Handbook for Building Analytics

Ver 2019

Optimizing Watts to Light Up City.

Written by Thompson Wong

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Introduction

This handbook is written by Thompson based on his analytics experience on building data, this handbook is useful for junior data analyst/data scientist who step into building services engineering, gives them a quick start on consultancy project and chiller performance analysis. This handbook also provides necessary knowledge on building services system and equipment.

General Function Used in Analytics

$$\Delta T = T_{Tchwr} - T_{chws}$$

$$Q_{ev} = mc * \Delta T$$

$$Pcc = \frac{3 * I_{phase} * V_{L-N} * p.f.}{1000}$$

$$Pcc = \frac{\sqrt{3} * I_{phase} * V_{L-L} * p.f.}{1000}$$

$$COP = \frac{Q_{ev}}{Pcc}$$

$$COP_2 = \frac{Q_{ev}}{Q_{cd} - Q_{ev}}$$

$$kWh_{15mins} * 4 = kW_{15mins}$$

$$PV = nRT$$

$$P_{kW,hydraulic} = \frac{q\rho gh}{3.6 * 10^6}, where\ q\ mean\ flow,\ \rho\ mean\ density$$

$$P_{kW,shaft} = \frac{P_{kW,hydraulic}}{\eta}, where\ \eta\ mean\ efficiency$$

General Energy Saving Opportunities (EMSD)

Air-conditioning and Ventilation Installation

	Common Issues Encountered in RCx	Energy Saving Opportunity (ESO)	Related Equipment / System
1	Inaccuracy of sensors and/or insufficient sensors	• Check the accuracy of sensors and take calibration follow manufacture's recommendations; • Check if the sensing range of sensor compatible with operating condition; • Check if the position of installed sensor are appropriate or in accordance with manufacturer's instruction; • Conduct periodic checking on any out-of-range values.	All system / CCMS
2	Temperature difference (△T) of main supply and return chilled water temperature is too low	• Check and clean coil; • Check thermostat settings; • Verify that all coils have interlocking controls that insure that the control valve is closed; • Check if defective modulating valve operation and/or improper control/setting of AHU/PAU.	Central air conditioning (Water-side)
3	Failure of chilled water zone control	• Inspect zone valve condition and repair/replace defective zone valve/controller	Central air conditioning (Water-side)
4	Condensation on surface of chilled water pipeworks and/or accessories	• Inspect the insulation and repair defective insulation	Central air conditioning (Water-side)
5	Operating chiller capacity is greater than the required cooling load during cool climate	• Adopt chilled water temperature reset to save chiller energy while cooling loads can still be catered	Central air conditioning (Water-side)
6	Blockage of condenser tube	• Periodic maintenance of condenser tube through monitoring of the pressure drop and the differential temperature; • Consider to adopt automatic cleaning system for condenser tube can reduce the frequency and periodic maintenance which ensure the chiller efficiency and its expected life	Central air conditioning (Water-side)

	Common Issues Encountered in RCx	Energy Saving Opportunity (ESO)	Related Equipment / System
7	AHU Fan with constant speed design only or Variable air volume control by fan inlet guide vanes or modulating damper	• Replace defective or loosen belt	Central air conditioning (Air-side)
8	Indoor air temperature is too low	• Review/adjust the setpoint of room thermostat to match with operation need; • Check for sensor located properly.	Central air conditioning (Air-side)
9	Indoor air distribution (Unbalancing in VAV air supply system)	• Check variable-air-volume boxes working properly; • Perform air balancing and adjust air dampers; • Replace defective damper or activator	Central air conditioning (Air-side)
10	Air leakage from air duct	• Inspect and repair air ductwork	Central air conditioning (Air-side)
11	Unsatisfactory cleanliness of air filter and/or cooling coil	• Replace/clean air filter and/or cooling coil	Central air conditioning (Air-side)
12	Incomplete or missing ductwork and pipework insulation	• Add ductwork and pipework insulation to reduce the amount of energy lost in transmitting heated or cooled fluids	Central air conditioning (Air-side)
13	Review equipment operating schedules	• Check, update and review all equipment operation schedule which are on only when they are necessary	Central air conditioning (Air-side)

Lighting Installation

	Common Issues Encountered in RCx	Energy Saving Opportunity (ESO)	Related Equipment / System
1	Over-illuminated at some areas	• Overlit or underlit areas should be corrected; • Consider to de-lamping some lighting at overlit areas.	Lighting
2	Lighting is "ON" during no occupancy period / non-peak hour period	• Add timer control or occupancy sensor control to match the operation schedule; • Replace malfunction timer and/or occupancy sensor.	Lighting
3	Insufficient calibration of Lighting control system	Time based • Correct operating time schedule - lights are operating only when the building is occupied Occupancy based • Adjust time-delay settings to suit the requirements of each space; • Check sensor's position. Lighting level based • Photocell controls should be checked to ensure desired daylighting dimming or daylight switching response; • Setpoints should be adjusted so that the desired light levels are maintained.	Lighting

Electrical Installation

	Common Issues Encountered in RCx	Energy Saving Opportunity (ESO)	Related Equipment / System
1	Insufficient review power quality of electrical distribution network	• Check the operation of capacitor bank and/or harmonic filter to enhance overall power quality and/or match operation needs/efficiency requirement	Electrical
2	Insufficient review the total power factor for a circuit which is lower than the design value	• Install power factor correction device if economically viable	Electrical
3	Total harmonic distortion of current for a circuit exceed the limited design percentage	• Install harmonic filter at the source of distortion to limit THD	Electrical
4	Insufficient power monitoring device	• Install sufficient metering facilities to monitor the power consumption and energy performance of outgoing circuits	Electrical
5	Insufficient review of Tariff	• Minimize of maximum demand in peak hour; • If possible, equipment should run during the less expensive off-peak hours; • Consider applying pre-cooling strategies	Electrical

