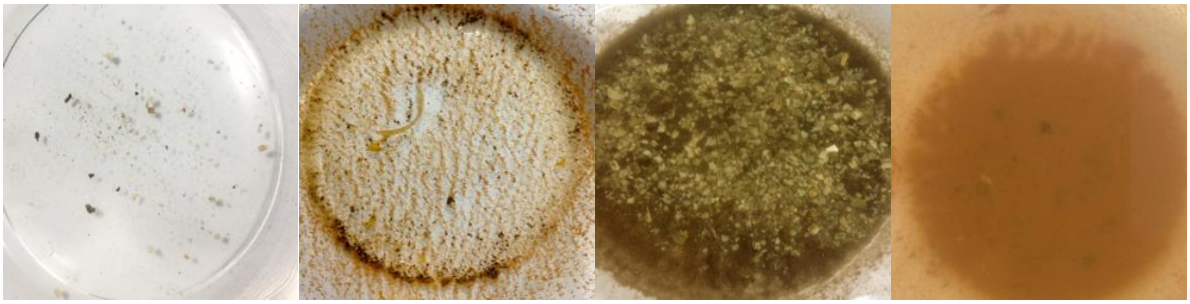


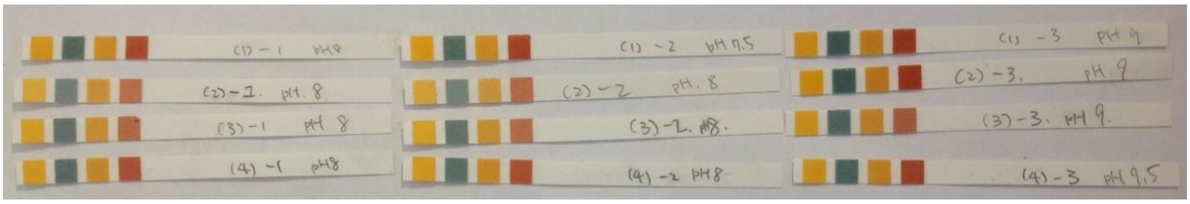
FIGURE 6-11:NONE OPERATING SAMPLES

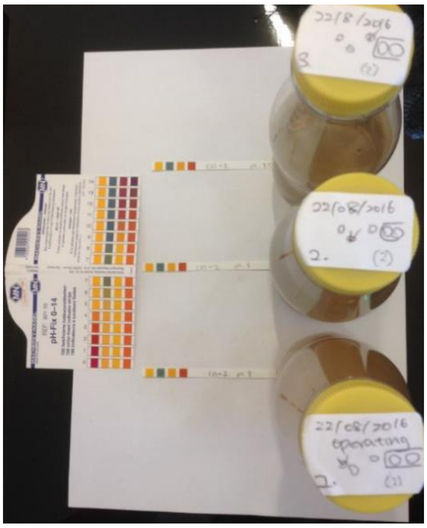
Chilled water, separator 3. (New Old)

Chilled water does not have any problem on whether or not is operating because it is always operating. It is also obvious that there are some blue impurities in the sample. The blue impurities are fibres being accidently mixed into chilled water pipeline. The detailed discussion is in dirt/impurity section. The amount of dirt within the samples are relatively similar. The oldest dirt sample also contains the most dirt.

6.4.2 pH Test – results and discussions

The pH test results are shown in the chart. Each of the water samples is tested by macherey-nagel pH-Fix test strips. The result generally fits what literature review have shown. The pH value for chilled water expects to be pH 8.8 to 9.5. The pH value for condenser water expects to be pH 7.0 to 8.0 while Colin Clark building uses the metal cooling tower. The pH value might vary depending on what kind of chemical water treatment is currently applied, so that might be the reason why some tests have slightly different values. The colours in the picture change while the strips become dry. The clear picture is presented in the appendix: pH test section.





pH test results:

	Separator 1	Separator 2	Separator 3
Type	Condenser	Condenser	Chilled
08/05	8	7.5	9
08/22	8	8	9
09/15	8	8	9
10/10	8	8	9.5

The pH value for condenser water is around 8.

The pH value for chilled water is around 9.

6.4.3 Impurity Analysis – results and discussions

There are numerous amounts of dirt contained in the chilled water and condenser water systems. As the analysis before, the dirt amount in the beginning is very high. The dirt amount did not decrease until the third water sample extraction for the non-operating separator. However, the dirt amount generally decreases through time. There is no sample to prove that dirt amount can decrease to zero.

6.4.3.1 Types of dirt/impurity

The literature review states that there are many types of dirt. The dirt sample generally contains the common dirt list. Although it is hard to distinguish the dirt material based on its appearance, this section gives a reasonable justification of what dirt contents the water samples have.

6.4.3.2 Common material list and its appearance.

- Calcium carbonate $CaCO_3$, such as limestone
- Calcium phosphate $Ca_3(PO_4)_2$

- Calcium silicate Ca_2O_4Si
- Calcium sulfate $CaSO_4$
- Magnesium silicate
- Gravel
- Dust
- Algae, moss and microorganism
- Slime

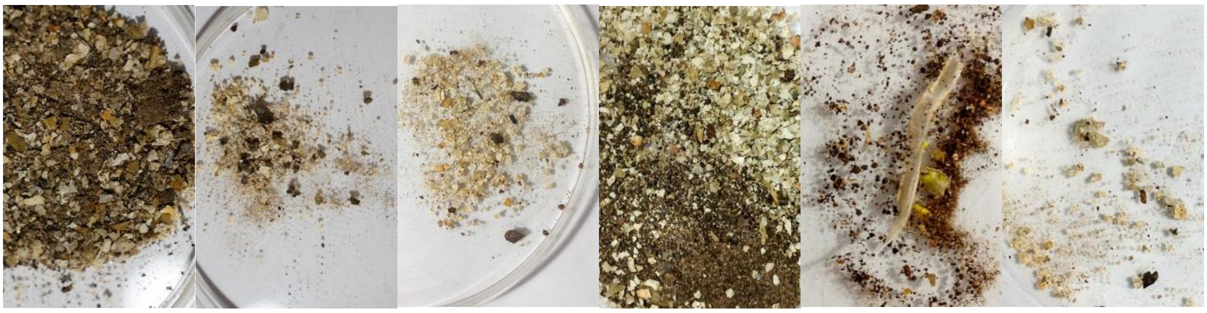
6.4.3.3 The appearances

Calcium carbonate	**Calcium phosphate**	**Calcium silicate**	**Calcium Sulfate**	**Slime**
				

FIGURE 6-11: COMMON PROBLEM FOR CHILLED WATER SYSTEM (YAOXIAN, 2011)

6.5 Condenser water dirt/impurity

The condenser dirt generally covers all of the listed scales and dirt, especially limestone (calcium carbonate). It is hard to identify algae moss in the dirt sample because the algae and moss might have been dissolved and converted to microorganism.



On the other hand, there are also some impurities which are not listed in the common scale list.

- ***Plastic***

It is obvious that plastics in the impurities are from the Teflon tap. The Teflon tape used to wrap the thread has exactly the same colour and shape. There are all yellow colour. The length is much longer than other impurities. The plastic (Teflon tape) is actually not one of the impurities within the water system. It is reasonable to believe that Teflon tap impurity has never entered into water pipe system. The reason is that it is possibly residual Teflon tape stocks on the valve entrance. While collecting the sample, the water also residual Teflon tape impurities out.

- ***Seed***

There are some seeds in the condenser water sample. It is assumed that seeds are from the cooling towers. It might also have been seeds blown by the wind that cause them to get collected by the cooling water. As seeds are considerably light in weight to be deposited to the bottom of the cooling towers, it is therefore, assumed to be flowing with the condenser water.

- ***Leaf debris***

Leaf debris might come from the same sources as seed. They could possibly have been blown the the wind and got collected in the cooling towers.

- ***Twig debris***

Plant twig debris might come from the same source as seeds. Debris is blown by the wind and gets collected by the cooling towers. Seed, branches of plants, and leaf debris might cause biological fouling so, it is very important to remove them.

The other interesting phenomenon is that two water samples (from separator 1 and separator 2) from the first set of collection has totally different colours. Figures below show that both of them have very high turbidity. However, they are in different colours. The sample from separator 1 is drab orange colour but, sample from separator 2 is drab green.

Separator 1,

Not operating

Separator 2,

Operating

According to the information provided by UQ Property and Facilities Division, separator 1 is the first operating separator. Therefore, the drab orange colour might come from the initial dirt/impurity content. The dirt analysis on 08/05 – separator 1: dirt sample gives some possible reasons.

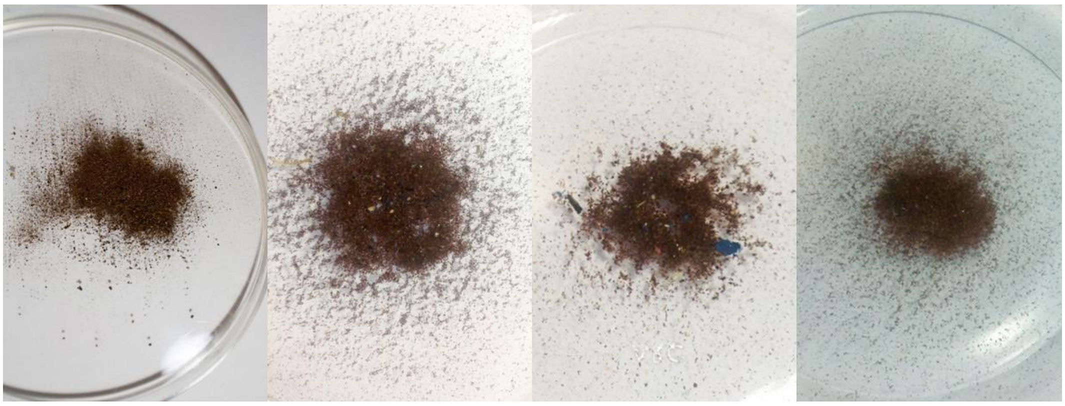
1. There are very high amounts of rust in the pipeline.
2. There are high amounts of bacteria.
3. There are high amounts of calcium phosphate.

These three situations can all create the drab orange colour. The detailed chemical examination is needed to identify its actual substance. However, the results show that the twin separator can remove all of the particles within the pipeline because water samples from later parts are much cleaner than initial samples.

6.6 Chilled water dirt/impurity.

The water samples from the chilled water generally contain gravel or dust. These gravel and dust come from the chilled water pipe. The amount of dirt in the early sample is slightly more than the later samples but, the change is not much.

However, in the 3rd sample, there are some unique impurities. A little twig and some blue impurities are inside the impurities. Blue impurities are fibre because the shapes and edges are similar to fibre. Branches and fibre are not supposed to be inside the closed system so, they probably got inside the system during installation.



Chapter VII: Commercial Drive &Suggestion

Chapter Summary

The final chapter analysis the commercial drive and gives sugeestion on how to improve the thesis results. A twin separators dirt/impurity removal schedule is suggested.

7.1 Commercial drive

The cost analysis of the lifecycle of chilled water cooling system is created for customers to review the actual cost of the water system and separator. The cost of HVAC chilled water system depends on its location and relative factors. An example below lists out all of the potential costs.

7.1.1 Lifecycle cost

A study case was done by ASHRAE technical committee. In the case study, the chiller and cooling tower have 20 years of life and they cost $220,000. The major overhaul of chiller is around $90,000. The annual costs are listed as below.

Sections	Cost
Preventative maintenance	$1,400
Labour	$10,000
Water	$2,000
Chemical Treatment	$1,800

TABLE 7-1: COST OF CHILLED WATER AND COOLING TOWER IN US DOLLARS

The price changes with 3% inflation rate within the study period. The annual electric cost is $18,750 with 5% increment rate each year. This calculation is based on a 8% discount rate. As the case study shows, there is huge influence from labour and water.

The case study is done in America. Therefore, all of the relative costs would be different in Australia. Given the case is in Brisbane, the lifecycle cost would be higher because the labour and water price are higher in Australia. The equations of life cycle cost analysis are listed below. (ashrae, 2015)

- ***The total owning and operating cost comparison***

$$Life\ cycle\ cost = C + \left(\frac{sum\ of\ repair}{Replacement\ costs}\right) + (Economic\ life * Annual\ Energy\&Maintenance\ cost)$$

$$\rightarrow\ C = total\ capital\ cost = A + (B * n * \frac{i}{1-(1-i)^{-n}})$$

$$C = total\ capital\ cost\ (\$), A = first\ Cost\ out\ of\ pocket\ (\$),$$

$$B = Borrow\ funds\ (\$), i = interest\ rate, n = number\ of\ years\ of\ loan$$

The twin separators can decrease the lifecycle cost by removing all of the dirt and impurities within the water system. Twin separators can also remove the air bubbles within the water system which decrease the possibility of biological fouling. Therefore, it is good to install twin separators on both chilled and condenser water system to decrease the lifecycle cost.

7.2 Suggestion& Future directions

All of the research and experiment results show that OaseTECH twin separators can improve the quality of chilled and condenser water system with no potential noise problem. However, from the work of this thesis, the results of COP is still fragmentary. In order to improve the accuracy of the data, a longer post-installation data samples are needed. This thesis is only able to collect the data from July to August because the installation schedule was delayed from April to July. A whole year long data is suggested in order to demonstrate the actual improvement of COP. Besides the cooling load and energy consumption, the schedules of events or activities for the three buildings are needed in order to clearly demonstrate the effects of such activities on the cooling load of the building.

- ***Dirt removal schedule***

There is no set schedule for UQ Property and Facilities Division to remove the dirt from the twin separators. Although the amount of dirt dramatically decreases to very little amount, it is recommended to remove the dirt from twin separators once every three months. The collected dirt and impurity samples should be kept for future studies and research.

- ***More detailed energy consumption measurement***

The current measurement of energy consumption ports measures the whole plant room. Therefore, meters could have also measured some irrelevant devices which are not included in HVAC system. If there are more detailed information on the measurement of energy consumption for each device, the COP can be much more accurate.

Chapter VIII: Conclusion

The University of Queensland cooperated with OaseTECH, a Chinese leading manufactory company in fluid technology to study the effect of twin separator on HVAC Chilled water system. The new twin separators are installed on the top of the Colin Clark building (69) plant room. In the beginning of this thesis, literature reviews and study of chilled water air conditioning system was done. The location is the University of Queensland in Brisbane. The research on Brisbane weather shows that July and August 2016 in Brisbane are warmer than July and August 2015. The global weather in 2016 has the hottest temperature in history. The Colin Clark HVAC chilled water system supplies cooling for these three buildings, Sir Edwards Building (14), Duhig North (12) and Duhig Link (12A). The building structure and the factors of heat gain for three UQ buildings were also analysed and put into the simulation software eQUEST. eQUEST is a building energy simulation software based on DOE-2.2 created by one of the American national labs. A small model of a building is designed to validate eQUEST. The validation results show that eQUEST can calculate the building heat gain correctly. The building data of three buildings were input into eQUEST so, a 3D model and simulation results were generated. The results were compared with actual cooling loads of 2014 to 2015. The comparison shows that although there are some differences, eQUEST can basically simulate the trend of heat gain of the buildings. eQUEST also simulates the cooling load required for three buildings. In order to maintain a comfortable temperature of the building, chilled water air-conditioning system has to cool the simulated amount of heat within the three buildings.

Although the installation of twin separators was delayed, twin separators were successfully installed in the beginning of July. Two months of post installation HVAC performance data were studied and analysed. The post installation data is compared with pre-installation data and the results from eQUEST simulation. The results show that Colin Clark plant room has a higher cooling load in 2016 which in contrast with the weather from research. Although the preliminary results indicate that HVAC system has a higher coefficient of performance in 2015, the results were considered fragmentary. There are several possibilities why results might be erroneous. First, there were not enough of data because there were only 2-month of data available for this project. Secondly, activities or events held in these buildings could have possibly caused a high cooling load in 2015 at which these effects could not be excluded in this study. Thirdly, the electricity consumption in July and August in both the year of 2015 and 2016 shows no relative pattern. Therefore, this coefficient of performance result might be incorrect. Hence, more data are needed to gain more accurate results.

In terms of the commercial drive, twin separator is expected to increase the life cycle cost of the chilled water system. The dirt samples removed from the chilled/condenser water system were also analysed. There were four sets of samples taken from 08/05/2016 to 10/10/2016. The water and impurity analysis was also done. Other than the common impurities such as limestone and scales, there are other impurities such as leaves, fibres and seeds in the condenser and chilled water system. The samples showed that the amount of dirt inside the condenser and chilled water system have both decreased since the separators were installed. The noise test for plant room also shows that there is no potential noise problem for twin separators.

Theoretically, twin separators are going to increase the efficiency by removing air bubbles and dirt from the condenser and chilled water system. All the research and experiment results show that OaseTECH twin separators can improve the quality of chilled and condenser water system with no potential noise problem. Hence, from the work of this thesis, it is recommended to install twin separators on HVAC chilled water cooling system in commercial buildings.

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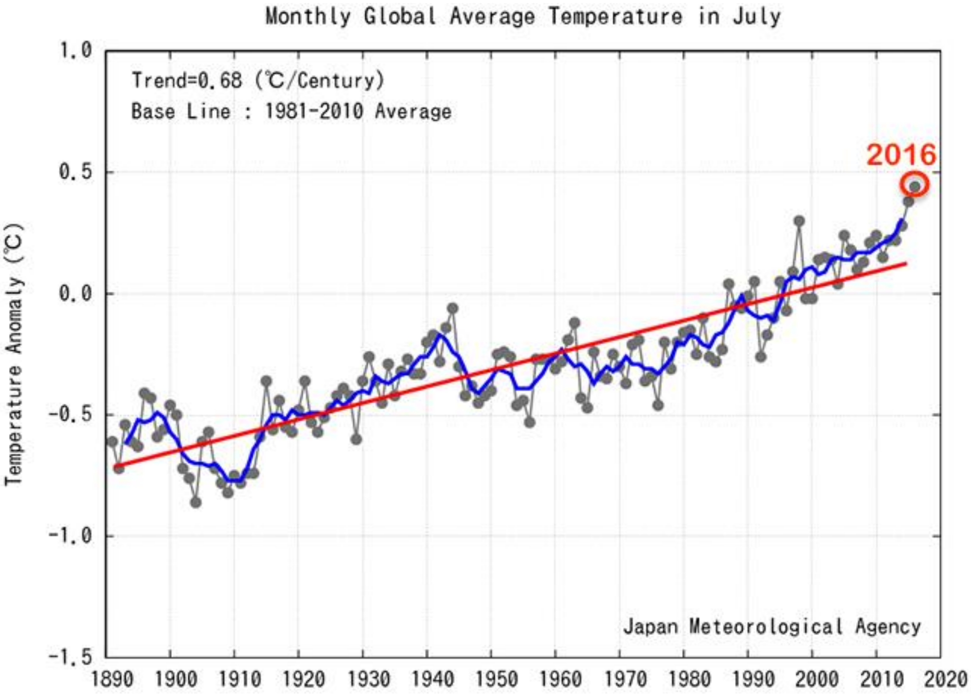
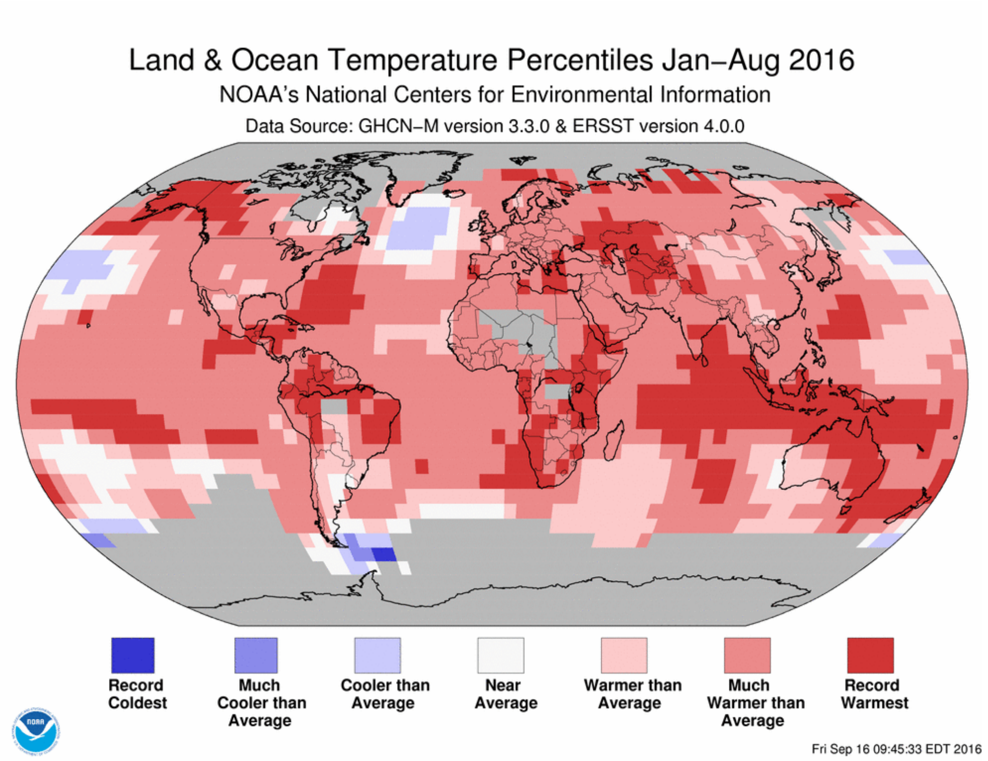
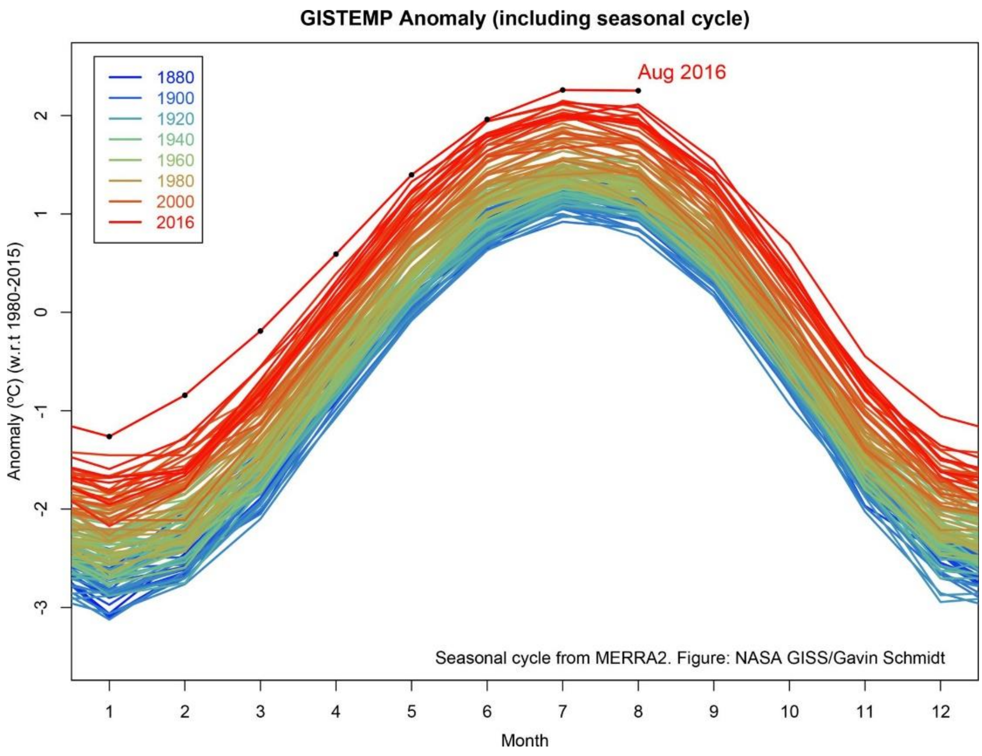
Appendix:

Appendix: A - Weather


Monthly Global Average Temperature in July
Trend=0.68 (℃/Century)
Base Line : 1981-2010 Average
2016
Temperature Anomaly (℃)
1.0
0.5
0.0
-0.5
-1.0
-1.5
1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020
Japan Meteorological Agency

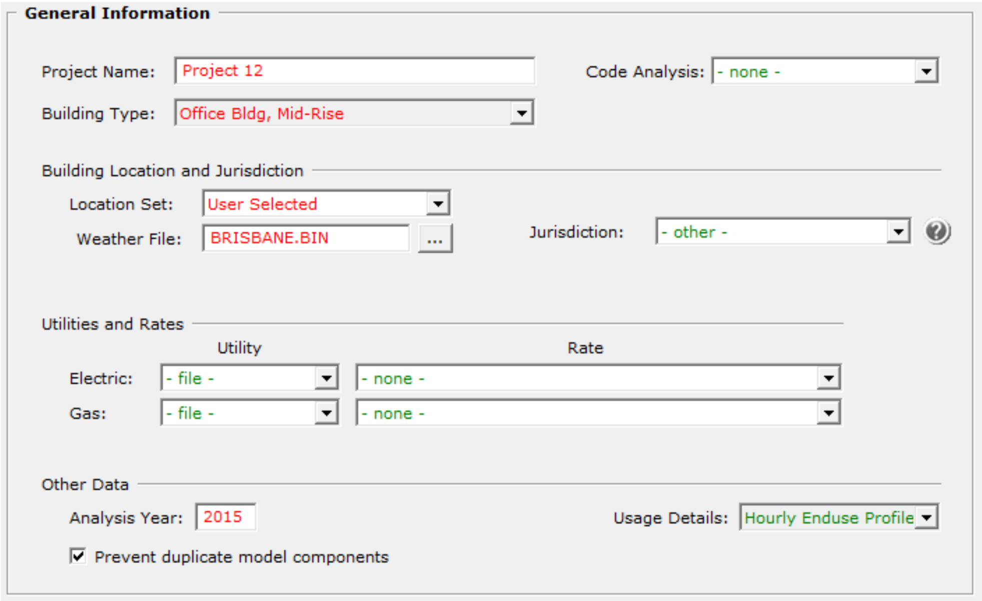

Land & Ocean Temperature Percentiles Jan–Aug 2016
NOAA's National Centers for Environmental Information
Data Source: GHCN–M version 3.3.0 & ERSST version 4.0.0
Record Coldest
Much Cooler than Average
Cooler than Average
Near Average
Warmer than Average
Much Warmer than Average
Record Warmest
Fri Sep 16 09:45:33 EDT 2016

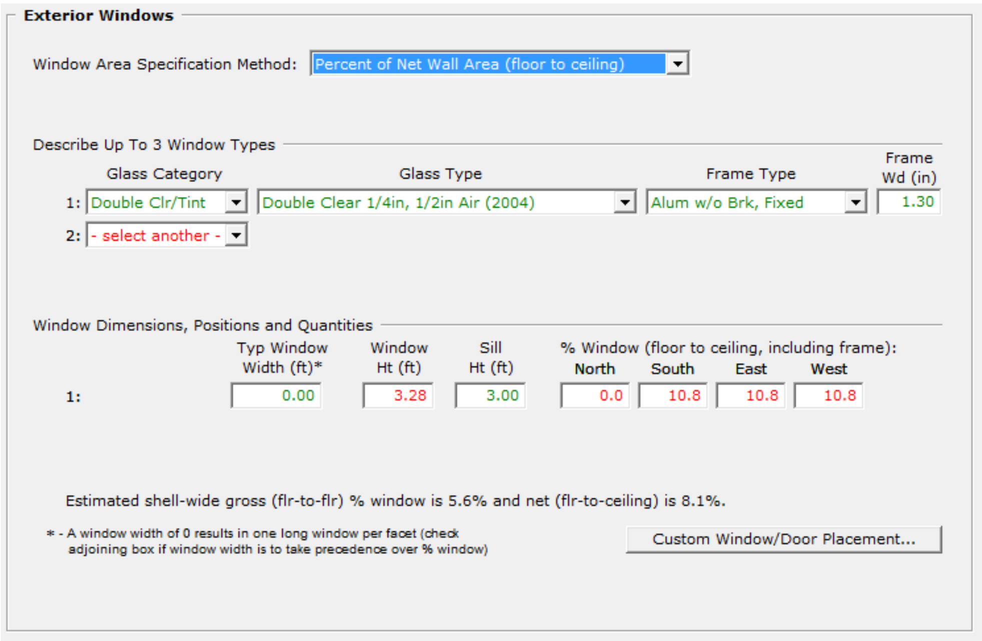

GISTEMP Anomaly (including seasonal cycle)
1880
1900
1920
1940
1960
1980
2000
2016
Aug 2016
Anomaly (ºC) (w.r.t 1980-2015)
2
1
0
-1
-2
-3
Seasonal cycle from MERRA2. Figure: NASA GISS/Gavin Schmidt
1
2
3
4
5
6
7
8
9
10
11
12
Month

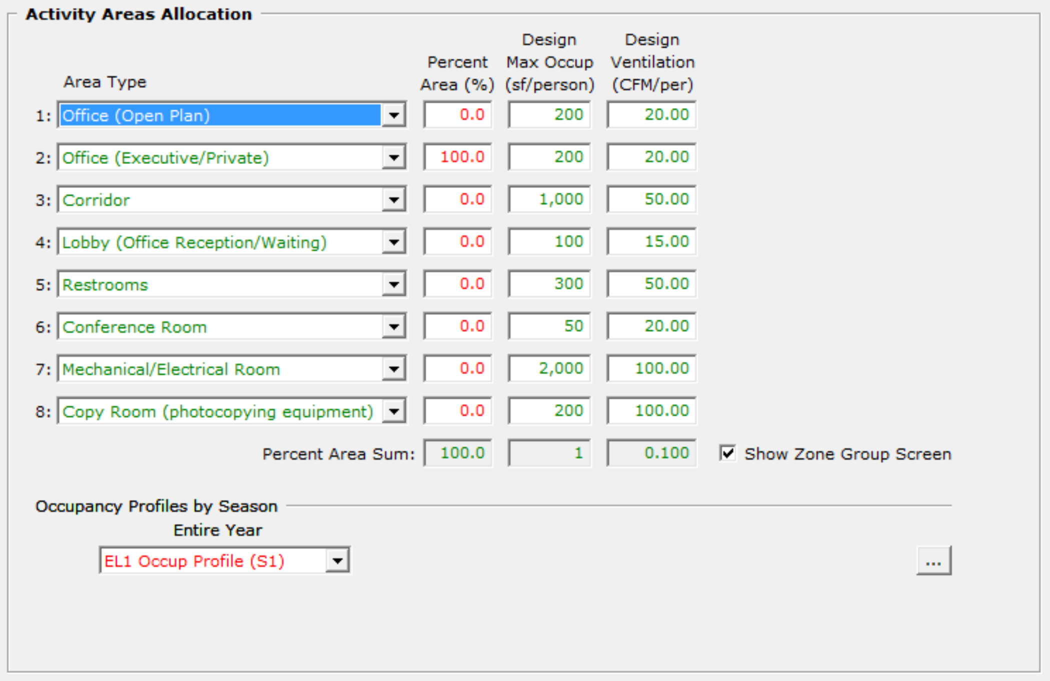
Appendix: B – Simple model by hand

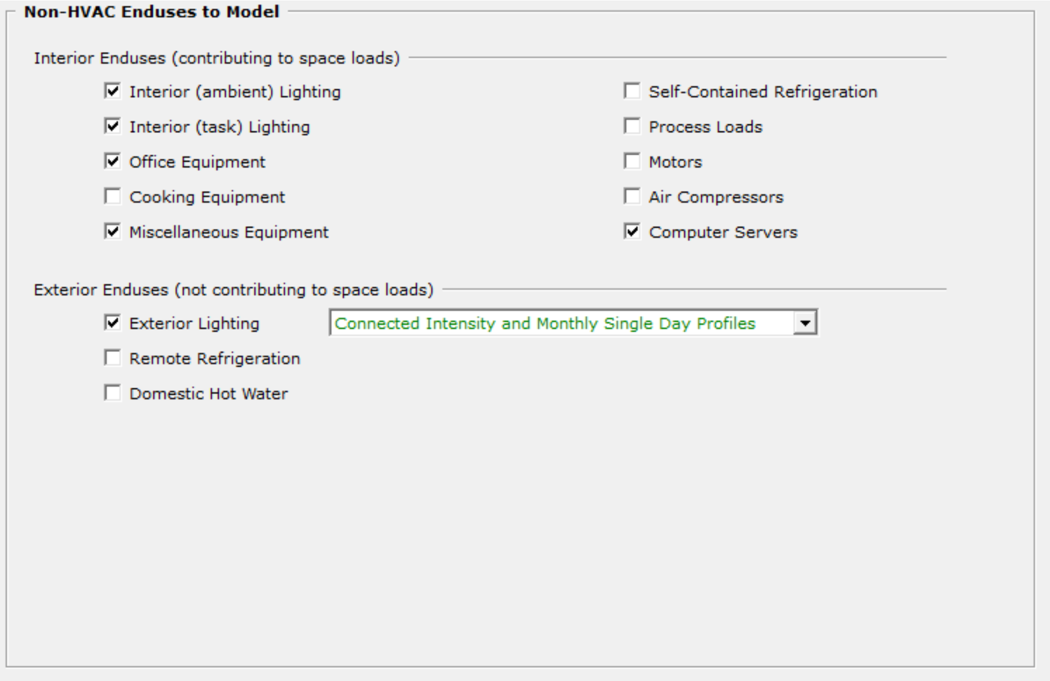
Heat gain calculator, BTU / hour				Gain, in BTU/hr = (surface area / R) * temp diff					
Cooling loads, interim case									
	Inside temp =	72							
Room	Element	ft^2	R	A * U	°F diff	Gain	Notes		
House	Floor, w carpet	0	1	0	-19	0	slab on insul	Independent	
	, /LJKWLQJ	:DWWV 100				341	all power	of outside temp	
	, 3HRSOH	1				341	family		
	Total insides	0		0		682			
	Outside temp =	105							
	Floor	100	30	3	33	110		Dependent	
	Ceiling	100	30	3	68	227	attic @ 140°	on outside temp	
	N wall	100	19	5	33	174	minus winds	and insolation	
	S wall	100	19	5	33	174	minus winds		
	W wall	100	19	5	33	174	minus winds		
	E wall	100	19	5	33	174	minus winds		
	Windows	11	2	5	33	178	all 20		
	Skylights	0	2	0	33	0	all 4		
	, ,QILOWUDWLRQ	16,000	0.018	0.40	33	3,802			
	Total, outsides	611		33		5,011			
	Total, ins + outs	611		33		5,693			
	#Insolation is not estimated and can be large so calcs are interim-case. Shading also								
	is not estimated and offsets insolation to some degree.								
	# Infiltration = cu. Ft. * air heat transfer factor * air changes/hr * temp. diff								
	#Compute the volume of the structure, use the 0.018 transfer factor, and assume 0.4 for air changes.								
	#Infiltration has a big effect so try several values for air changes per hour to gauge impact.								
	#Units are in US unit because eQUEST calculates in US units								
	, SHUVRQ VHDWHG DSSUR[:						%78		
	, : %78								

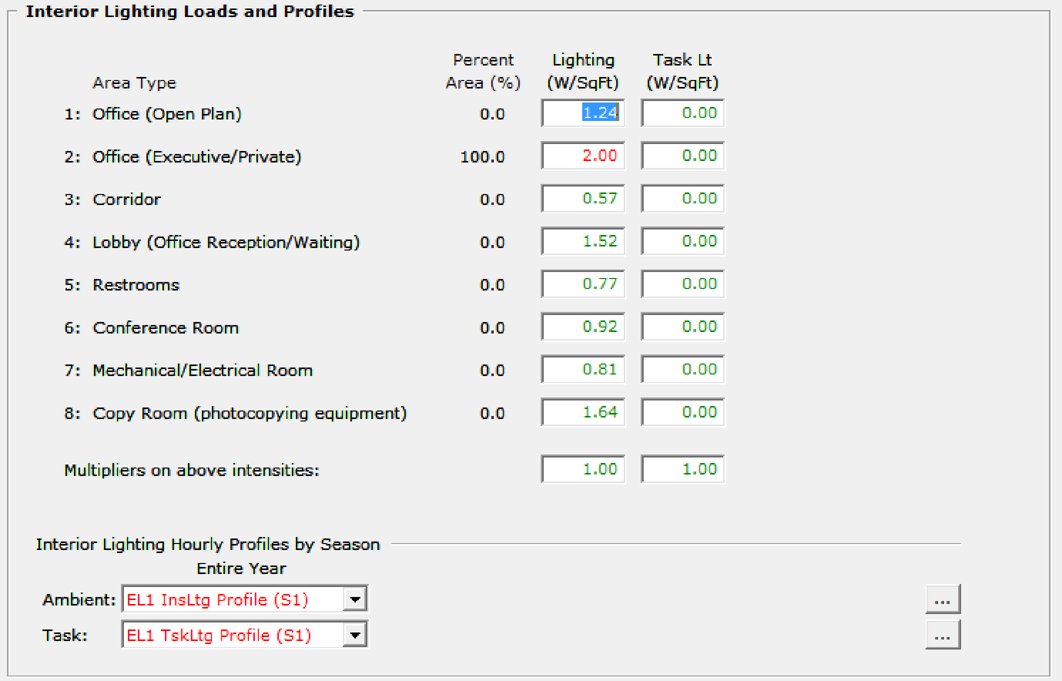
Appendix C:eQUEST Simple Model






Activity Areas Allocation
Area Type
Percent Area (%)
Design Max Occup (sf/person)
Design Ventilation (CFM/per)
1: Office (Open Plan) 0.0 200 20.00
2: Office (Executive/Private) 100.0 200 20.00
3: Corridor 0.0 1,000 50.00
4: Lobby (Office Reception/Waiting) 0.0 100 15.00
5: Restrooms 0.0 300 50.00
6: Conference Room 0.0 50 20.00
7: Mechanical/Electrical Room 0.0 2,000 100.00
8: Copy Room (photocopying equipment) 0.0 200 100.00
Percent Area Sum: 100.0 1 0.100
Show Zone Group Screen
Occupancy Profiles by Season
Entire Year
EL1 Occup Profile (S1)
...


