GENERAL OVERVIEW – BREWERY REFRIGERATION FACT SHEET

Refrigeration for Brewing production facilities is mostly misunderstood, and the implementation often misguided. The systems are generally not tailored to the unique variances of the brewing process resulting in refrigeration designs based on limited engineered criteria.

The brewery size and production output will determine the type and complexity of the refrigeration system. The brewery operation is consistent regardless of the brewing capacity and the refrigeration principles remain the same.

Installed refrigeration systems are usually characterised by either of the following:

1. Poorly applied with undersized equipment incapable of incorporating peak demands
2. Conservative oversized equipment regulated with basic control functionality; Prone to short cycling with sluggish response to the system demands.

Refrigeration is an integral service for producing consistent beer quality. The operation of this equipment constitutes a significant percentage of the total site power consumption. A better understanding of the process requirements enables enhanced refrigeration systems. Best practice strategies incorporated into the refrigeration design, equipment selection, plant implementation and optimised functional controllability, reduce operating costs significantly.

REFRIGERATION SYSTEM ENERGY OPTIMISATION

1. Basic rule of refrigeration optimised design is an operating plantroom with the highest Coefficient of Performance (COP). Design COP (refrig kW / power kW) is targeted at the highest level.to achieve the highest refrigeration output for the least power input.
2. Efficient refrigeration systems operate at the lowest possible compression ratio (difference between the compressor suction low pressure and discharge high pressure) for the prevailing duty.
3. NH_3 based refrigeration systems are significantly more energy efficient but usually incur more capital cost at the low capacity range. An evaluation is required to establish an acceptable payback period. .
4. Multiple compressors or compressors with a large capacity turn down ratio is more effective to efficiently adapting to the wide duty demands of the brewing process.
5. Air cooled condensers are the most commonly used in packaged glycol chillers are the most inefficient. Condenser alternatives include:

    - Evaporative condensers
    - Water cooled condensers requiring cooling towers and associated water treatment equipment chemicals and service
    - Adiabatic evaporative air cooled condensers (hybrid air cooled) requiring no water treatment equipment chemicals and service and use significantly less water than water cooled systems

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6. Operating the secondary refrigerant to enable the cold liquor chiller to operate on a separate compressor at higher refrigerant suction pressures is a good power optimisation strategy. This means the cold liquor is directly chilled by the base primary refrigerant rather than by the secondary refrigerant. Requires dedicated compressor sets for each duty which tends to be more costly.
7. Variable speed drives utilised on the main plant equipment including compressors, glycol pumps, water pumps, condenser fans yields energy saving and provides accurate controllability. Electronic commuted (EC) fans operate more efficiently than standard fan motors and provide a variable speed capability.

    - Centrifugal type pumps and fans have a cube root power saving relationship to speed (speed / 2 = power / 8).
    - Compressors are positive displacement and have a proportional power saving (speed / 2 = power / 2).

8. Buffer storage tanks for secondary refrigerants (typically glycol or water) ease the peak demand impacts. This approach reduces the average refrigeration capacity and can reduce the equipment size. It also reduces the reactive nature of the plant to system loads by smoothing out the plant operation. This reduces the peak demand cost section of the regular power bill.
9. A central PLC controller is a key component to maintain plantroom reliability and consistently achieve reduced energy costs. The inclusion of a PLC provides a superior system functionality and dynamic capability.

SYSTEM DUTY MANAGEMENT

Brewery production have two (2) main impact loads that contribute to the refrigeration capacity requirements. These include the fermenter post fermentation tank chill back and the cold liquor brew cast out requirements for the wort cooler.

Excessive equipment operating concurrently will unnecessarily engage refrigeration capacity and use power. Production management is important for limiting the peak demands on the refrigeration plant and reducing the refrigeration capacity requirements at the design phase.

Establishing a mapped duty load schedule gives an estimate of the maximum refrigeration capacity required and provides an overview of the envisaged refrigeration plant operation.

SECONDARY REFRIGERANT RETICULATION

Refrigeration in the brewing process comprises a secondary refrigerant (glycol, ethanol) reticulated to field equipment. The secondary refrigerant is mechanically pumped in a closed loop reticulation from a common refrigeration chiller plant. The secondary refrigerant supply temperature is commonly maintained at not less than -5°C. The supply temperature is governed by the fermentation time and post fermentation chill back period.

Buffer Tank System Arrangements

The secondary refrigerant reticulation systems are either a single or dual circuit arrangement with the following:

Single Secondary Circuit

1. A single circuit system incorporating chiller, one pump, field equipment with no buffer tank will operate almost as an instantaneous duty demand system. This generally requires larger equipment capacity with a higher capacity turndown than the other options. These systems have little thermal or volume buffer.

The system is subject to larger peak load impacts, higher power cost and requires a good control system to achieve system stability. There is limited scope for the secondary supply pump control on field demand as the chiller which is in series requires a minimum flow to ensure viability.