Lift and Escalator Installation

	Common Issues Encountered in RCx	Energy Saving Opportunity (ESO)	Related Equipment / System
1	Insufficient administrative approach to optimize the operating quantity of Lift/Escalator with operation needs	• Assign only one or two lifts available to casual end-users after normal working hours and on holidays; • Encourage the end-users to walk up or down one or two storeys rather than taking the lift	Lift & Escalator
2	Insufficient monitoring on power quality on lift and escalator	• To provide electric filter to improve both the power factor and total harmonic distortion, irrespective of DCTL, VV or VVVF typed.	Lift & Escalator
3	Little energy saving measures in lift car and machine room	• Switch on the lighting in the lift machine room only when it is occupied; • Switch off all lightings and ventilation fans inside the lift car automatically when the lift is parked; • Switch off all ventilation fans and airhandling units in the lift machine room when all lifts have been parked for a significant period (e.g. at night)	Lift

Building Services

CHILLER PLANT OPTIMIZATION

i) Chilled Water Reset

Chilled-water reset means to change the chilled water temperature leaving the chiller based on some parameter. Increasing the leaving chilled water temperature reduces compressor power usage by reducing lift at both full and part-load conditions. However, at part-load conditions, design chilled water temperature may not be necessary, especially for comfort cooling applications, so reset is possible. Increasing the chilled water temperature may result in greater humidity levels in the conditioned spaces. Higher coil temperatures resulting from the increased chilled water temperature will reduce the latent heat capacity of the coils and the ability of the air distribution system to remove space humidity.

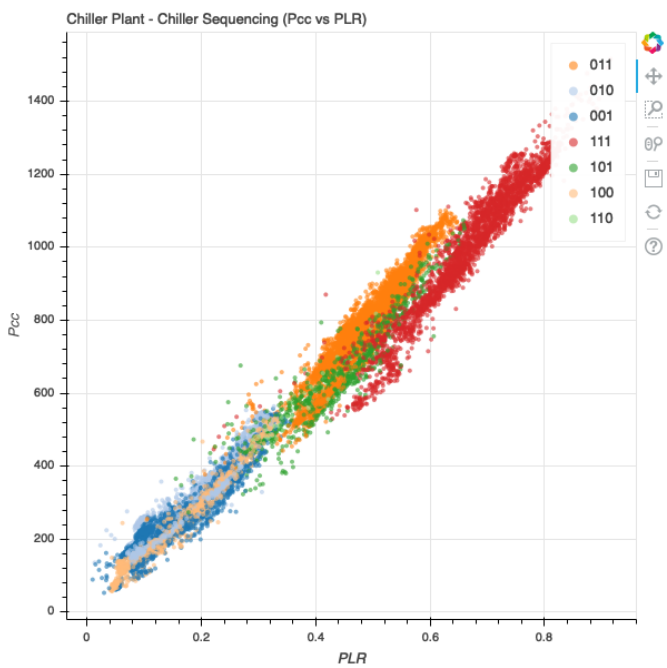
Chilled water temperature can be reset as a function of:

- Ambient air temperature (most common) – used when the ambient temperature is the best indication of load
- Return chilled water temperature – used when return water temperature is the best indication of load. This method is typically used when it is desired to maintain a fixed Δt in the chiller plant.

ii) Chiller Sequencing - Combination

The chiller sequeuncing combination has been shown in following figure. 0 mean off, 1 mean on. You can observe the chiller group combination performance from the following graph by cluster analysis. The next steps is using statistics and linear regression as stronger evidence.

Example: 010 mean only chiller 2 in operation



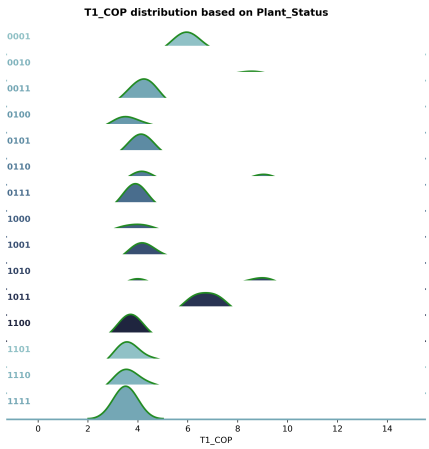
<u>Chiller Sequencing - Combination</u>

- At range PLR 0~0.3, Chiller 2 (010) shall have better performance since lower cluster trend
- At range PLR 0.3~0.7, Chiller 1&3 (010) shall have better performance due to lower cluster trend
- More precisely, you can use statistical modelling or machine learning for the power reduction

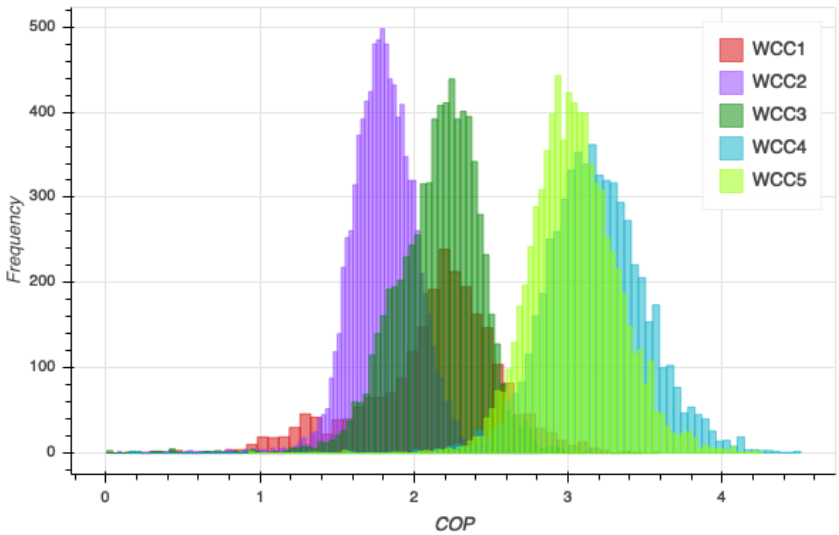
iii) Chiller Sequencing Control - Add / Drop Priority