Non-HVAC Enduses to Model
Interior Enduses (contributing to space loads)
Interior (ambient) Lighting
Interior (task) Lighting
Office Equipment
Cooking Equipment
Miscellaneous Equipment
Self-Contained Refrigeration
Process Loads
Motors
Air Compressors
Computer Servers
Exterior Enduses (not contributing to space loads)
Exterior Lighting
Connected Intensity and Monthly Single Day Profiles
Remote Refrigeration
Domestic Hot Water



Interior Lighting Loads and Profiles

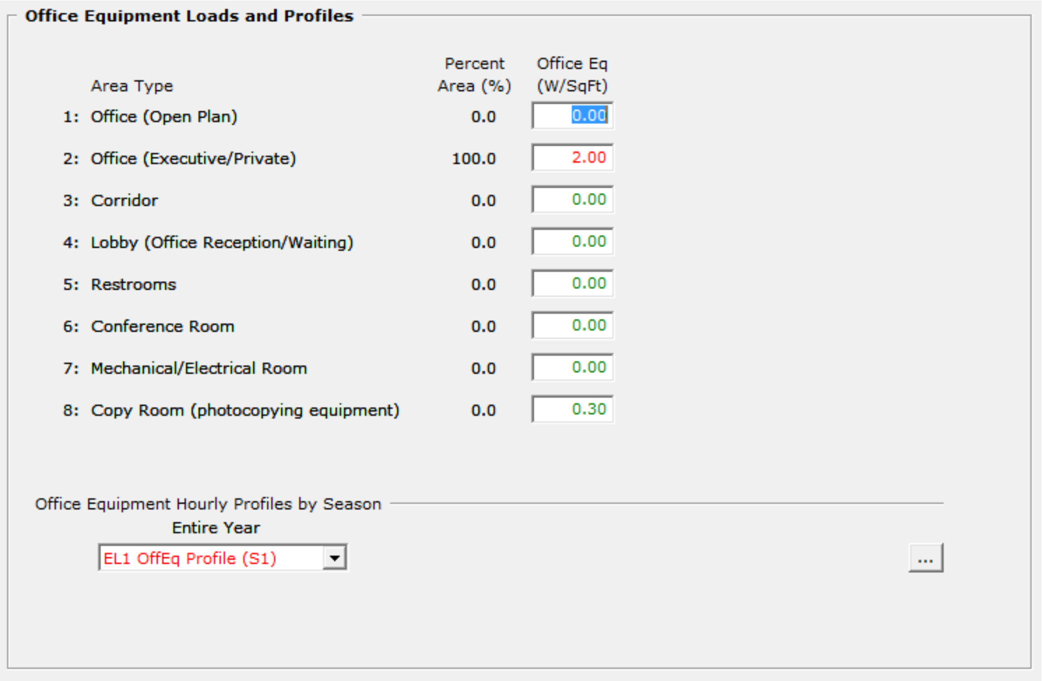
Area Type	Percent Area (%)	Lighting (W/SqFt)	Task Lt (W/SqFt)
1: Office (Open Plan)	0.0	1.24	0.00
2: Office (Executive/Private)	100.0	2.00	0.00
3: Corridor	0.0	0.57	0.00
4: Lobby (Office Reception/Waiting)	0.0	1.52	0.00
5: Restrooms	0.0	0.77	0.00
6: Conference Room	0.0	0.92	0.00
7: Mechanical/Electrical Room	0.0	0.81	0.00
8: Copy Room (photocopying equipment)	0.0	1.64	0.00
Multipliers on above intensities:		1.00	1.00

Interior Lighting Hourly Profiles by Season

Entire Year

Ambient: EL1 InsLtg Profile (S1)

Task: EL1 TskLtg Profile (S1)



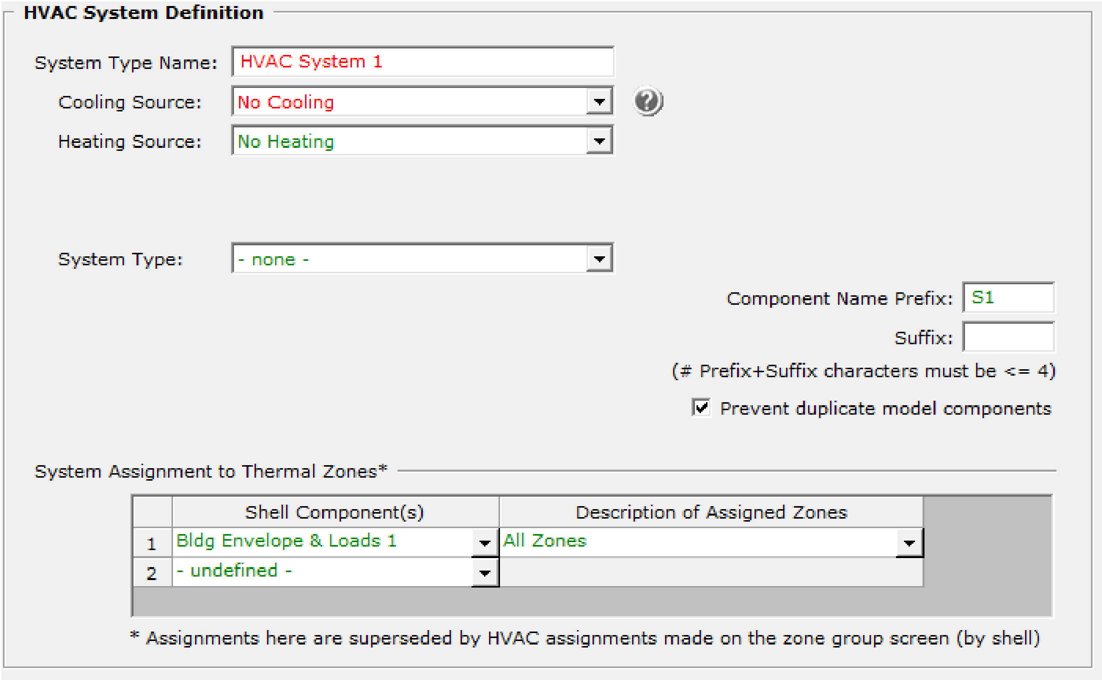
Office Equipment Loads and Profiles

Area Type	Percent Area (%)	Office Eq (W/SqFt)
1: Office (Open Plan)	0.0	0.00
2: Office (Executive/Private)	100.0	2.00
3: Corridor	0.0	0.00
4: Lobby (Office Reception/Waiting)	0.0	0.00
5: Restrooms	0.0	0.00
6: Conference Room	0.0	0.00
7: Mechanical/Electrical Room	0.0	0.00
8: Copy Room (photocopying equipment)	0.0	0.30

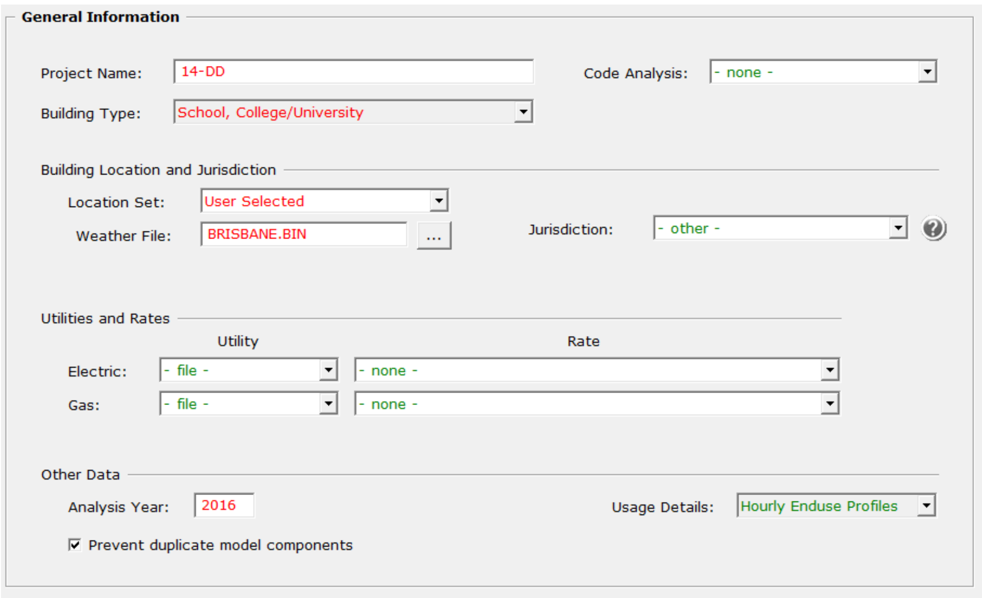
Office Equipment Hourly Profiles by Season

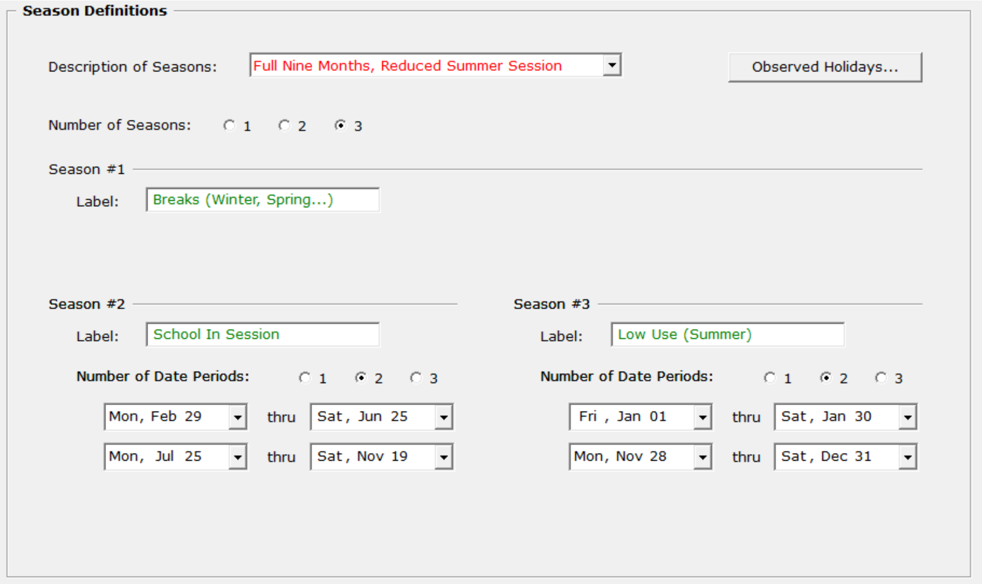
Entire Year

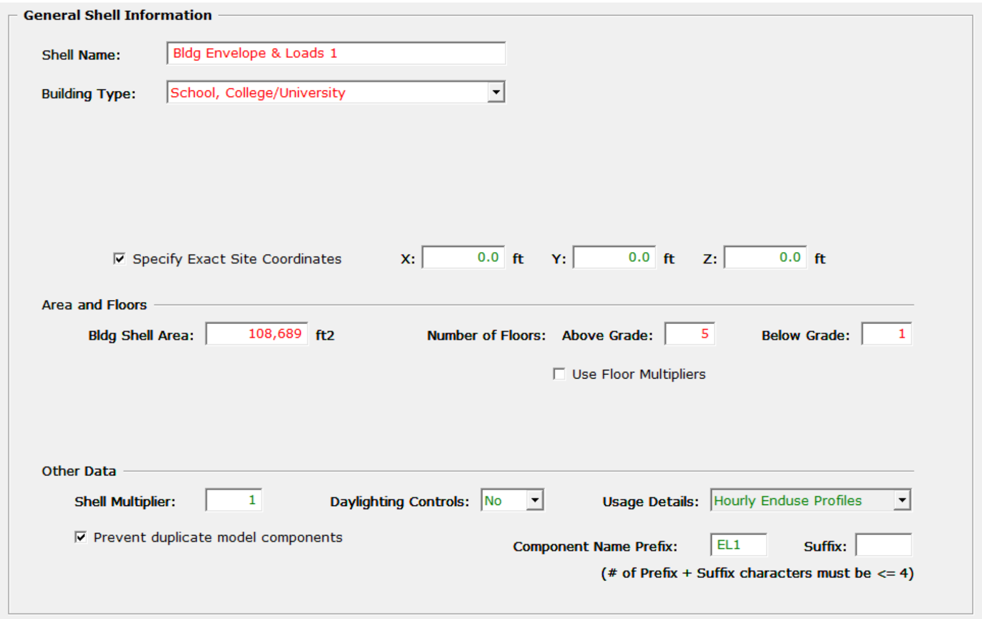
EL1 OffEq Profile (S1)

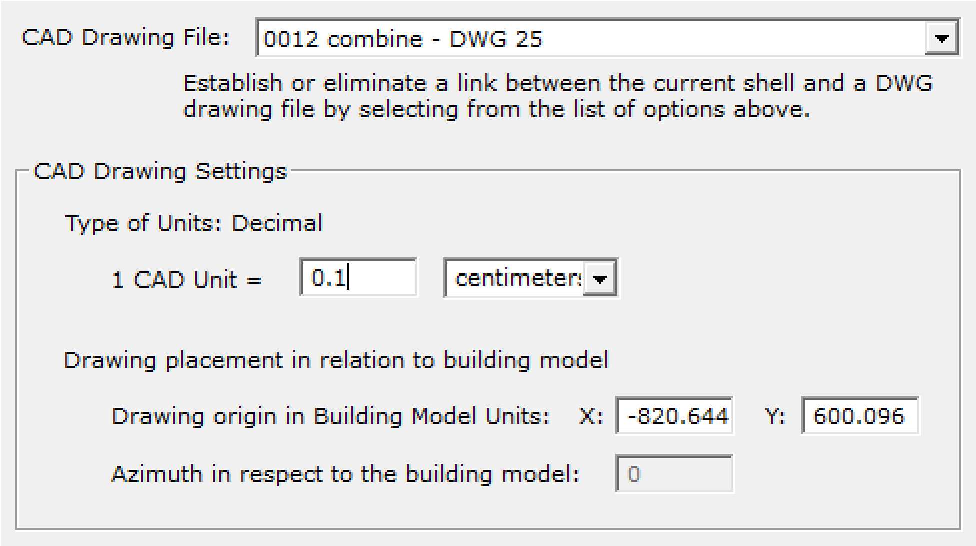


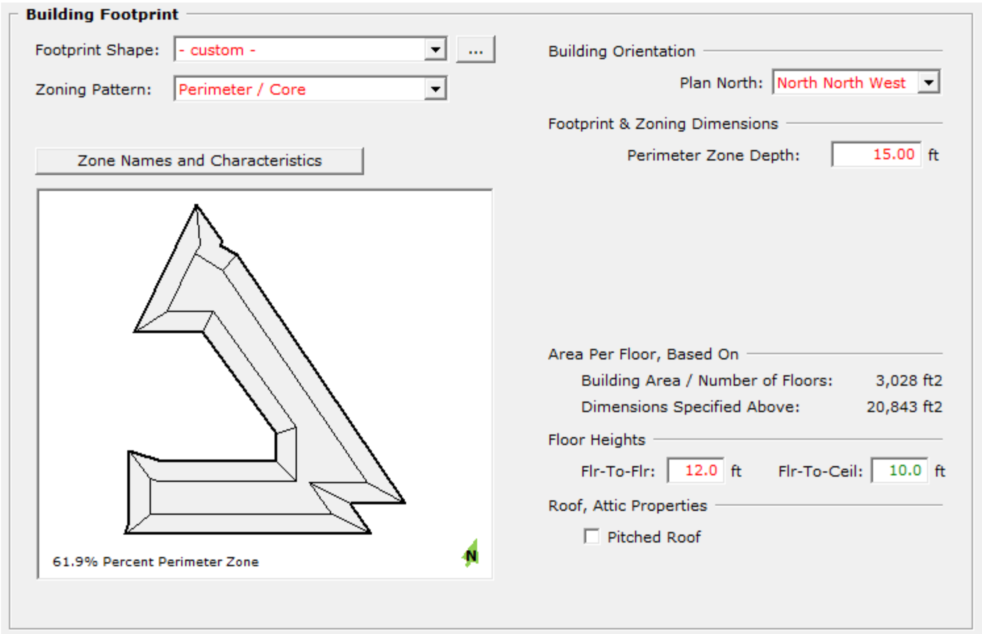
Appendix D: eQUEST Three Buildings

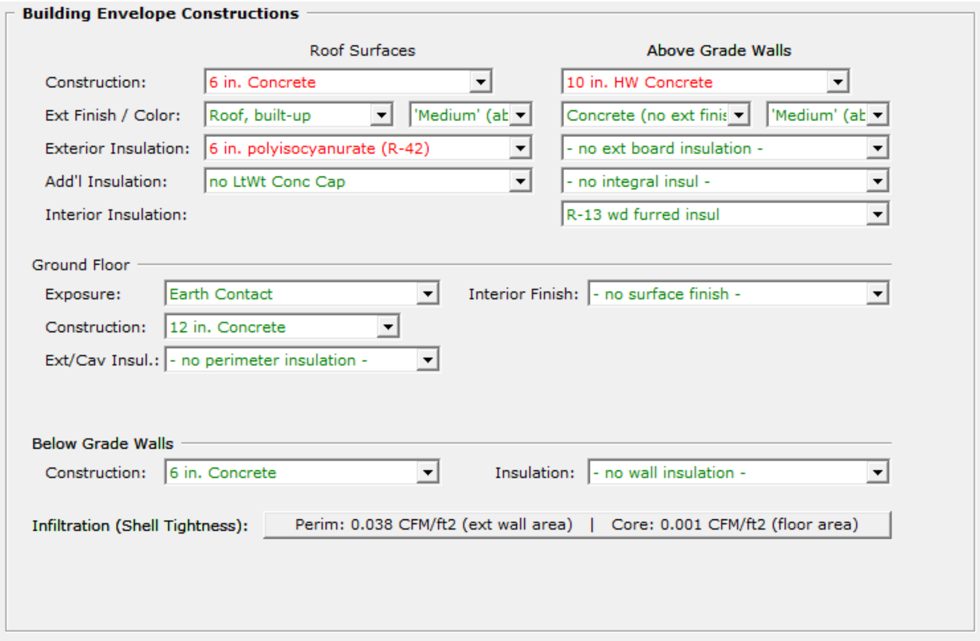


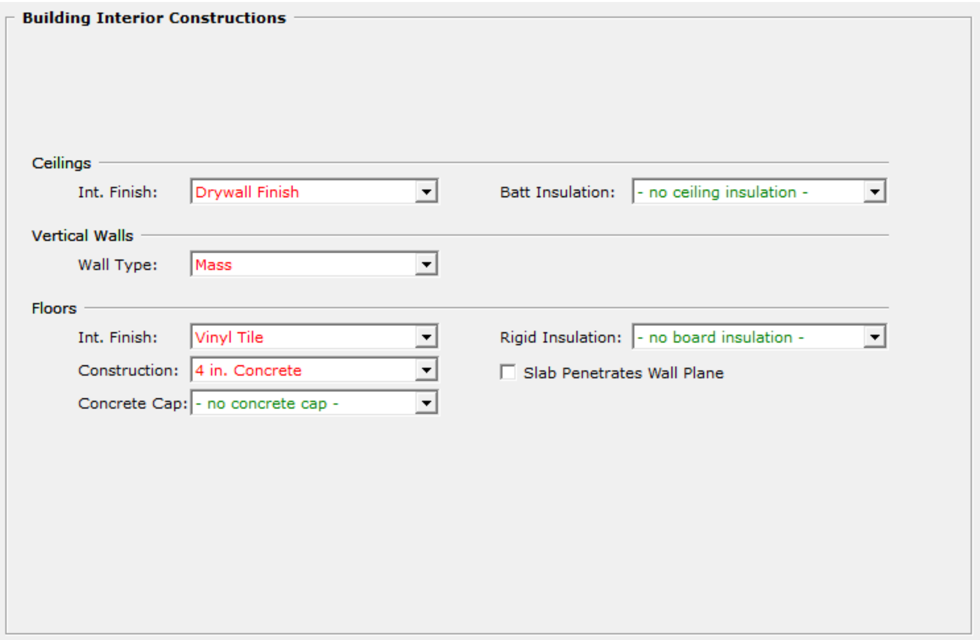

Season Definitions
Description of Seasons:
Full Nine Months, Reduced Summer Session
Observed Holidays...
Number of Seasons: 1 2 3
Season #1
Label:
Breaks (Winter, Spring...)
Season #2
Label:
School In Session
Number of Date Periods: 1 2 3
Mon, Feb 29 thru Sat, Jun 25
Mon, Jul 25 thru Sat, Nov 19
Season #3
Label:
Low Use (Summer)
Number of Date Periods: 1 2 3
Fri , Jan 01 thru Sat, Jan 30
Mon, Nov 28 thru Sat, Dec 31

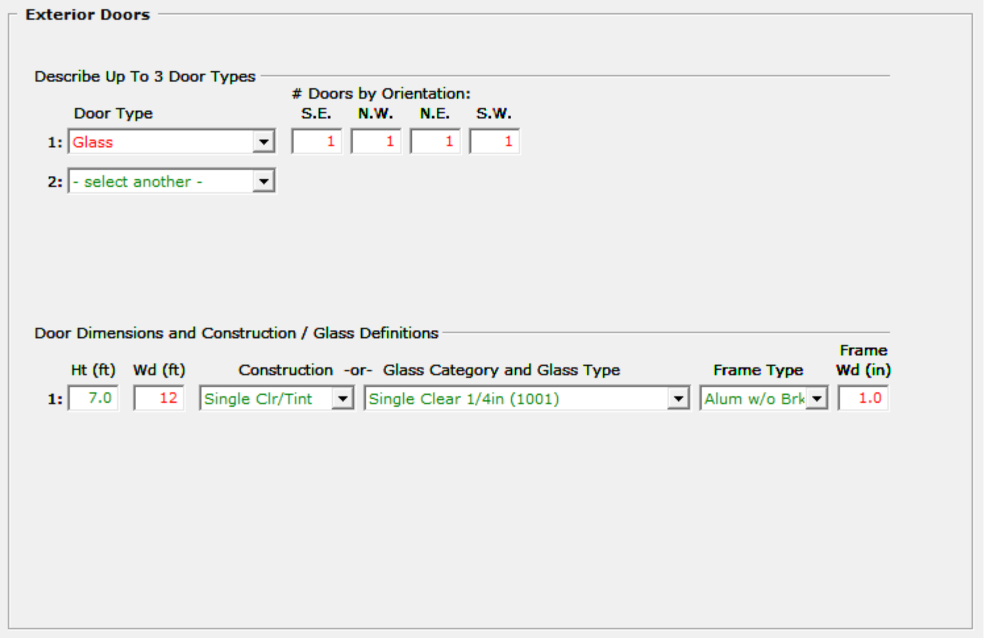

General Shell Information
Shell Name:
Bldg Envelope & Loads 1
Building Type:
School, College/University
Specify Exact Site Coordinates
X: 0.0 ft
Y: 0.0 ft
Z: 0.0 ft
Area and Floors
Bldg Shell Area: 108,689 ft2
Number of Floors: Above Grade: 5
Below Grade: 1
Use Floor Multipliers
Other Data
Shell Multiplier: 1
Daylighting Controls: No
Usage Details: Hourly Enduse Profiles
Prevent duplicate model components
Component Name Prefix: EL1
Suffix:
(# of Prefix + Suffix characters must be <= 4)

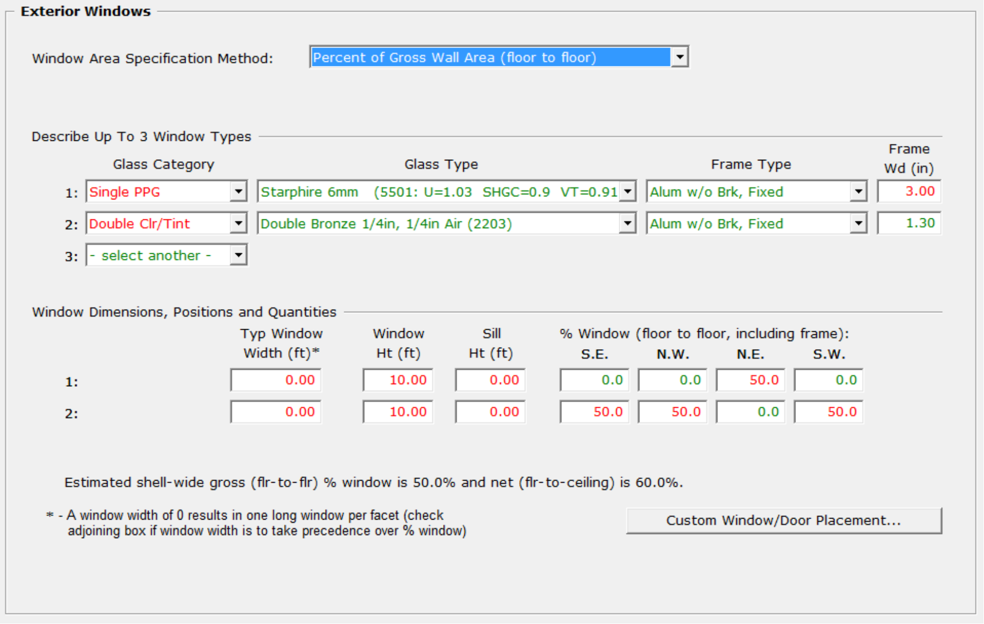

CAD Drawing File:
0012 combine - DWG 25
Establish or eliminate a link between the current shell and a DWG drawing file by selecting from the list of options above.
CAD Drawing Settings
Type of Units: Decimal
1 CAD Unit =
0.1
centimeter:
Drawing placement in relation to building model
Drawing origin in Building Model Units:
X:
-820.644
Y:
600.096
Azimuth in respect to the building model:
0

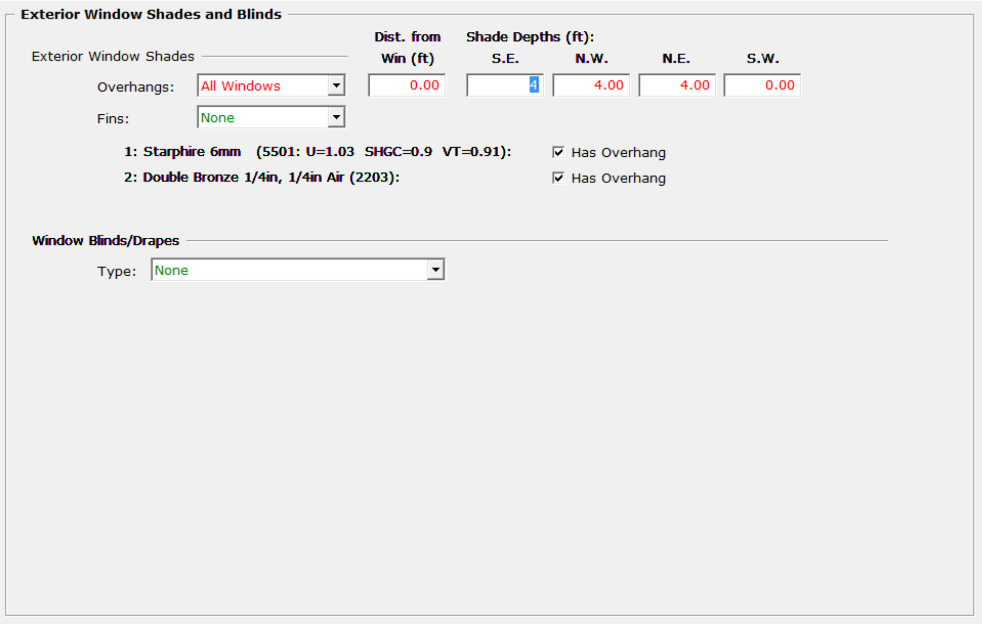

Building Footprint
Footprint Shape:
- custom -
Zoning Pattern:
Perimeter / Core
Zone Names and Characteristics
61.9% Percent Perimeter Zone
N
Building Orientation
Plan North:
North North West
Footprint & Zoning Dimensions
Perimeter Zone Depth:
15.00
ft
Area Per Floor, Based On
Building Area / Number of Floors:
3,028 ft2
Dimensions Specified Above:
20,843 ft2
Floor Heights
Flr-To-Flr:
12.0
ft
Flr-To-Ceil:
10.0
ft
Roof, Attic Properties
Pitched Roof