2. A single circuit system as detailed above but with a secondary refrigerant buffer tank included will operate better than system 1. The system requires lower equipment capacity, has less impact of peak loads and with a good control system be less reactive. The single pump still means that the same flow rate that goes to the chiller also supplies the field equipment which has the same limitations of control and power optimisation.

The buffer tank can be arranged as a 'cold' supply temperature or a 'warm' return temperature. The 'warm' buffer tank is a technically sound system that provides a thermal storage that enables compressor capacity adaptability to the system duty. The limit is that it has no cold supply buffer in the event of chiller cycling which is accommodated with reasonable chiller capacity turn down.

The 'cold' buffer tank provides a better cold storage volume but with less thermal storage. This means they are less efficient and technically problematic with only one pump as the chiller is installed on the common return before the buffer tank.

Dual Secondary Circuit

1. A dual circuit system incorporating primary and secondary circuits is superior to the single circuit system. The primary circuit is dedicated to the chiller whilst a secondary circuit is dedicated to the field equipment. Each circuit has a separate pump which enables a thermal and volume buffer, enhanced potential energy saving and greater flow rate adaptability to the variable system duty demands.
2. The dual circuit arrangement can be arranged with one common buffer tank or a separate buffer tank connected to each circuit. A single common stratified temperature buffer tank is a cost effective approach. The single tank incorporates the two circuits with appropriately located pump connections to enable the tank to operate in two temperature sections. These sections can also be separated by an internal tank baffle for the system return and supply. Any circuit flow imbalance between primary and secondary circuits are accommodated by a weir type overflow over the baffle. This concept incorporates the benefits of the traditional 'hot' and 'cold' tank arrangement but with a more compact size at a reduced cost.

   An alternate two separate tank arrangement includes a 'hot' and 'cold' tank for the system return and supply respectively with an interconnect overflow line for circuit flow imbalance. This concept is a well proven method for larger buffer tank volumes with a circuit separation to utilise the pumps as required. The two separate tanks are advantageous for optimisation on both chiller capacity and field demand . The flow balance on the circuits is important as it is undesirable for the tank buffer to mix excessively and dilute the temperature effectiveness on either side.

Chiller System Control Optimisation

The following control options are for the secondary refrigerant chiller and reticulation:

1. The single circuit system with no buffer tank is limited as the demand for chiller capacity will drive the operation almost instantaneously. The supply or return temperature can be the control variable but the return is generally less volatile than the supply temperature. The single circuit means supply flow low limit limitations to ensure the chiller has a minimum flow rate. An automatic bypass relief valve is installed at the end of the line to maintain a minimum flow rate. This will generally result in a lower return temperature and less chiller capacity requirements albeit on an instantaneous demand basis.
2. The single circuit system with one 'warm' return buffer tank is less reactive than the system without a buffer tank. The tank smooths the immediate load impact on the chiller capacity. The chiller control remains with an automatic bypass relief valve to maintain a minimum flow rate but operates with greater stability and with less overall power consumption. These systems have a chiller with multiple compressors or superior capacity regulation to enable the chiller to run for longer periods efficiently without cycling.
3. The single circuit system with one 'cold' return buffer tank has less thermal storage and is more thermally reactive than the system with a 'warm' buffer tank. Whilst it provides some supply volume storage is not as energy efficient. The tank smooths the immediate load impact on the chiller capacity. The chiller control remains with an automatic bypass relief valve to maintain a minimum flow rate but operates with greater stability and with less overall power consumption. These systems have a chiller with multiple compressors or superior capacity regulation to enable the chiller to run for longer periods efficiently without cycling .
4. A dual circuit system incorporating a common buffer tank temperature zoned for a primary and secondary circuit is a better energy optimisation approach. The individual pump on each circuit offers better chiller minimum flow supply, greater pump optimisation and independent regulation for system power reduction to suit the prevailing system demands.
   As the demand reduces in the field, the secondary pump reduces speed to maintain the set pump discharge pressure. The chiller primary pump normally operates at a constant speed and the flow imbalance corrected by the interconnected balance line
5. A dual circuit system incorporating separate 'hot' and 'cold' buffer tanks with a dedicated primary and secondary circuit is generally a better energy optimisation approach particularly on larger systems. The individual pump on each circuit offers better chiller flow supply control and operational efficiency, greater pump optimisation and independent regulation for system power reduction to suit the prevailing system demands. The secondary field pump and the chiller primary pump operates under the same control as the dual circuit common buffer tank system.
6. A variation for the dual circuit system with separate buffer tanks is a combined buffer tank floating level control. This allows the level on each tank to float up and down independently corresponding to the system and chiller requirements. The basis is that the tank level will vary on each side in an opposing manner on any cyclic stage. The instrumentation and control requirements and cost are higher and is better suited to larger systems.