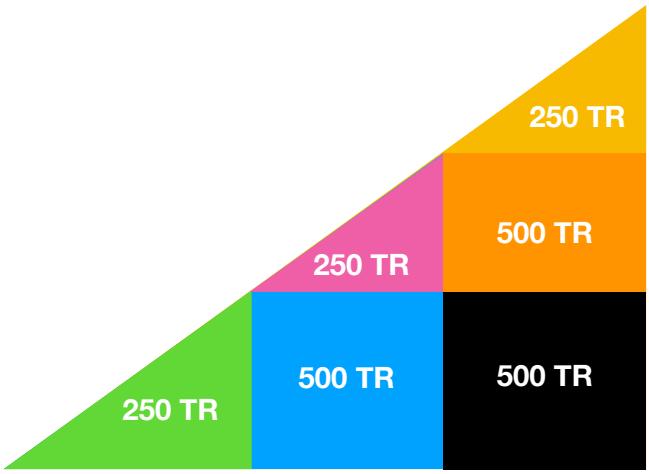
Multi condition for chiller add/drop, such as adding time duration to limit instant value errors. Which will be very helpful on the signal accuracy.

A. Add / Drop
   1. T = 15 mins
   2. Tchwr >= 13.5°C
   3. Tchws >= 8.5°C
   4. Delta T >= design condition
   5. By-pass flow rate is equal to single chiller
   6. RLA %
   7. Cooling Capacity (Qev)
   8. No. Operating Chiller
      a) Building Profile



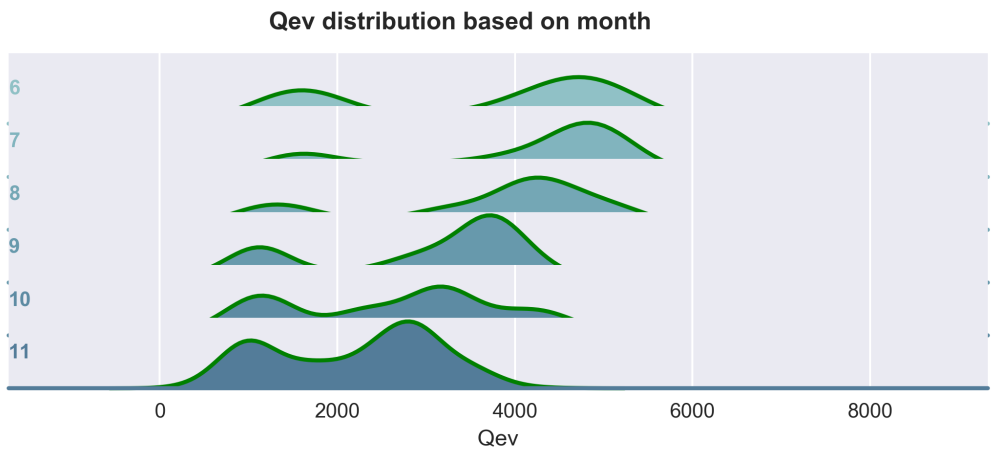
B. Operation Priority
   1. VSD chiller First
   2. High Performance Index will be prior





iv) Chiller Sequencing Control - Operating No.

The most efficient method to achieve energy saving is fulfilling cooling demand also minimising the operating no. as possible. Adopting a table and load profile to predict cooling demand and then calculate the most minimum operating no.



	Qev/TR	800	560	160
Operating No.		2	2	1
PLR	3376.32	2813.6	1969.52	562.72
0	0	0.00	0.00	0.00
0.1	337.632	0.06	0.09	0.60
0.2	675.264	0.12	0.17	1.20
0.3	1012.896	0.18	0.26	1.80
0.4	1350.528	0.24	0.34	2.40
0.5	1688.16	0.30	0.43	3.00
0.6	2025.792	0.36	0.51	3.60
0.7	2363.424	0.42	0.60	4.20
0.8	2701.056	0.48	0.69	4.80
0.9	3038.688	0.54	0.77	5.40
1	3376.32	0.60	0.86	6.00

The ultimate goal for control is predictive demand control, which can be done by forecasting of next day cooling demand, pre-calculate the energy consumption of specific group chiller operation, and determine the best efficient chillers. The forecasting can be done by statistical modelling like distribution probability or autoregressive method (ARIMA), or apply deep learning algorithm (LSTM). The major difference between statistical modelling and deep learning is the dimension of data. Traditional statistical modelling forecasting is 1 dimensional (cooling capacity), while deep learning algorithm can take multi parametric as training which means you can pass it (hour, outdoor temperature, cooling capacity, relative humidity, control setpoint etc.). available libraries: keras, pytorch-lightning, fast.ai, scikit-learn, prophet, Kats by Facebook.