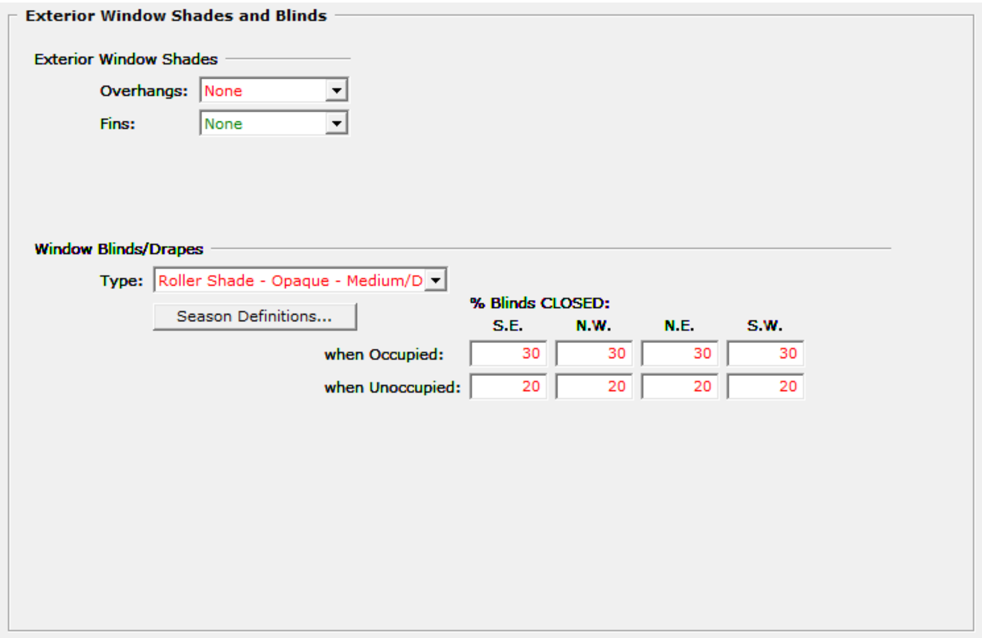

Building Envelope Constructions
Roof Surfaces
Above Grade Walls
Construction: 6 in. Concrete | 10 in. HW Concrete
Ext Finish / Color: Roof, built-up | 'Medium' (ab | Concrete (no ext finis | 'Medium' (ab
Exterior Insulation: 6 in. polyisocyanurate (R-42) | - no ext board insulation -
Add'l Insulation: no LtWt Conc Cap | - no integral insul -
Interior Insulation: R-13 wd furred insul
Ground Floor
Exposure: Earth Contact
Interior Finish: - no surface finish -
Construction: 12 in. Concrete
Ext/Cav Insul.: - no perimeter insulation -
Below Grade Walls
Construction: 6 in. Concrete
Insulation: - no wall insulation -
Infiltration (Shell Tightness): Perim: 0.038 CFM/ft2 (ext wall area) | Core: 0.001 CFM/ft2 (floor area)

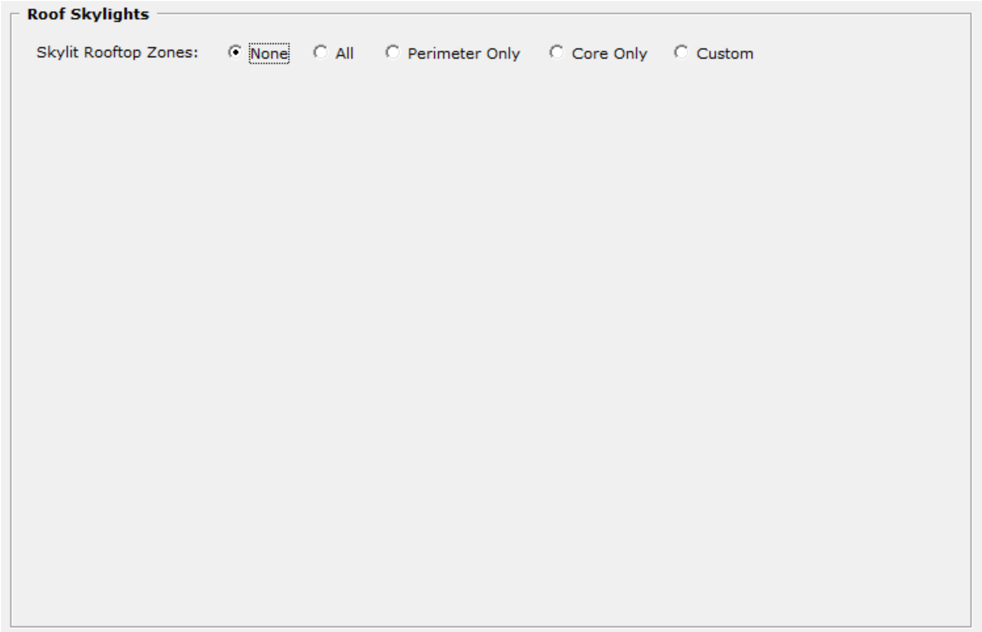

Building Interior Constructions
Ceilings
Int. Finish: Drywall Finish
Batt Insulation: - no ceiling insulation -
Vertical Walls
Wall Type: Mass
Floors
Int. Finish: Vinyl Tile
Rigid Insulation: - no board insulation -
Construction: 4 in. Concrete
Slab Penetrates Wall Plane
Concrete Cap: - no concrete cap -

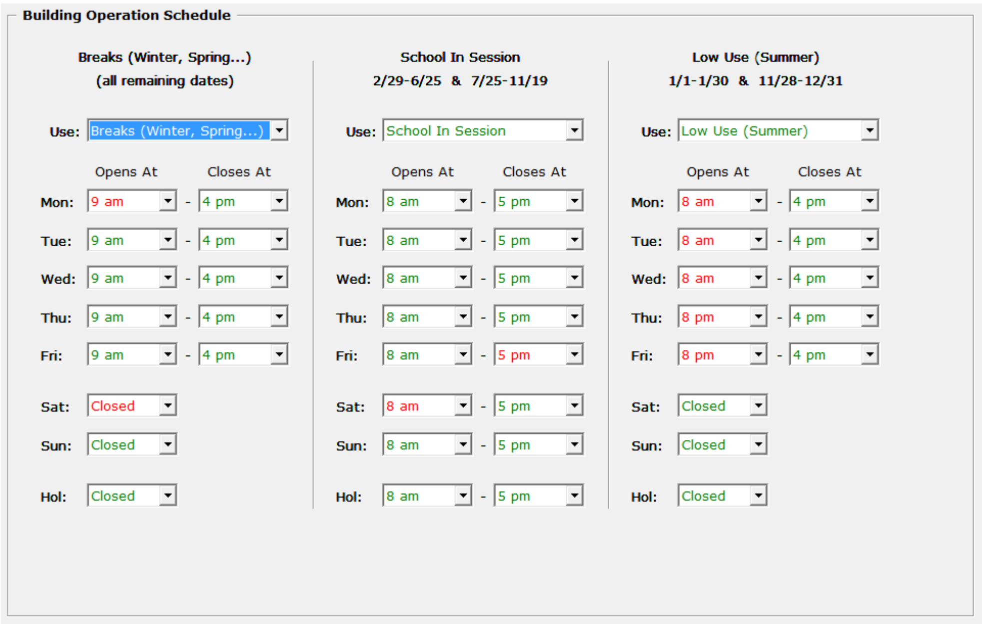

Exterior Doors
Describe Up To 3 Door Types
Doors by Orientation:
Door Type
S.E.
N.W.
N.E.
S.W.
1: Glass
1
1
1
1
2: - select another -
Door Dimensions and Construction / Glass Definitions
Ht (ft)
Wd (ft)
Construction -or- Glass Category and Glass Type
Frame Type
Frame Wd (in)
1: 7.0
12
Single Clr/Tint
Single Clear 1/4in (1001)
Alum w/o Brk
1.0

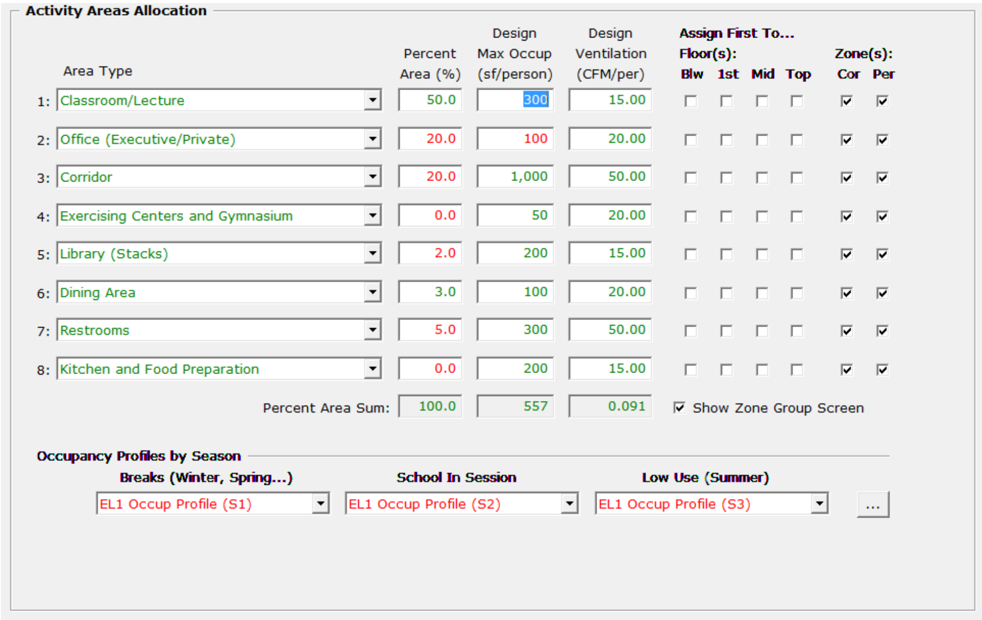

Exterior Windows
Window Area Specification Method:
Percent of Gross Wall Area (floor to floor)
Describe Up To 3 Window Types
Glass Category
Glass Type
Frame Type
Frame Wd (in)
1: Single PPG
Starphire 6mm (5501: U=1.03 SHGC=0.9 VT=0.91
Alum w/o Brk, Fixed
3.00
2: Double Clr/Tint
Double Bronze 1/4in, 1/4in Air (2203)
Alum w/o Brk, Fixed
1.30
3: - select another -
Window Dimensions, Positions and Quantities
Typ Window Width (ft)*
Window Ht (ft)
Sill Ht (ft)
% Window (floor to floor, including frame):
S.E.
N.W.
N.E.
S.W.
1: 0.00
10.00
0.00
0.0
0.0
50.0
0.0
2: 0.00
10.00
0.00
50.0
50.0
0.0
50.0
Estimated shell-wide gross (flr-to-flr) % window is 50.0% and net (flr-to-ceiling) is 60.0%.
* - A window width of 0 results in one long window per facet (check adjoining box if window width is to take precedence over % window)
Custom Window/Door Placement...

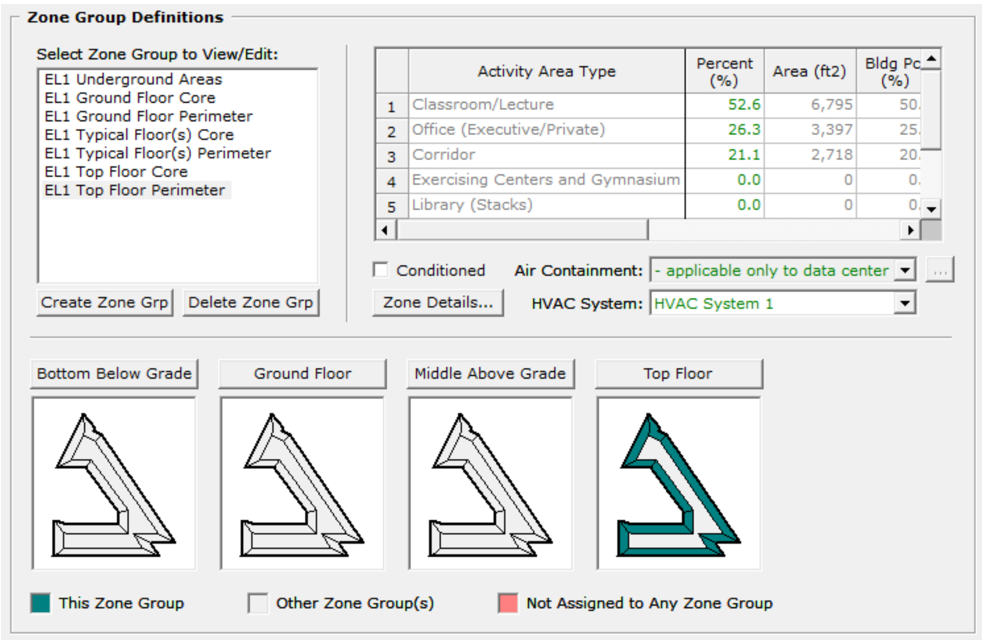

Exterior Window Shades and Blinds
Exterior Window Shades
Dist. from Win (ft)
Shade Depths (ft):
S.E.
N.W.
N.E.
S.W.
Overhangs:
All Windows
0.00
4
4.00
4.00
0.00
Fins:
None
1: Starphire 6mm (5501: U=1.03 SHGC=0.9 VT=0.91):
Has Overhang
2: Double Bronze 1/4in, 1/4in Air (2203):
Has Overhang
Window Blinds/Drapes
Type:
None

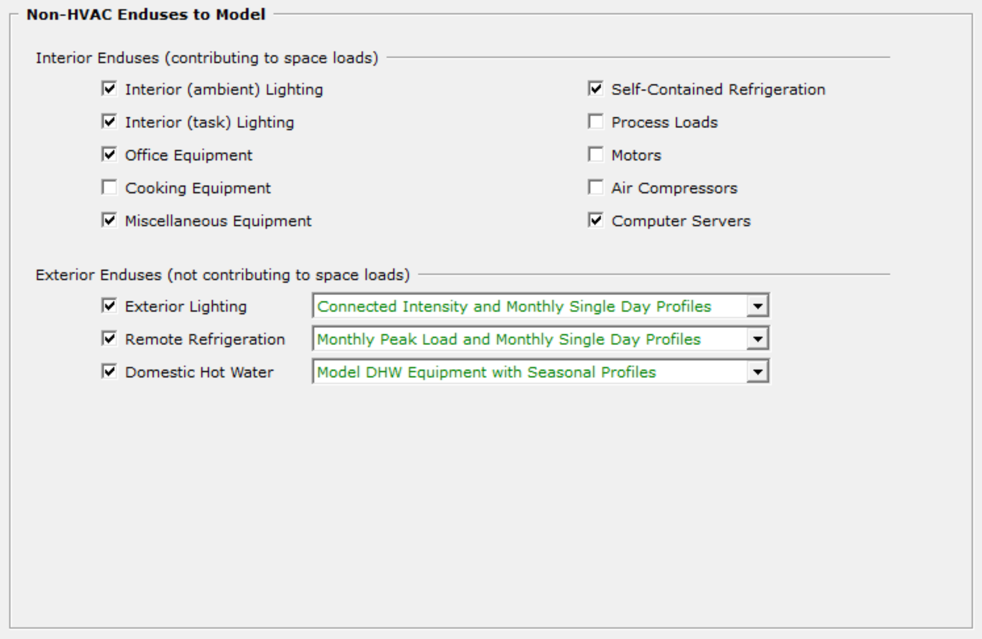

Exterior Window Shades and Blinds
Exterior Window Shades
Overhangs:
None
Fins:
None
Window Blinds/Drapes
Type:
Roller Shade - Opaque - Medium/D
Season Definitions...
% Blinds CLOSED:
S.E.
N.W.
N.E.
S.W.
when Occupied:
30
30
30
30
when Unoccupied:
20
20
20
20

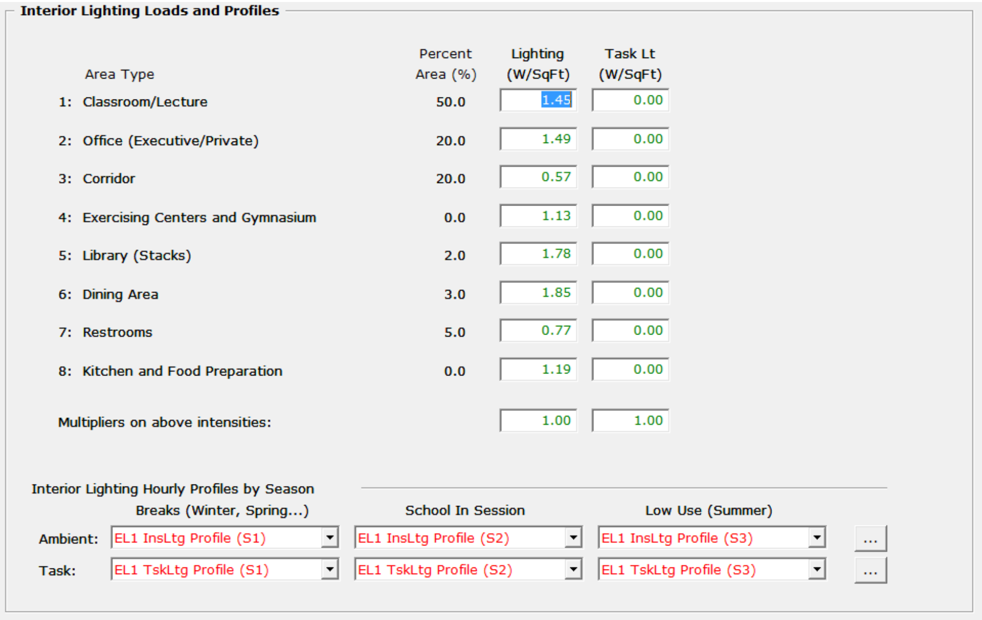

Roof Skylights
Skylit Rooftop Zones:
None
All
Perimeter Only
Core Only
Custom

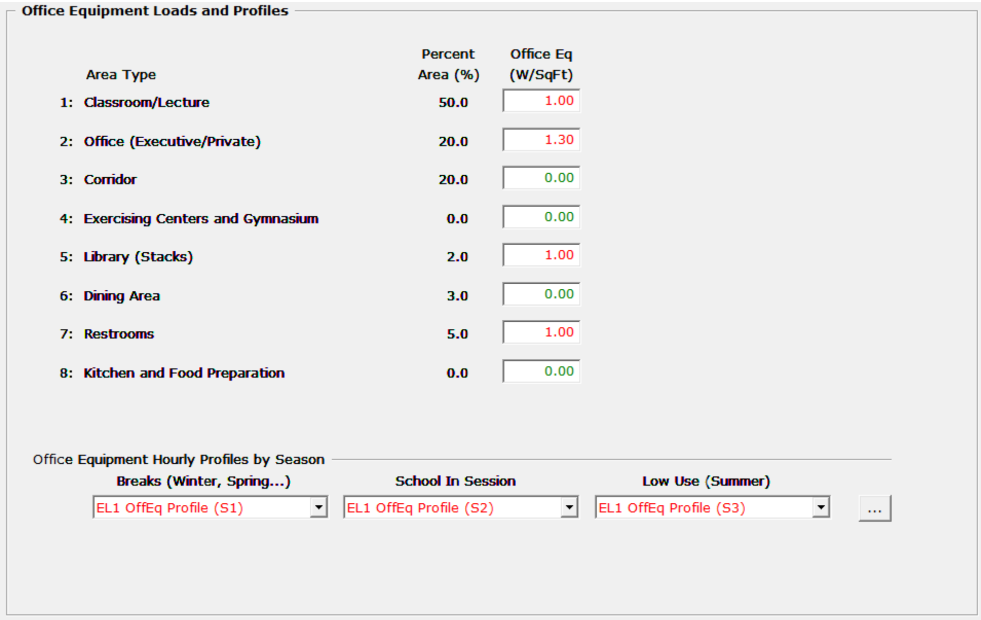

Building Operation Schedule
Breaks (Winter, Spring...)
(all remaining dates)
School In Session
2/29-6/25 & 7/25-11/19
Low Use (Summer)
1/1-1/30 & 11/28-12/31
Use: Breaks (Winter, Spring...)
Use: School In Session
Use: Low Use (Summer)
Opens At
Closes At
Mon: 9 am - 4 pm
Tue: 9 am - 4 pm
Wed: 9 am - 4 pm
Thu: 9 am - 4 pm
Fri: 9 am - 4 pm
Sat: Closed
Sun: Closed
Hol: Closed
Mon: 8 am - 5 pm
Tue: 8 am - 5 pm
Wed: 8 am - 5 pm
Thu: 8 am - 5 pm
Fri: 8 am - 5 pm
Sat: 8 am - 5 pm
Sun: 8 am - 5 pm
Hol: 8 am - 5 pm
Mon: 8 am - 4 pm
Tue: 8 am - 4 pm
Wed: 8 am - 4 pm
Thu: 8 pm - 4 pm
Fri: 8 pm - 4 pm
Sat: Closed
Sun: Closed
Hol: Closed


Activity Areas Allocation
Area Type
Percent Area (%)
Design Max Occup (sf/person)
Design Ventilation (CFM/per)
Assign First To...
Floor(s):
Blw 1st Mid Top
Zone(s):
Cor Per
1: Classroom/Lecture 50.0 300 15.00
2: Office (Executive/Private) 20.0 100 20.00
3: Corridor 20.0 1,000 50.00
4: Exercising Centers and Gymnasium 0.0 50 20.00
5: Library (Stacks) 2.0 200 15.00
6: Dining Area 3.0 100 20.00
7: Restrooms 5.0 300 50.00
8: Kitchen and Food Preparation 0.0 200 15.00
Percent Area Sum: 100.0 557 0.091
Show Zone Group Screen
Occupancy Profiles by Season
Breaks (Winter, Spring...)
School In Session
Low Use (Summer)
EL1 Occup Profile (S1)
EL1 Occup Profile (S2)
EL1 Occup Profile (S3)


Zone Group Definitions
Select Zone Group to View/Edit:
EL1 Underground Areas
EL1 Ground Floor Core
EL1 Ground Floor Perimeter
EL1 Typical Floor(s) Core
EL1 Typical Floor(s) Perimeter
EL1 Top Floor Core
EL1 Top Floor Perimeter
Activity Area Type
Percent (%)
Area (ft2)
Bldg Pc (%)
1 Classroom/Lecture 52.6 6,795 50.
2 Office (Executive/Private) 26.3 3,397 25.
3 Corridor 21.1 2,718 20.
4 Exercising Centers and Gymnasium 0.0 0 0.
5 Library (Stacks) 0.0 0 0.
Conditioned
Air Containment:
- applicable only to data center
Create Zone Grp
Delete Zone Grp
Zone Details...
HVAC System:
HVAC System 1
Bottom Below Grade
Ground Floor
Middle Above Grade
Top Floor
This Zone Group
Other Zone Group(s)
Not Assigned to Any Zone Group


Non-HVAC Enduses to Model
Interior Enduses (contributing to space loads)
Interior (ambient) Lighting
Interior (task) Lighting
Office Equipment
Cooking Equipment
Miscellaneous Equipment
Self-Contained Refrigeration
Process Loads
Motors
Air Compressors
Computer Servers
Exterior Enduses (not contributing to space loads)
Exterior Lighting
Connected Intensity and Monthly Single Day Profiles
Remote Refrigeration
Monthly Peak Load and Monthly Single Day Profiles
Domestic Hot Water
Model DHW Equipment with Seasonal Profiles


Interior Lighting Loads and Profiles
Area Type
Percent Area (%)
Lighting (W/SqFt)
Task Lt (W/SqFt)
1: Classroom/Lecture 50.0 1.45 0.00
2: Office (Executive/Private) 20.0 1.49 0.00
3: Corridor 20.0 0.57 0.00
4: Exercising Centers and Gymnasium 0.0 1.13 0.00
5: Library (Stacks) 2.0 1.78 0.00
6: Dining Area 3.0 1.85 0.00
7: Restrooms 5.0 0.77 0.00
8: Kitchen and Food Preparation 0.0 1.19 0.00
Multipliers on above intensities: 1.00 1.00
Interior Lighting Hourly Profiles by Season
Breaks (Winter, Spring...)
School In Session
Low Use (Summer)
Ambient:
EL1 InsLtg Profile (S1)
EL1 InsLtg Profile (S2)
EL1 InsLtg Profile (S3)
Task:
EL1 TskLtg Profile (S1)
EL1 TskLtg Profile (S2)
EL1 TskLtg Profile (S3)

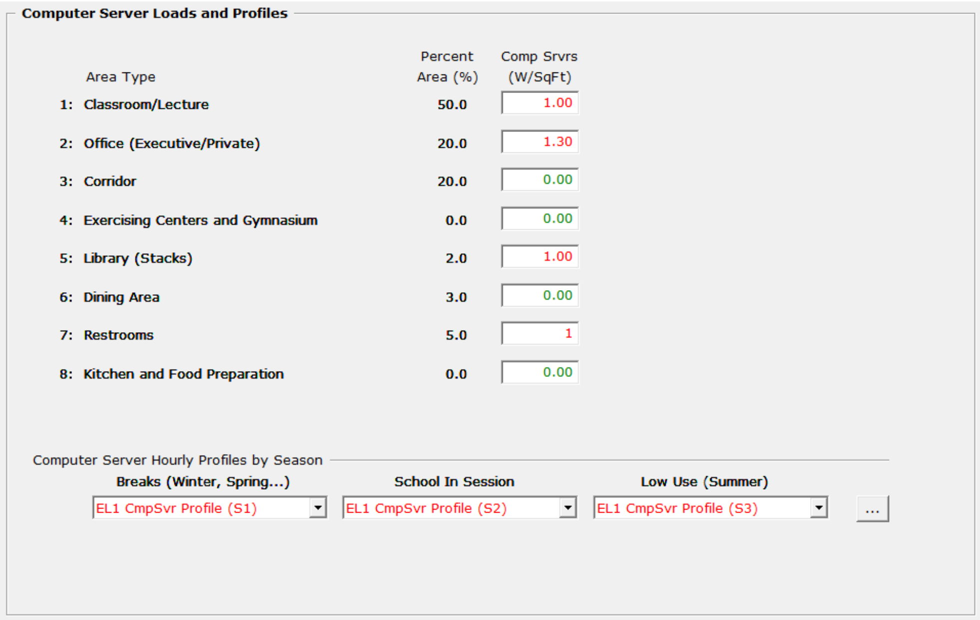


Office Equipment Loads and Profiles

Area Type	Percent Area (%)	Office Eq (W/SqFt)
1: Classroom/Lecture	50.0	1.00
2: Office (Executive/Private)	20.0	1.30
3: Corridor	20.0	0.00
4: Exercising Centers and Gymnasium	0.0	0.00
5: Library (Stacks)	2.0	1.00
6: Dining Area	3.0	0.00
7: Restrooms	5.0	1.00
8: Kitchen and Food Preparation	0.0	0.00

Office Equipment Hourly Profiles by Season

Breaks (Winter, Spring...)	School In Session	Low Use (Summer)
EL1 OffEq Profile (S1)	EL1 OffEq Profile (S2)	EL1 OffEq Profile (S3)

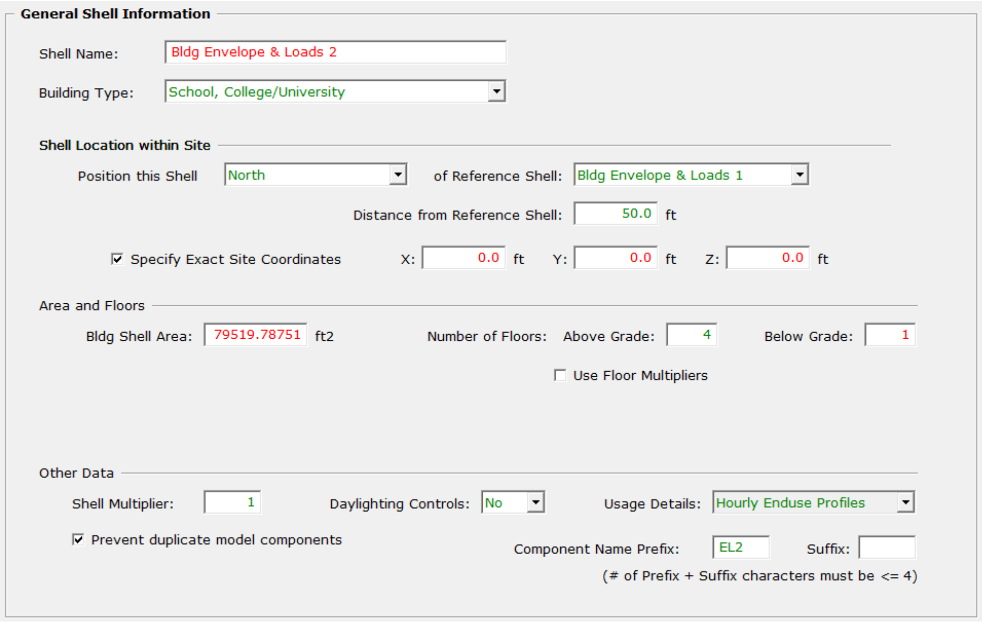


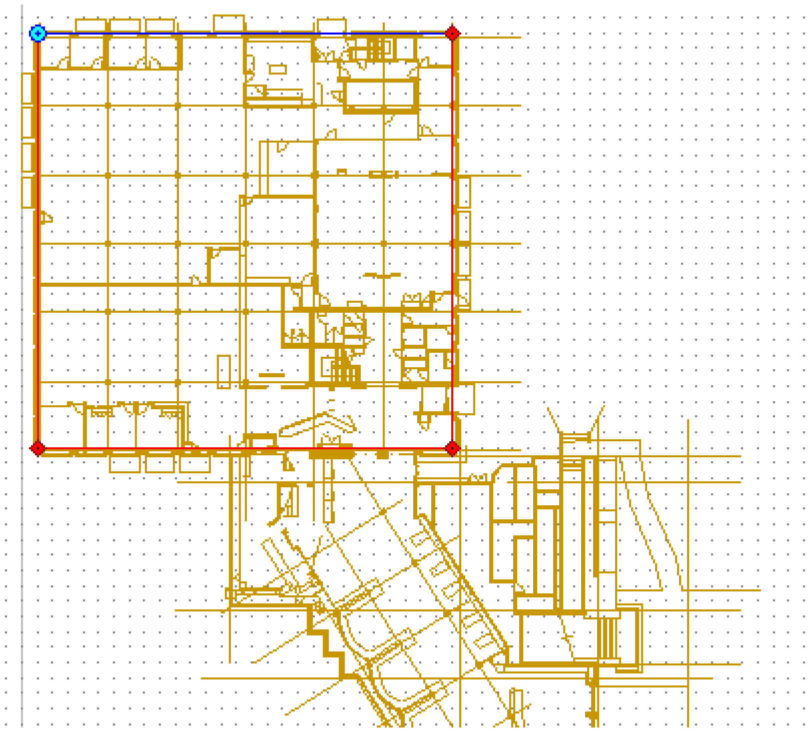
Computer Server Loads and Profiles

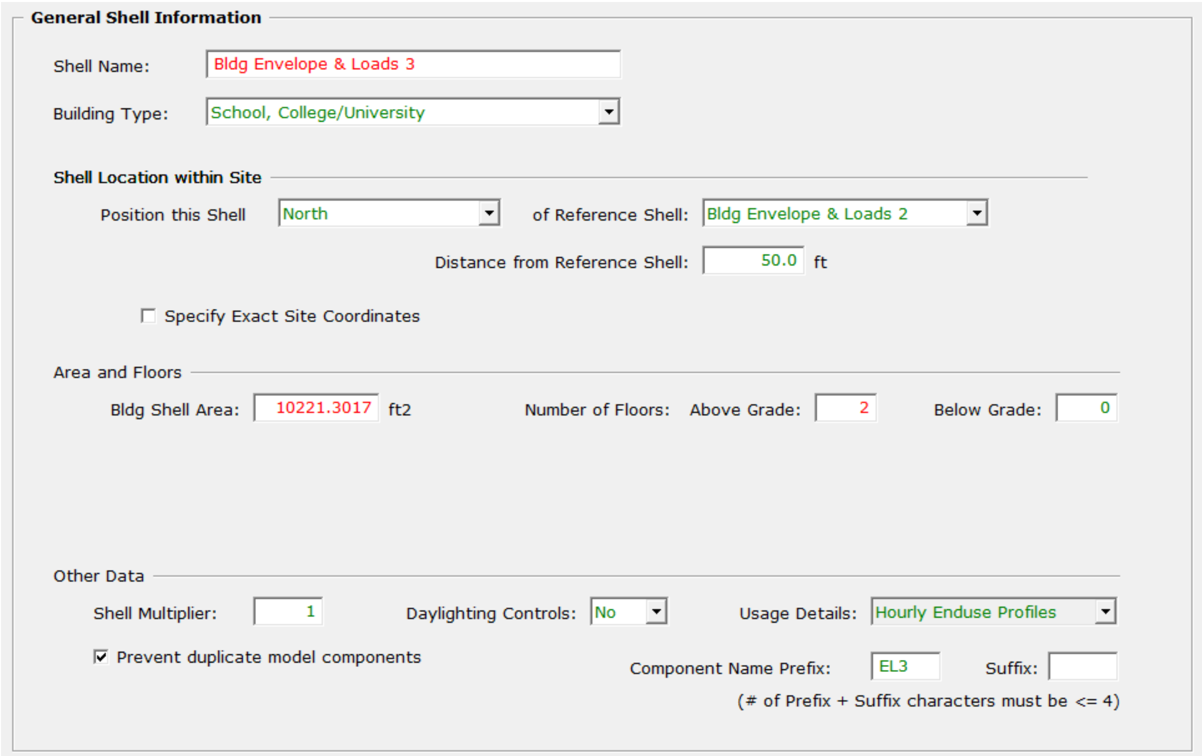
Area Type	Percent Area (%)	Comp Srvrs (W/SqFt)
1: Classroom/Lecture	50.0	1.00
2: Office (Executive/Private)	20.0	1.30
3: Corridor	20.0	0.00
4: Exercising Centers and Gymnasium	0.0	0.00
5: Library (Stacks)	2.0	1.00
6: Dining Area	3.0	0.00
7: Restrooms	5.0	1
8: Kitchen and Food Preparation	0.0	0.00

