Improving Winery Refrigeration Efficiency

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1 INTRODUCTION

Temperature control is a critical parameter in quality wine production. Cooling provided by refrigeration is a particularly important operation in Australian wineries, given the warm climates found in many regions.

Refrigeration is typically the largest consumer of electricity in Australian wineries, accounting for 50%–70% of total electricity usage. Electricity costs will inevitably rise with time, particularly with the introduction of schemes to manage greenhouse gas emissions. Improving the efficiency of winery refrigeration is therefore of considerable interest. The Grape and Wine Research and Development Corporation (GWRDC) funded a project by Commercial Services at The Australian Wine Research Institute (AWRI) to help the wine industry improve refrigeration efficiency and decrease electricity usage and/or costs.

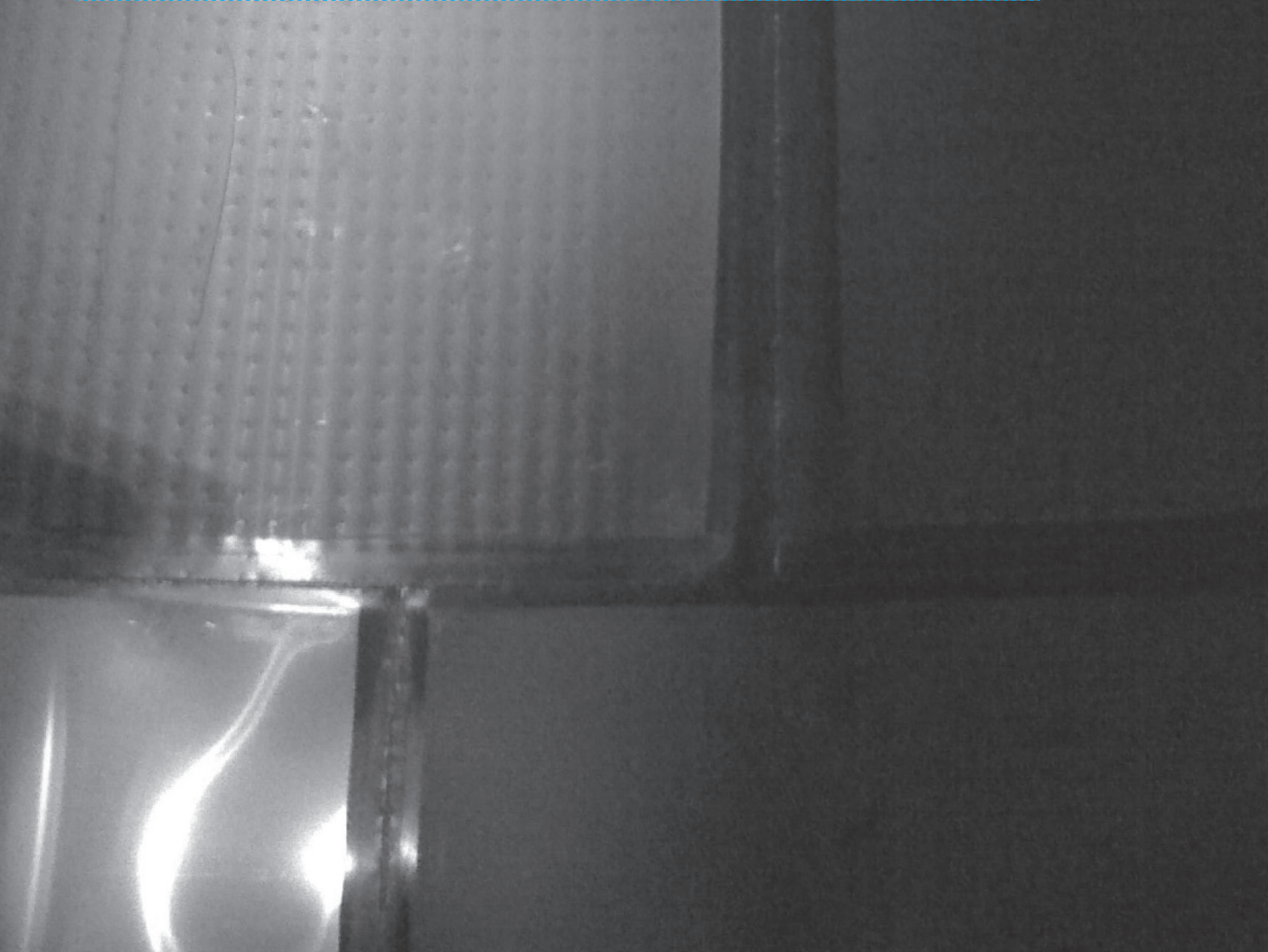
This reference guide provides a brief overview of winery refrigeration and potential improvement opportunities. Case studies investigating some of these opportunities in more detail have been performed and these are available for download from the AWRI and GWRDC websites. Excerpts from some of these studies are included in this guide.

2 WINERY COOLING USES

Key uses of refrigeration in Australian wineries are presented in Table 1, together with a brief description of their main purpose.