RULES OF THUMB TO JUDGE HVAC DESIGN

1. General Design 200 W/ m2 or 200 ft2/TR

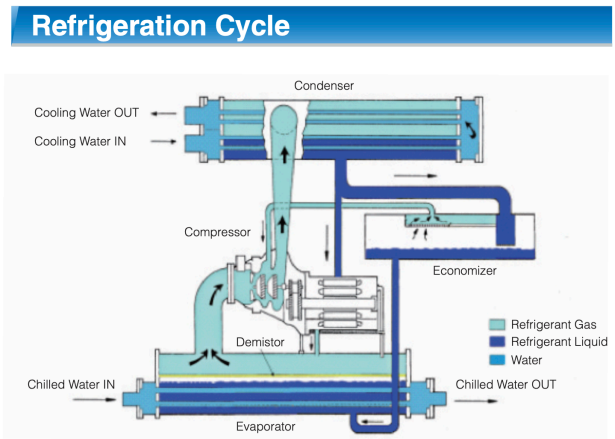
~To be continued

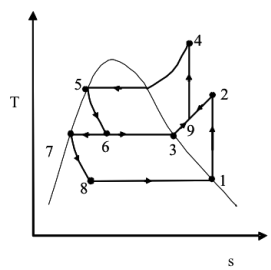
FAULT DETECTION & DIAGNOSIS

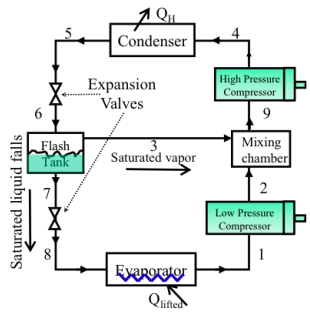
i) Two Stage Chiller

Hight efficient chiller, consists of general chiller components with Economizer which is used for collecting evaporative refrigerant during passing the evaporator. Therefore, the refrigeration cycle in evaporator is more efficient due to higher percentage of refrigerant to process cooling. In addition, the economizer also provides compressor a sub-cooling effect on 1st stage compression. An economizer is a type of sub-cooler that uses part of the total refrigerant flow from the condenser to cool the rest of the refrigerant flow. The evaporated refrigerant then enters the compressor at an intermediate pressure level. The cold gas from the economizer can also be used to provide extra cooling for the compressor.

The sub-cooling of the main refrigerant flow (m2) reduces the quality of the inlet vapor to the evaporator, which increases the cooling capacity. The high efficiency of the SWEP BPHE economizer minimizes the required temperature difference between the sub-cooling and the evaporating streams, which in turn increases the overall efficiency of the system.





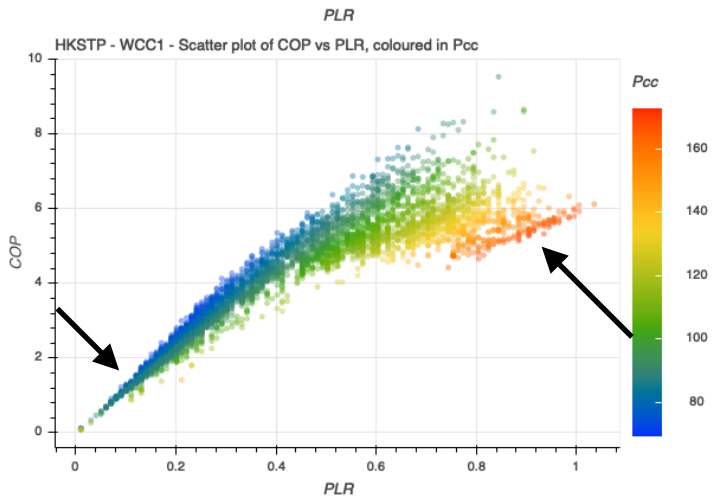


why two-stage compressor is efficient?

1. reduce the pressure lift
2. two compressor to share the compression. single big compressor have higher energy consumption than two small compressors
3. increase refrigeration cycle efficiency(more liquid refrigerant in evaporator, since gas refrigerant transferred to 2nd stage compressor. besides, the 1st compressor can have great compression ratio due to the % of mixed refrigerants)
4. pre-cooling on the exit of 1st stage gas refrigerant
5. compressor work done is not linear (e.g. 800/500/200), the compression pressure is 1.6 for mid to high. 2.5 for low to mid. if a single compressor, its compression pressure is 4.0

ii) Minimum / Maximum Power Input

Chiller have its own operation characteristics, minimum power for avoiding frosting in compressor. Maximum power for protecting chiller compressor, no over current cause any form of compressor broken. The figure shows the minimum power line and maximum power line since the expression:



$$\frac{COP}{PLR} = \frac{1}{Pcc} = \frac{Qev_{full}}{Pcc} = slope\ m$$

The slope represents the rate of change at specific points, In light load, fixed power input, but step up cooling output. So the COP is linear relation with PLR in light load (PLR 0~0.3).

Usually, chiller have a preset PLR 0.2~0.3 (wcc/acc) to achieve **FREEZE PROTECTION** so that chilled water would not be freezes through low refrigerant temperature. Ice berg will be caused by long time light PLR since 0°C refrigerant will freeze water to ice. Then no heat exchange effect, and ice frosting the evaporator and compressor. Minimum power input shall be the minimum consumption for whole chiller operation cycle, such as the rotation of compressor blade. Its minimum power can cater more cooling generation actually, so that COP is linear increase with PLR.

Maximum power is used to protect chiller, avoid over current. So the power is limited, but cooling demand is still exist, then chiller will go an uncontrollable status.

iii) Chiller Surge

Chiller surge is a condition in which refrigerant flows in reverse from the condenser back to the compressor, which can lead to severe damage.

What Is Surge?

Each chiller system has a maximum lift (head pressure), which is the difference between condenser refrigerant pressure and evaporator refrigerant pressure. Lift can also be measured by the difference between the leaving chilled-water temperature (LCHWT) and the entering condenser-water temperature (ECWT). If this differential increases to where it exceeds the system's pumping capacity, refrigerant will flow backward through the compressor wheel every few seconds. Pressure builds up in the compressor, causing the refrigerant to surge forward again, and the cycle repeats. This reverse-load can damage the thrust assembly, bearings and gearbox, and can cause a rupture in the safety disc or blow the relief valve. Surge is identifiable by its loud, distinctive sound, sometimes likened to an elephant's squeal or a surging jet engine, as well as a fluctuation in compressor amperage. Surge will have following consequences:

- Loss of performance
- Pressure instability
- Amperage peaks
- Vibrations and noise
- Bearing wears

What Causes Surge?