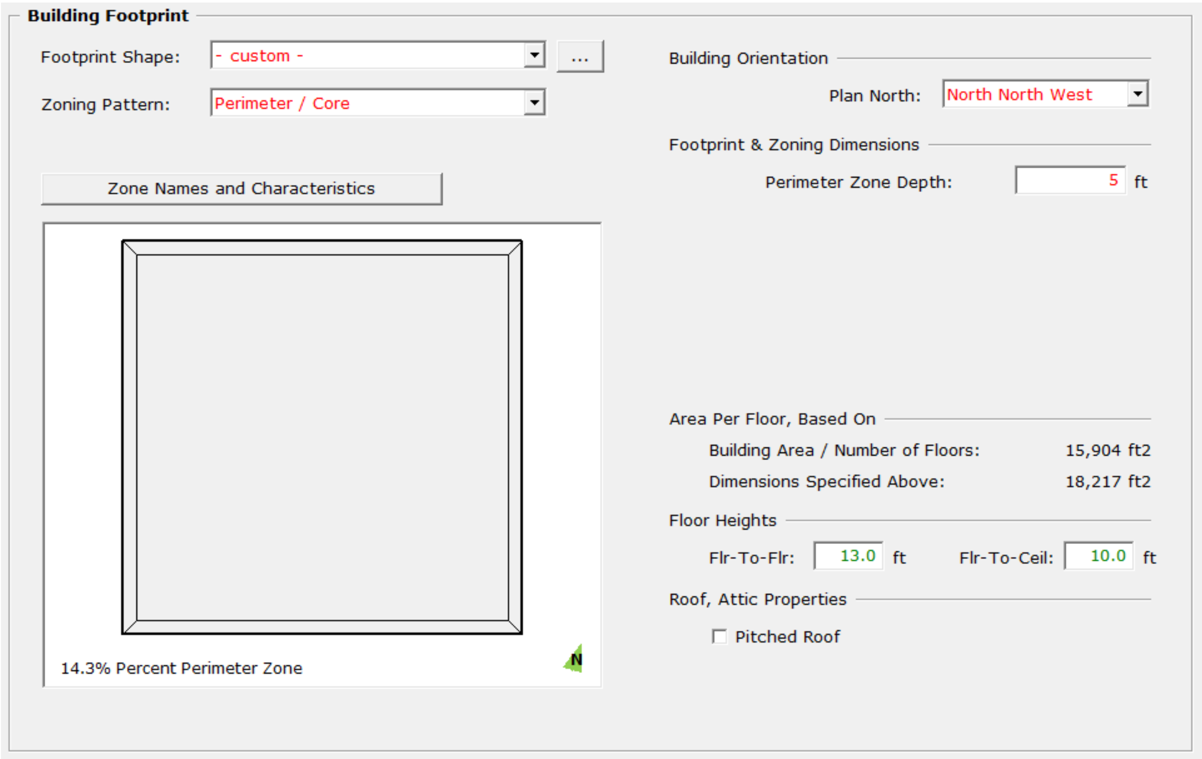
Computer Server Hourly Profiles by Season

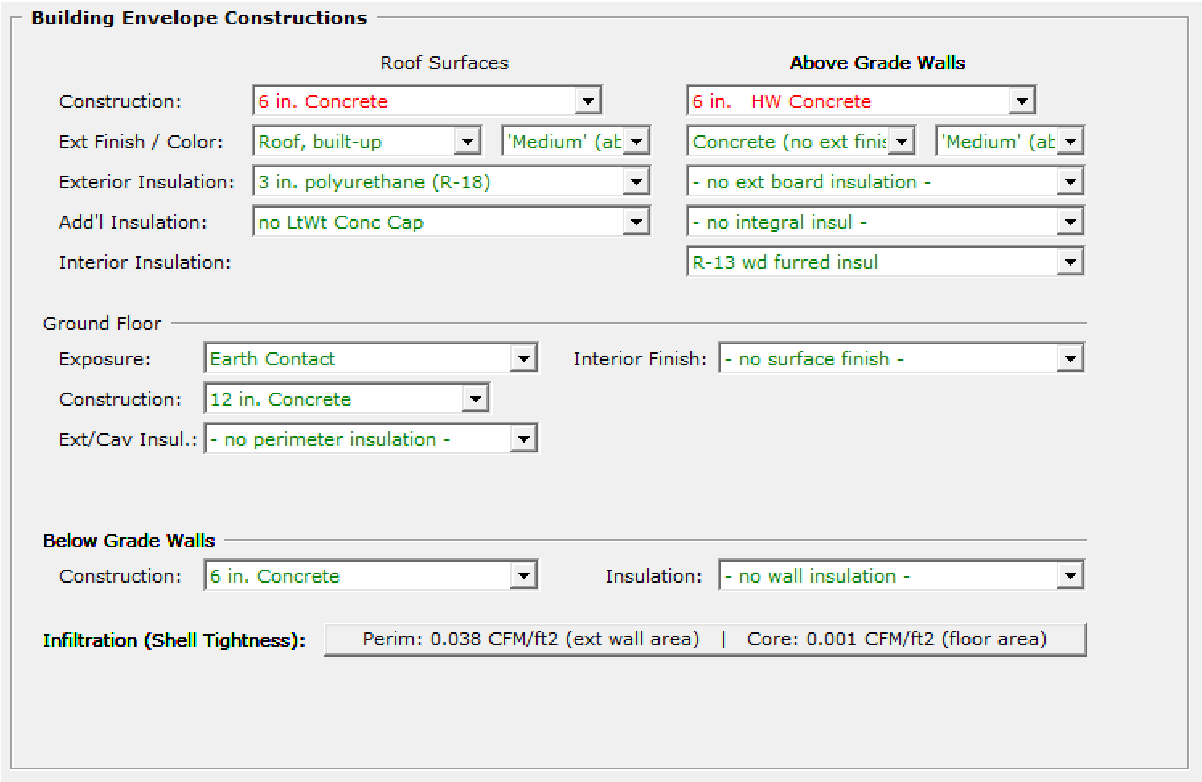
Breaks (Winter, Spring...)	School In Session	Low Use (Summer)
EL1 CmpSvr Profile (S1)	EL1 CmpSvr Profile (S2)	EL1 CmpSvr Profile (S3)

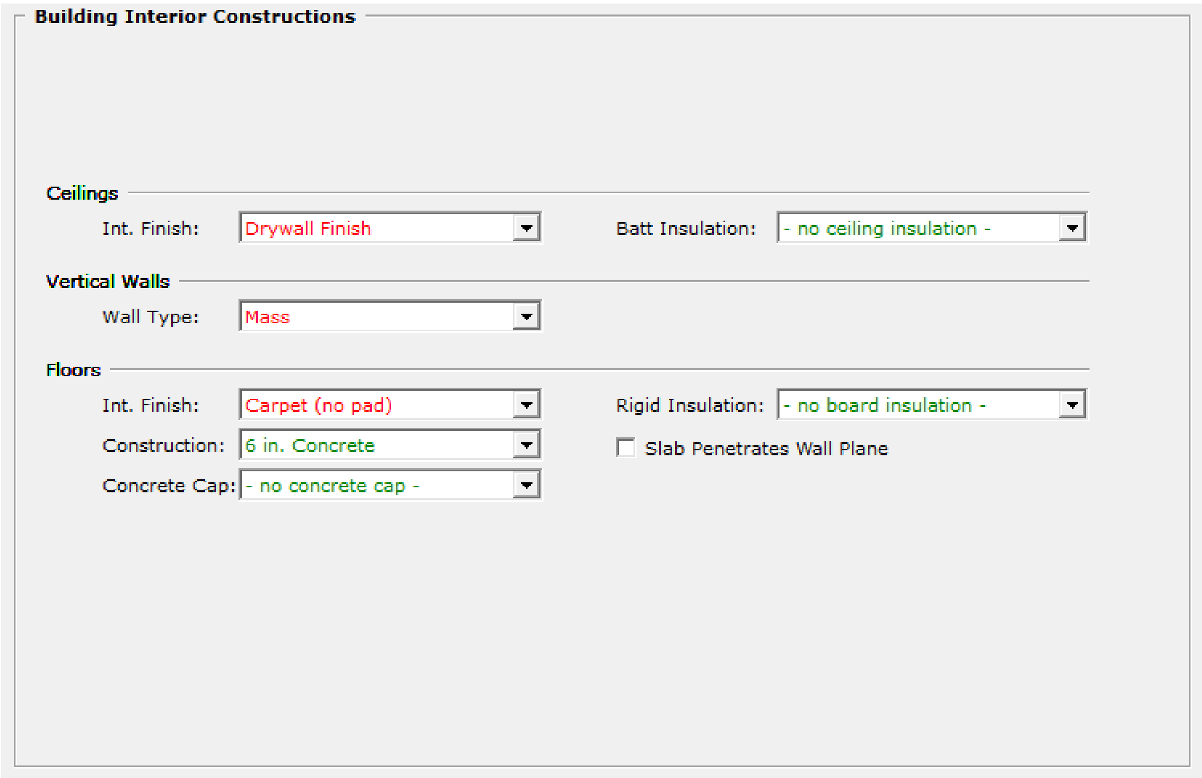

General Shell Information
Shell Name: Bldg Envelope & Loads 2
Building Type: School, College/University
Shell Location within Site
Position this Shell North of Reference Shell: Bldg Envelope & Loads 1
Distance from Reference Shell: 50.0 ft
Specify Exact Site Coordinates X: 0.0 ft Y: 0.0 ft Z: 0.0 ft
Area and Floors
Bldg Shell Area: 79519.78751 ft2
Number of Floors: Above Grade: 4 Below Grade: 1
Use Floor Multipliers
Other Data
Shell Multiplier: 1
Daylighting Controls: No
Usage Details: Hourly Enduse Profiles
Prevent duplicate model components
Component Name Prefix: EL2 Suffix:
(# of Prefix + Suffix characters must be <= 4)

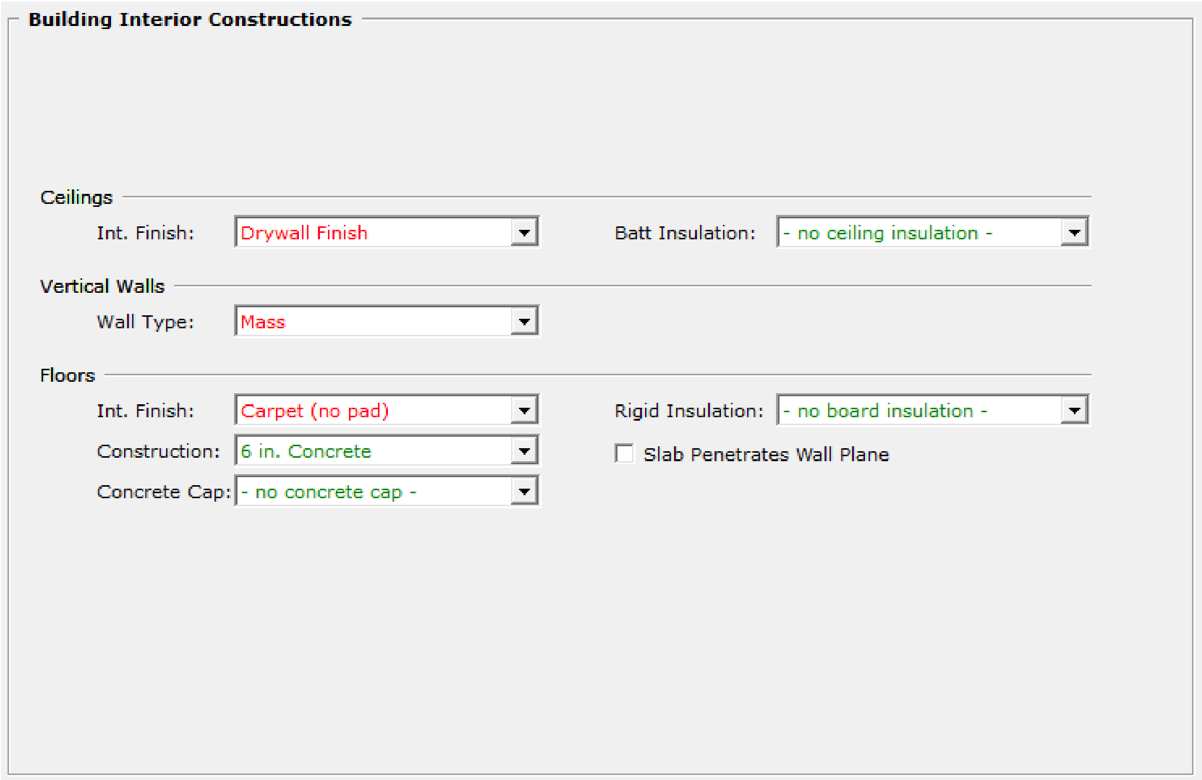


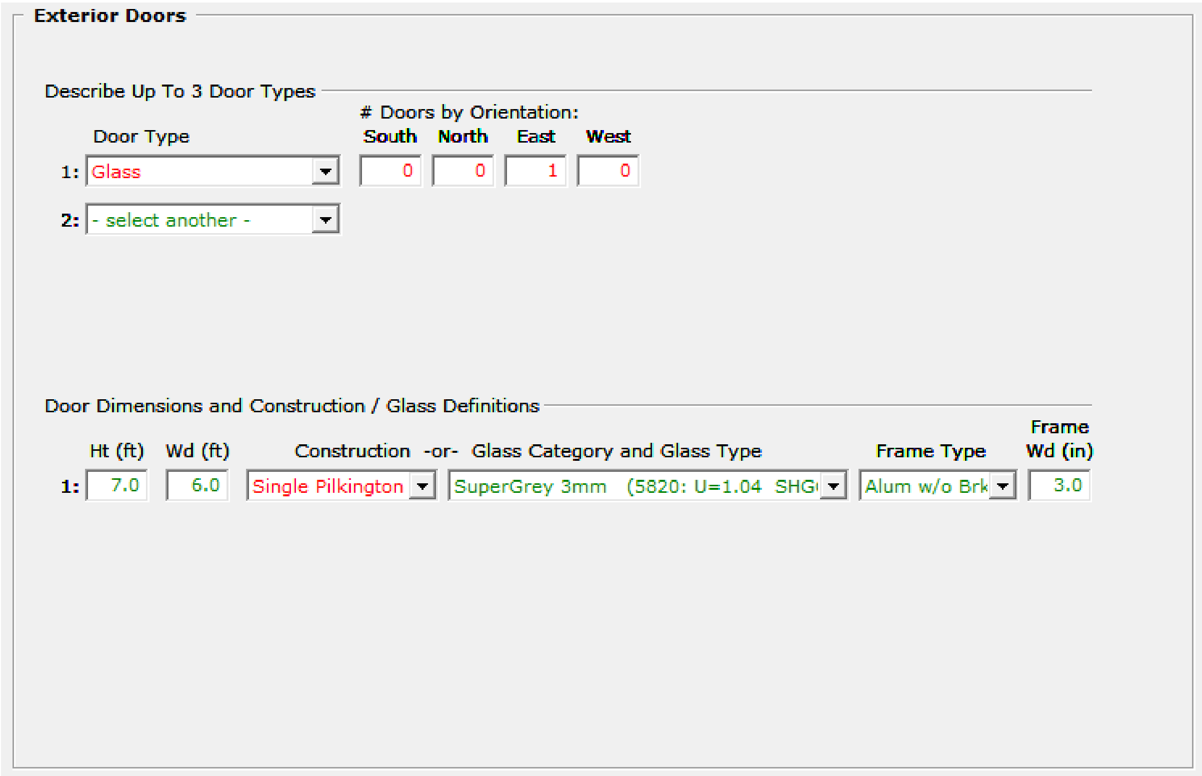

General Shell Information
Shell Name: Bldg Envelope & Loads 3
Building Type: School, College/University
Shell Location within Site
Position this Shell North of Reference Shell: Bldg Envelope & Loads 2
Distance from Reference Shell: 50.0 ft
Specify Exact Site Coordinates
Area and Floors
Bldg Shell Area: 10221.3017 ft2
Number of Floors: Above Grade: 2 Below Grade: 0
Other Data
Shell Multiplier: 1
Daylighting Controls: No
Usage Details: Hourly Enduse Profiles
Prevent duplicate model components
Component Name Prefix: EL3 Suffix:
(# of Prefix + Suffix characters must be <= 4)

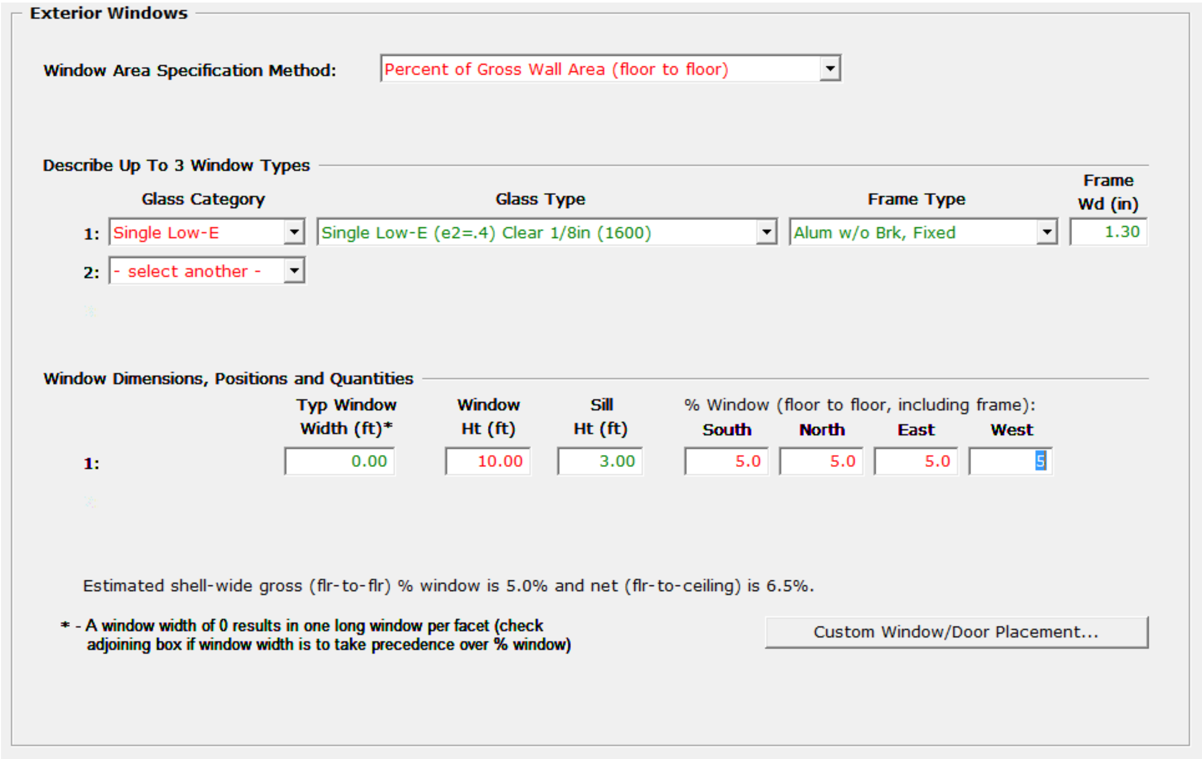

Building Footprint
Footprint Shape: - custom -
Zoning Pattern: Perimeter / Core
Zone Names and Characteristics
14.3% Percent Perimeter Zone
N
Building Orientation
Plan North: North North West
Footprint & Zoning Dimensions
Perimeter Zone Depth: 5 ft
Area Per Floor, Based On
Building Area / Number of Floors: 15,904 ft2
Dimensions Specified Above: 18,217 ft2
Floor Heights
Flr-To-Flr: 13.0 ft Flr-To-Ceil: 10.0 ft
Roof, Attic Properties
Pitched Roof

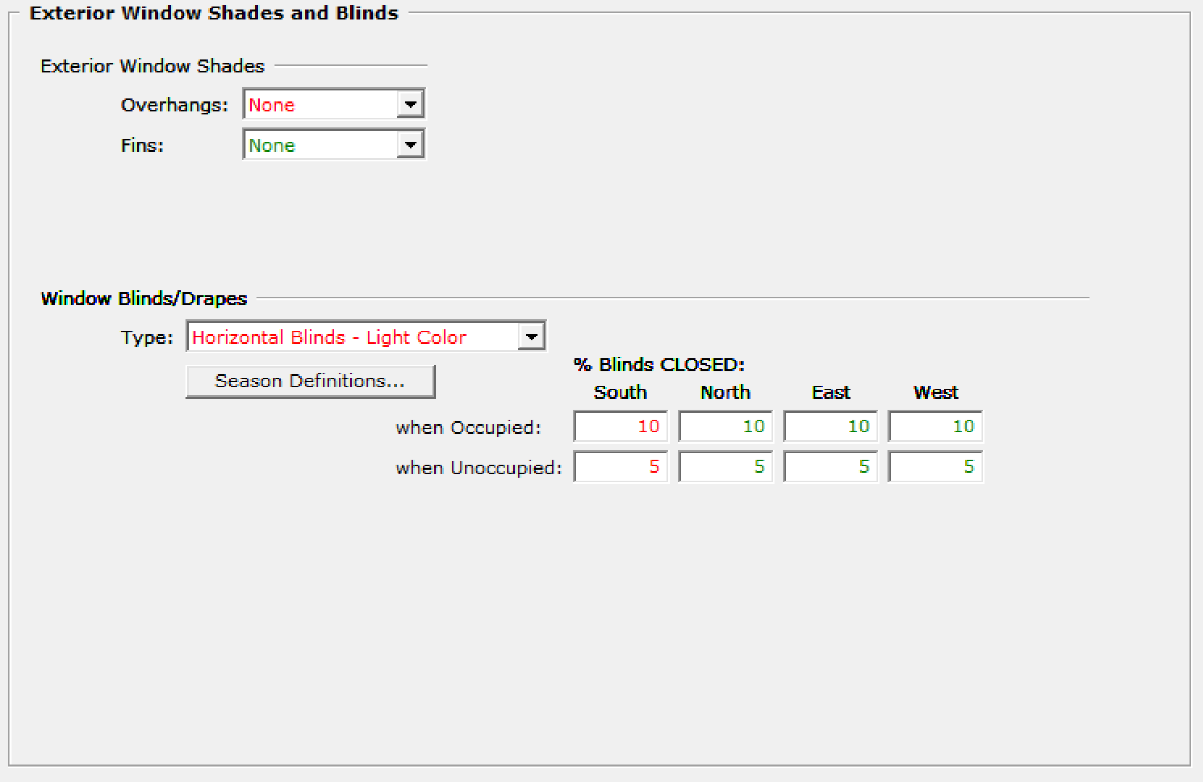

Building Envelope Constructions
Roof Surfaces
Above Grade Walls
Construction:
6 in. Concrete
6 in. HW Concrete
Ext Finish / Color:
Roof, built-up
'Medium' (ab
Concrete (no ext finis
'Medium' (ab
Exterior Insulation:
3 in. polyurethane (R-18)
- no ext board insulation -
Add'l Insulation:
no LtWt Conc Cap
- no integral insul -
Interior Insulation:
R-13 wd furred insul
Ground Floor
Exposure:
Earth Contact
Interior Finish:
- no surface finish -
Construction:
12 in. Concrete
Ext/Cav Insul.:
- no perimeter insulation -
Below Grade Walls
Construction:
6 in. Concrete
Insulation:
- no wall insulation -
Infiltration (Shell Tightness):
Perim: 0.038 CFM/ft2 (ext wall area) | Core: 0.001 CFM/ft2 (floor area)

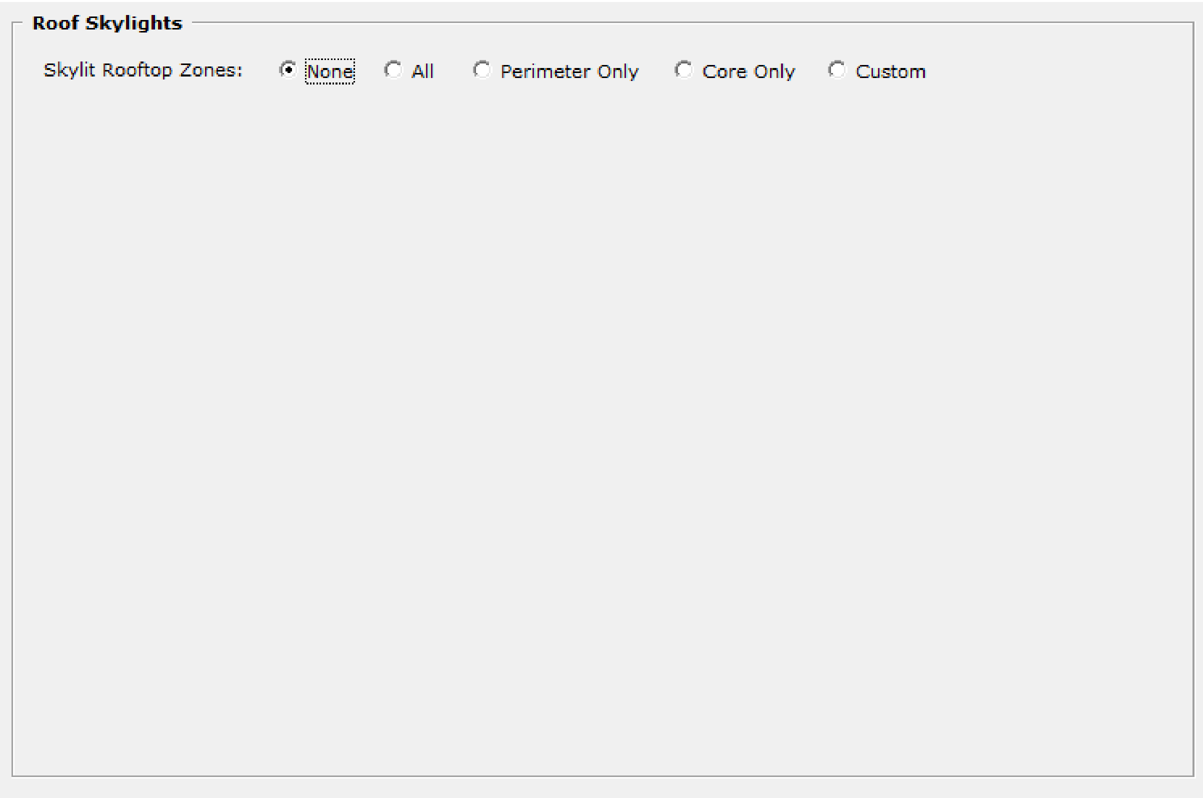

Building Interior Constructions
Ceilings
Int. Finish:
Drywall Finish
Batt Insulation:
- no ceiling insulation -
Vertical Walls
Wall Type:
Mass
Floors
Int. Finish:
Carpet (no pad)
Rigid Insulation:
- no board insulation -
Construction:
6 in. Concrete
Slab Penetrates Wall Plane
Concrete Cap:
- no concrete cap -

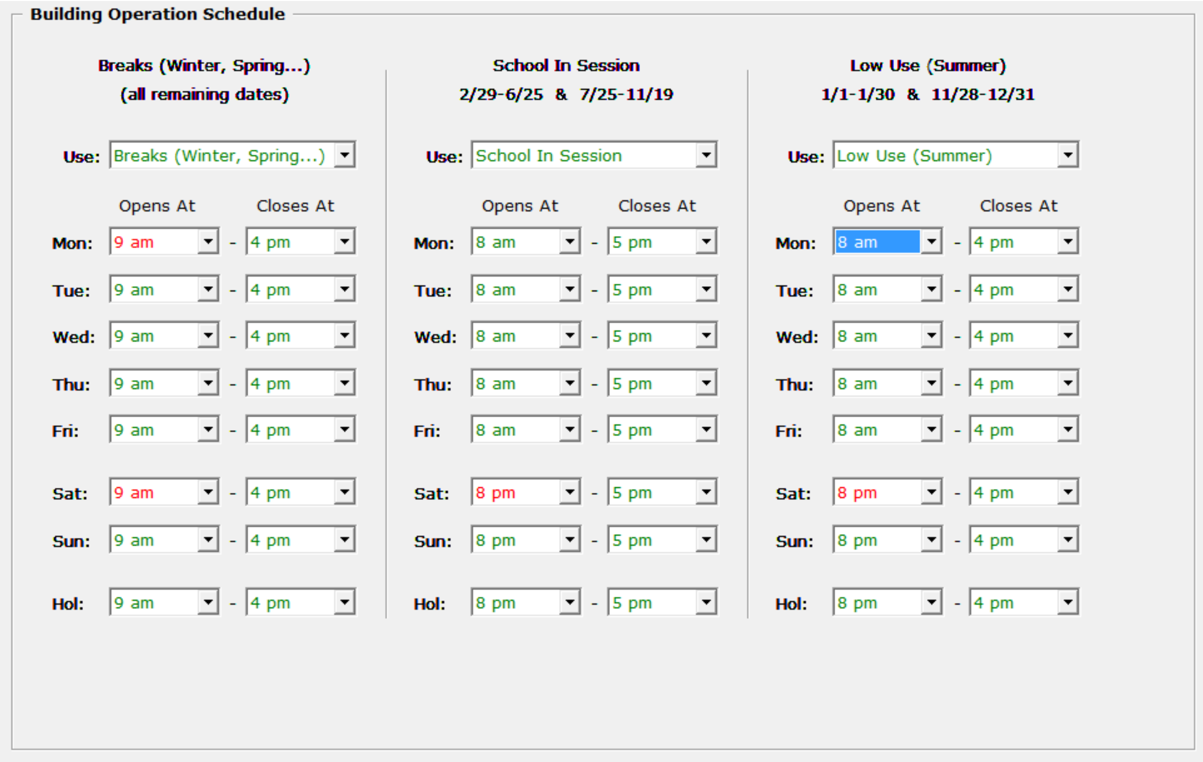

Building Interior Constructions
Ceilings
Int. Finish: Drywall Finish
Batt Insulation: - no ceiling insulation -
Vertical Walls
Wall Type: Mass
Floors
Int. Finish: Carpet (no pad)
Rigid Insulation: - no board insulation -
Construction: 6 in. Concrete
Slab Penetrates Wall Plane
Concrete Cap: - no concrete cap -

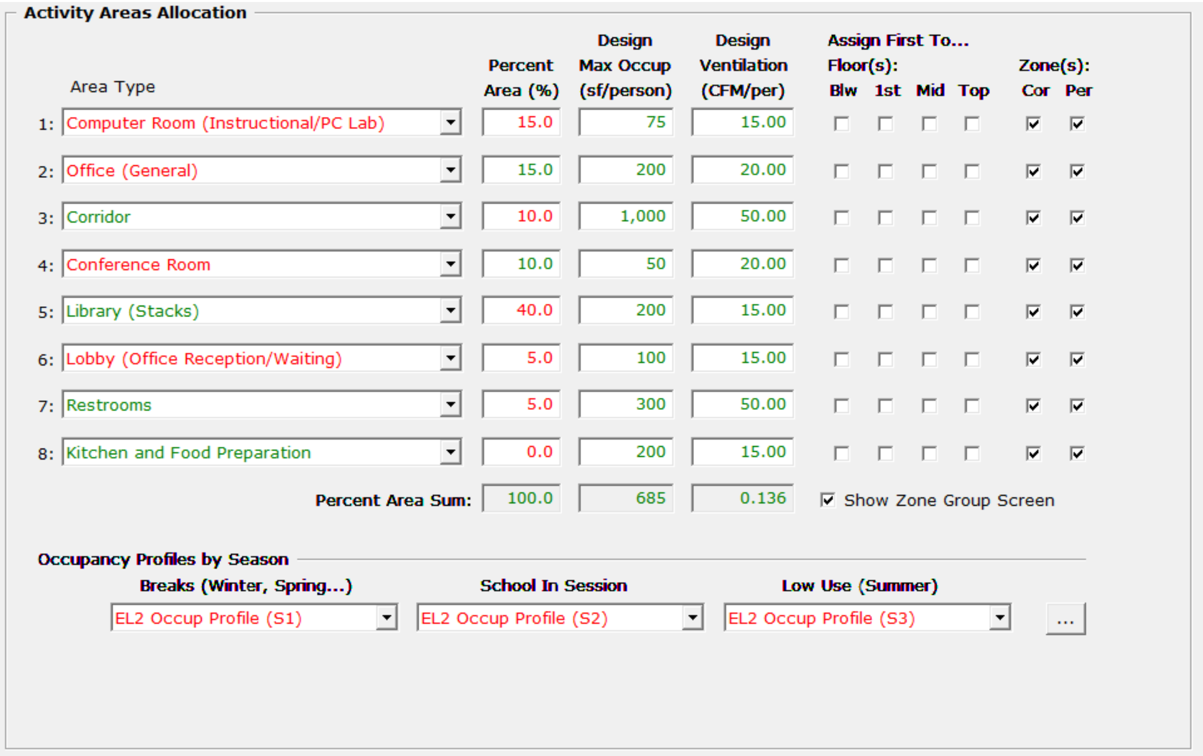

Exterior Doors
Describe Up To 3 Door Types
Doors by Orientation:
Door Type
South North East West
1: Glass 0 0 1 0
2: - select another -
Door Dimensions and Construction / Glass Definitions
Ht (ft) Wd (ft) Construction -or- Glass Category and Glass Type Frame Type Frame Wd (in)
1: 7.0 6.0 Single Pilkington SuperGrey 3mm (5820: U=1.04 SHG Alum w/o Brk 3.0

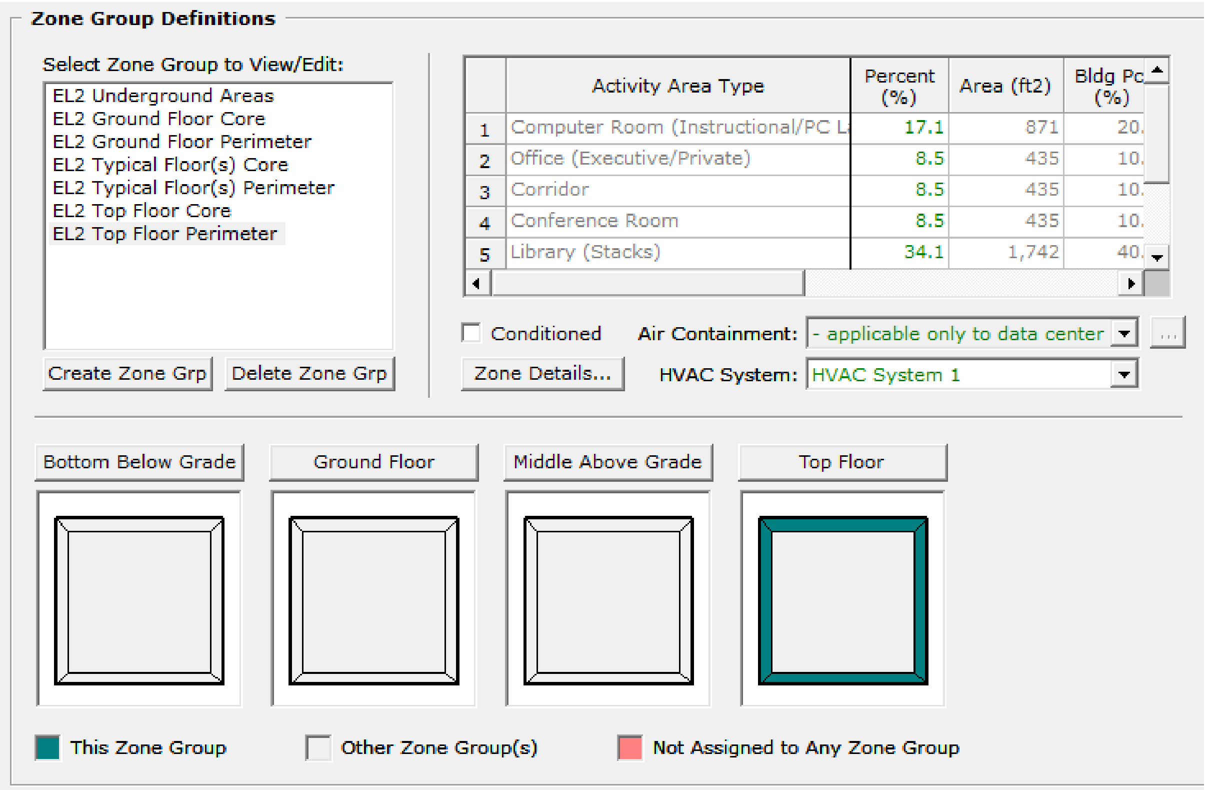

Exterior Windows
Window Area Specification Method:
Percent of Gross Wall Area (floor to floor)
Describe Up To 3 Window Types
Glass Category
Glass Type
Frame Type
Frame Wd (in)
1: Single Low-E
Single Low-E (e2=.4) Clear 1/8in (1600)
Alum w/o Brk, Fixed
1.30
2: - select another -
Window Dimensions, Positions and Quantities
Typ Window Width (ft)*
Window Ht (ft)
Sill Ht (ft)
% Window (floor to floor, including frame):
South
North
East
West
1: 0.00 10.00 3.00 5.0 5.0 5.0 5
Estimated shell-wide gross (flr-to-flr) % window is 5.0% and net (flr-to-ceiling) is 6.5%.
* - A window width of 0 results in one long window per facet (check adjoining box if window width is to take precedence over % window)
Custom Window/Door Placement...

