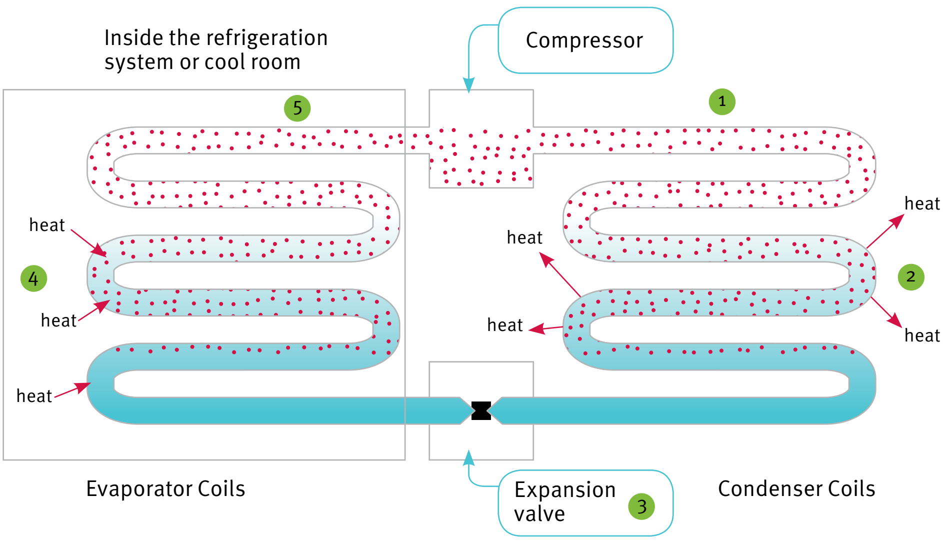
REFRIGERATION EFFICIENCY – U5

Eco-efficiency resources for the food processing industry

Keep your cool — keep your cash

*Most food factories use refrigeration to store products and raw ingredients. Refrigeration can use large amounts of energy. Often cooling towers are used in the refrigeration process which also uses large amounts of water (refer to **Cooling tower efficiency (U2)** fact sheet for more information). Therefore efficient use of refrigerators can lead to water, energy and cost savings. This fact sheet provides a list of opportunities to assist processors to improve refrigeration efficiency.*

Food and drink processors typically use the vapour compression cycle refrigeration system, using a fluid called a **refrigerant**. The refrigerant changes state from a gas to a liquid in a closed circuit.



1. The gas is compressed in the compressor where it heats up as it becomes pressurised. **2.** The hot gas then passes through the condenser where it loses heat to air or water surrounding the coils and condenses back into a liquid. **3.** As the liquid flows through the expansion valve, it moves from the higher-pressure condenser zone to the lower-pressure evaporator zone, cooling the liquid to a lower temperature and pressure than the air in the cool/refrigeration room. **4.** Because heat moves from higher temperature to lower temperature, the liquid starts to absorb heat from the cool/refrigeration room reducing the temperature in that room. The liquid evaporates back to a gas. **5.** It is this warm gas that feeds back into the compressor, completing the refrigeration cycle.

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Reduce evaporator losses

Evaporator losses can be reduced by increasing the evaporator pressure or temperature. A high evaporation pressure/temperature indicates the system is drawing heat from the product without expending too much energy.

A $1^{\circ}C$ increase in evaporating temperature increases the compressor efficiency by two to four per cent[1]

Thermostat setting

Setting thermostats only as low as necessary will keep the evaporating temperature as high as possible, absorbing less heat energy into the refrigerant and therefore reducing the load on the compressor.

Correctly sized evaporators

Size the evaporator to suit the load. A small evaporator may have a low capital cost but may require a larger compressor to cope with the load and so have higher operating costs.

Clean and defrost evaporator coils

When necessary, clean and defrost evaporator coils to prevent the build up of ice and subsequent reduction of heat transfer efficiency.

If water is used for defrosting, investigate opportunities to reduce or reuse the water elsewhere in the plant. Good ventilation can also assist in defrosting.

WATER REDUCTION THROUGH CHANGES IN DEFROST METHODS

Australia Food Corporation, a food processing company, saved 7900 kL of water a year by altering work practices to defrost its freezers. The freezers, which snap freeze meat patties prior to transportation, were defrosted daily by filling them with water.