Chillers are designed to meet specific system requirements and operating conditions. With proper maintenance and operation within design intent, a properly selected chiller will not surge. Changes in operating conditions, however, can cause surge to occur, particularly under low load conditions. Surge can be attributed to maintenance issues including fouled tubes, low refrigerant charge, or non-condensables in the refrigerant. It can also be caused by poor control of water flow rates and condenser water temperatures. Low load issues (surge issues) can be avoided or corrected with hot gas bypass or VFDs. Some ways to get around this though are by fitting a variable speed drive, or variable frequency drive, onto the induction motor which drives the compressor. This will change the rotational speed of the compressor to modulate its capacity. Some chillers may have a hot gas bypass built in, and this is used to allow the capacity to be reduced, while maintaining a sufficient gas flow through the compressor. Some manufacturers will also fit variable diffusers into the compressors. This reduces the gap in the diffuser for which the refrigerant can flow into the volute, maintaining the gas velocity. When the refrigerant flow rate is too low in (low load, high lift) case, and so the velocity of the gas, and therefore the pressure generated by the compressor is too low to overcome the pressure in the condenser.

The summary of causes of surge:

- Too high condensing temperature
- Too much incondensable in a low pressure unit
- Cooling tower temperature too high
    - Too much refrigerant
    - Dirty tubes
    - Too low water flow rate
- Lack of refrigerant
- Too long part load operation
    - unit might surge during a long time at part load (15 to 20%), it is then recommended to reduce condenser inlet water temperature of 1°F per 10% load reduction

Example

Let's say that this chiller is working at it's maximum rating. It's maximum lift is from 300 kPa to 900 kPa. (3 Bar to 9 Bar). That means it will take refrigerant in from the evaporator at a pressure of 300 kPa (3 Bar) and it will compress it and force it into the condenser to it's maximum which is 900 kPa (9 Bar).

The chiller can therefore provide 600 kPa (6 Bar) of lift. (900 kPa – 300 kPa).

Now, let's say that the pressure in the condenser reaches 1000 kPa (10 Bar). Obviously, that is much higher than the maximum pressure that can be provided from the compressor. When the pressure in the condenser is higher than the pressure that can be applied by the compressor, then chiller surge will occur.

It is important to note that these numbers are just for example purposes. As mentioned, please do check with your chiller manufacturer to find out what your surge line is and what your chiller lift is.
When chiller surge occurs, the pressure in the condenser has become too great and the refrigerant starts to push back. This causes it to start flowing in the opposite direction, backwards, through the discharge line and into the compressor.

The compressor will still continue to rotate because it's job is to push refrigerant into the discharge line and into the condenser. As the pressure is already too great the refrigerant will flow back through into the impeller blades and out through the suction line into the evaporator.

This is not a good scenario for the chiller. It can cause some really serious damage to the chiller. You'll know when this occurs because the chiller's going to make a really loud, groaning, kind of squealing noise. That noise will be coming from the compressor. You'll probably also experience some quite large swings in the amount of amps being drawn by the compressor also.
(chiller surge repeat cycle: Pcc+, Refrigerant-, Pcc-, surge, repeat…)

iv) Hot Gas by Pass

Hot gas bypass valves are a simple and very effective way to add a false load on an evaporator coil. What is a false load you ask. Well, as we have learned in the past, refrigerant pressures are directly related to the ambient temperature surrounding them. For example, if the return air in a system is close to set point, regardless of what that set point is, the suction pressure will be lower than if the return air was five degrees above set point, correct? By adding hot gas from the discharge line into the evaporator, we can increase the evaporator pressure and temperature. Because this load is not put there by heat from the return air, the load is referred to as false. Hot gas bypass valves can be used in many different applications where the load on the evaporator varies, from residential, to server rooms, to process cooling equipment. Using a hot gas bypass valve can also prevent short cycling of a compressor and prevent evaporator freezing in low load conditions. As a space or process temperature reaches set point, hot gas can be added to the evaporator to raise its temperature. With increased evaporator temperature, set point will take longer to achieve, thus increasing compressor run times all the while preventing evaporator freeze up. Keep in mind though, it is normal in some applications for evaporators to freeze during normal operation, like in low temperature refrigeration applications.

In fact, this is only used on some chillers. It is used to create an artificial cooling load to stop the chiller from cycling, stalling, surging as well as protecting the evaporator from freezing under low load conditions. A control valve is used along with a pressure reducing valve to recirculate hot refrigerant from the compressor discharge line and send it straight to the inlet of the evaporator, thus bypassing the condenser so heat is added to the evaporator to create the false load. This is a pretty inefficient strategy, the energy that went into the compression of the refrigerant will provide no usable cooling effect. If you’re using this strategy then your chiller is likely way oversized.

Example Of Use

A large lecture hall is filled with people, the load will be high and the system will most likely run at 100% capacity to cool the space. During an intermission, people leave for a break, the load drops and the room approaches set point. The hot gas bypass valve opens putting a false load on the evaporator, since the evaporator temperature has been increased, the supply air serving the lecture hall will also be increased preventing set point to be reached. As people re-enter the hall, a true load will increase evaporator temperature and the hot gas bypass will close. This prevents compressor short cycling with varying loads, compressor stops and starts are a major factor in compressor failure over time.

Let's take a look at how the valve operates. There are mechanical valves and electrical valves.

Mechanical

The mechanical hot gas bypass valve (HGB) is fed discharge gas (hot gas) teed off from the discharge line. The output of the valve is directly piped to the inlet of the evaporator after the TX

valve. In some situations, where multiple evaporators are used, it may be piped into the suction line. There are some disadvantages to this though, like improper oil return to the compressor. They are adjusted manually, the Sporlan ADRSE-2, from the video below is adjusted using an Allen key. Adjusting the valve inwards will allow more hot gas to flow through the valve, backing out the adjustment will allow less hot gas to flow through the valve. When setting up the valve, you may need to simulate a low load condition. For instance, if you want to maintain a suction pressure of 60 psi in the evaporator, perform the following steps. Simulate a low load condition, allow the pressure to drop below 60 psi. Starting with the hot gas adjustment backed all the way out, slowly begin to adjust the valve inwards until the flow of hot gas raises the evaporator pressure to the desired setting of 60 psi. The valve will maintain that set point by monitoring evaporator pressure and adding hot gas as needed.