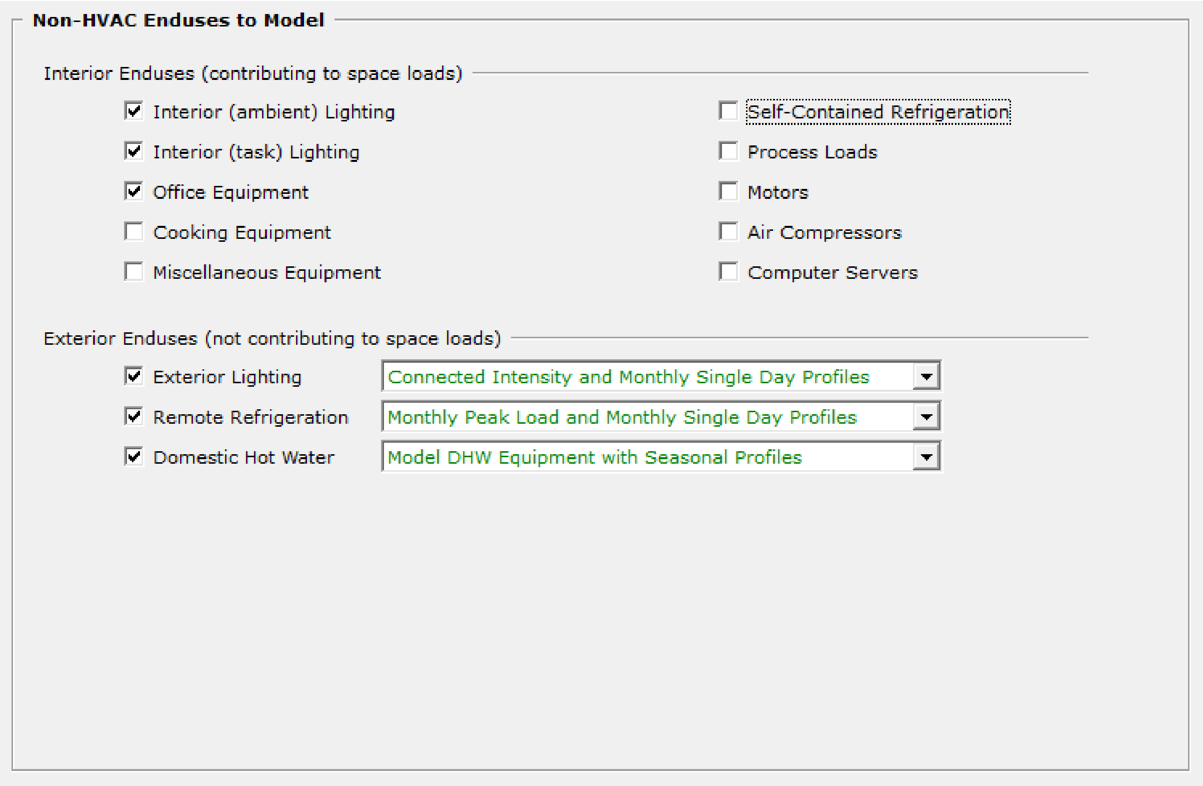

Exterior Window Shades and Blinds
Exterior Window Shades
Overhangs: None
Fins: None
Window Blinds/Drapes
Type: Horizontal Blinds - Light Color
Season Definitions...
% Blinds CLOSED:
South
North
East
West
when Occupied: 10 10 10 10
when Unoccupied: 5 5 5 5

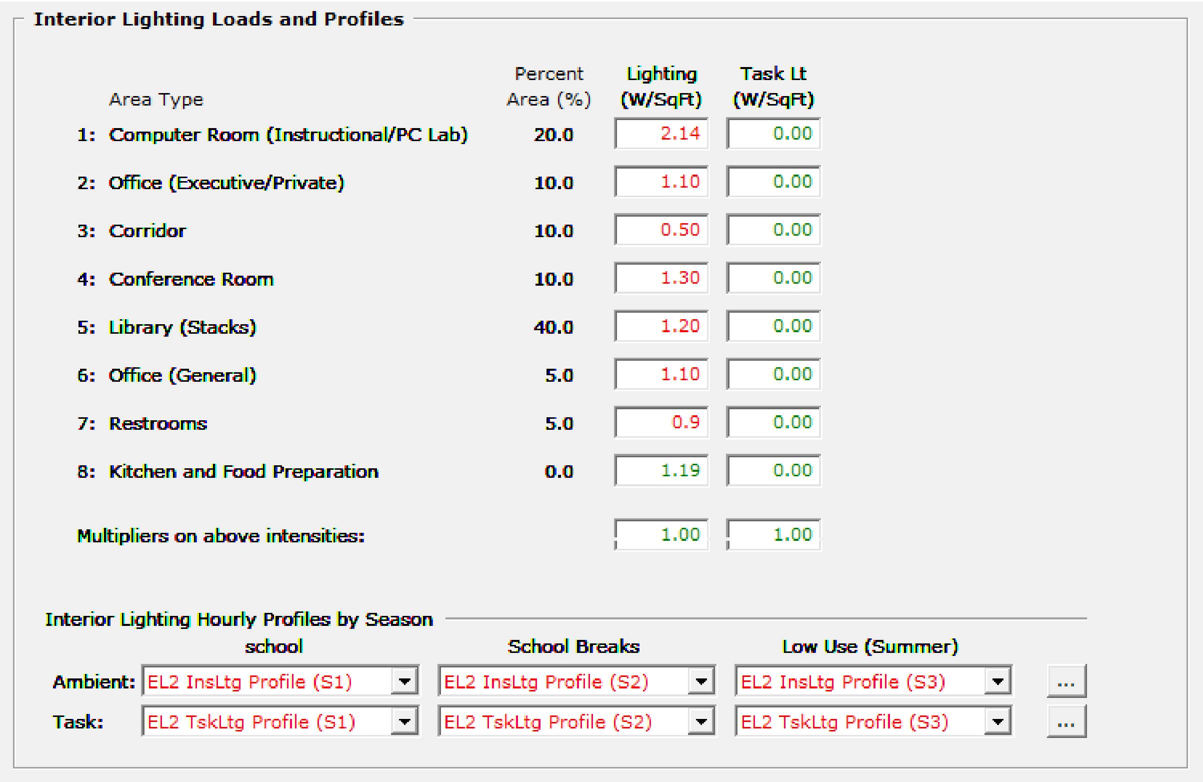

Roof Skylights
Skylit Rooftop Zones:
None
All
Perimeter Only
Core Only
Custom

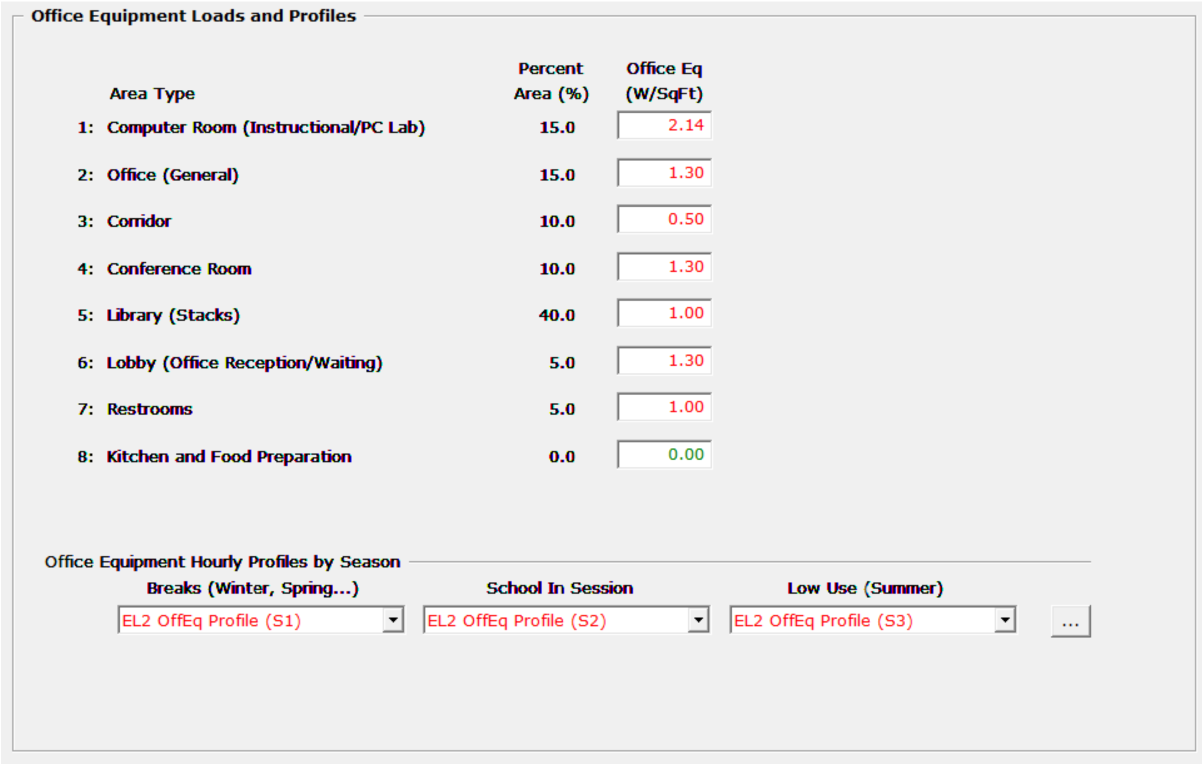

Building Operation Schedule
Breaks (Winter, Spring...)
(all remaining dates)
School In Session
2/29-6/25 & 7/25-11/19
Low Use (Summer)
1/1-1/30 & 11/28-12/31
Use: Breaks (Winter, Spring...)
Use: School In Session
Use: Low Use (Summer)
Opens At
Closes At
Mon: 9 am - 4 pm
Tue: 9 am - 4 pm
Wed: 9 am - 4 pm
Thu: 9 am - 4 pm
Fri: 9 am - 4 pm
Sat: 9 am - 4 pm
Sun: 9 am - 4 pm
Hol: 9 am - 4 pm
Mon: 8 am - 5 pm
Tue: 8 am - 5 pm
Wed: 8 am - 5 pm
Thu: 8 am - 5 pm
Fri: 8 am - 5 pm
Sat: 8 pm - 5 pm
Sun: 8 pm - 5 pm
Hol: 8 pm - 5 pm
Mon: 8 am - 4 pm
Tue: 8 am - 4 pm
Wed: 8 am - 4 pm
Thu: 8 am - 4 pm
Fri: 8 am - 4 pm
Sat: 8 pm - 4 pm
Sun: 8 pm - 4 pm
Hol: 8 pm - 4 pm


Activity Areas Allocation
Area Type
Percent Area (%)
Design Max Occup (sf/person)
Design Ventilation (CFM/per)
Assign First To...
Floor(s): Blw 1st Mid Top
Zone(s): Cor Per
1: Computer Room (Instructional/PC Lab) 15.0 75 15.00
2: Office (General) 15.0 200 20.00
3: Corridor 10.0 1,000 50.00
4: Conference Room 10.0 50 20.00
5: Library (Stacks) 40.0 200 15.00
6: Lobby (Office Reception/Waiting) 5.0 100 15.00
7: Restrooms 5.0 300 50.00
8: Kitchen and Food Preparation 0.0 200 15.00
Percent Area Sum: 100.0 685 0.136
Show Zone Group Screen
Occupancy Profiles by Season
Breaks (Winter, Spring...)
School In Session
Low Use (Summer)
EL2 Occup Profile (S1)
EL2 Occup Profile (S2)
EL2 Occup Profile (S3)


Zone Group Definitions
Select Zone Group to View/Edit:
EL2 Underground Areas
EL2 Ground Floor Core
EL2 Ground Floor Perimeter
EL2 Typical Floor(s) Core
EL2 Typical Floor(s) Perimeter
EL2 Top Floor Core
EL2 Top Floor Perimeter
Activity Area Type
Percent (%)
Area (ft2)
Bldg Pc (%)
1 Computer Room (Instructional/PC L 17.1 871 20.
2 Office (Executive/Private) 8.5 435 10.
3 Corridor 8.5 435 10.
4 Conference Room 8.5 435 10.
5 Library (Stacks) 34.1 1,742 40.
Create Zone Grp
Delete Zone Grp
Conditioned
Air Containment: - applicable only to data center
Zone Details...
HVAC System: HVAC System 1
Bottom Below Grade
Ground Floor
Middle Above Grade
Top Floor
This Zone Group
Other Zone Group(s)
Not Assigned to Any Zone Group


Non-HVAC Enduses to Model
Interior Enduses (contributing to space loads)
Interior (ambient) Lighting
Interior (task) Lighting
Office Equipment
Cooking Equipment
Miscellaneous Equipment
Self-Contained Refrigeration
Process Loads
Motors
Air Compressors
Computer Servers
Exterior Enduses (not contributing to space loads)
Exterior Lighting
Connected Intensity and Monthly Single Day Profiles
Remote Refrigeration
Monthly Peak Load and Monthly Single Day Profiles
Domestic Hot Water
Model DHW Equipment with Seasonal Profiles


Interior Lighting Loads and Profiles
Area Type
Percent Area (%)
Lighting (W/SqFt)
Task Lt (W/SqFt)
1: Computer Room (Instructional/PC Lab) 20.0 2.14 0.00
2: Office (Executive/Private) 10.0 1.10 0.00
3: Corridor 10.0 0.50 0.00
4: Conference Room 10.0 1.30 0.00
5: Library (Stacks) 40.0 1.20 0.00
6: Office (General) 5.0 1.10 0.00
7: Restrooms 5.0 0.9 0.00
8: Kitchen and Food Preparation 0.0 1.19 0.00
Multipliers on above intensities: 1.00 1.00
Interior Lighting Hourly Profiles by Season
school
School Breaks
Low Use (Summer)
Ambient: EL2 InsLtg Profile (S1) EL2 InsLtg Profile (S2) EL2 InsLtg Profile (S3)
Task: EL2 TskLtg Profile (S1) EL2 TskLtg Profile (S2) EL2 TskLtg Profile (S3)



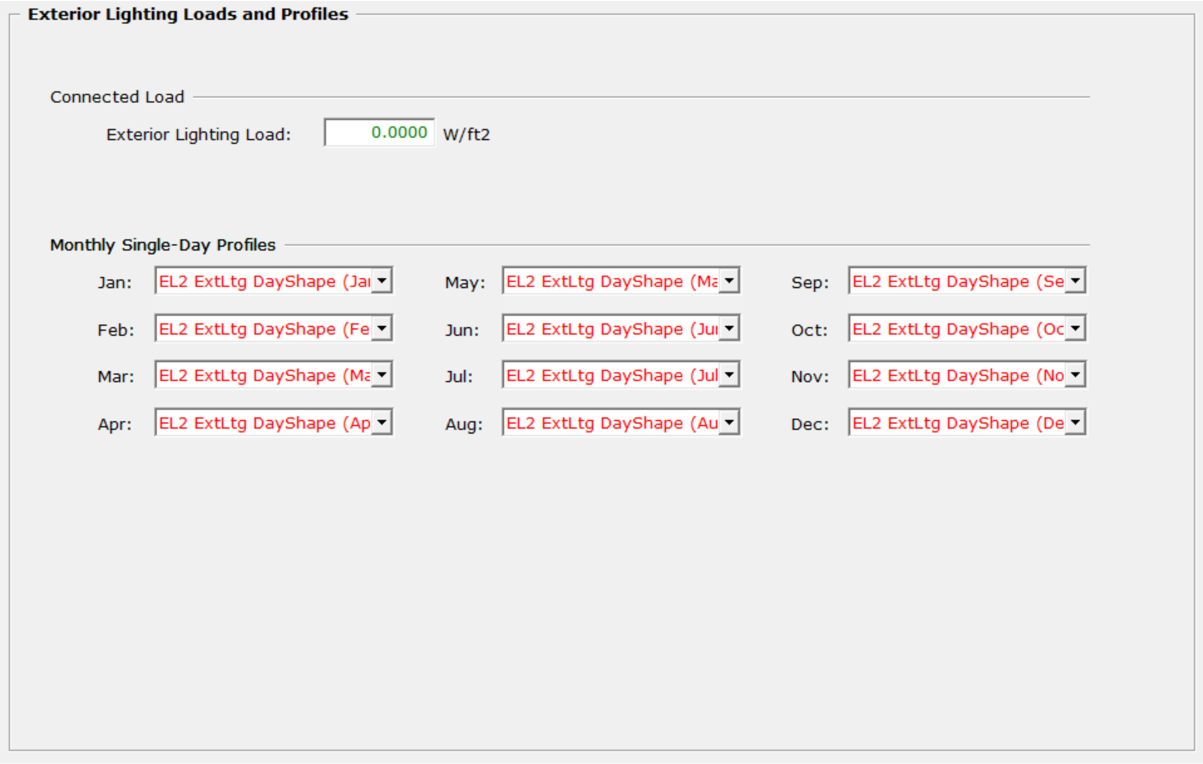
Office Equipment Loads and Profiles

	Area Type	Percent Area (%)	Office Eq (W/SqFt)
1:	Computer Room (Instructional/PC Lab)	15.0	2.14
2:	Office (General)	15.0	1.30
3:	Corridor	10.0	0.50
4:	Conference Room	10.0	1.30
5:	Library (Stacks)	40.0	1.00
6:	Lobby (Office Reception/Waiting)	5.0	1.30
7:	Restrooms	5.0	1.00
8:	Kitchen and Food Preparation	0.0	0.00

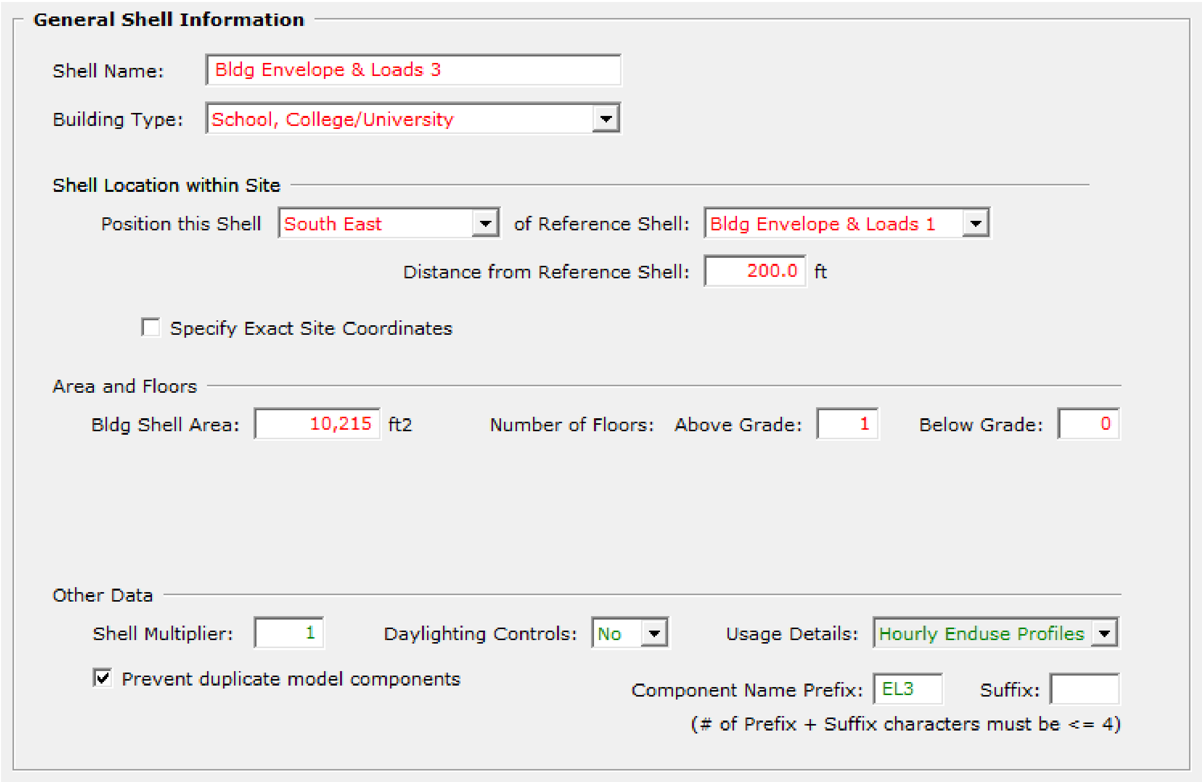
Office Equipment Hourly Profiles by Season

Breaks (Winter, Spring...)	School In Session	Low Use (Summer)
EL2 OffEq Profile (S1)	EL2 OffEq Profile (S2)	EL2 OffEq Profile (S3)

...


Exterior Lighting Loads and Profiles
Connected Load
Exterior Lighting Load:
0.0000
W/ft2
Monthly Single-Day Profiles
Jan:
EL2 ExtLtg DayShape (Jai
Feb:
EL2 ExtLtg DayShape (Fe
Mar:
EL2 ExtLtg DayShape (Mi
Apr:
EL2 ExtLtg DayShape (Ap
May:
EL2 ExtLtg DayShape (Mi
Jun:
EL2 ExtLtg DayShape (Jui
Jul:
EL2 ExtLtg DayShape (Jul
Aug:
EL2 ExtLtg DayShape (Au
Sep:
EL2 ExtLtg DayShape (Se
Oct:
EL2 ExtLtg DayShape (Oc
Nov:
EL2 ExtLtg DayShape (No
Dec:
EL2 ExtLtg DayShape (De

BUildling 12A


General Shell Information

Shell Name: Bldg Envelope & Loads 3

Building Type: School, College/University

Shell Location within Site

Position this Shell: South East — of Reference Shell: Bldg Envelope & Loads 1

Distance from Reference Shell: 200.0 ft

☐ Specify Exact Site Coordinates

Area and Floors

Bldg Shell Area: 10,215 ft2 — Number of Floors: Above Grade: 1 — Below Grade: 0

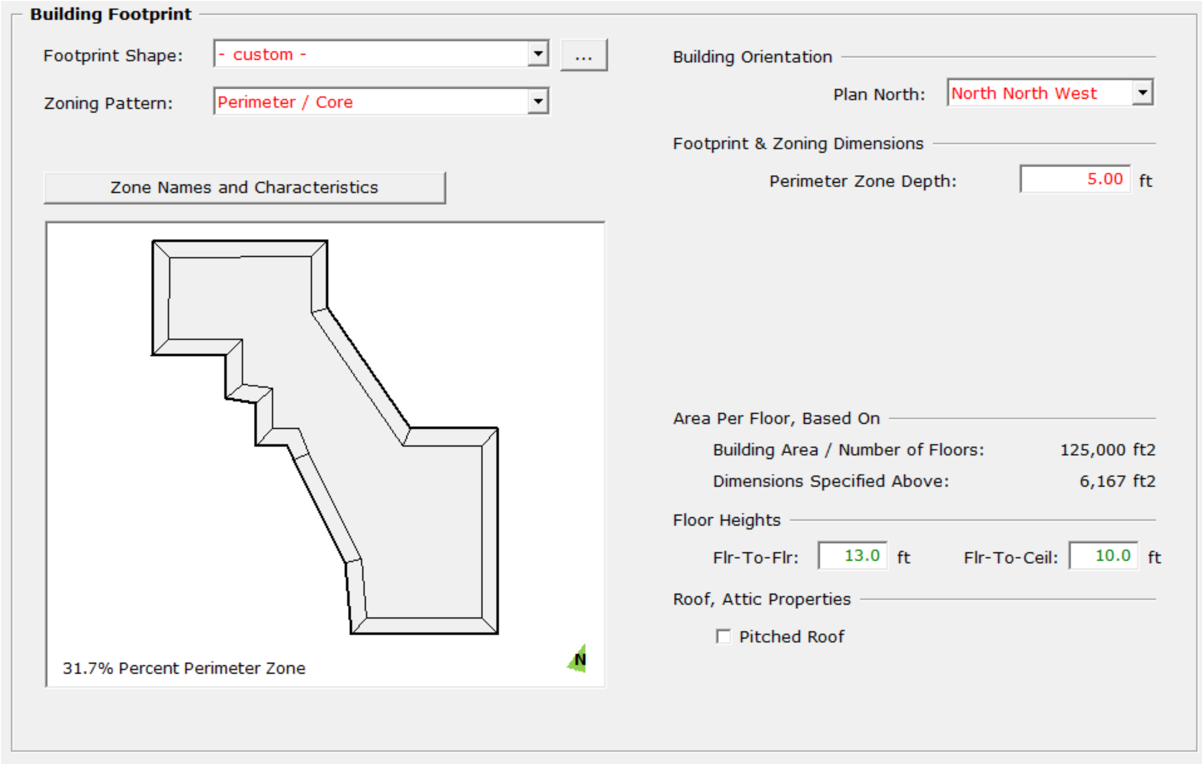
Other Data

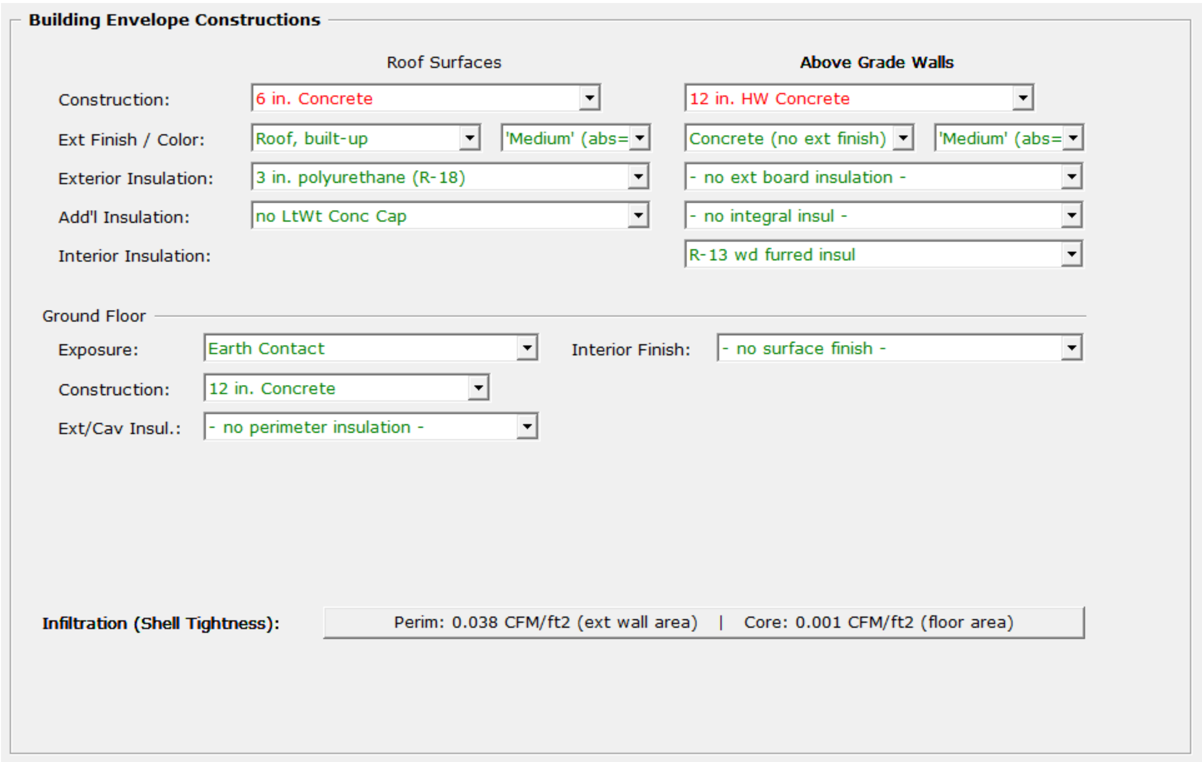
Shell Multiplier: 1 — Daylighting Controls: No — Usage Details: Hourly Enduse Profiles