Table 1. Key uses of refrigeration in Australian wineries

Process	Purpose
Must cooling	Limits phenolic oxidation and premature fermentation
Juice clarification	Aids settling of juice solids
Fermentation	Controls fermentation rate
Cold stabilisation	Removes tartrate crystals to prevent precipitation after bottling
Wine storage	Limits the rate of oxidative browning and volatilisation of aroma compounds
Space cooling	Cools offices, wine or barrel storage areas



3 WINERY REFRIGERATION SYSTEMS

3.1 THE REFRIGERATION CYCLE

Refrigeration is the process of moving heat from a location where it is undesirable to another location. Winery refrigeration systems typically employ a vapour-compression cycle to achieve this, as illustrated in Figure 1. The heat is transferred from the juice, wine or brine to the evaporating refrigerant at the evaporator and the heat is rejected to air and/or water as the refrigerant condenses in the condenser.

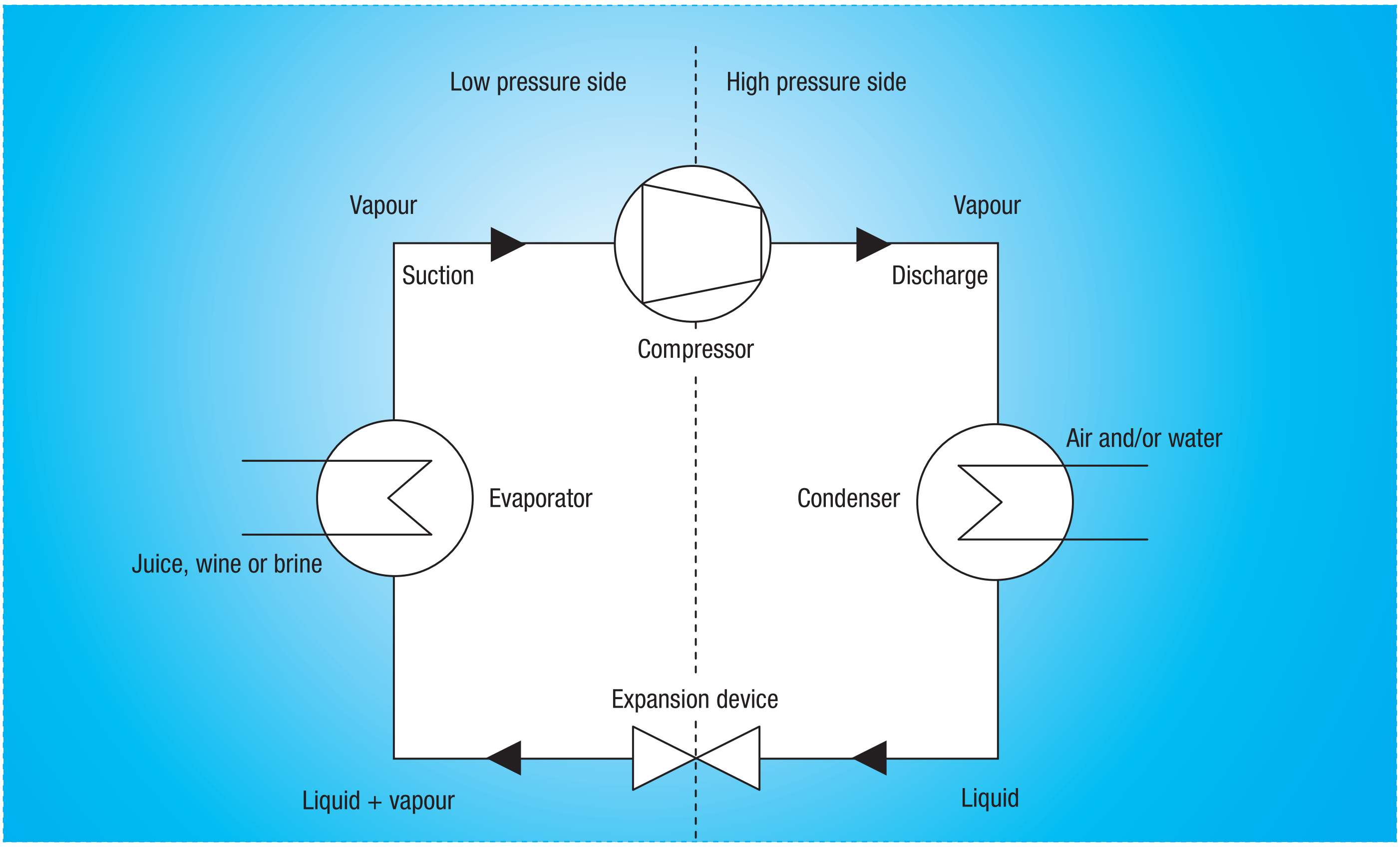


Figure 1. Simplified single-stage vapour-compression refrigeration cycle

3.2 BRINE RETICULATION SYSTEMS

In wineries, wine or juice may be heat exchanged directly with the evaporating refrigerant in which case the heat exchange operation is described as 'direct expansion'. Alternatively, a secondary coolant ('brine') may be heat exchanged with the evaporating refrigerant and then distributed around the winery to be used to cool juice or wine.

Brine systems are commonly used in Australian wineries. They are generally simpler and more flexible than systems that employ direct expansion. They also provide some stored cooling.

Brine is water with a freezing-point suppressant added. Proprietary freezing-point suppressant mixtures are commonly used. The active ingredients in the most common commercial product are ethanol and propylene glycol. The inclusion of propylene glycol means that sufficient freezing-point suppression can be provided without the brine containing so much ethanol (>24%) that the brine is classified as a class 3 flammable liquid. Corrosion inhibitors and colorants/tracer chemicals used to facilitate leak detection are also commonly included.