Field Equipment Installation

The following control options are for controls of the brewery field equipment:

1. The fermenter tanks and bright beer tanks are generally jacketed for the coolant medium to be connected. The fermentation heat generated varies over the fermentation period and thus the vessels often have three (3) separate jacketed coolant sections to suit the demands. For example, the three (3) sections are used in chill back mode and peak fermentation phase, Two (2) sections are commonly used over low heat generation stages of the fermentation process and one (1) section when in a temperature maintenance/holding mode.
   The following control valves are equipped to the tanks:
   - 2-way solenoid valve per jacketed section energised open as required. The typical electrical servo operated diaphragm valve is more likely to wire draw the valve seat in these applications. This issue will not allow the valve to fully close shut and leakage occurs. A pneumatic actuated solenoid valve is preferred to avoid this issue.
   - Manual adjusted balance valve installed per tank as a minimum or installed per jacket if possible. Balance valves installed on each equipment item enables the system reticulation with a hydronic balance to be undertaken. The result is an even distribution to equipment extended to the end of the reticulation supply.
2. Heat exchangers for specific applications such as cold liquor chillers, pasteurisers and DAL chillers are equipped with the following control valves:
   - 2-way modulating control valve regulating the cooling duty of the process flow stream as required. A pneumatic actuated control valve is a preferred option. A 2-way valve throughout enables regulation of the secondary main supply pump to suit the prevailing flow requirements. When more demand is required, the field valves will open which reduces the discharge pump pressure. On falling pump pressure, the pump speed will increase to increase flow.
   - Manual adjusted balance valves installed as per the tanks allow a hydronic balance to ensure system flow distribution.
3. Systems that have no VSD installed on the supply pump, a 2-way modulating control valve is installed at the end of the field common pipe runs. The valve will operate to regulate a differential pressure measured between the common supply and return line to open on an increasing pressure differential.

COLD LIQUOR SYSTEM DESIGN

The cold liquor is produced to batch transfer for the wort cooling requirements on a regular brew cycle basis throughout the day's production. The cold liquor is accumulated in a cold liquor storage tank and maintained at a storage temperature down to 3°C. Conventionally, the wort is cooled from up to 98°C to 10°C in a single stage. The resultant warm liquor is then transferred to a warm liquor storage tank for use in the fermentation process.

The transferred cold liquor is not recirculated back to the cold liquor storage tank and ambient make up water is required to maintain a sufficient tank level to sustain the day's production. The ambient make up is chilled through a cold liquor chiller by the common secondary refrigerant reticulation. Depending on the common secondary refrigerant temperature an a-temperate higher temperature secondary refrigerant is required to avoid internal freeze up the heat exchanger.

Single Stage Wort Cooling

Single stage wort cooling systems are the most commonly used but design often have room for improvements. The cold liquor chiller represents a high impact load on the plantroom chiller capacity.

Reducing this impact and the associated high run costs is achieved by spreading the duty over an extended period,

The key for energy optimisation is an ambient make up rate as low as practicable. The following are the important criteria for reducing refrigeration capacity and efficiency benefits:

1. Generous cold liquor tank volume
2. Mapping cold liquor transfer rates, wort cooling times and batch frequency with the tank volume governs the minimum ambient make up flow rate
3. Minimum ambient water make up flow rate means reduced refrigeration capacity requirements
4. Ambient make up continuing until cold liquor tank upper level is reached including during cold liquor transfer for wort cooling
5. System designed for ambient make up phase and tank temperature maintenance phase. The selection of the cold liquor chiller and the installation arrangement is important for equipment effectiveness in both modes.

2 Stage Wort Cooling

A 2-stage wort cooling process can be adopted were the initial stage is done by ambient water that transfers to the warm liquor storage tank and the final stage by a conventional chilled water circuit. The advantages of 2-stage wort cooling include the following:

1. Refrigeration duty is reduced by sharing the duty with the stage 1 ambient water
2. Flowrate of the ambient water can be independently regulated from the chilled water flow rate. Waste due to excessive warm liquor production and auxiliary heating requirements are reduced.
3. Chilled water is a closed loop circuit and has no hygienic quality requirements.

REFRIGERANT OPTIONS

The refrigeration industry is currently subject to a Government regulated refrigerant phase out scheduled over the next 7 years. The choice of refrigerants has become a complex question with a variety of options available. Similar to the replacement process of high Ozone Depleting Potential (ODP) HCFC refrigerants R12 and R22 in the 1980s, various commonly used HFC refrigerants such as R404A, R410A and R134A with high global warming potential (GWP) ratings are now being phased out.

The refrigerant phase out is achieved by government regulatory authorities setting progressively decreasing supply quotas to increase the price significantly over time.

Transitional refrigerant drop in options are offered but future trends are towards natural refrigerants such as ammonia, CO_2, propane and hydrofluoro-olefins (HFO) due to their environmentally zero impact rating.

In large facilities, ammonia systems are still the most efficient and economically viable refrigerant option. The safety issues are well addressed and AS compliance requirements documented. The refrigerant charge levels are reduced on new installations and servicing support is widely available.

For small and medium sized facilities, the development of low charge NH_3 glycol chillers are providing an option for traditional chillers. The use of HFC chillers will continue for some time but changes are inevitable. The smaller range of chillers will tend to be supplied charged with hydrofluoro-olefins (HFO) refrigerant.

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