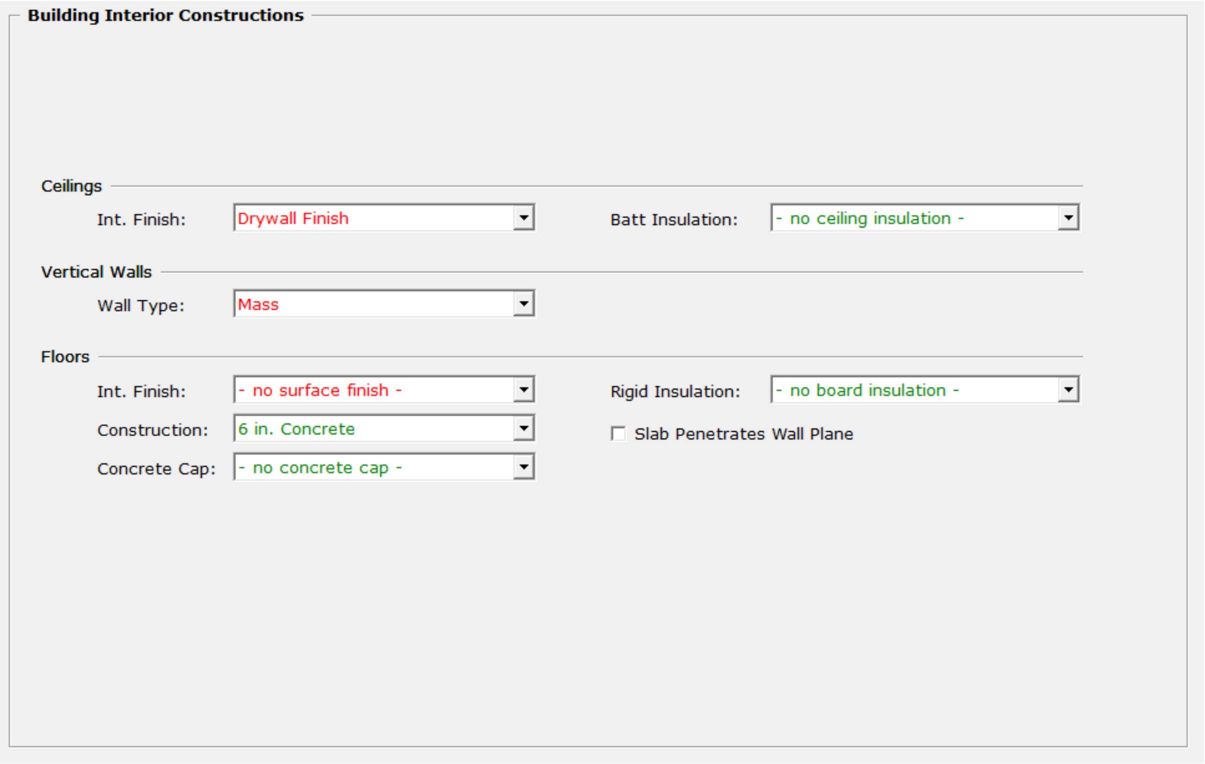
☑ Prevent duplicate model components

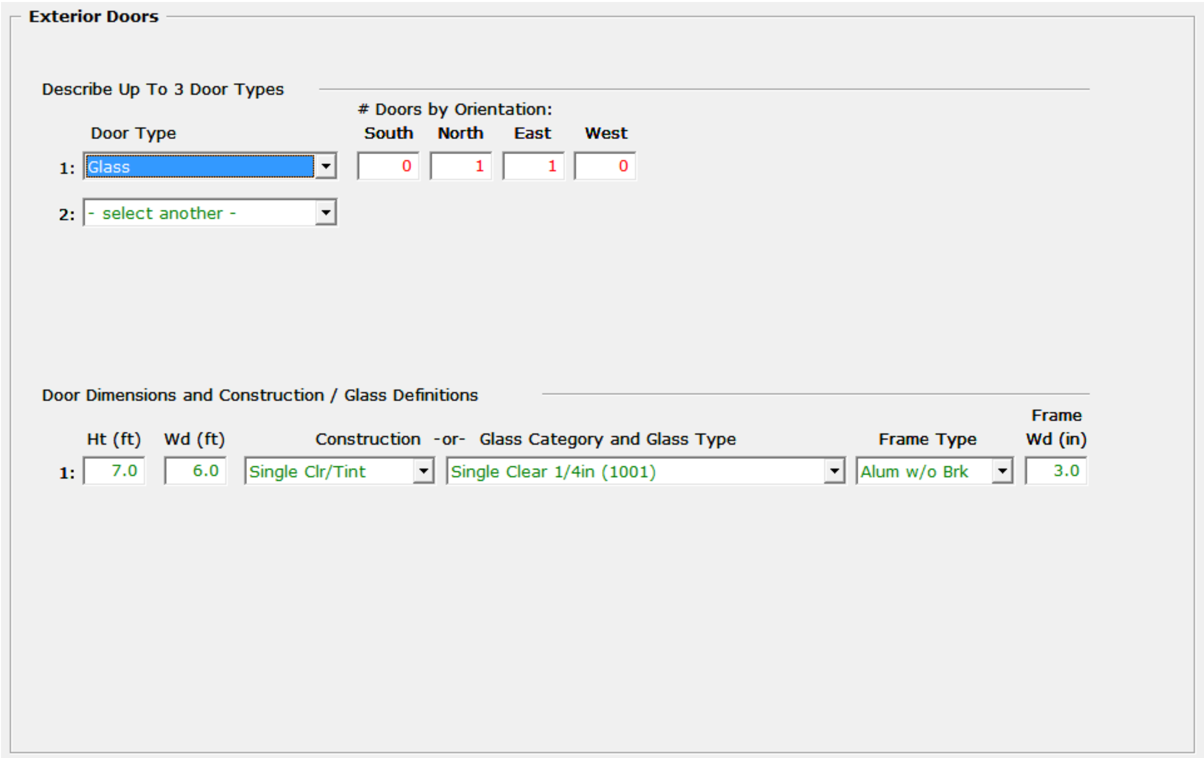
Component Name Prefix: EL3 — Suffix:

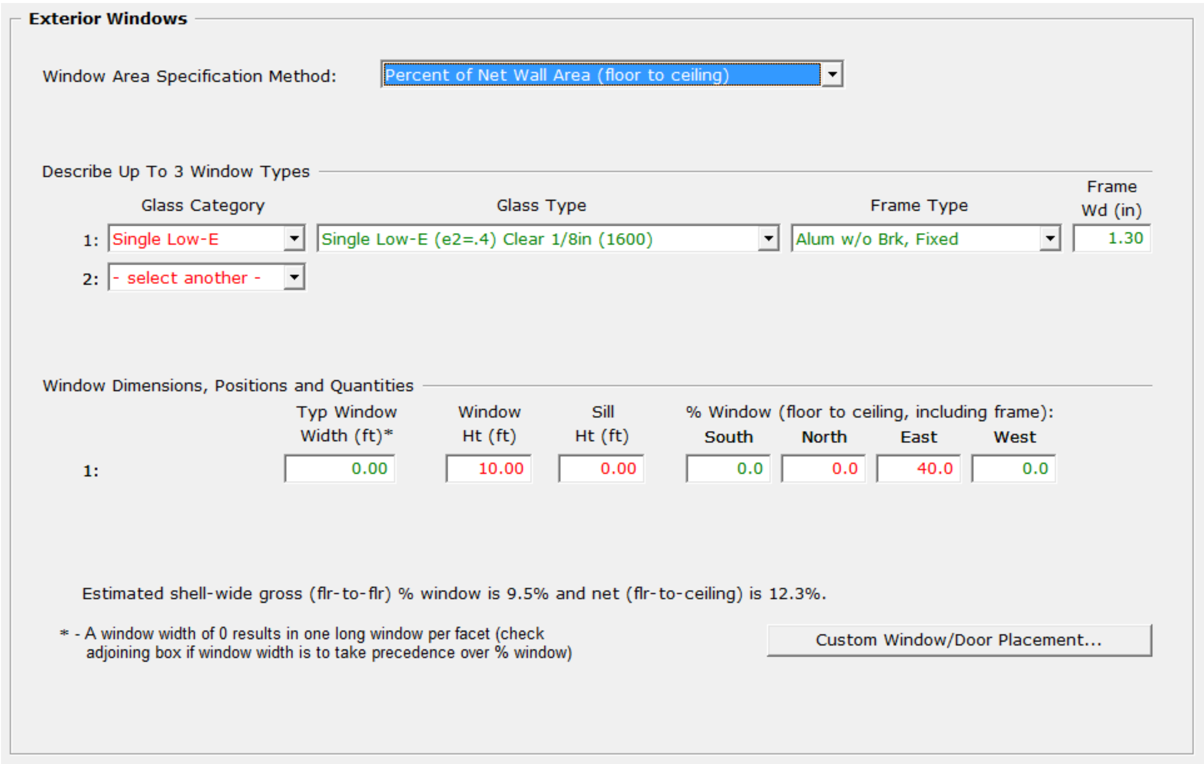
(# of Prefix + Suffix characters must be <= 4)

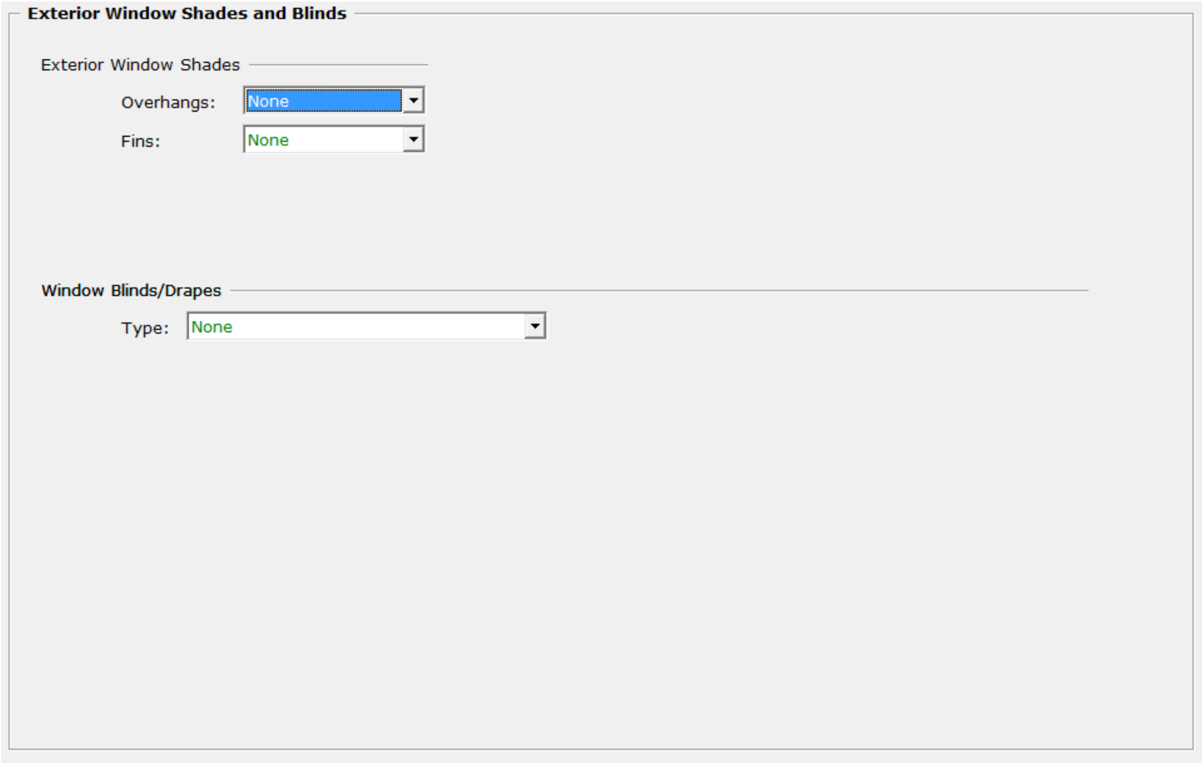

Building Footprint
Footprint Shape: - custom -
Zoning Pattern: Perimeter / Core
Zone Names and Characteristics
31.7% Percent Perimeter Zone
N
Building Orientation
Plan North: North North West
Footprint & Zoning Dimensions
Perimeter Zone Depth: 5.00 ft
Area Per Floor, Based On
Building Area / Number of Floors: 125,000 ft2
Dimensions Specified Above: 6,167 ft2
Floor Heights
Flr-To-Flr: 13.0 ft
Flr-To-Ceil: 10.0 ft
Roof, Attic Properties
Pitched Roof

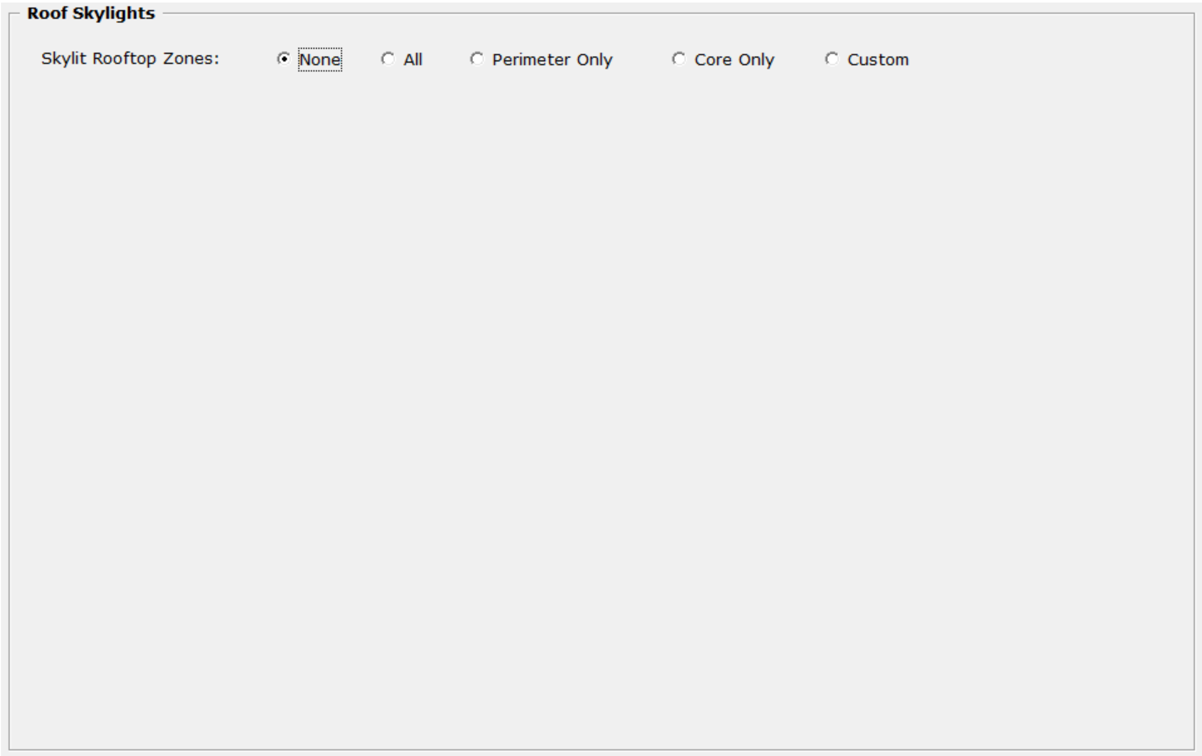

Building Envelope Constructions
Roof Surfaces
Above Grade Walls
Construction: 6 in. Concrete
12 in. HW Concrete
Ext Finish / Color: Roof, built-up
'Medium' (abs=
Concrete (no ext finish)
'Medium' (abs=
Exterior Insulation: 3 in. polyurethane (R-18)
- no ext board insulation -
Add'l Insulation: no LtWt Conc Cap
- no integral insul -
Interior Insulation: R-13 wd furred insul
Ground Floor
Exposure: Earth Contact
Interior Finish: - no surface finish -
Construction: 12 in. Concrete
Ext/Cav Insul.: - no perimeter insulation -
Infiltration (Shell Tightness):
Perim: 0.038 CFM/ft2 (ext wall area) | Core: 0.001 CFM/ft2 (floor area)

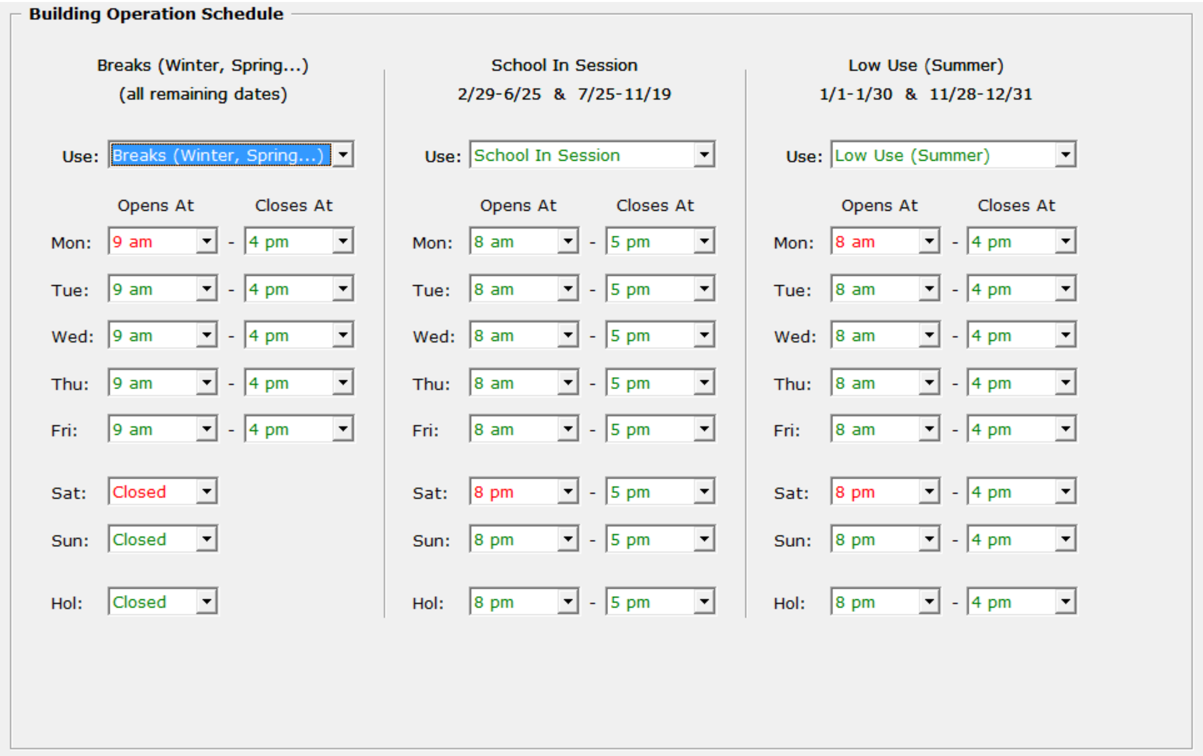

Building Interior Constructions
Ceilings
Int. Finish:
Drywall Finish
Batt Insulation:
- no ceiling insulation -
Vertical Walls
Wall Type:
Mass
Floors
Int. Finish:
- no surface finish -
Rigid Insulation:
- no board insulation -
Construction:
6 in. Concrete
Slab Penetrates Wall Plane
Concrete Cap:
- no concrete cap -


Exterior Doors
Describe Up To 3 Door Types
Doors by Orientation:
Door Type
South
North
East
West
1:
Glass
0
1
1
0
2:
- select another -
Door Dimensions and Construction / Glass Definitions
Ht (ft)
Wd (ft)
Construction -or- Glass Category and Glass Type
Frame Type
Frame Wd (in)
1:
7.0
6.0
Single Clr/Tint
Single Clear 1/4in (1001)
Alum w/o Brk
3.0


Exterior Windows
Window Area Specification Method:
Percent of Net Wall Area (floor to ceiling)
Describe Up To 3 Window Types
Glass Category
Glass Type
Frame Type
Frame Wd (in)
1:
Single Low-E
Single Low-E (e2=.4) Clear 1/8in (1600)
Alum w/o Brk, Fixed
1.30
2:
- select another -
Window Dimensions, Positions and Quantities
Typ Window Width (ft)*
Window Ht (ft)
Sill Ht (ft)
% Window (floor to ceiling, including frame):
South
North
East
West
1:
0.00
10.00
0.00
0.0
0.0
40.0
0.0
Estimated shell-wide gross (flr-to-flr) % window is 9.5% and net (flr-to-ceiling) is 12.3%.
* - A window width of 0 results in one long window per facet (check adjoining box if window width is to take precedence over % window)
Custom Window/Door Placement...

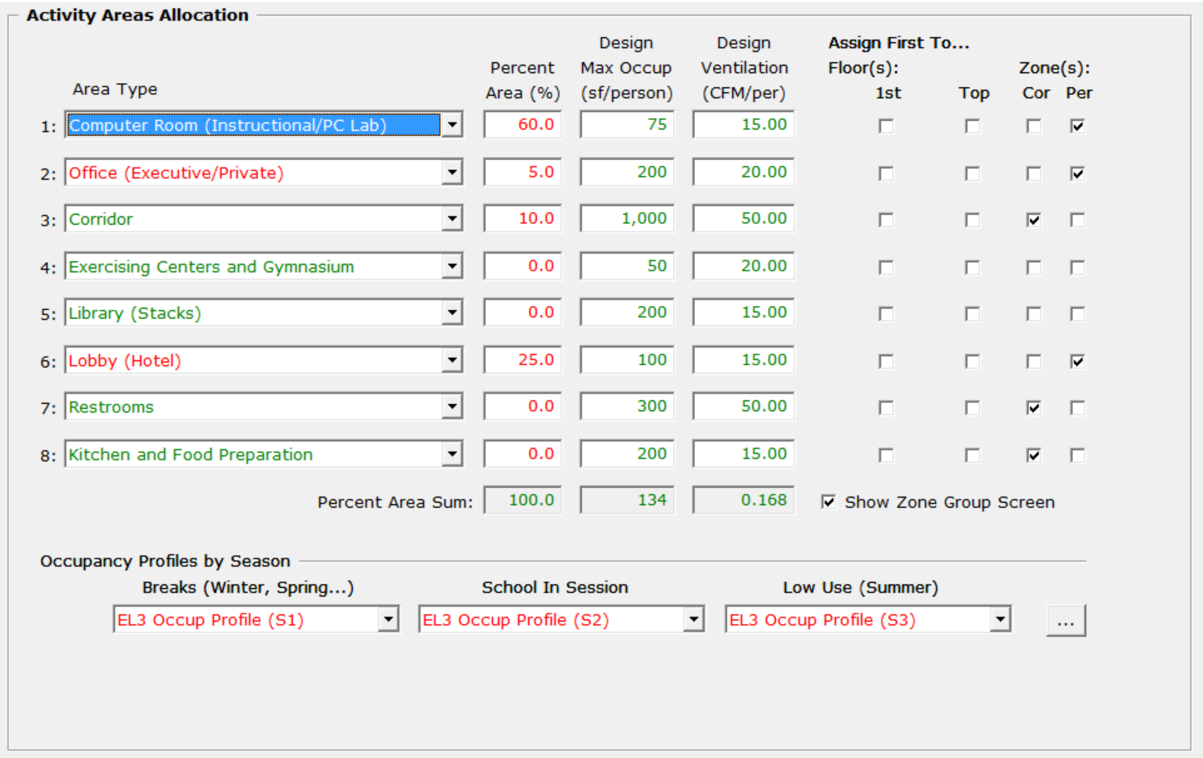

Exterior Window Shades and Blinds
Exterior Window Shades
Overhangs: None
Fins: None
Window Blinds/Drapes
Type: None


Roof Skylights
Skylit Rooftop Zones:
None
All
Perimeter Only
Core Only
Custom



Building Operation Schedule

	Breaks (Winter, Spring…) (all remaining dates)		School In Session 2/29-6/25 & 7/25-11/19		Low Use (Summer) 1/1-1/30 & 11/28-12/31	
Use:	Breaks (Winter, Spring…)		School In Session		Low Use (Summer)	
	Opens At	Closes At	Opens At	Closes At	Opens At	Closes At
Mon:	9 am	4 pm	8 am	5 pm	8 am	4 pm
Tue:	9 am	4 pm	8 am	5 pm	8 am	4 pm
Wed:	9 am	4 pm	8 am	5 pm	8 am	4 pm
Thu:	9 am	4 pm	8 am	5 pm	8 am	4 pm
Fri:	9 am	4 pm	8 am	5 pm	8 am	4 pm
Sat:	Closed		8 pm	5 pm	8 pm	4 pm
Sun:	Closed		8 pm	5 pm	8 pm	4 pm
Hol:	Closed		8 pm	5 pm	8 pm	4 pm

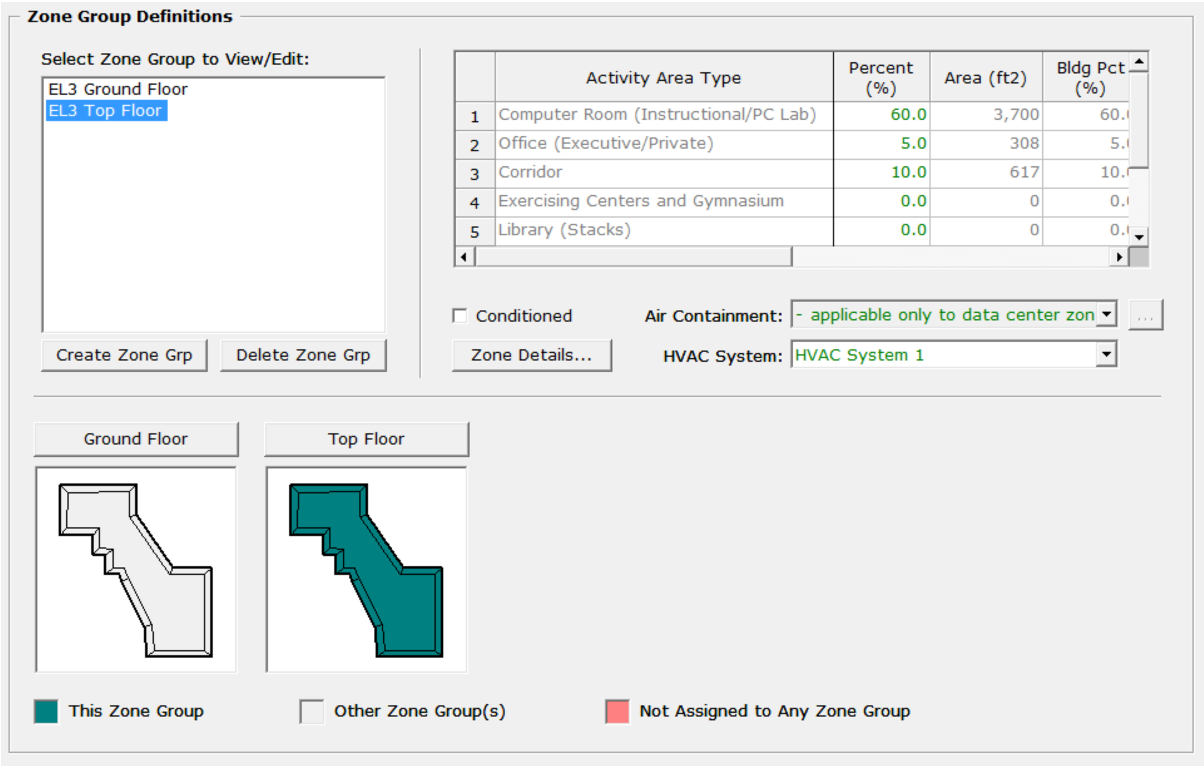


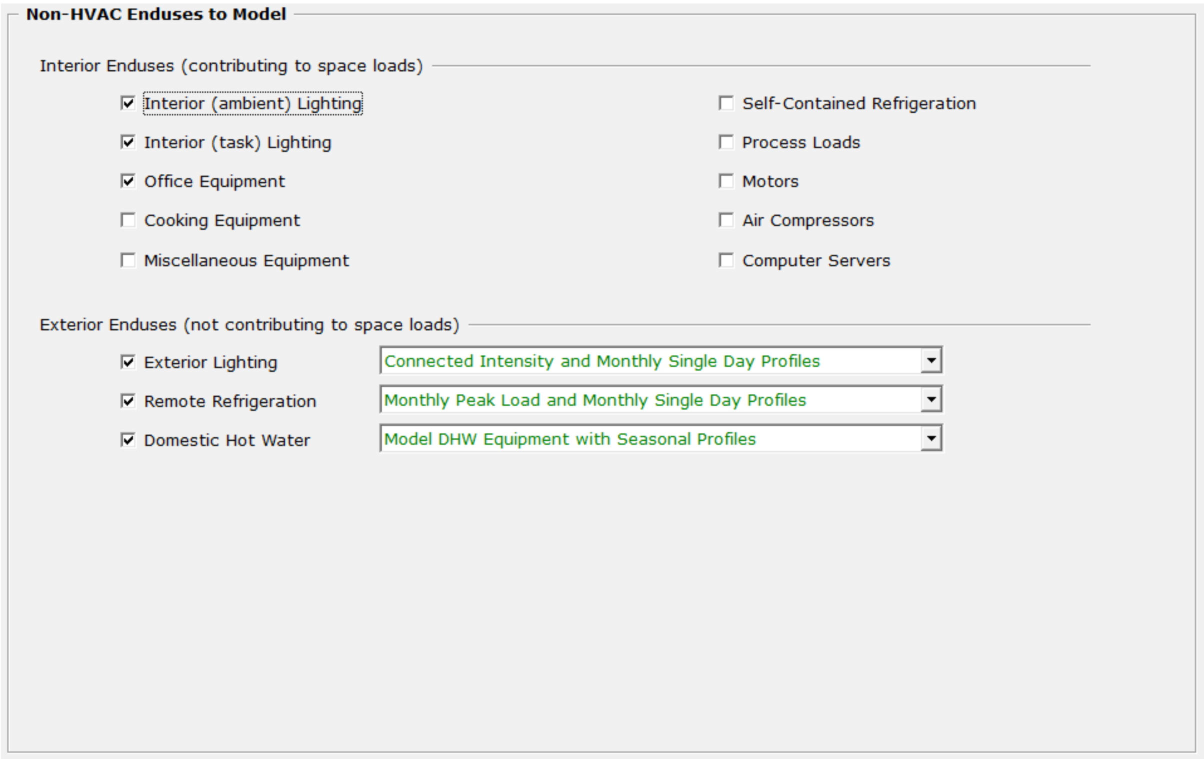
Activity Areas Allocation

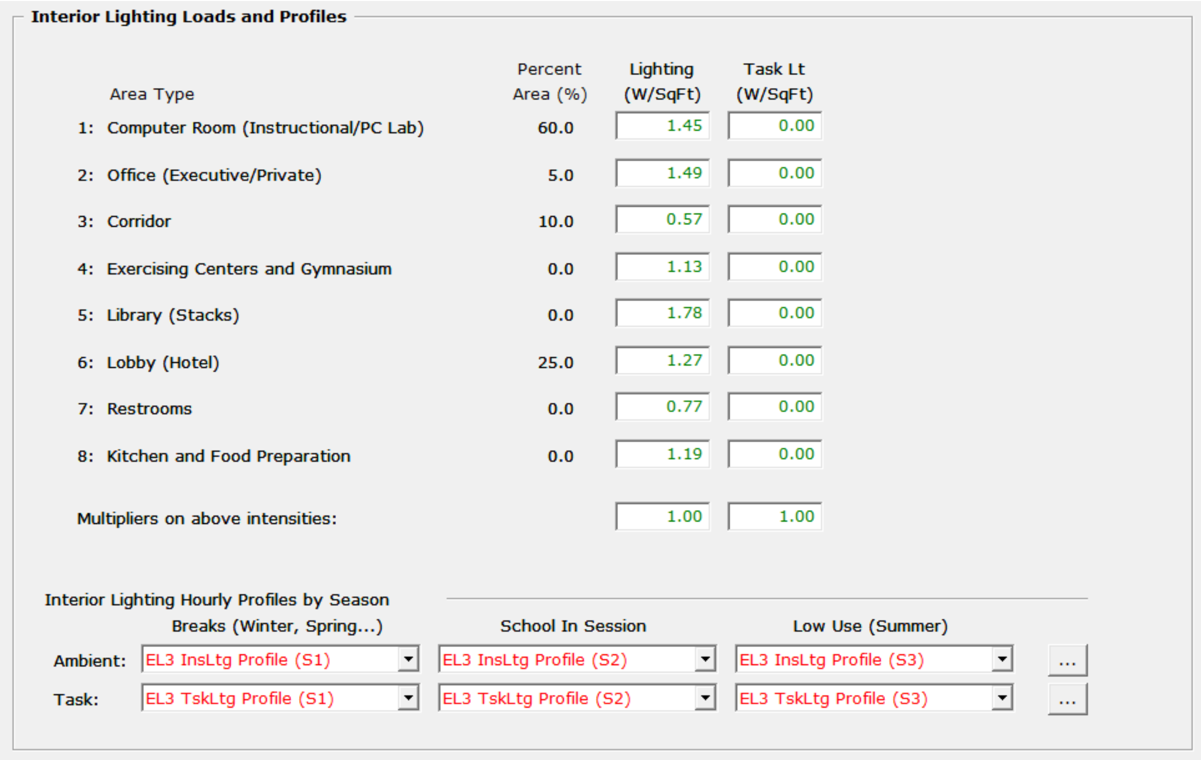
	Area Type	Percent Area (%)	Design Max Occup (sf/person)	Design Ventilation (CFM/per)	Assign First To… Floor(s): 1st	Top	Zone(s): Cor	Per
1:	Computer Room (Instructional/PC Lab)	60.0	75	15.00	☐	☐	☐	☑
2:	Office (Executive/Private)	5.0	200	20.00	☐	☐	☐	☑
3:	Corridor	10.0	1,000	50.00	☐	☐	☑	☐
4:	Exercising Centers and Gymnasium	0.0	50	20.00	☐	☐	☐	☐
5:	Library (Stacks)	0.0	200	15.00	☐	☐	☐	☐
6:	Lobby (Hotel)	25.0	100	15.00	☐	☐	☐	☑
7:	Restrooms	0.0	300	50.00	☐	☐	☑	☐
8:	Kitchen and Food Preparation	0.0	200	15.00	☐	☐	☑	☐
	Percent Area Sum:	100.0	134	0.168	☑ Show Zone Group Screen			