A simplified brine reticulation system is illustrated in Figure 2.

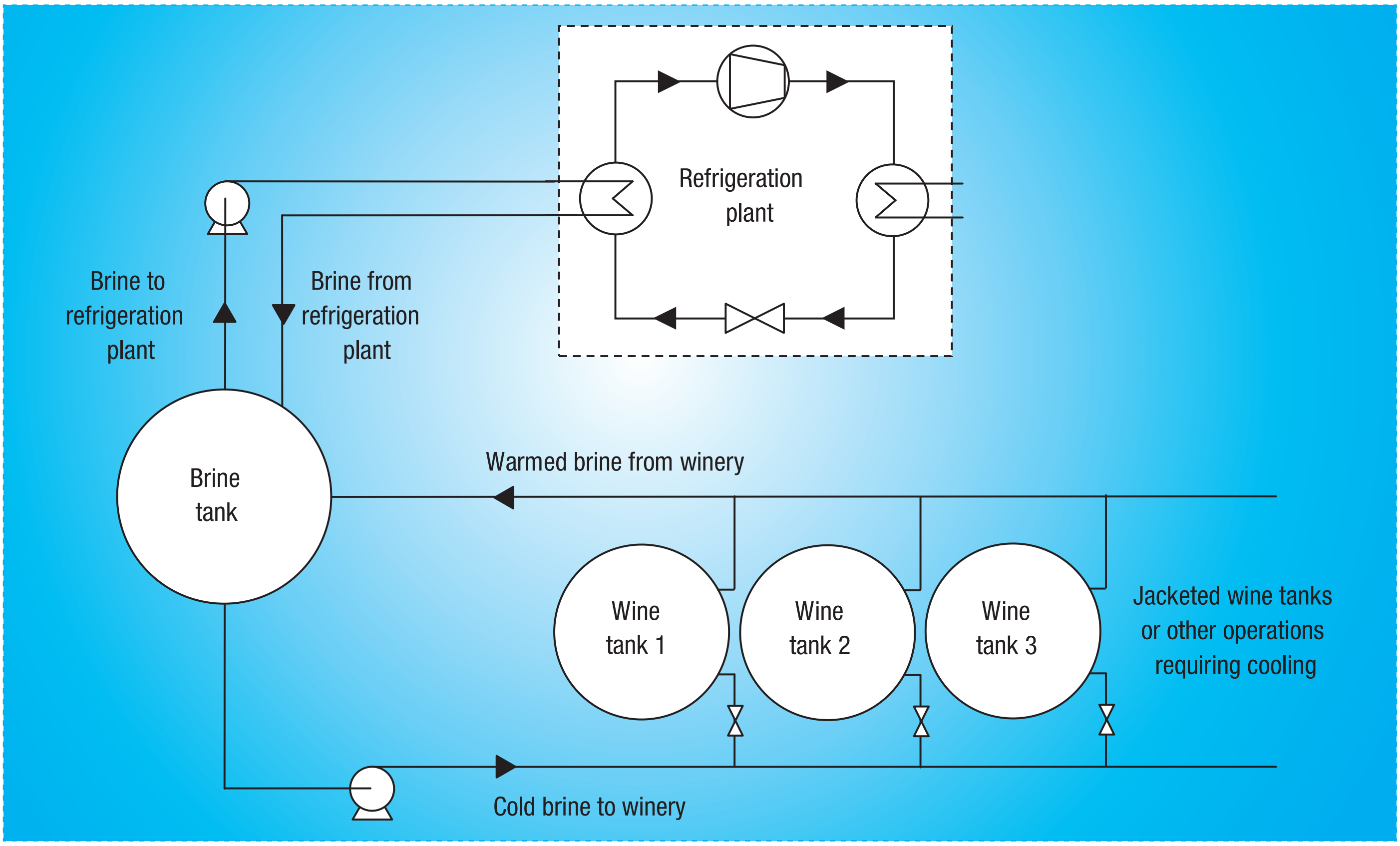


Figure 2. Simplified brine reticulation system

3.3 REFRIGERATION SYSTEMS USED IN DIFFERENT SIZED WINERIES

While refrigeration systems vary depending on the winery and supplier, some generalisations may be made.

Smaller wineries will tend to use packaged chillers in which all components of the refrigeration plant are integrated in one unit, while larger wineries typically have customised refrigeration plants. With a packaged chiller, a brine reticulation system is used, whereas some direct expansion cooling may be incorporated with customised refrigeration plants. Ammonia is typically employed as the refrigerant in larger refrigeration plants, but packaged chillers tend to use hydrofluorocarbon (HFC) refrigerants.

Packaged chillers typically have air-cooled condensers where refrigerant, contained in small diameter condenser tubes, is cooled by fans. Water-cooled condensers where refrigerant is heat exchanged with water may also be used. In that instance, water may subsequently be passed through a cooling tower before reuse. Evaporative condensers are generally used in large refrigeration plants. These are essentially a combination of a condenser and a cooling tower in one device; water passes over tubes containing the refrigerant and fans drive away the evaporating water. Evaporative condensers more readily condense refrigerant than air-cooled condensers, reducing the amount of compression that the compressor should need to perform

3.4 REFRIGERATION EFFICIENCY

The efficiency of a refrigeration plant is described by its coefficient of performance (COP). The COP is the ratio of the cooling power provided at the evaporator to the electrical power input to drive the compressor (electrical power input to drive auxiliaries like condenser fans and pumps is sometimes also included).