Electronic

The electronic hot gas bypass valve (EHGB) uses the same concept as it's mechanical counter part but operates a little differently. For example, the Sporlan SDR series uses a 12 VDC stepper motor. A controller must be used in conjunction with the valve and be capable of monitoring temperature and pressure. The electronic set up can be used for more accurate control of evaporator temperature. The electronic valve can also be piped to the evaporator inlet or the suction line. You will need an interface to set up this valve, an Allen key will not suffice.

Piping Configurations

Generally speaking, there are three ways of piping in a hot gas bypass line.

1. Evaporator inlet with a distributor, with this method, the hot gas bypass line shall be piped after the TX valve but before the distributor. An auxiliary side connection (ASC) should be used, the ASC prevents TX valve operating issues as hot gas flows into the evaportor.
2. Evaporator inlet with no distributor, this configuration follows the same principles as above.
3. Directly into the suction line, this configuration can be employed when multiple evaporators are used. It should be noted that oil return to the compressor could be an issue due to refrigerant bypassing the evaporator coil.

v) Wet Compression

Wet compression is contrast of dry compression. If the refrigerant is found in both liquid and vapour form at this stage, it is called wet compression. Dry compression actually is talking about the refrigerant vapor have superheat during the compressor suction process, 5°C in general situation. Which is used to avoid no liquid in compression. If the refrigerant is purely in a vapour form, it is called dry compression.

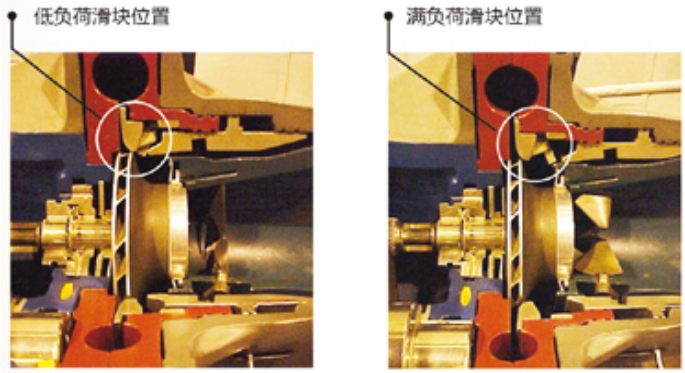
The major reason why liquid state is not allowed to exist in compression cycle is protecting chiller. hammer will be occurred after the compression. Compressor blade will shot liquid refrigerant at high speed to container, chiller components will be broken during long time hammer.

vi) Chocking

Chocking is happened in low load condition. Under light load condition, gas cannot enter condenser in normally, it will straight the vane wheel / impellor, the vibration become more serious.

Compressor performance will be depreciated under long term chocking, gas pressure and flow become more fluctuant. Bigger noise and vibration, pillow, vane, motor will easy to be broken. To avoid this, hot gas by pass is available but energy wasted.

麦克维尔独有专利设计散流滑块，在负荷变化时，专利技术——可移动的散流滑块以导叶位置定位，调节散流通道大小，提高离心压缩机的压力提升能力，从而使机组在10%-100%（双压缩机机组在5%-100%）之间无级调节平稳运行而不会发生“喘振”，不需采用耗能的热气旁通调节方式。当机组负荷降低时，导叶开启度逐渐下降，排气量减少，散流滑块逐渐往内侧移动，排气通道减小，提高排气速率以保证制冷剂的排气压力足以克服冷凝压力，正常排出避免发生喘振。当机组处于满负荷时，散流滑块完全打开，排气通道最大，气体以均匀的流速流出叶轮进入冷凝器。



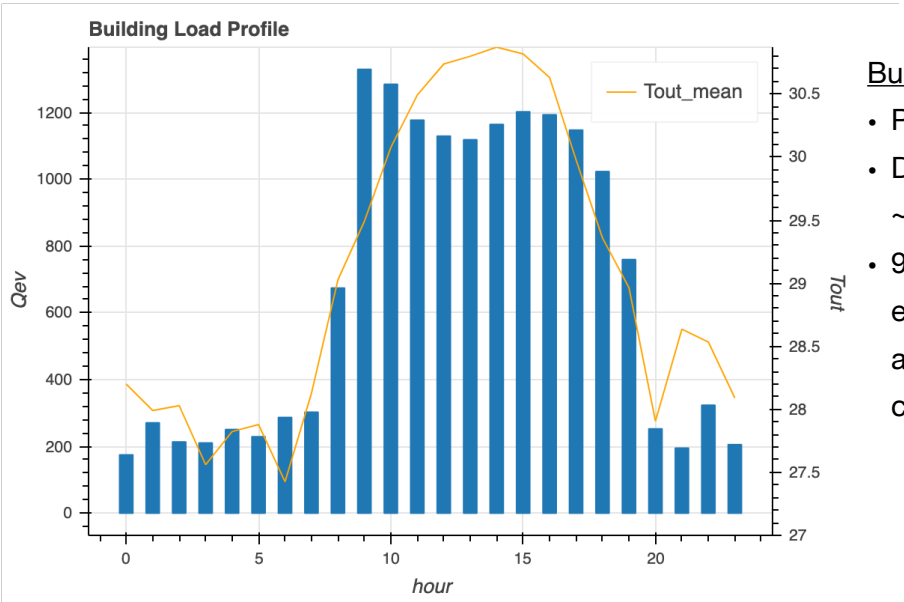
防喘振散流滑块设计

vii) Emergency Oil Supply

Oil is essential components on chiller operation. When event happened (oil pump fail, power interruption), 当意外发生时弹簧会随压力的变化自动回升，将油箱中的油压送到压缩机的各个运动部件润滑点，供油压力与油泵提供的油压相同，供高速运行之一切元件顺利停机。紧急供油：离心机的转速较高，当突然断电时，叶轮与电机由于惯性不会立即停止转动。如果此时供油不畅，可能会出现烧毁齿轮及轴承的情况。