Occupancy Profiles by Season

Breaks (Winter, Spring…)	School In Session	Low Use (Summer)	
EL3 Occup Profile (S1)	EL3 Occup Profile (S2)	EL3 Occup Profile (S3)	…


Zone Group Definitions
Select Zone Group to View/Edit:
EL3 Ground Floor
EL3 Top Floor
Create Zone Grp
Delete Zone Grp
Activity Area Type
Percent (%)
Area (ft2)
Bldg Pct (%)
1 Computer Room (Instructional/PC Lab) 60.0 3,700
2 Office (Executive/Private) 5.0 308
3 Corridor 10.0 617
4 Exercising Centers and Gymnasium 0.0 0
5 Library (Stacks) 0.0 0
Conditioned
Air Containment:
- applicable only to data center zon
Zone Details...
HVAC System:
HVAC System 1
Ground Floor
Top Floor
This Zone Group
Other Zone Group(s)
Not Assigned to Any Zone Group


Non-HVAC Enduses to Model
Interior Enduses (contributing to space loads)
Interior (ambient) Lighting
Interior (task) Lighting
Office Equipment
Cooking Equipment
Miscellaneous Equipment
Self-Contained Refrigeration
Process Loads
Motors
Air Compressors
Computer Servers
Exterior Enduses (not contributing to space loads)
Exterior Lighting
Connected Intensity and Monthly Single Day Profiles
Remote Refrigeration
Monthly Peak Load and Monthly Single Day Profiles
Domestic Hot Water
Model DHW Equipment with Seasonal Profiles

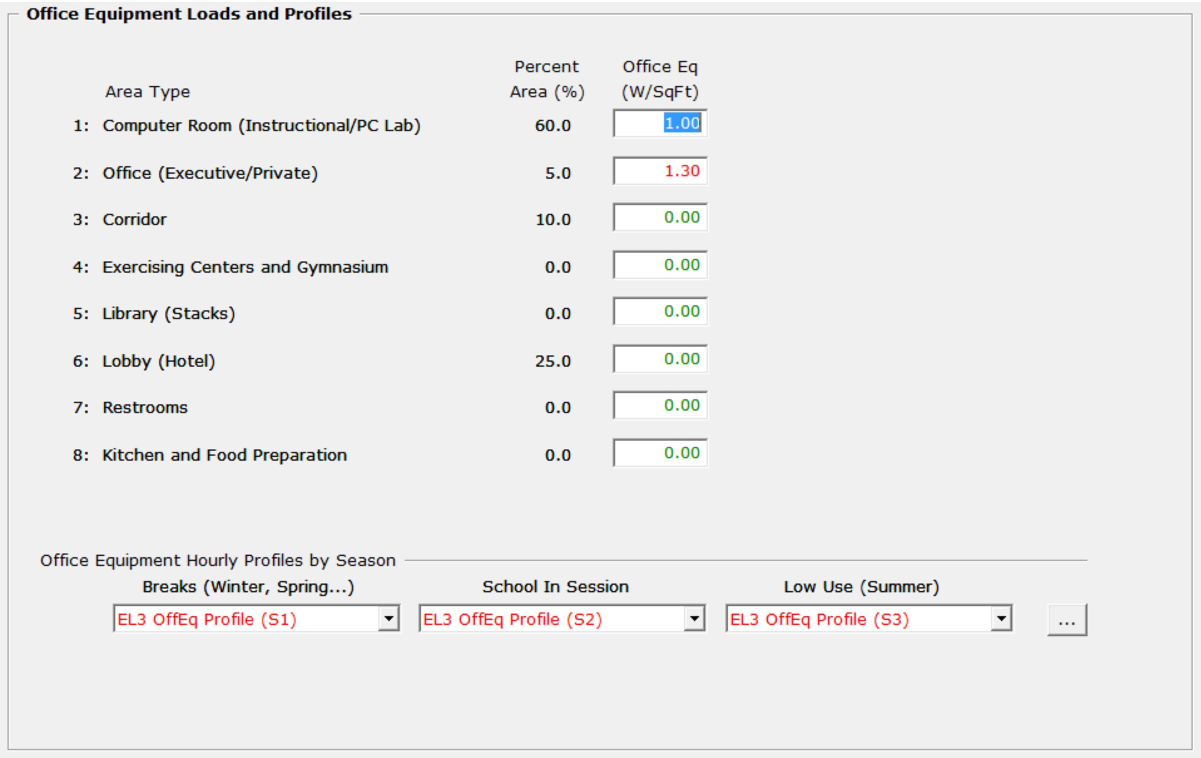


Interior Lighting Loads and Profiles

	Area Type	Percent Area (%)	Lighting (W/SqFt)	Task Lt (W/SqFt)
1:	Computer Room (Instructional/PC Lab)	60.0	1.45	0.00
2:	Office (Executive/Private)	5.0	1.49	0.00
3:	Corridor	10.0	0.57	0.00
4:	Exercising Centers and Gymnasium	0.0	1.13	0.00
5:	Library (Stacks)	0.0	1.78	0.00
6:	Lobby (Hotel)	25.0	1.27	0.00
7:	Restrooms	0.0	0.77	0.00
8:	Kitchen and Food Preparation	0.0	1.19	0.00
	Multipliers on above intensities:		1.00	1.00

Interior Lighting Hourly Profiles by Season

	Breaks (Winter, Spring...)	School In Session	Low Use (Summer)
Ambient:	EL3 InsLtg Profile (S1)	EL3 InsLtg Profile (S2)	EL3 InsLtg Profile (S3)
Task:	EL3 TskLtg Profile (S1)	EL3 TskLtg Profile (S2)	EL3 TskLtg Profile (S3)

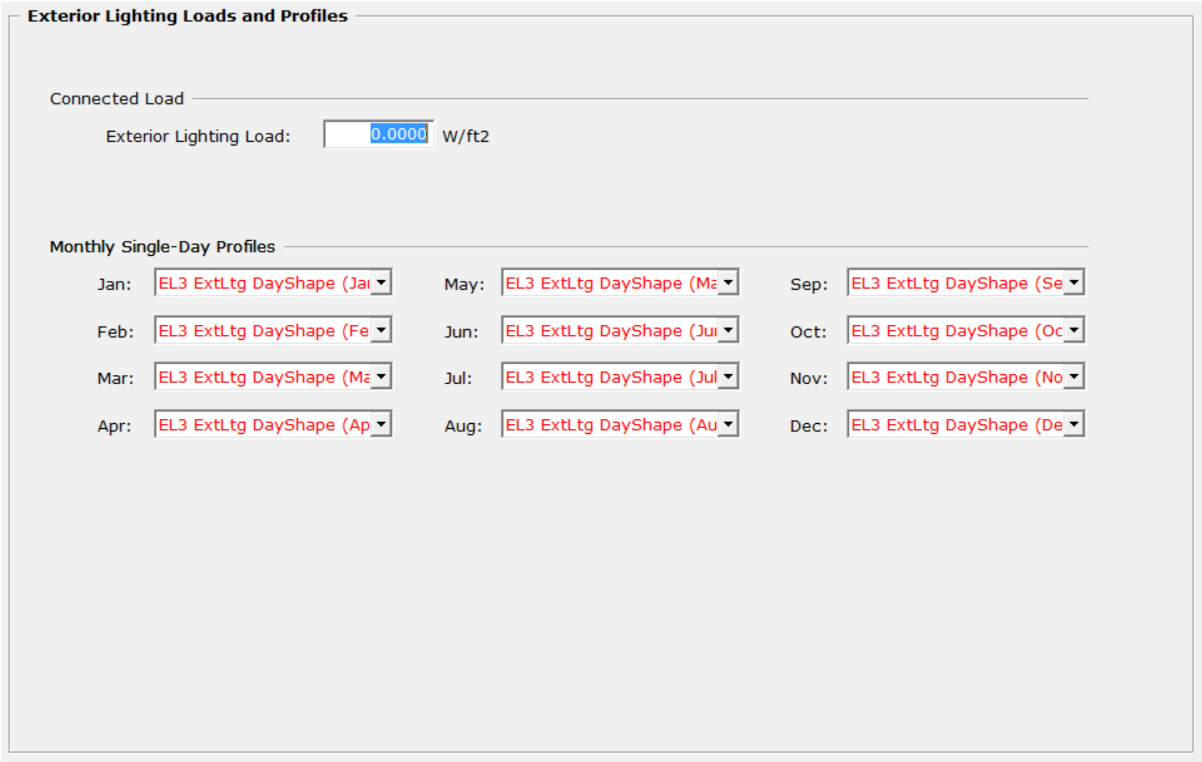


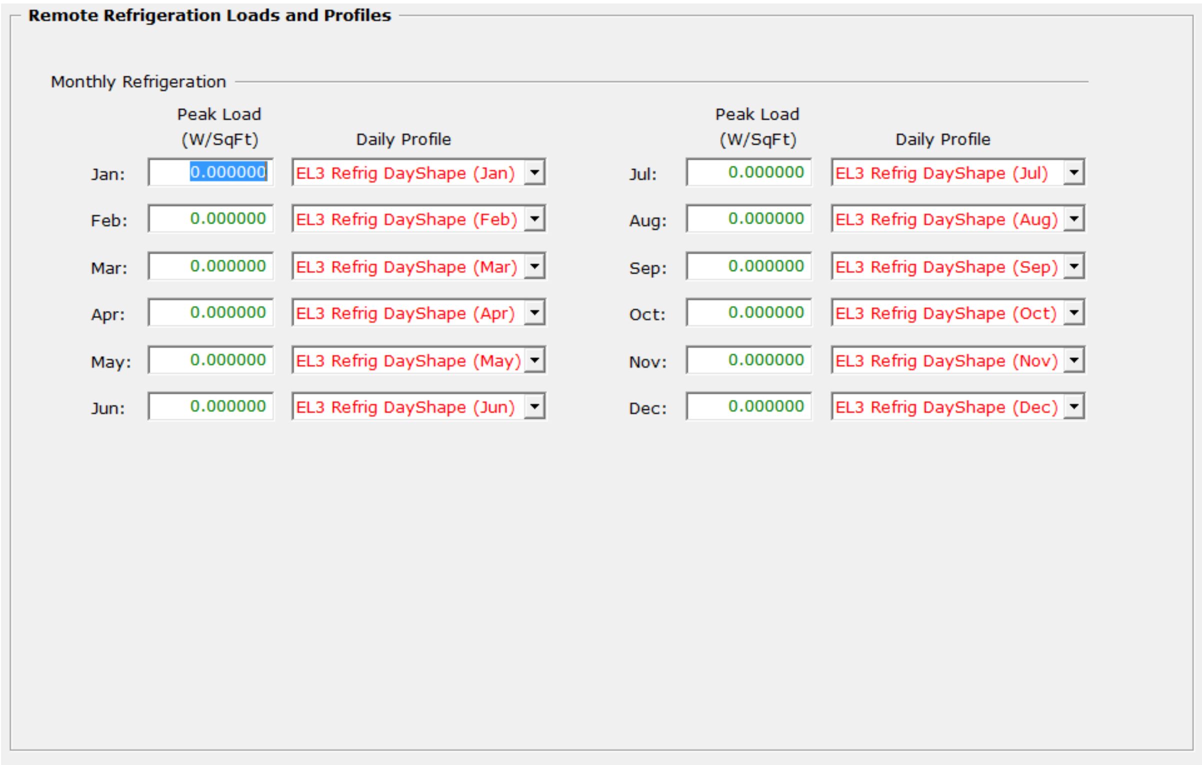
Office Equipment Loads and Profiles

	Area Type	Percent Area (%)	Office Eq (W/SqFt)
1:	Computer Room (Instructional/PC Lab)	60.0	1.00
2:	Office (Executive/Private)	5.0	1.30
3:	Corridor	10.0	0.00
4:	Exercising Centers and Gymnasium	0.0	0.00
5:	Library (Stacks)	0.0	0.00
6:	Lobby (Hotel)	25.0	0.00
7:	Restrooms	0.0	0.00
8:	Kitchen and Food Preparation	0.0	0.00

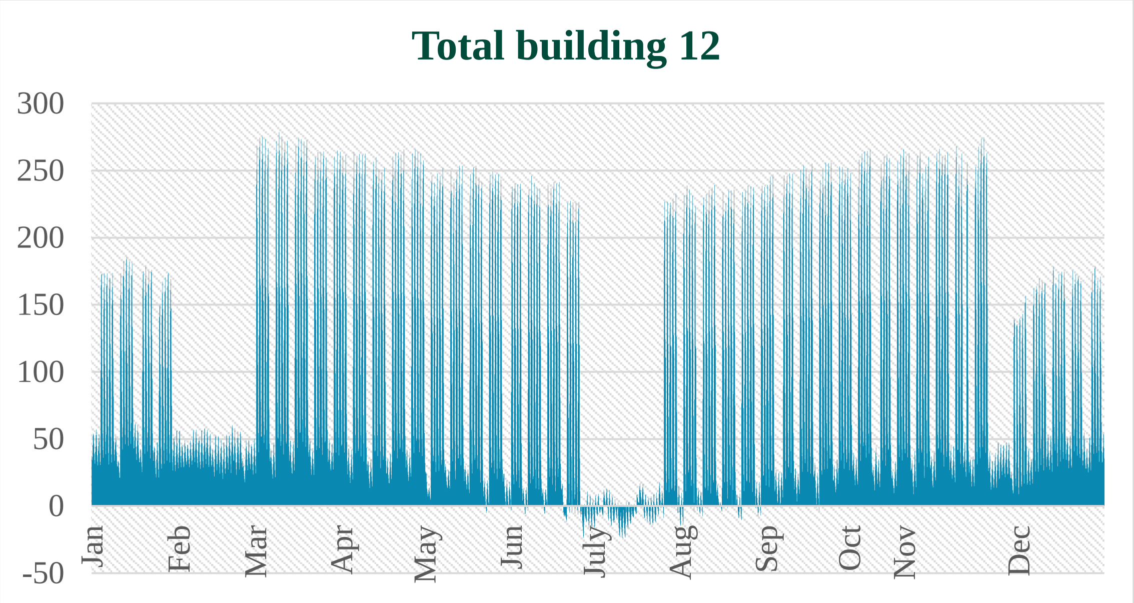
Office Equipment Hourly Profiles by Season

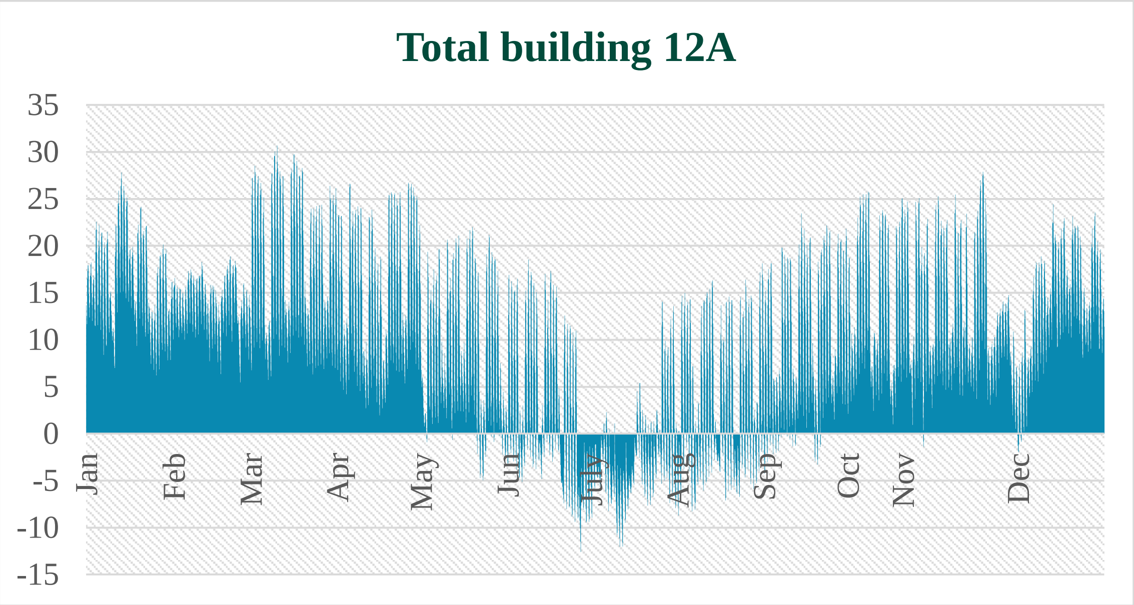
Breaks (Winter, Spring...)	School In Session	Low Use (Summer)
EL3 OffEq Profile (S1)	EL3 OffEq Profile (S2)	EL3 OffEq Profile (S3)

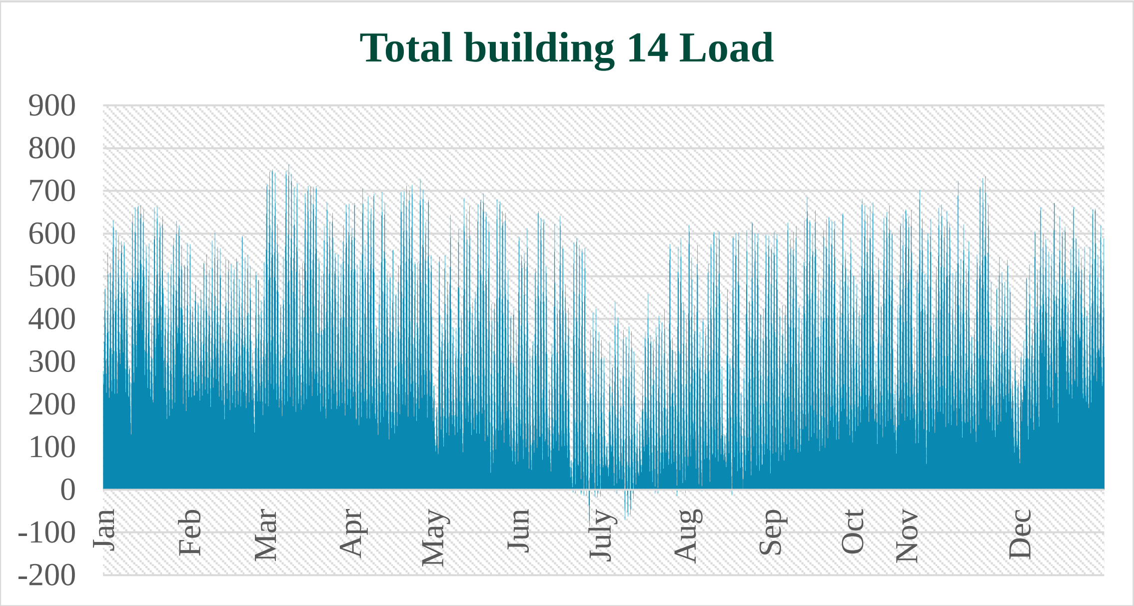

Exterior Lighting Loads and Profiles
Connected Load
Exterior Lighting Load: 0.0000 W/ft2
Monthly Single-Day Profiles
Jan: EL3 ExtLtg DayShape (Ja
Feb: EL3 ExtLtg DayShape (Fe
Mar: EL3 ExtLtg DayShape (Ma
Apr: EL3 ExtLtg DayShape (Ap
May: EL3 ExtLtg DayShape (Ma
Jun: EL3 ExtLtg DayShape (Ju
Jul: EL3 ExtLtg DayShape (Jul
Aug: EL3 ExtLtg DayShape (Au
Sep: EL3 ExtLtg DayShape (Se
Oct: EL3 ExtLtg DayShape (Oc
Nov: EL3 ExtLtg DayShape (No
Dec: EL3 ExtLtg DayShape (De

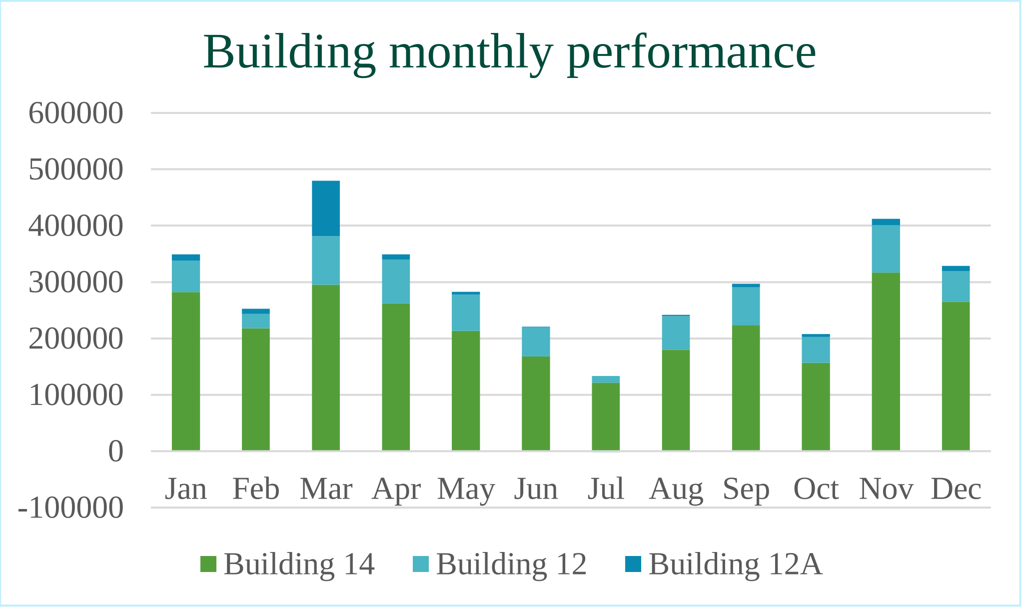

Remote Refrigeration Loads and Profiles
Monthly Refrigeration
Peak Load (W/SqFt)
Daily Profile
Jan: 0.000000 EL3 Refrig DayShape (Jan)
Feb: 0.000000 EL3 Refrig DayShape (Feb)
Mar: 0.000000 EL3 Refrig DayShape (Mar)
Apr: 0.000000 EL3 Refrig DayShape (Apr)
May: 0.000000 EL3 Refrig DayShape (May)
Jun: 0.000000 EL3 Refrig DayShape (Jun)
Jul: 0.000000 EL3 Refrig DayShape (Jul)
Aug: 0.000000 EL3 Refrig DayShape (Aug)
Sep: 0.000000 EL3 Refrig DayShape (Sep)
Oct: 0.000000 EL3 Refrig DayShape (Oct)
Nov: 0.000000 EL3 Refrig DayShape (Nov)
Dec: 0.000000 EL3 Refrig DayShape (Dec)

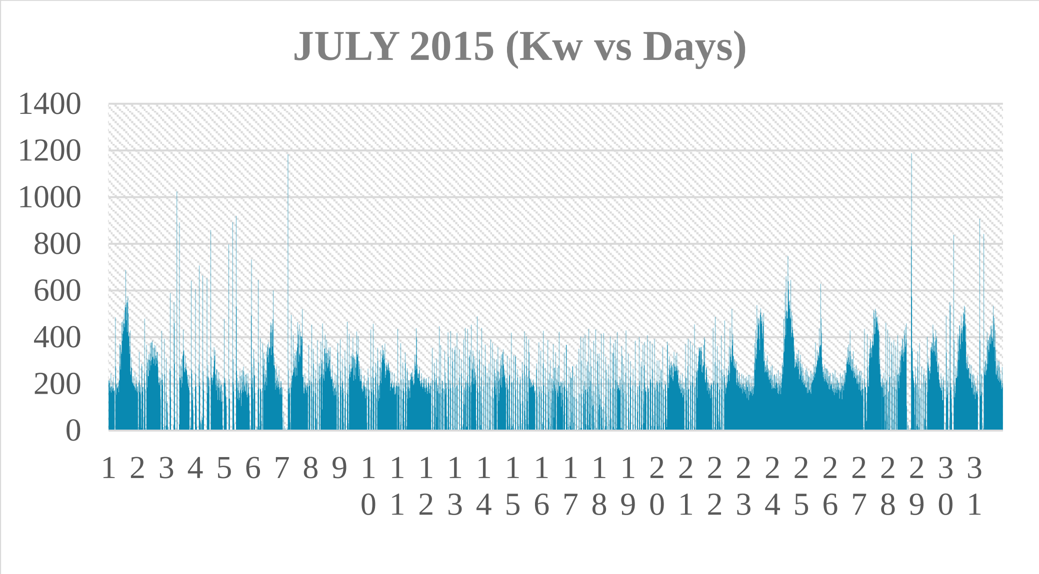
Appendix: E – 3 Buildings eQUEST result

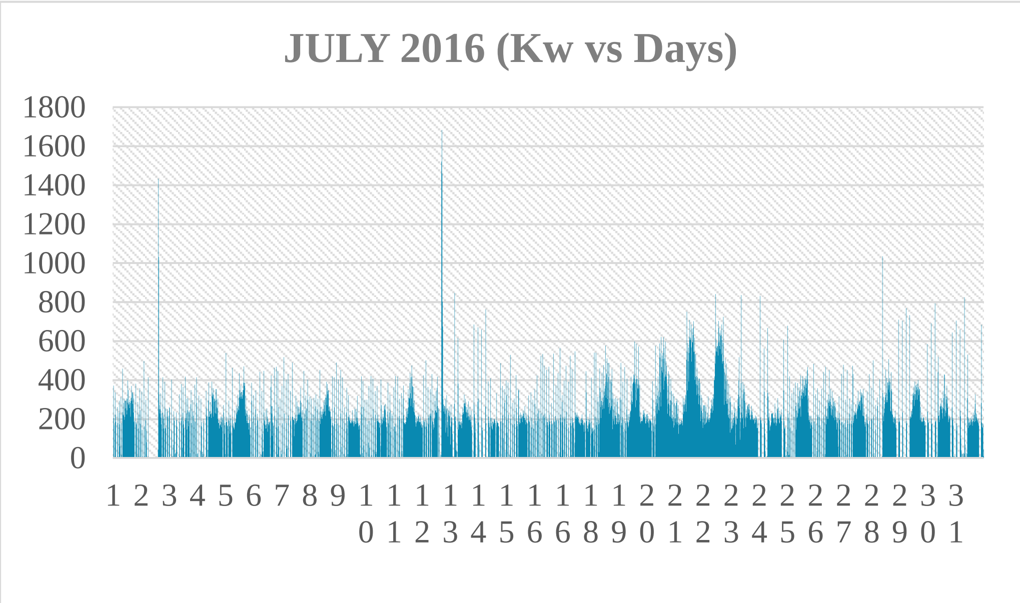


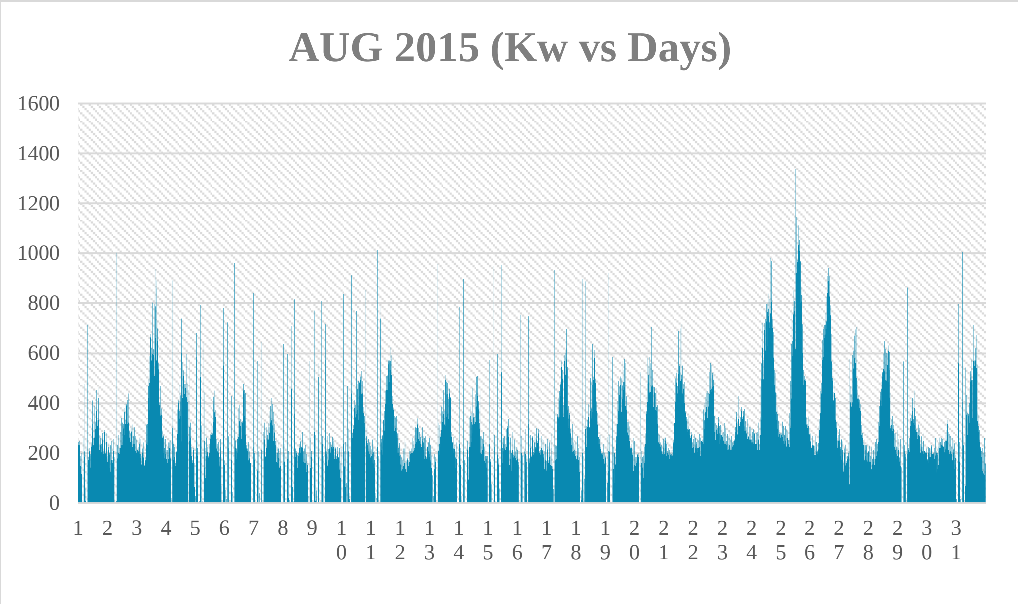


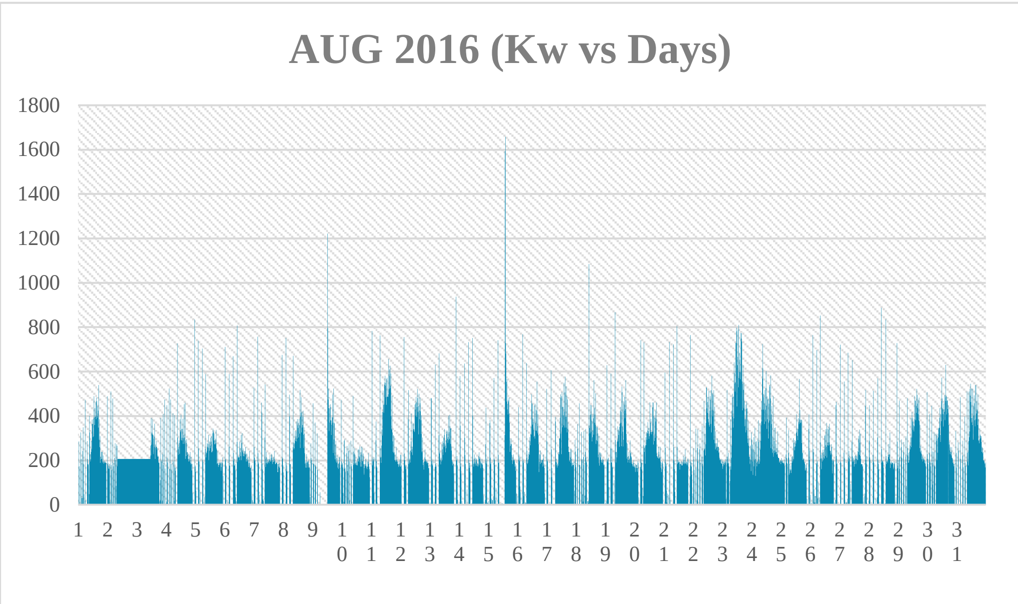

Total building 14 Load
900
800
700
600
500
400
300
200
100
0
-100
-200
Jan
Feb
Mar
Apr
May
Jun
July
Aug
Sep
Oct
Nov
Dec


Building monthly performance
600000
500000
400000
300000
200000
100000
0
-100000
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Building 14
Building 12
Building 12A


JULY 2015 (Kw vs Days)
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


JULY 2016 (Kw vs Days)
1800
1600
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 16 18 19 20 21 22 23 24 25 26 27 28 29 30 31


AUG 2015 (Kw vs Days)
1600
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


AUG 2016 (Kw vs Days)
1800
1600
1400
1200
1000
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Appendix: F – Numerical Results