COP = Cooling Power (kW) / Electrical Power Input (kW)

In contrast with non-refrigeration measurements of efficiency, COP can be and generally is higher than 100% or 1. This is possible because the electrical power input is not directly converted to cooling, but rather it is being used to pump heat from one location to another.

COP is highly dependent on both equipment design and operating conditions. When assessing the capacity and COP of a refrigeration plant, it is critical that data is at conditions relevant to winery operation. In particular, COP varies considerably with compressor suction and discharge pressures and depending on whether the plant is being run at part load. A major market for packaged chillers is commercial building air-conditioning systems. The operating conditions in that environment are very different to those at a winery where lower brine temperatures (e.g. –7 °C as opposed to +5 °C) and therefore lower suction pressures are typically employed. Figure 3 presents the COP for one packaged chiller at a range of brine and ambient temperatures.

Refrigeration plant COP and capacity data reported by manufacturers will not include the heat gains and pumping electricity requirements associated with the brine system.

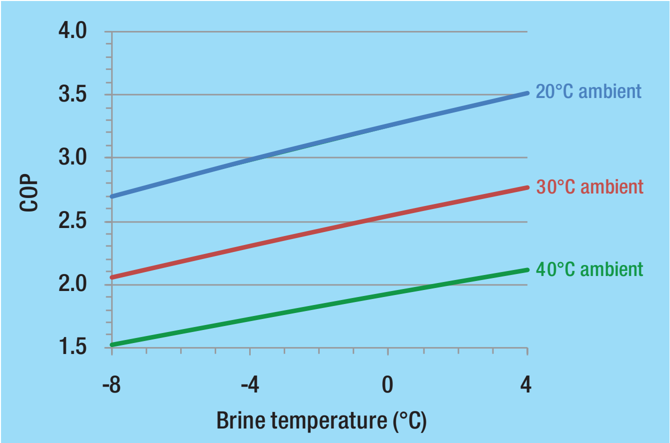


Figure 3. Influence of brine and ambient temperatures on COP for one packaged chiller operating at maximum capacity

ENERGY AND POWER

Energy and power are frequently confused with each other. Energy exists in a variety of forms, including heat (cold is negative heat) and electricity. The Joule (J) is the metric unit of energy. Power is the rate at which energy is generated or consumed. The metric unit of power is the Watt (W), which is equivalent to 1 Joule/second (J/s). 1 J and 1 W are small amounts and therefore units of kJ and kW are often used in practice. 1 kJ = 1000 J, 1 kW = 1000 W = 1000 J/s.

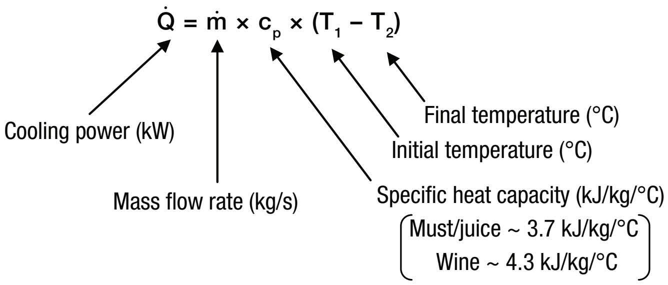
Electricity is billed in part on the basis of the quantity of kilowatt-hours (kWh) used. This is a measure of energy use not power. It is the rate of energy consumption (kW) multiplied by the time of that consumption (h). 1 kWh = 3,600 kJ.

3.5 COOLING REQUIREMENTS

The design of a winery cooling system should be performed on a case by case basis by an appropriately qualified supplier/refrigeration engineer.

To assist in discussions with suppliers/engineers, wineries should start by developing a list of the operations requiring cooling (must chilling, juice chilling, fermentation, wine storage, cold stabilisation, etc.). This list should include information on these operations likely to influence cooling requirements (volumes, flow rates, product and ambient temperatures, cooling rates, fermentation rates, etc.) and the timing of these operations throughout the year – the overlap of different operations will be critical in understanding the total cooling requirements.

Peak cooling requirements typically occur during vintage. The key operations responsible for this demand are removing heat generated by the fermentation reaction, and chilling must and juice. The fermentation reaction releases approximately 10 kJ/L/°Baumé. Cooling requirements associated with must and juice chilling can be estimated using the following fundamental equation:



As an example, let us consider a winery that has peak refrigeration requirements occurring when the winery is simultaneously fermenting 50,000 L at a rate of 2 °Bé/day (0.000023 °Bé/s), must chilling 5,000 kg/h (1.4 kg/s) from 20 °C to 10 °C, and cooling 10,000 L (11,000 kg) of white juice at a rate of 2 °C/h (0.00056 °C/s) in order to settle juice solids.

The principal cooling requirements associated with each operation are:

Fermentation
50,000 L × 10 kJ/L/°Bé × 0.000023 °Bé/s = 11.5 kW.

Must chilling
1.4 kg/s × 3.7 kJ/kg/°C × 10 °C = 51.8 kW.