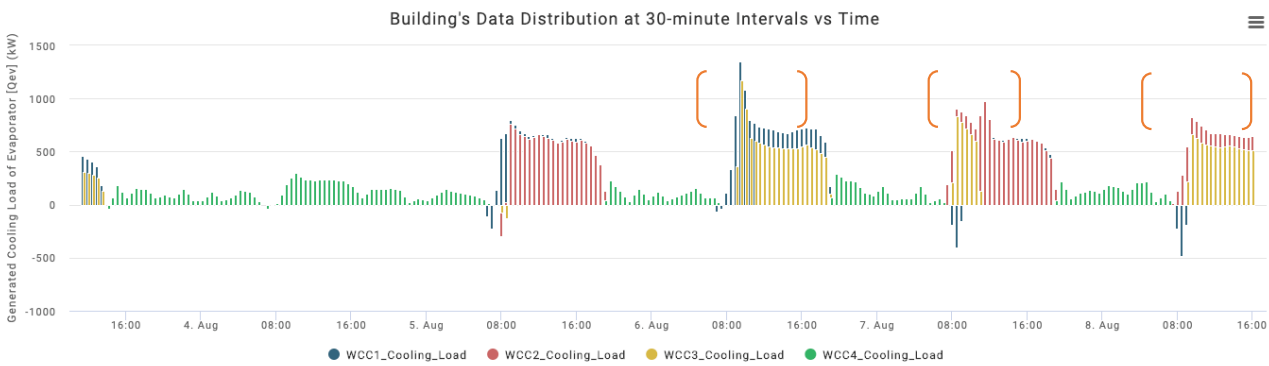
viii) Pre-Cooling

Pre-Cooling is an economic method to achieve energy saving. Peak Energy Demand, Thermal Comfort, COP Improvement. 1) kVA can be reduced through the proper adjustment on pre-cooling period, usually kVA is expensively charged by power company. Shifting the chiller on/off period following the peak/off-peak charge can help client to save energy. 2) Cooling Generation and System Performance can be improved, which means if you successfully implement pre-cooling features to your building, chilled water can be set higher but thermal comfort can maintain the equivalent impact as normal setting since the building fabric has been cooled and release cooling effect, an economic option for energy saving on chiller load and electricity consumption. During pre-cooling stage, PAU/AHU shall not do any air extraction / air exchange with outdoor to achieve faster building fabric pre-cooling and energy saved.



Building Load Profile

- Pre-cooling starting at 8 a.m.
- Daily cooling demand is ~1000 kW
- 9~10 a.m. has significant extra cooling since Tout still at lower level (29°C), which can be saved

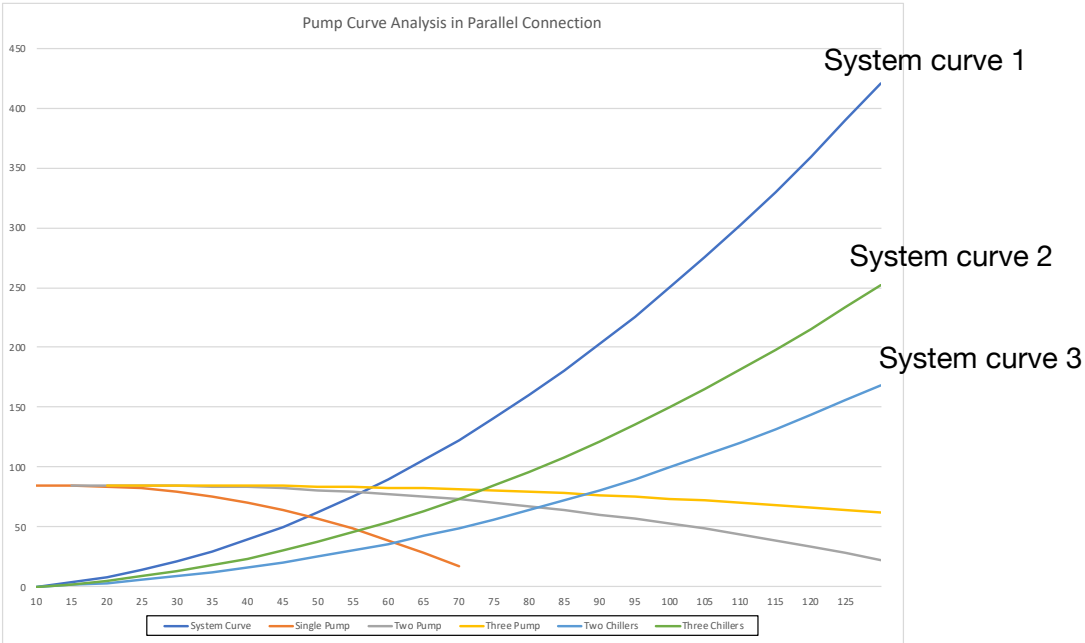


ix) Free-Cooling

Free-Cooling is another method to achieve energy saving. Free-Cooling take advantages of outdoor environment characteristics, usually applied in winter. The improvement can be reflected in IAQ, IEQ, Chiller Consumption, Energy Efficiency. Once the ambient temperature is lower than building load or indoor setpoint, then a free-cooling is achievable. AHU/PAU damper can set as 100% fully opened to achieve free-cooling through colder air supply.