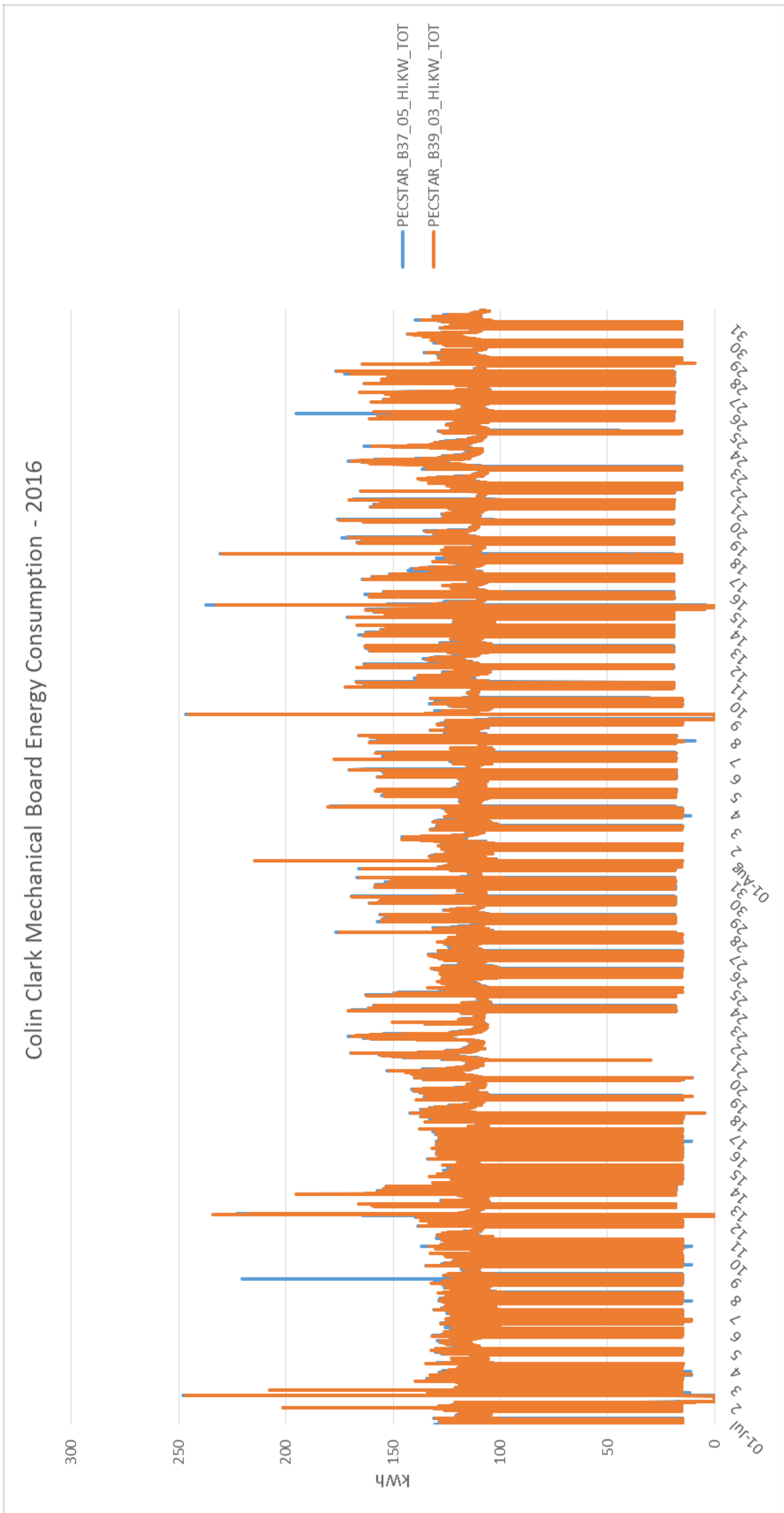
Total building 12&12A												
	January	Feb	March	April	May	June	july	Aug	Sept	Oct	Nov	Dec
Btu/hr	215524977.3	105706337.7	326155732.5	291246181.1	236356026.9	186525999.3	40150945.53	215585074	247476487.6	171657406.7	317787511.8	207372689.4
kW	63164.12895	30979.46617	95586.79928	85355.82079	69269.1063	54665.36836	11767.07931	63181.7416	72528.19128	50307.81449	93134.31616	60774.92946
sum	average											
2561545370	292080.4299											
750714.7622	85.60031496											

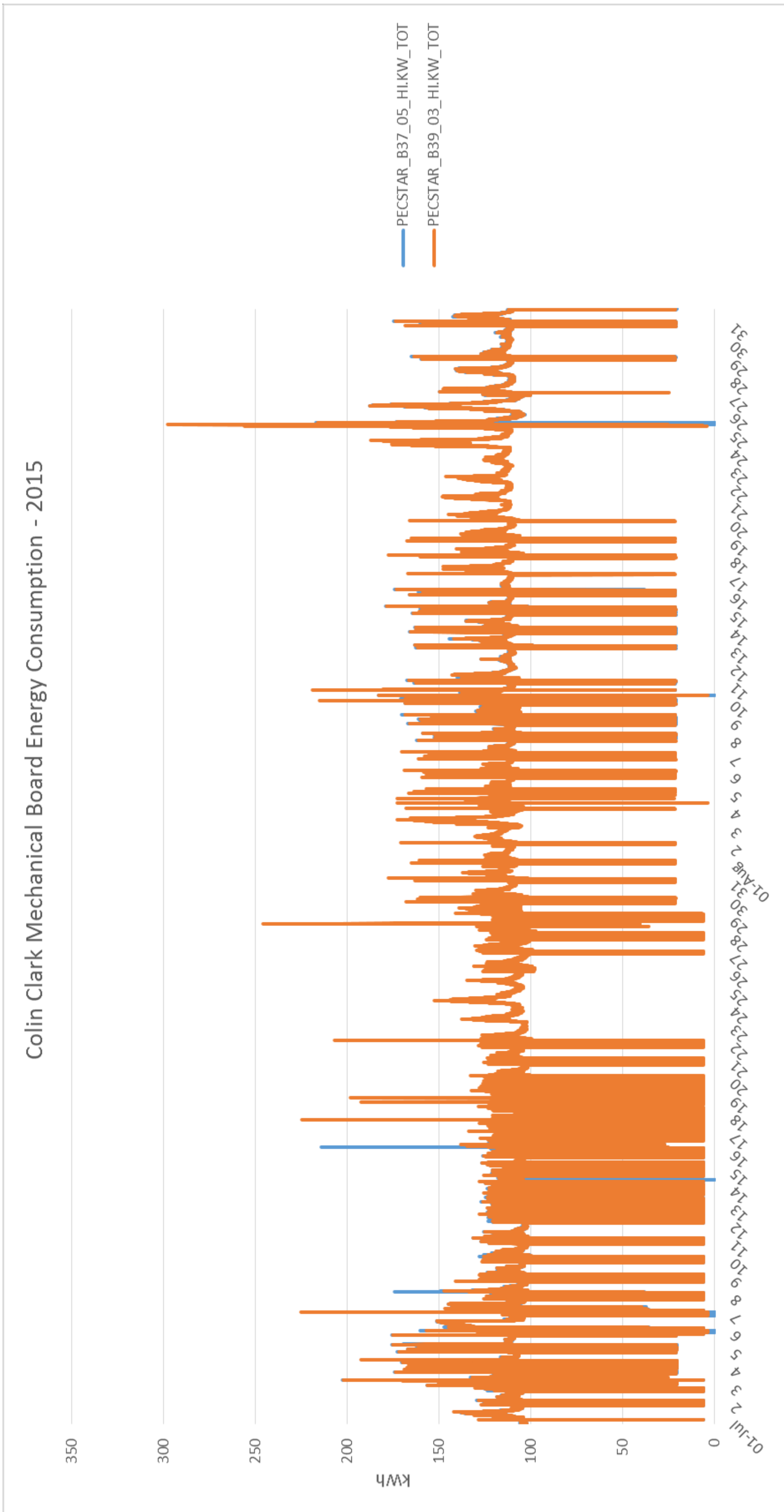
Building 12												
	January	Feb	March	April	May	June	july	Aug	Sept	Oct	Nov	Dec
Btu/hr	189943797	86744489.2	295021125.3	265492070.1	218297956.2	176138011.7	39752446.62	203808800	228198297.1	156616058.2	288293316.3	185213155.5
kW	55667.02586	25422.29755	86462.14762	77808.03674	63976.80877	51620.95004	11650.29082	59730.4567	66878.31195	45899.63085	84490.42164	54280.61185
sum	average											
2333519523	266079.7632											
683886.9904	77.98027256											

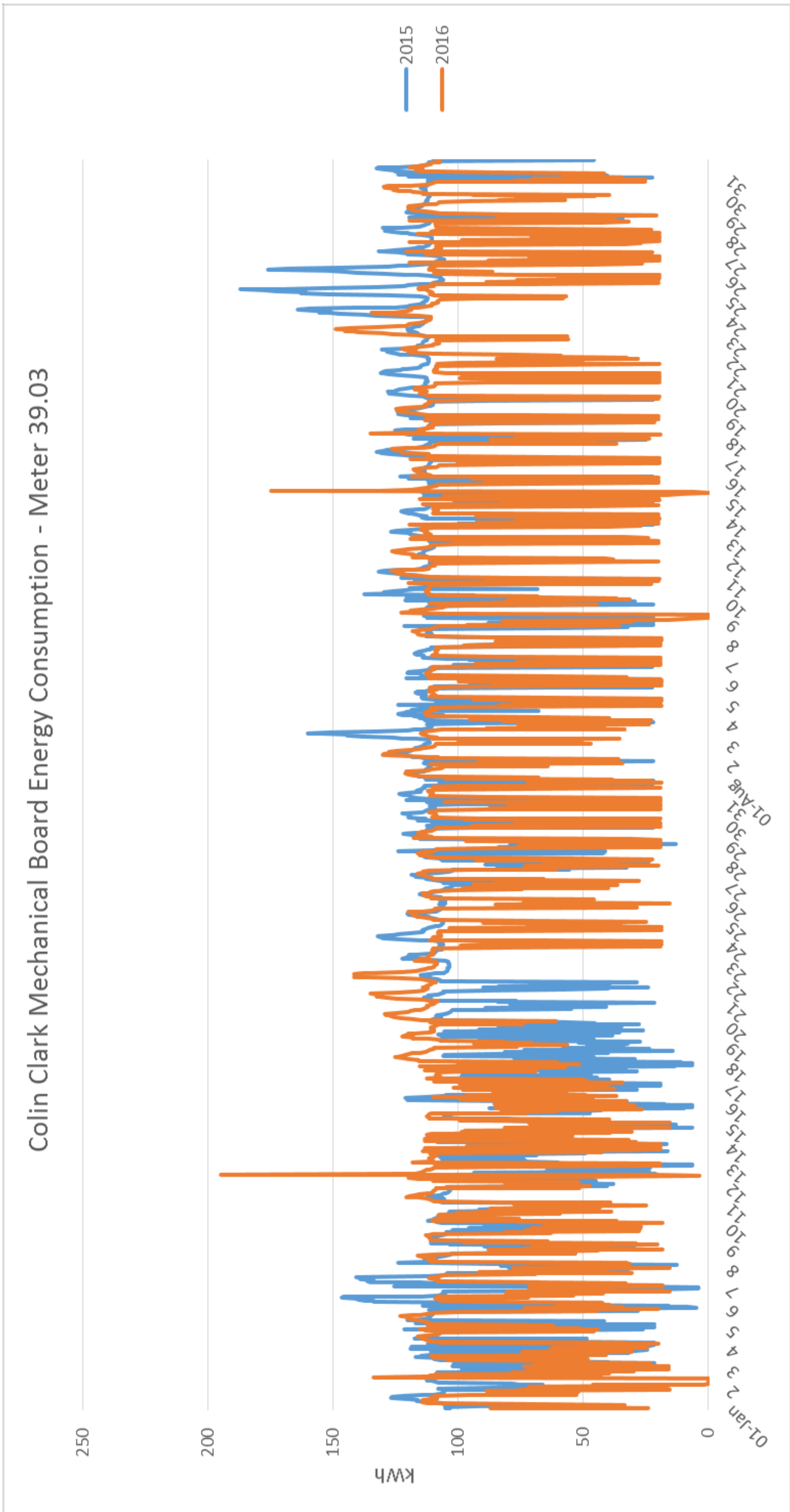
Building 12A												
	January	Feb	March	April	May	June	july	Aug	Sept	Oct	Nov	Dec
Btu/hr	38223908.85	29947768.49	334972164.6	30937987.73	18055595.47	4646013.452	-6015212.22	6700919.09	20080222.39	18438480.24	37405043.36	32073677.26
kW	11202.32067	8776.823618	98170.64019	9067.028199	5291.572118	1361.611988	-1762.88449	1963.84532	5884.931631	5403.784555	10962.33491	9399.865908
sum	average											
270445443.4	30837.56481											
79259.72699	9.037597149											

	Building 14	REAL MONTHLY	Building 12&12A	Total Simulation	Building 12	Building 12A	Building 12(%)	Building 12A(%)	Building 14(%)
Jan	282386.2	501699	63164.13	345550.4	55667.02586	11202.32	16.10967	3.241878	81.72072
Feb	218269.1	430652	30979.47	249248.6	25422.29755	8776.824	10.19958	3.521314	87.57085
Mar	294973.3	538527	95586.8	390560.1	86462.14762	98170.64	22.13799	25.13586	75.52571
Apr	262327	309060	85355.82	347682.8	77808.03674	9067.028	22.37903	2.607845	75.45009
May	213693.3	244064	69269.11	282962.4	63976.80877	5291.572	22.60965	1.870062	75.52004
Jun	168019.8	178221	54664.5	222684.3	51620.95004	1361.612	23.18122	0.611454	75.45202
Jul	121600.8	152120	11767.08	133367.9	11650.29082	-1762.88	8.735455	-1.32182	91.17698
Aug	179948.3	166276	63181.74	243130	59730.45669	1963.845	24.56729	0.807735	74.01319
Sep	223907.7	233324	72528.19	296435.9	66878.31195	5884.932	22.5608	1.985229	75.53326
Oct	156767.5	346790	50307.81	207075.3	45899.63085	5403.785	22.16567	2.609574	75.70555
Nov	316531.4	479878	93134.32	409665.7	84490.42164	10962.33	20.62424	2.675922	77.26578
Dec	265262.8	412901	60774.93	326037.7	54280.61185	9399.866	16.64857	2.883061	81.35954

Appendix: G – Energy Consumption


Colin Clark Mechanical Board Energy Consumption - 2016
kWh
0
50
100
150
200
250
300
PECSTAR_B37_05_HI.KW_TOT
PECSTAR_B39_03_HI.KW_TOT


Colin Clark Mechanical Board Energy Consumption - 2015
PECSTAR_B37_05_HI.KW_TOT
PECSTAR_B39_03_HI.KW_TOT
kWh
0
50
100
150
200
250
300
350
01-Jul
01-Aug



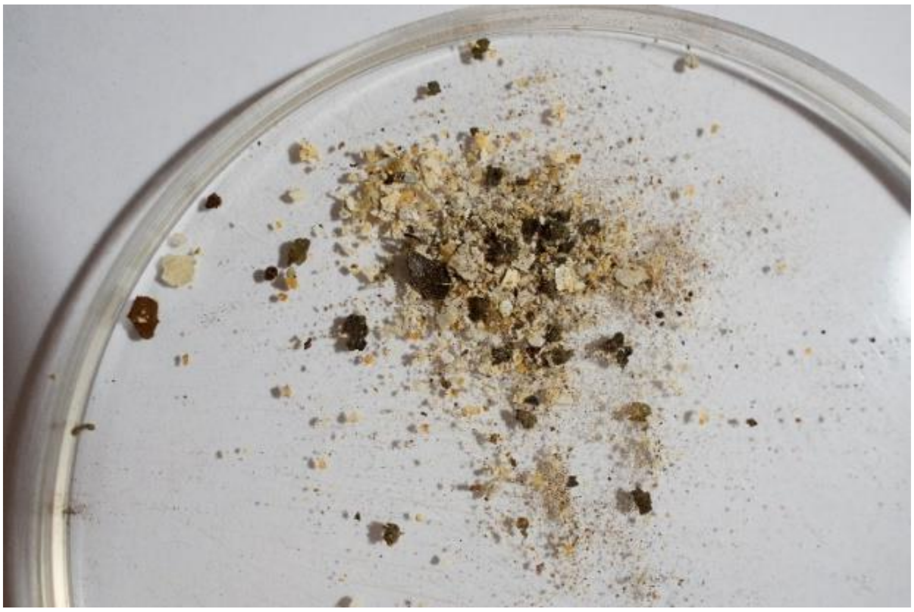
Colin Clark Mechanical Board Energy Consumption - Meter 39.03
2015
2016
kWh
250
200
150
100
50
0
01-Jan
01-Aug

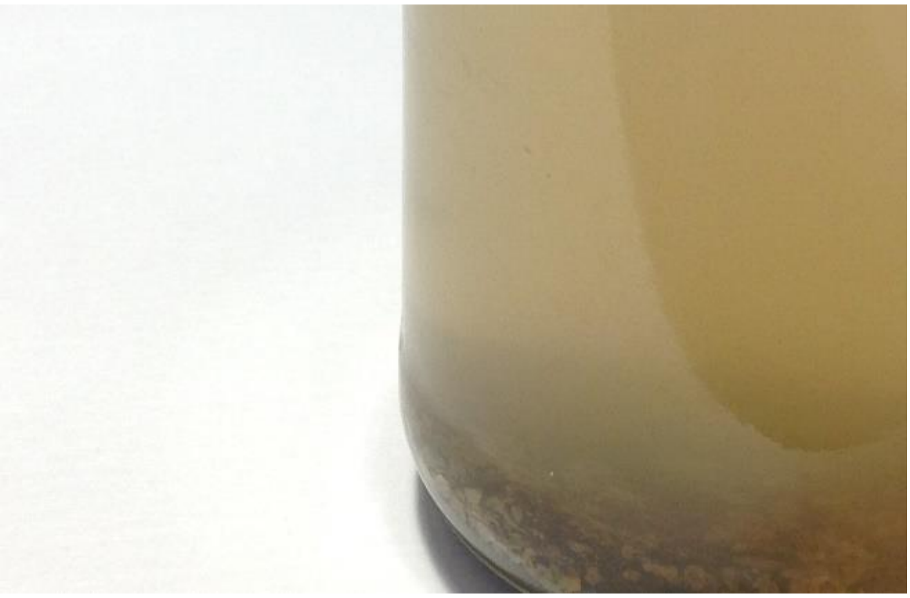
Appendix: H – Water samples

2016/08/05 sets:

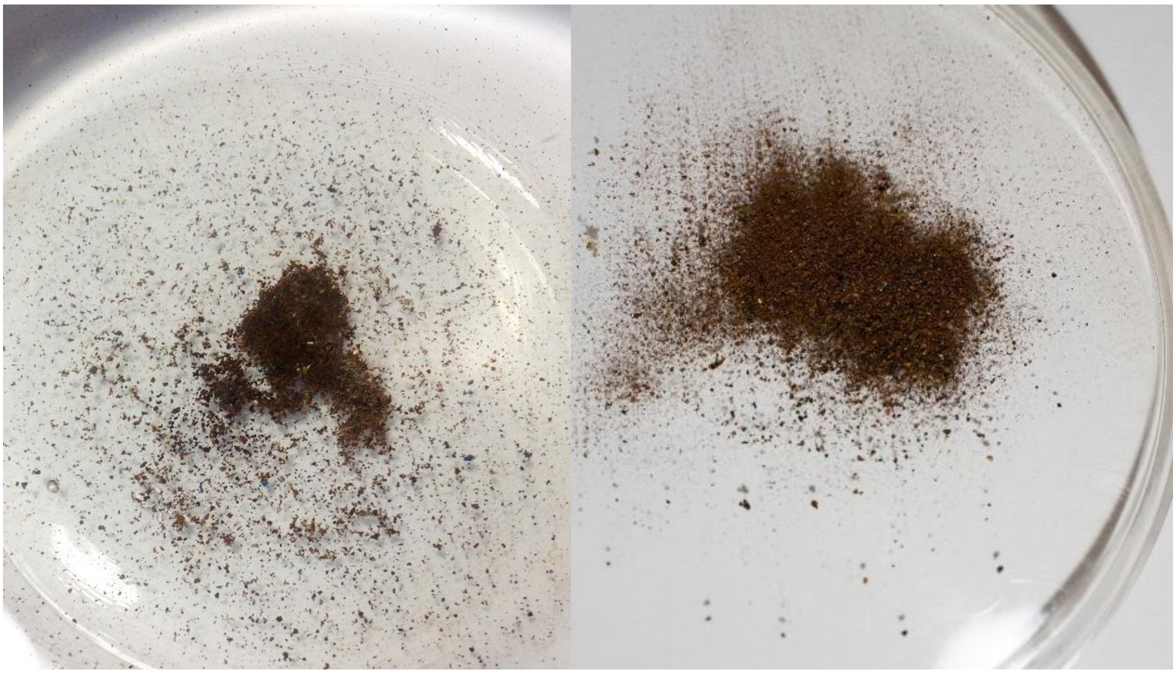
2016/08/05 - Separator 1. Condenser water, not operating.

2016/08/05 - Separator 2. Condenser water, operating.





2016/08/05 - Separator 3. Chilled water, operating.

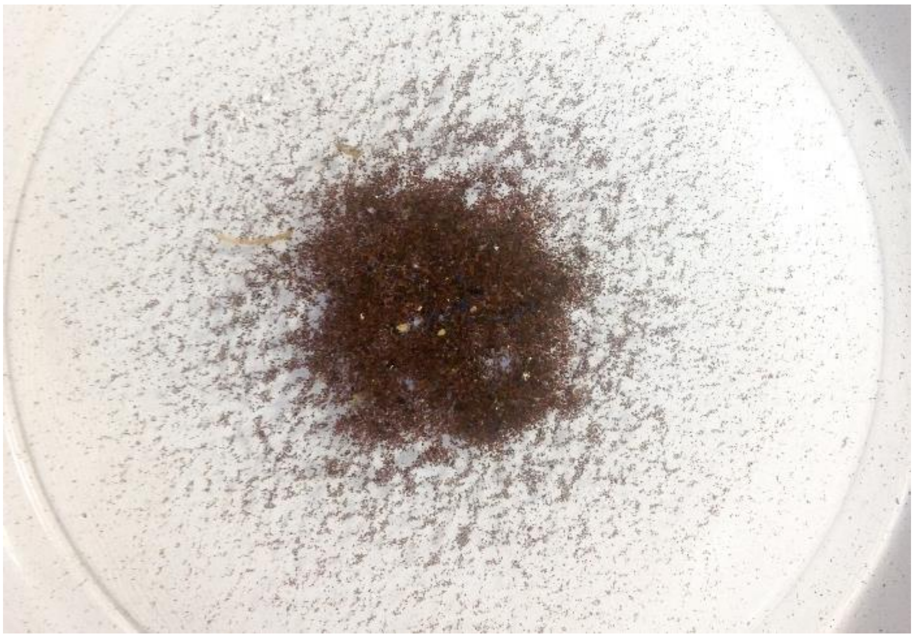


2016/08/22 sets:

2016/08/22 - Separator 1. Condenser water, operating.

2016/08/22 - Separator 2. Condenser water, not operating.

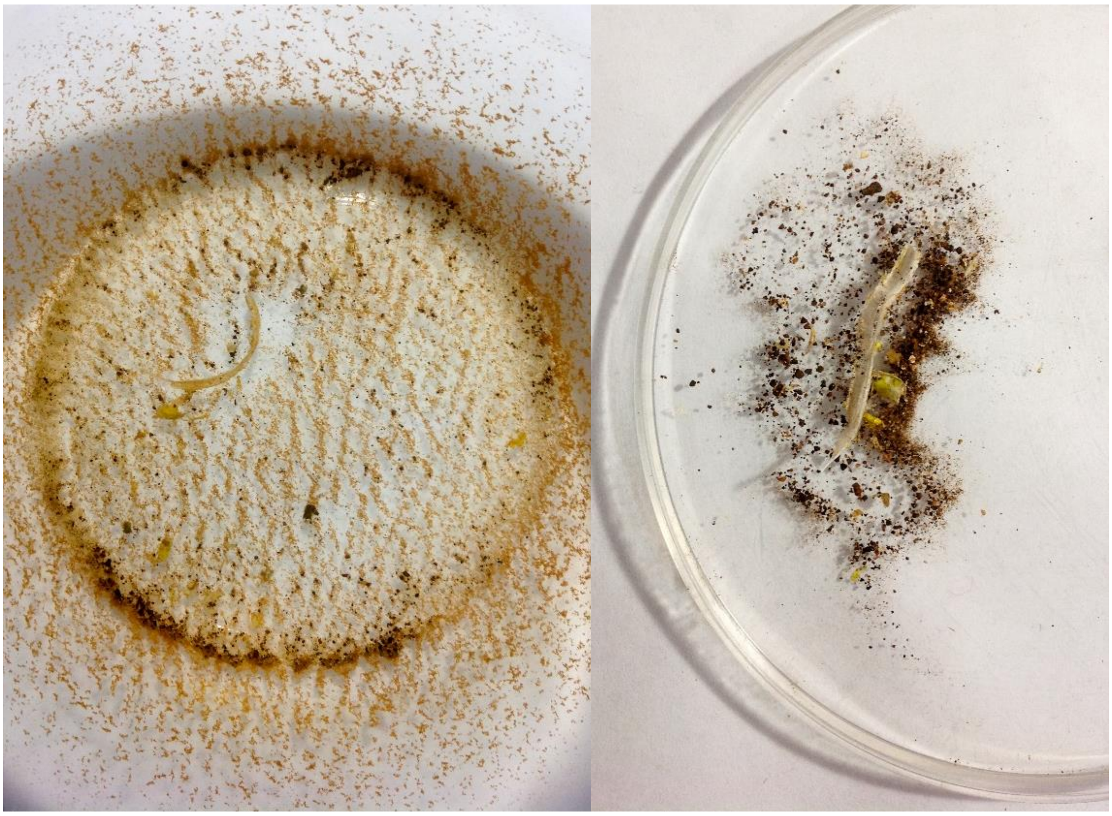
2016/08/22 - Separator 3. Chilled water, operating.



2016/09/15 sets:

2016/09/15 - Separator 1. Condenser water, operating.

2016/09/15 - Separator 2. Condenser water, not operating.

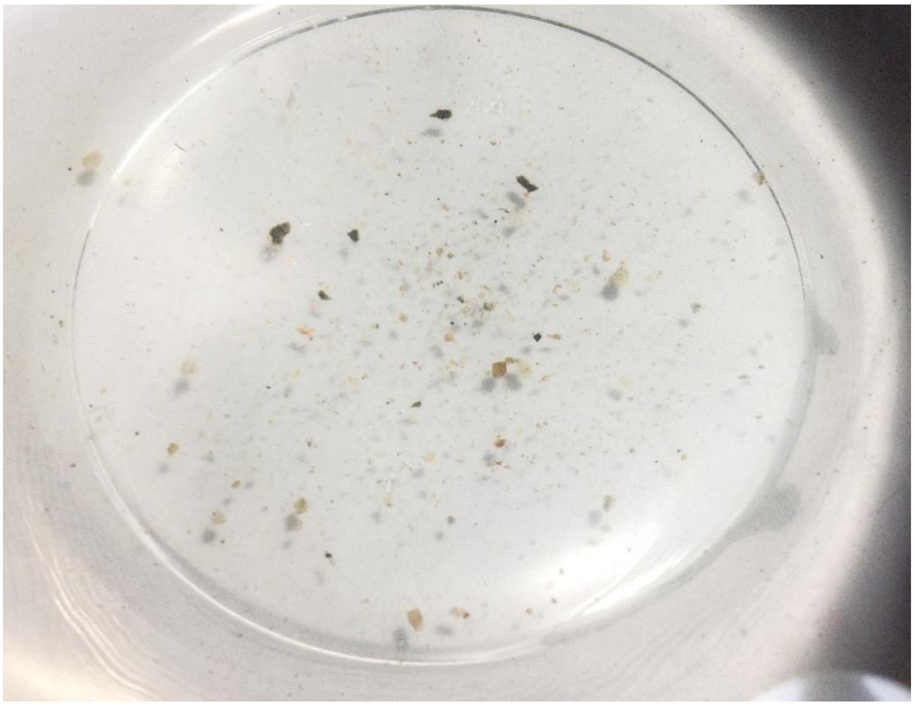


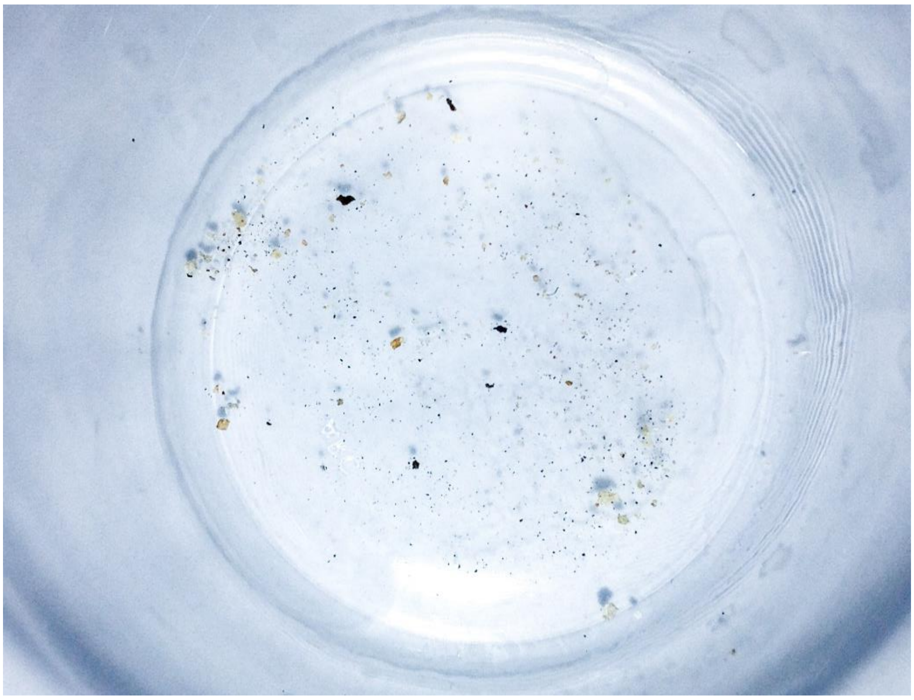
2016/09/15 - Separator 3. Chilled water, operating.

2016/09/15 sets:

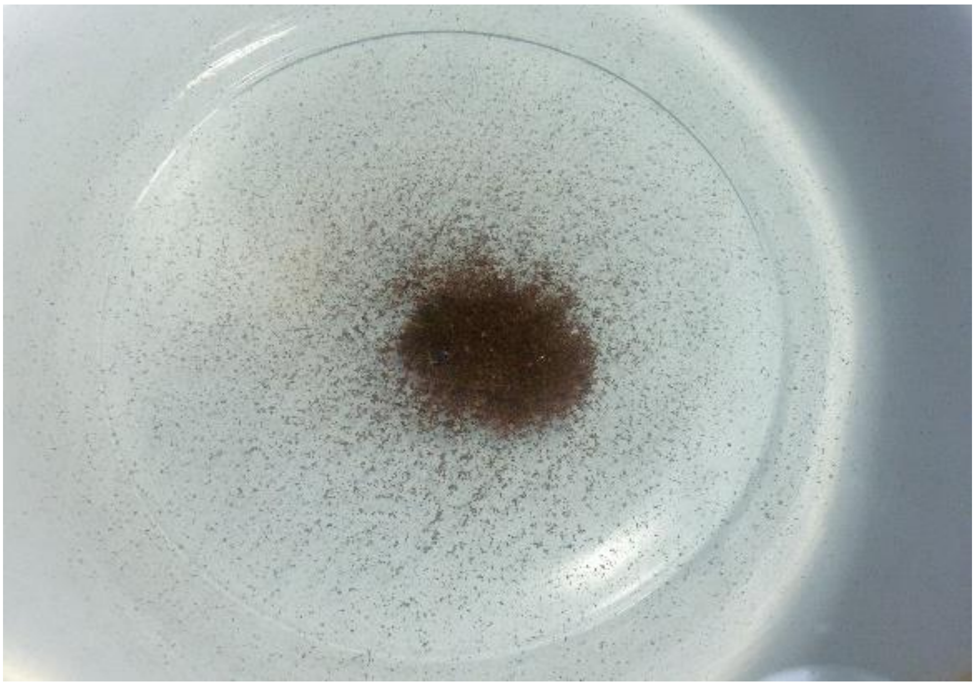
2016/09/15 - Separator 1. Condenser water, operating.

2016/09/15 - Separator 2. Condenser water, not operating.

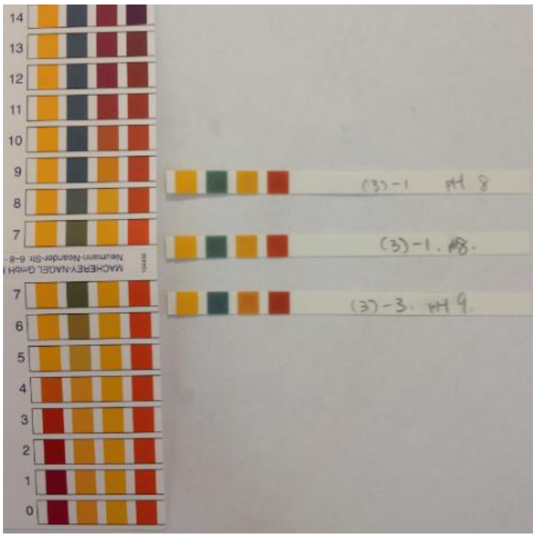


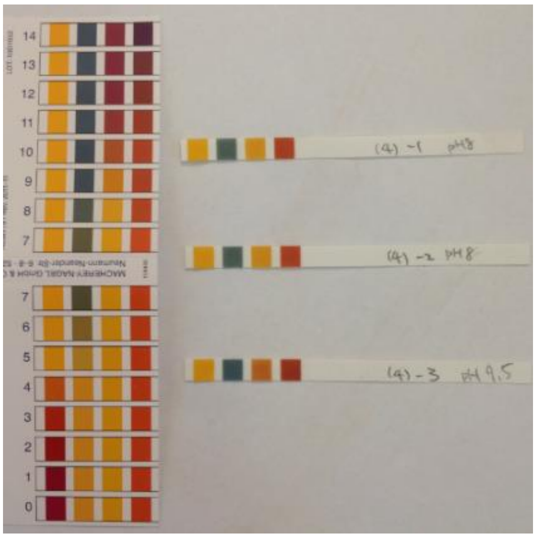


2016/09/15 - Separator 3. Chilled water, operating.



Appendix: I – pH test results






(2)-3. pH. 8.5
(2)-2 pH. 8
(2)-1. pH. 8
(1)-3 pH 9
100 indicateurs à couleurs fixées