Milk cooling

1. Introduction

Effective milk cooling is essential to ensure the quality of the product. This Quick Note describes the key components and features of the common systems Australian farmers use to cool their milk.

2. Interpretation and relevance to Australian conditions

Most farmers in Australia have a requirement that their milk must be cooled to 4 ^{o}C within 3½ hrs from the start of milking, so cooling milk quickly for storage is an integral part of every farm's quality assurance / food safety plan. Doing this task efficiently will reduce operating costs and so improve milking productivity.

3. Relationship to CowTime goals

Surveys show that milk cooling accounts for about 30% of the total energy costs of operating a dairy, so designing and operating an efficient milk cooling system can significantly reduce energy demand and shed operating costs.

4. Features of cooling milk

A basic understanding of milk cooling systems can help farm managers ask good questions and make informed decisions about their milk cooling components. When it comes to cooling milk there is no one solution for all farms. Each operation must consider:

- How much milk am I cooling and storing?
- What will the temperature be of the milk when it reaches the vat?
- How cold must the milk be stored at and how quickly must this happen?
- What is my power supply like?
- How cold is my available water for pre-cooling?
- What might be my future production increases be?

Milk can be entirely cooled in the vat or chilled before it hits the vat or be cooled using a combination of precooling and vat cooling.

Pre-cooling milk

Most farms now pre-cool milk before it enters the storage vat. Pre-coolers remove heat from milk very quickly due to the large surface area available for heat exchange.

A plate cooler consists of a series of very thin stainless steel plates. Water flows along one side of each plate while milk flows along the other. Heat is transferred from the milk to the water via the plate. The capacity of a plate cooler is adjusted by adding or subtracting plates. A plate cooler that is working well should cool milk to within 2^{o}C of the temperature of the incoming cooling fluid. A typical plate cooler is depicted in Figure 1.

The 'M-series' plate coolers are the most common type found in Australian dairies and are available in 'single' bank' and 'double' bank configurations. The 'M-series' is designed to handle milk flow rates of up to 4,500 litres per hour.

Industrial plate coolers are more suitable in situations where milk flow rates exceed 4,500 litres per hour. Industrial plate coolers are much bigger in size than the 'M-series' and are designed for flow rates up to 12,000 litres per hour.

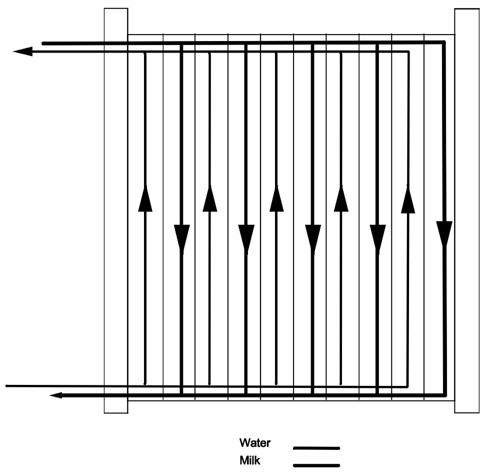

Figure 1:Single bank plate cooler
(source Hakim & Schmidt)

Factors affecting performance of pre-coolers

There are several factors which can impact on the efficiency of the pre-cooler. These are:

The ratio of the flow rate of cooling fluid to milk:

The system should be designed for the peak flow of milk expected from the milk pump. An even flow of milk will help make the plate cooler system easier to size and make efficient use of the cooling water. ‘M-series’ plate coolers work most efficiently with a water to milk flow ratio of 3:1, whilst 2:1 or even 1.5:1 is adequate for the newer industrial models.

Available surface area:

The peak flow rate of milk expected from the milk pump will determine the type of pre-cooler (size of the plates) and number of plates required.

Plate compression:

Allow about 3mm per each plate and gasket. If too tight the fluid flow will be restricted. Measure the overall thickness of the plates before disassembly. Never take the plates completely off the guide rails.

Plate cleanliness:

Contaminants in either the water or milk that adhere to the plates will affect heat exchange capacity and reduce performance. Blockages to the flow can restrict flow over the heat exchange surfaces.

Source water temperature:

Ideally plate coolers should use water that is the coldest available on the farm. Although some fluctuation in source temperature can be expected over the year, this is an inexpensive way to initially reduce the temperature of the milk from around 35^{o}C to 18 - 20^{o}C, reducing the load on the refrigeration system significantly.

Chilling fluids for use in pre-cooling

Many larger farms have a two staged plate cooler that first uses bore or surface water and then in a second stage uses chilled water or a chilled water-glycol mix. The chilled water can either be refrigerated on demand (instant chilling) or it can be chilled overnight on off-peak power and stored until required (cooling tower, refrigerated thermal storage or ice bank).