Juice chilling
11,000 kg × 3.7 kJ/kg/°C × 0.00056 °C/s = 22.8 kW

This gives a total of 86.1 kW. Once other heat loads such as warming of juice/wine from ambient conditions are factored in, the total heat load will be somewhat higher, perhaps 110 kW. Furthermore, there will also be heat gains associated with the brine reticulation system. The refrigerant plant may therefore need to have a cooling capacity of 130 kW to meet those process cooling requirements.

It is stressed that these methods provide order of magnitude estimates only and should not be relied upon for system design. However, methods of this nature might be useful in understanding/cross-checking recommendations from suppliers. Appropriate safety margins should always be employed in calculations and refrigeration plants should be designed/selected to operate efficiently throughout the year, not just at peak requirements.

3.6 ENVIRONMENTAL ISSUES

Refrigeration contributes to global warming principally through the use of electricity, which has predominantly been generated by coal-fired power stations. Some refrigerants are greenhouse gases themselves so fugitive emissions can also contribute to global warming.

Fugitive emissions of some refrigerants can also deplete the ozone layer and this was the driver in phasing out particular groups of refrigerants. Chlorofluorocarbons (CFCs) were phased out in 1995 and hydrochlorofluorocarbons (HCFCs) will be phased out by 2020 in accordance with the Montreal Protocol on Substances that Deplete the Ozone Layer (Department of Sustainability, Environment, Water, Population and Communities 2010).

The ozone depleting and global warming potentials of several refrigerants, representing each of the key refrigerant groups, are presented in Table 2.

Notably, ammonia, which is a common refrigerant in larger wineries, has both low ozone depleting and global warming potentials. HFCs like R134a that are typically used in newer packaged chillers, instead of R12 or R22, while having no ozone depleting potential, still have considerable global warming potentials. As of 1st July 2012, a levy is collected on some synthetic refrigerants at the point of manufacture/import at a rate equivalent to the carbon price. Given their high global warming potentials, this has resulted in large price increases on those refrigerants.

Table 2. Environmental impacts of refrigerants

ASHRAE[a] number	Name (Group)	ODP[b]	GWP_{100}[c]
R717	Ammonia	0	< 1
R12	Dichlorodifluoromethane (CFC)	1	10,900
R22	Chlorodifluoromethane (HCFC)	0.055	1,810
R134a	1,1,1,2-Tetrafluoroethane (HFC)	0	1,430
R290	Propane (HC)	0	20
R744	Carbon dioxide	0	1

[a]American Society of Heating, Refrigerating and Air-Conditioning Engineers.
[b]Ozone Depleting Potential: Index of a substance's ability to deplete stratospheric ozone.
[c]Global Warming Potential: Index of a substance's ability to contribute to global warming.
Environmental impacts from ASHRAE (2009).

4 IMPROVEMENT OPPORTUNITIES

Refrigeration-related improvement opportunities for wineries are outlined in this section. These opportunities are grouped broadly into two categories; low-cost and higher-cost improvement opportunities. Low cost opportunities are generally associated with changes in operating practices, while higher cost improvement opportunities often involve more significant refrigeration plant/winery modifications.

At the time of writing, there are grants available as part of the Australian Government's Clean Technology Food and Foundries Investment Program ($200 million total) for capital investment and associated activities that generate carbon and energy savings. Depending on company and project size, grants may be provided to fund up to 50% of project cost. Projects related to implementing many of the improvement opportunities outlined in this reference guide may be applicable. Please refer to the AusIndustry website (www.ausindustry.gov.au) for specific details on the program.

4.1 LOW COST IMPROVEMENT OPPORTUNITIES

4.1.1 Turning off the refrigeration plant when not in use

It can be advantageous to turn the refrigeration plant off, or to change the temperature settings so that it runs infrequently, when cooling is not going to be required for a significant period of time. Specific procedures for plant shut-down and start-up should be obtained from the refrigeration equipment supplier. The compressor oil heaters may need to be kept on or at least energised for a significant period prior to start-up in order to prevent excessive absorption of the refrigerant in the lubricating oil and possible damage to the compressor on start-up.

In turning refrigeration plants with a brine system off or running them infrequently, evaporation of freezing-point suppressants like ethanol also needs to be managed. Evaporation rate will be higher at higher temperatures. A pure ethanol solution would evaporate significantly around 13 ˚C. A brine solution may typically contain only 20% ethanol with the remainder principally being water, and some propylene glycol, which are likely to retard the evaporation of ethanol. While it is not entirely clear at what temperature there will be significant ethanol evaporation it would seem prudent to try and maintain ethanol based brines at a maximum of around 10 ˚C to limit evaporation.

PLANT SHUT-DOWN EXAMPLE

Cooling was not required at one small winery for approximately 4 months each year. The winery's packaged chiller had usually been left on during this period. One year, the chiller was switched off during this period, reducing annual winery electricity consumption by approximately 20%.

4.1.2 Temperature rationalisation

Temperature requirements should be discussed and objective protocols put in place for both winemaking and other site operations.

In winemaking operations, a balance often needs to be struck between the perceived risk of warmer temperatures and the cost of electricity to provide that cooling. This balance will vary for different styles and values of product. A method for wineries quickly to estimate potential savings from storing wine at warmer temperatures is provided in the box below so that wineries can make a judgement for their own products.