x) Pump Curve and System Curve

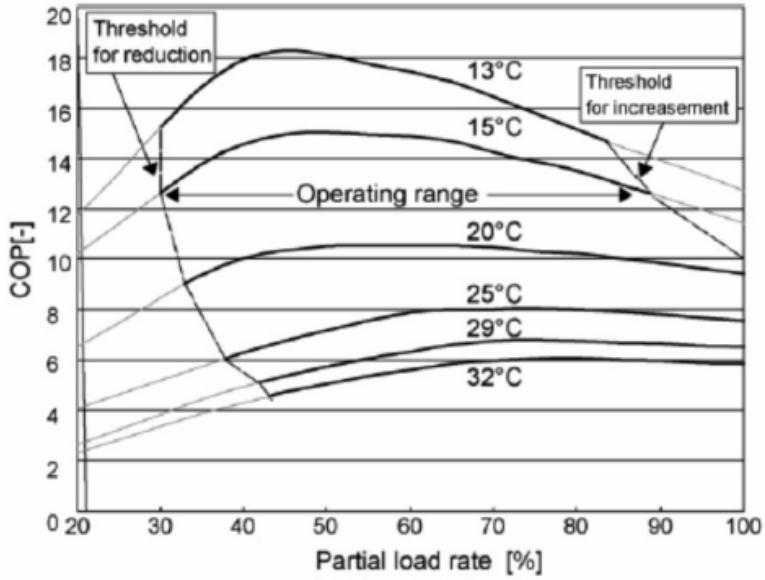
The Pump Curve is different with respect to different connection. Parallel and Series, Flow increment and Head increment respectively. When the system have by-pass pipe, the system curve shall be in a horizontal line because the Δp . Once the head pressure increased, the extra chilled-water will by-pass through by-pass pipe to maintain equivalent pressure. Once the head pressure dropped, the chilled water flow will be boosted to maintain head and flow to meet system demand.



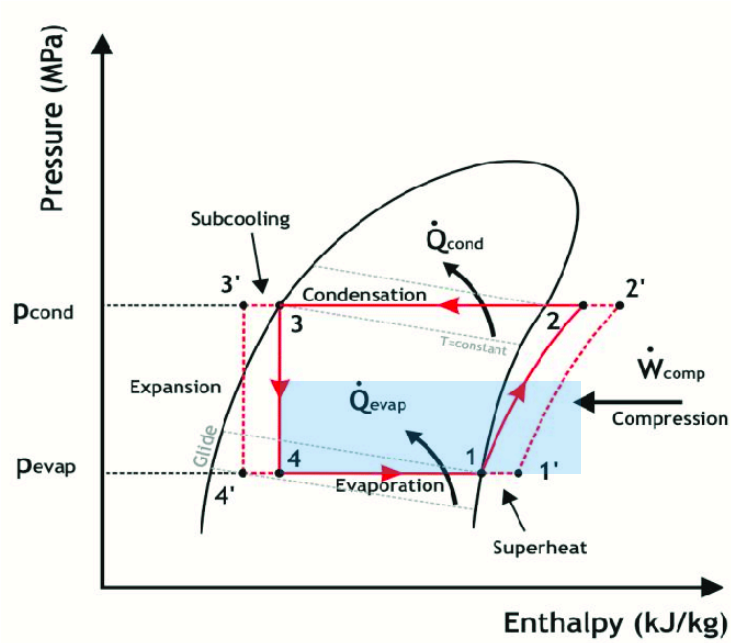
Once the system flow is increased or decreased, the system curve will be moved forward or backward depends on the system demand (operating terminal unit amounts). Chillers will not fully follow the curve operating even it is constant flow since the relation of pump curve is not related

xi) COP Larger than its nominal

There are many reason that why COP higher than its nominal, but one thing should be bear in mind: **Under what condition the chiller in operation now?** Chiller manufacturer usually based on summer condition (32°C/7°C) as reference to design the chiller components, so its performance shall not exceed its nominal in summer time. But it is possible to exceed under winter (lower condensing pressure and temperature).



The chiller have better performance under lower **lift** (The difference between condenser and evaporator). Here are the example to illustrate how chiller can have better COP in winter.



In winter, the condensing return temperature will decrease to 20°C, the chiller lift will decrease by 50% if setpoint doesn't changed

The refrigeration effect still maintain, which means power reduced but Qev keep at high cooling generation rate, chiller productivity increased

xii) Compressor Power Relationship

~ to be continued

xiii)

Data Science Knowledge Point

1. **ANALYTICS PROCESS**
2. **FUNDAMENTAL OF FORECASTING ALGORITHM**

The forecasting algorithm has two majors, time series based and causality based. Time series based algorithm such as smoothing, autoregressive, seasonal autoregressive. Causality based algorithm such as simple question by SVM , multi classification problem by decision tree, continuous problem by linear regression etc. When it is possible to model, it is not a model package to build the world, but a two-stage model. For example, to predict the consumption of a customer group, you can use a two-category model to predict whether it will consume, and then use a continuous model to predict the amount of consumption. In this way, the number of consuming users multiplies the predicted amount of consumption, you can get the total consumption. This is a typical approach.

Why forecasting is hard in all industry? Because: In order to highlight the effect of the model, the book deliberately selects a data set with good quality and complete data.

In reality, the troubles are far from constant:

1. No data. In many cases, the data to be predicted is just one line of "Monthly Total Consumption", and there is no other data…
2. Still no data. Many companies are separated from Tmall, Douyin, and Amazon, and cannot get first-hand data. They can only use a little data exported from the background to mess around…
3. There is no data. Most companies are not monopolistic companies such as Tou Teng A, and only take very one-sided data. The most common thing is that most of the company's users are attracted by spending money, and the user only has one mobile phone number + one preferential order.....

This leads to a funny situation: Many companies use causality models, and the most influential variable must be the intensity of promotion. Even if the stepwise regression method is used for modelling, the variable of promotion intensity can directly eliminate all other variables. The prediction result becomes: the greater the promotion, the more users join and the more purchases.

As soon as this result is thrown out, it must be evaluated by the business as: "It's all nonsense, I knew it!"

This is the second biggest problem in reality: how to measure business effects. For example, the predicted sales volume is 10 million. If the business reaches 9 million, it will say: the forecast is not accurate at all, and the backlog of goods has been created. If the business reaches 11 million, I will say: If the forecast is not accurate at all, I am still good. In short, as long as you

are not 100% accurate, he has reasons to rely on you. You can even jump horizontally repeatedly. For example: "Originally, if the business can meet the standard, we can save some investment when we see the forecast and say it can meet the standard. The result is not up to the standard. It is all because the forecast interferes with the business judgment..."

3. MACHINE LEARNING PROCESS

~ to be continued