Two stage pre-cooling has the advantage of delivering milk to the vat at close to 4 ^{o}C. Some of these systems also allow the bulk of milk cooling to be undertaken using off-peak power, reducing the operating costs and spreading the demand for farm electricity use.

Cooling towers:

Cooling towers can be very effective at cooling water especially in areas of low humidity. Water can be cooled to within 5 ^{o}C of the wet bulb temperature in a properly designed plant. The most effective plants are fan forced and turn over a large store of water every hour. They operate overnight to cool a large volume of water, usually 4½ times the volume of the daily (peak) milk yield. There are restrictions in Victoria on the operation of fan-forced cooling towers. In Victoria cooling towers must be registered and have an audited operations and maintenance plan.

Ice banks:

Ice banks generate ice along evaporator coils using night-rate power. The ice is used to chill water for the pre-cooler. The warm water is then returned from the pre-cooler to the top of the ice bank and cooled again as it runs down the ice. These systems can require more maintenance than other systems and are not as energy efficient as a direct expansion vat. If working on night rate electricity rates they may save money even though they use more energy. Ice banks take up less space than storage of chilled water.

Instant chillers:

Another option is to use a refrigeration system to cool water or a glycol/water mixture. Glycol systems tend to use a very small volume of fluid and create the chilled fluid on demand (at milking time). Note that a system that is designed to chill milk to 4oC in line (ie prior to vat entry) will need a much larger (and therefore expensive) compressor than an in-vat system.

Thermal stores:

Thermal storage systems chill water using off peak power and require an insulated storage tank to hold a large (enough for a day’s milking) volume of chilled water. Using more energy than a direct expansion vat they have advantages relating to installation and maintenance procedures.

Cooling milk during storage

Direct expansion

In refrigerated / direct expansion vats the refrigerant (commonly R22 in Australia) is pumped into the jackets (evaporators commonly referred to as ‘dimple plates’) on the internal surfaces of the milk vat. Here the refrigerant expands as it takes heat from the milk, is pumped out of the jackets, compressed, then pushed into the condenser. The hot refrigerant is cooled by air (or water) flowing through the condenser fins. The cooled gas condenses into a liquid and is pumped back in to the jackets around the milk vat to start the cycle again.

Direct expansion is the simplest and most energy efficient way of cooling milk to the required storage temperature. It has the disadvantage of maximum power draw during and after milking which is generally peak rate. If large electric motors are used there can be problems in areas of poor power supply or where generators are used.

Direct expansion refrigeration systems are pressurised, which means they require a skilled technician when there is need for maintenance.

Low-pressure / glycol systems

Another common option is to replace the vat's pressurised gas refrigerant system with a low-pressure system that supplies cooled liquid to the dimple plates. The refrigeration is not attached to the vat but works to cool the fluid that is pumped through the vat. This fluid can either be cooled at the time of demand or be refrigerated off-peak and stored for use at milking.

An advantage of this system is that the cooling fluid circulating through the vat is not under high pressure so the risks of vat failure are reduced. This makes this system ideal for recycled vats. It is also possible to cool the fluid at off peak rate or during a time of lower power demand.

5. Potential issues with implementation

The major challenge with implementation of the information is getting good advice for each individual farm. There is no one size fits all solution for the industry, only general guidelines. Each manager must consider costs, reliability of service and repairs as well as available power supply and milk company demands. Be sure to use a cooling specialist that has a good track record in the industry and <u>can advise you of the relative energy efficiency of your options.</u> Be sure to get a detailed quote that describes the performance of the system you are going to use.

6. Robustness of this information

This information is the combination of advice from industry service providers and research groups.

7. References and further reading

Milk and milk cooling with Packo, produced by the Fullwood Packo Group

Hakim, G. and Schmidt, W. (1994), Cooling milk on dairy farms, Dairy Research and Development Corporation, Melbourne.

Rogers, G. and Alexander, A. (2000) A survey of electricity usage on Bonlac farms, Bonlac Foods, Fonterra.

CowTime (2006) CowTime Quick Note 4.6 How effective is your plate cooler? www.cowtime.com.au

Murray Goulburn Co-operative Co. Ltd (2001) Better milk cooling on Murray Goulburn farms. Brunswick, Victoria.

Genesis Automation. Steps to reducing energy costs on your dairy farm. www.genesisauto.com.au/html1/dairy.htm

Lakeside cooling towers. www.lakesidect.com.au/pmc.htm

The illustration is from Hakim and Schmidt.