For general site operations low temperatures should not be used unless there is a sound reason for doing so. As an example, dry goods that do not need to be stored cold should not be stored in a refrigerated product warehouse. There is

WARMER WINE STORAGE

The approximate saving in refrigeration electricity costs from maintaining wine at a temperature of T_{High} (e.g. 10 °C) instead of T_{Low} (e.g. 5 °C) in a wine tank of diameter D (e.g. 3.3 m) and height L (e.g. 7.3 m) with aluminium clad 75 mm thick polystyrene insulation can be estimated using the equation:

$$\text{Saving (\$/kL/week)} = 0.006 \times \left(\frac{1}{L} + \frac{4}{D}\right) \times (T_{High} - T_{Low})$$

Assumptions: Unit electricity cost = $0.15/kWh, COP_{+brine} = 2 (A modified COP for estimation purposes that incorporates brine reticulation loop heat gains and pumping requirements), overall heat transfer coefficient = 0.47 W/m²/°C, and T_{High} is lower than the average ambient temperature.

both an energy requirement to cool these materials down and also likely increased heat gains to the warehouse from the outside environment associated with increased traffic to access the dry goods.

4.1.3 Night-time grape harvesting

Diurnal variations in grape temperature should be taken advantage of to minimise must cooling requirements. Grapes on the vine not exposed to sun closely follow the ambient temperature. If grapes are harvested at night when it is cool, there is reduced heat energy in the grapes, which otherwise may have needed to be removed by refrigeration at the winery.

4.1.4 Night-time cooling

Off-peak night-time electricity is often considerably cheaper than peak electricity. There is therefore advantage in shifting load from peak to off-peak tariffs by cooling wine at night rather than during the day. Wine stored in insulated tanks may be able to be maintained within an acceptable temperature range by night-time cooling alone.

If control systems are in place that allow the refrigeration plant compressor discharge (head) pressure to reduce (i.e. float) appropriately when the ambient temperature is lower, the refrigeration plant COP will also increase, yielding additional savings.

Night-time cooling is one of the most attractive in-winery refrigeration-related improvement opportunities as there is little risk to product quality. The wine is still being stored at essentially the same temperature, it is just that the electricity is being purchased on a less expensive tariff.

4.1.5 Brine temperature

When warmer brine temperatures are used, higher refrigeration plant compressor suction pressures can often be employed, resulting in considerable improvements in refrigeration plant COP.

Low brine temperatures (e.g. -5 to -10 °C) are often used year round in wineries. This is partly related to achieving reasonably fast product cooling rates using only tank jackets for heat exchange.

For operations where the process temperature is relatively high (e.g. fermentation, bulk wine storage) acceptable cooling rates can often still be achieved using much warmer brine, while still using only tank jackets for heat exchange. For operations that are performed at low temperatures (traditional cold stabilisation and to a lesser extent must chilling and juice cold settling) sub-zero brine temperatures are still required to ensure that there is sufficient temperature differential between the brine and juice/wine to provide a reasonable rate of cooling.

The required brine temperature is dictated by the lowest temperature operation on the brine reticulation loop. Scheduling is one tool that can be used to minimise the amount of time that that very low brine temperatures have to be used. For example, all cold stabilisation operations could be scheduled to occur in specific periods in the year instead of intermittently throughout the year. Another option is to find alternatives to those operations requiring low brine temperatures. Crystallisation inhibitors (e.g. carboxymethylcellulose, mannoproteins), electrodialysis, or packaged rapid contact systems (some refrigeration will still be required but this would usually be supplied by a dedicated refrigeration system) are alternative options available for cold stabilisation. Flotation systems can be used for juice clarification. Must chilling requirements may be reduced by night-time harvesting.

Even very small changes in refrigerant suction pressure can result in considerable improvements in COP. Therefore it is generally advisable to use as high brine temperatures as practicable for as much of the time as possible. It must be cautioned that COP improvements will only be realised if the control systems in place actually increase the suction pressure when warmer brine is used.

WARMER BRINE EXAMPLE

In a trial performed at one winery, red wine fermentations were adequately controlled using +4 °C brine circulated through the existing tank jackets. The cooling rate was reportedly slower than that achieved by the winery in previous vintages using sub-zero brine temperatures. Measurements reported on the winery's packaged chiller display screen confirmed that its control system did increase the suction pressure when the warmer brine was used.

4.1.6 Brine concentration

The freezing-point suppressant should be maintained at a concentration such that the brine would freeze at a temperature 5 ˚C below the lowest operating temperature (White et al.1989). Excessive concentrations should not be used as apart from being quite expensive, they will result in diminished heat transfer properties and increased pumping costs.

4.1.7 Brine pumping between the chiller and the brine tank

The pump moving brine through the chiller should not generally be running constantly as this is unnecessarily wasting electricity and may be preventing desirable stratification in the brine tank between cold brine at the bottom and the warm brine returning from the winery at the top.

Packaged chillers usually come with a built-in temperature probe at the brine inlet to the evaporator. Anecdotally, to avoid using a separate brine tank temperature measurement, the pump between the chiller and brine tank is sometime set to run permanently, such that this measurement is representative of the temperature in the brine tank. Operation of the chiller and this pump based on a temperature probe in the brine tank negates the need to run the pump continuously. It should be noted that with intermittent operation of this pump, the pump will have to be run for a period before the chiller compressor starts and for a period after it stops in addition to just when the compressor is running, to prevent the evaporator from freezing.

