Eco-efficiency for Australian dairy processors

Fact sheet 3: Refrigeration optimisation

The cost of operating a refrigeration system can be up to 20% of total energy costs in a dairy processing plant.[1] Dairy processors typically use the vapour compression cycle refrigeration system consisting of a compressor, a condenser, evaporator and expansion valve.

Components of a refrigeration system

The efficiency of a refrigeration system is measured by the 'Coefficient of System Performance' (COSP), which is the quantity of refrigeration produced divided by the total energy required by the system. The work horse of a refrigeration system is the compressor, which usually consumes between 80% and 100% of the system's total energy use. The purpose of the compressor is to draw low-pressure refrigerant vapour from the evaporator and compress it so that the vapour can be condensed back into a liquid by cooling with air or water. The liquid refrigerant is then reused to absorb heat from a chilled medium such as water or glycol.

Improving compressor efficiency

A process study by a Nestlé ice-cream processing plant in Victoria found that the compressors were operating when there was no load, there was a large number of start-ups, and the suction temperature of 12°C into the compressors was far above the design temperature of 3°C due to incorrect valve selection. The minimum condenser pressure was also being maintained at around 1000 kPa over the winter months. The plant improved the valve selection by upgrading the control system to correct the suction gas temperature, enabling the compressor to operate at a higher loading and minimise stopping. The condenser pressure was also modified to 750 kPa. The project cost $59 000 and now saves $100 000 annually in electricity costs. Compressor start-ups were reduced by 92% and the run hours by 22%. There was a 20% overall reduction in maintenance costs for the refrigeration plant.[2]

Increase the 'Coefficient of System Performance' (COSP)

It is important that the compressor, evaporator and condenser are suited to the refrigeration duty and that the system's efficiency (its COSP) is as high as possible. The COSP of refrigeration systems increases as the difference between the evaporating temperature and the condensing temperature reduces. Keeping the condensing temperature as low as possible and the evaporation temperature as high as possible is one way to improve the efficiency of the compressor.

'An increase of 1°C in evaporating temperature or a reduction of 1°C in condensing temperature will increase the compressor efficiency by 2–4%.'[3]

How can I reduce the condensing temperature?

- Ensure that the condenser is the correct size. A condenser that is too small for the refrigeration system may mean a small initial outlay, but running costs may be greatly increased by the need for a larger compressor. A condenser that is oversized, however, can sub-cool the refrigerant and affect the function of the expansion value.
- Allow the condensing temperature to float with low ambient temperatures in winter.

How can I increase the evaporating temperature?

- Ensure that the evaporator is the correct size.
- Do not set thermostats in cold rooms and freezers lower than necessary. In some cases this may not be possible, due to production and humidity requirements; however, be sure not to overcool more than is required.
- Keep the evaporator clean and defrost when necessary, especially when cooling air to below 0°C, as ice can build up on the coil. Hot gas from the outlet of the compressor can be used to defrost freezers, but control must be accurate. The defrost water may then be used elsewhere in the plant.

1 ETBPP *Reducing waste for profit in the dairy industry*, Environmental Technology Best Practice Programme, Good Practice Guide (GG242), 1999.
2 SEAV, Sustainable Energy Authority Victoria, Energy and Greenhouse Management Toolkit, Module 5, Government of Victoria, 2002, http://www.seav.vic.gov.au/advice/business/EGMToolkit.htm.
3 EEBPP, *Energy efficient refrigeration — the fundamentals*, UK Energy Efficiency Best Practice Program, GPG 280, 2000, www.envirowise.gov.uk.

Matching the compressor with the load

If a compressor is oversized it will operate at only partial load, and the energy efficiency may be reduced. A sequencing or capacity control system to match the compressor with the load could help to improve efficiency. The control system must be sophisticated enough to ensure that the load is properly shared. Some compressors are more efficient than others at part load, depending on the method of capacity control, and it is best to check with the manufacturer for a profile of efficiencies at varying loads.

The compressor, evaporator and condenser should suit the refrigeration duty.

Reducing the refrigeration load

Reduce heat ingress

Up to 10% of power consumption in refrigeration plants can be from heat ingress through doorways. It is important to encourage operators to observe good practice and keep doors closed. If this is not effective, consider automatic door closure (e.g. rapid roller doors or alarm systems). Plastic strip curtains or swinging doors are useful for frequently opened areas.

Lights and fans add to the heat load

Sensors and timers can be used to ensure lights are used only when necessary. Variable-speed drives, coupled with a programmable controller, can cycle fans off during low load times.

Refrigerant leakages

Leakages of refrigerant can reduce a system's efficiency by 40% and should be kept to less than 2% of the annual charge. You can calculate your approximate leakage rate from the amount of refrigerant you use to top up the system.

Absorption refrigeration increases system chilling capacity

Honeywell Farms in the USA uses a lithium bromide absorption chiller to cool liquid refrigerant of the main refrigeration system below its saturation temperature. The absorption chiller operates using the waste heat from a natural gas engine compressor; it increases the capacity of the existing refrigeration system by 8–10% by reducing the load on the compressor. Energy savings were calculated at $US90 400/yr, with a payback period of 3.8 years.[4]

Absorption refrigeration

Absorption chillers allow cooling to be produced from heat sources such as fossil fuels, incinerated garbage, biofuels, low-grade steam, hot water, exhaust gas or even solar energy, generally using a lithium bromide and water refrigerant. While the COSP of absorption refrigeration is relatively low compared with compression refrigeration (1 kW of refrigeration for 1 kW of energy), absorption chillers can utilise a waste heat source, thus emitting less greenhouse gases than conventional vapour compression refrigeration systems.

4 Caddet Renewable Energy 1996, *Retrofit cogeneration system at milk processing plant.*

This project (DAV447) was funded by Dairy Australia.
For further information see the *Eco-efficiency for the Dairy Processing Industry Manual*, August 2004
or contact the UNEP Working Group for Cleaner Production: phone 07 3365 1432, email p.prasad@uq.edu.au
Fact sheet published August 2004.

DAIRY AUSTRALIA
Delivering for the dairy industry