4.1.8 Brine reticulation around the winery

Brine should not be circulated to areas in the winery or through vessels where it is not needed as this can result in increased pumping requirements and ambient heat gains. Brine pumping contributes to overall refrigeration electricity usage. The control system should therefore ensure that brine reticulation pumps adapt appropriately to winery brine requirements and do not run unnecessarily at full speed when there is already appropriate brine pressure in the system.

4.1.9 Cooling with external heat exchangers

Tank jackets are widely used for winery cooling but they do not remove heat as efficiently as an external heat exchanger. Tank agitation does improve heat transfer to some extent. An advantage of tank jackets is that they are typically automated – generally someone just sets a temperature for the tank on a control system and that is it.

External heat exchangers can be very useful in some situations in providing more rapid cooling. Plate heat exchangers are considerably more effective at exchanging heat than tube-in-tube heat exchangers, however, they have small channels and therefore have higher pressure drops and are susceptible to blockages if solids are present.

EXTERNAL HEAT EXCHANGER EXAMPLE

In a winery trial, a small dimpled tube-in-tube heat exchanger was used to cool red ferments during pump-overs. The winery found this heat exchanger particularly useful for cooling 1-2 tonne ferments that had in previous years been cooled using cooling coils, which the winery had always found to be very ineffective.

4.1.10 Product heat exchange

Product heat exchange is a means of recovering useful energy. Pre-cooling wine for cold-stabilisation with wine finishing cold stabilisation using a plate heat exchanger is one example. If product heat exchange is not performed, the wine finishing cold stabilisation will gradually warm up possibly wasting the cooling that was originally imparted (whether or not it is truly wasted depends on whether or not the wine's lower temperature saves on refrigerated cooling later in that wine's lifetime). Product heat exchange does often involve increased planning. In the pre-cooling for cold stabilisation example, one wine must be ready to enter cold stabilisation at the same time as another wine has finished cold stabilisation.

4.1.11 Maintenance

Equipment should be properly maintained to ensure efficient operation. Condensers should be kept clean to maintain their effectiveness and bulky equipment like grape bins should not be left in a position where they can obstruct condenser air flow.

Depending on the style of refrigeration plant, and particularly where regular service arrangements are not in place, it may be worthwhile keeping a log of key operational parameters so that problems that will require a service call can be identified early (e.g. refrigerant leaks).

Before engaging a service technician it is worthwhile verifying that they have a good understanding of the operation of winery refrigeration systems (including equipment peripheral to the refrigeration plant itself, such as winery brine systems and control strategies) so that they can provide useful advice and guidance while on site. They may not be able to provide this support if their principal interest is the maintenance of building air conditioning systems.

4.1.12 Electricity bills

Wineries should closely inspect their electricity bill and understand exactly how their electricity usage is charged. From this they can objectively work to minimise their bill. For example, if there is a large differential between peak and off-peak electricity prices it is worthwhile working to shift peak electricity use to off-peak periods.

Pricing available through different electricity providers should be investigated/negotiated. Paying less for the same amount of electricity is much easier than making changes in the winery to reduce electricity use.

4.1.13 Auditing

A site audit/review of winery cooling, refrigeration use and control strategies can help identify and prioritise site specific improvement opportunities. Temporary power meters can sometimes be a useful tool to understand electricity use.

4.1.14 Reference charts

Reference wall charts that provide staff with quick information on key settings (brine temperatures, wine storage temperatures, agitator settings, etc.) can be useful. They can assist in standardising operations at best practice. At many wineries different practices are used by different staff for the same product.

4.1.15 Training

Staff should be trained on the basic practical aspects of winery refrigeration and cooling. An understanding of the key operating and cost principles will allow staff to make informed production decisions that minimise refrigeration costs and ensure product quality during busy production periods where decisions need to be made on the run.

4.2 HIGHER COST IMPROVEMENT OPPORTUNITIES

4.2.1 Process control

There are many process control efficiency opportunities both for the refrigeration plant itself and how it interacts with the winery. While these will be system dependent, some generalisations can be made.

For the refrigeration plant, process control systems should be in place that allow the compressor suction pressure to increase appropriately when warmer brine temperatures are used so that increased COPs are realised. Similarly, process control systems should be in place that allow the compressor discharge (head) pressure to reduce appropriately (i.e float)

NIGHT-TIME COOLING CONTROL EXAMPLE

Changes were made to a tank farm control system at one winery to facilitate dual tank temperature set-points. Tank set-point temperature from 2 am – 6 am was set to be 0.5 °C below the normal set-point and to be 0.5 °C above the normal set-point for the remainder of the day (i.e. if the normal set-point was 5 °C, the set-point was 4.5 °C for 2 am – 6 am, and 5.5 °C at other times). This strategy showed a shift of refrigeration plant operation from short repeated cycles throughout the day to operation predominantly at night for a sustained period.

PHASE CHANGES AND ENERGY

Sensible heat is the amount of energy released or absorbed by a substance during a change of temperature, without a change in phase. For example, 4.2 kJ/kg is required to increase the temperature of water by 1 ˚C. Therefore to raise the temperature of water by 10 ˚C, 42 kJ/kg is required.

The latent heat is the amount of energy released or absorbed during a phase change. The energy is used to change the state of the material. The temperature remains constant and therefore the heat is somewhat hidden or ‘latent’. For example, approximately 2400 kJ/kg of energy is required to evaporate water.

This large magnitude of latent heat relative to sensible heat is indicative of the importance of phase changes in heat transfer. For example, in the refrigeration cycle the evaporating refrigerant is able to remove a much larger quantity of heat from the brine/wine/juice at the evaporator compared with if the refrigerant just increased in temperature without changing phase.

The condensation of water vapour on uninsulated steel tanks significantly heating the wine inside the tank is another example of the importance of phase changes in heat transfer.

at lower ambient temperatures, so that increased COPs are realised during winter and at night. Process control systems and drives should also be in place that ensure the refrigeration plant is operating as efficiently as possible at part load.

Improvements to control systems that manage the scheduling of winery cooling operations are also advantageous, such as those that facilitate night-time cooling. There are sophisticated largely off-the-shelf winery cooling control systems available that can do this. These systems often also automate other improvements, such as setting the brine temperature at the highest level possible based on the lowest temperature wine tank on the brine loop, and prioritising cooling operations when there is limited refrigeration capacity available.

4.2.2 Insulation

Insulation plays an important role in minimising refrigeration requirements. This includes insulation for the refrigeration plant and brine reticulation system as well as for wine tanks.

Condensation on wine tanks is something that should be avoided. This occurs when the tank surface temperature is less than the dew-point temperature.

The phase change of water vapour in the air to liquid drops on the tank surface causes considerable heating. It is notable that once insulation is thick enough to prevent condensation further increases in insulation thickness only result in minor savings in heat gain (White et al. 1991). 75 mm thick polystyrene insulation with aluminium skin cladding is commonly used for winery tank insulation.

When water vapour condenses on brine distribution pipes and when this water vapour then freezes heat is transferred to the brine from the phase change.

When formed, ice can insulate to some degree but it is nowhere near as effective as purpose specific insulators. Furthermore, as ice accumulates the surface area exposed to air increases gathering more heat from it. White et al. (1989) reports that this largely counteracts any small benefit from the insulating ice layer.

At some wineries, red fermentors are not insulated because fermentation may be performed at warmer than ambient temperatures, at least during the night. However, if a tank jacket is used to provide cooling, it may be worthwhile to insulate the tank jacket itself. Otherwise, with typically low brine temperatures, water vapour will condense on the outside of the jacket and then freeze, wasting some energy and also causing an occupational health and safety hazard when the ice falls off.

4.2.3 Refrigeration plant heat recovery

In a refrigeration plant, heat is rejected from the refrigerant at the condenser. This heat could potentially be recovered and used for other winery purposes. Some packaged chillers can come factory-fitted with an additional heat exchanger in series with the condenser that can be used to preheat water to approximately 50 °C. In some refrigeration plants heat may be recovered from compressor cooling/lubricating fluids. In evaluating the merit of heat recovery, the timing of heat recovery and the timing of the use of that recovered heat must be considered. Storage tanks may be employed to balance warm water produced against warm water use to some extent, but issues such as the growth of microorganisms in mildly warm water need to be carefully managed. It is also important to ensure that system alterations that facilitate heat recovery do not negatively impact upon refrigeration plant efficiency.

5 REFERENCES AND FURTHER READING

There are many sources of information on refrigeration that can be consulted for a detailed treatment of refrigeration theory, equipment and improvement opportunities, both specific to the wine industry and to refrigeration more generally.

White et al. (1989) have written an excellent, user-friendly, practical reference on winery refrigeration and the winemaking textbook by Boulton et al. (1996) also includes a useful chapter on heating and cooling. An energy best practice guide for Australian wineries produced for the Department of Industry, Tourism and Resources (2003) is available from the website of the Department of Resources, Energy and Tourism.

Other authors, often funded by governments focussed on minimising global warming, have produced a range of publications related to optimising industrial refrigeration that are available for download on the internet. For example, Bellstedt (2010) has produced a detailed technical reference guide on industrial refrigeration improvement opportunities, which is available for download from the website of the NSW Department of Environment and Heritage.

Many of the fundamental principles behind refrigeration apply irrespective of whether a winery refrigeration system or a domestic refrigerator or air conditioner is being considered. Therefore explanations on the operation of these familiar domestic devices available in books or on the internet (including videos on www.youtube.com) can be useful in developing an understanding of winery refrigeration.

ASHRAE (2009) ASHRAE Handbook – Fundamentals (SI).

Bellstedt (2010) Energy saver, Industrial refrigeration technology report, Industrial refrigeration and chilled glycol and water applications. www.environment.nsw.gov.au. Accessed June 2012.

Boulton, R.B., Singleton, V.L., Bisson, L.F. and Kunkee, R.E. (1996) Principles and practices of winemaking. Chapman and Hall, United State of America.

Department of Industry, Tourism and Resources (2003) A guide to energy innovation in Australian wineries, Energy efficiency best practice. www.ret.gov.au. Accessed August 2010.

Department of Sustainability, Environment, Water, Population and Communities (2010) Montreal Protocol on Substances that Deplete the Ozone Layer. www.environment.gov.au. Accessed October 2010.

White, R., Adamson, B. and Rankine, B. (1989) Refrigeration for winemakers. Winetitles, Australia.

White, R., Adamson, B. and Stott, J. (1991) Insulation. The Australian and New Zealand Wine Industry Journal 6(2):107–112.

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