To reduce water use, freezer doors are opened at the end of production shift, allowing fans and warm air from hot water hoses used in cleaning to circulate and naturally defrost the freezers.

The defrosting cycle is now only run every six months for maintenance purposes. The initiative involved no capital expenditure, except for training of cleaning staff in the new work program, and saves the company 7,900 kL water annually, which is approximately $26,000 per year in water and trade waste charges. (Australian Food Corporation is an ecoBiz participant.)

Hot gas defrost

Hot discharge gas from the compressor can be used to defrost evaporators and offers an excellent alternative to water or air defrosting, saving energy and reducing the amount of moisture added into the cooling space. Defrost cycles can be set automatically to occur at the end of production shifts or breaks, helping to extend production run times.

HOT GAS DEFROST

SnapFresh, a prepared foods processor, uses hot compressor discharge gas that is routed through the outlet of the evaporator to thaw accumulated frost. This gas then condenses back into a liquid and flows back into a common liquid line. By using hot gas for defrosting instead of water or electric heaters, the site has saved 15 kL per week of defrost water in the blast freezer, as well as saving power and water that would otherwise be required to recondense the compressor gas.

1 Energy Efficiency Best Practice Program (EEBPP), 2000, Energy efficient refrigeration — the fundamentals, UK, GPG 280, www.envirowise.gov.uk

Reduce heat ingress

Heat ingress can be reduced by closing doorways and switching off lights, which can save up to 10 per cent of the power in refrigeration plants. Other methods to reduce heat ingress include:

- maintaining insulation and door seals to reduce losses
- installing floor insulation
- reducing heat from lighting by installing energy efficient lighting that produces less heat
- cleaning chillers with sanitising agents rather than hot water to prevent heat retention
- cooling the product as much as possible before placing in refrigerated areas by using ‘pull down’ rooms at peak load before moving the product to a large holding room
- utilise space in cold rooms effectively and consider whether unused space can be segregated
- encouraging good operator practice, such as closing doors and turning off lights in unoccupied refrigerated space by installing automatic door closers, light switches or alarms and using plastic strip curtains or swinging doors for frequently opened areas
- using sanitising agents rather than hot water to clean chillers. Concrete floors can absorb heat from hot water, increasing the temperature by up to 20 per cent.[2]

Self-closing doors and strip curtains can be used to minimise heat ingress to refrigerated areas.

Reduce condenser losses

A reduction of $1^{\circ}C$ in condensing temperature will increase the compressor efficiency by two to four per cent.[3]

Floating head pressure controls

Many plants operate with higher than necessary pressure (condensing pressure/temperature) over a range of outdoor temperatures. Allowing the head pressure to ‘float’ with ambient temperatures enables the refrigeration system to work only as hard as it needs to under any ambient conditions without compromising the reliability of the system.

While condenser fans operate continuously on a ‘floating’ head pressure, the savings in compressor energy use and wear compensate this cost. Eliminating the stopping and starting of fans can also prolong the lives of the fan and motor.[4]

Correctly size condensers

Size condensers to suit the load. If the condenser is too small the condensing temperature will increase or if it is too large, it will cause sub-cooling and vaporisation of the refrigerant.

Clean condensers

Keeping condensers clean and in good condition, e.g. not blocked or corroded, promotes efficient energy transfer.

Locate condensers to allow good airflow

Providing fresh air and unrestricted air flow (e.g. not against a wall or condenser housing) to condensers that reject heat into the outside air will prevent air recirculating back into the condenser inlet.

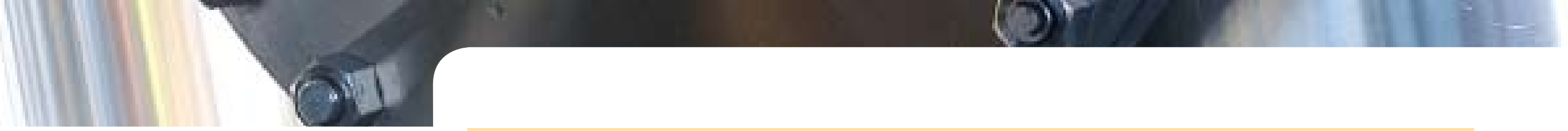
Variable speed drives (VSDs) on condenser fans

Installing VSDs on condenser fans can reduce operating costs by two to three per cent, especially on systems with fixed-head pressures as discussed previously.

Purging

Air entering the system through seals and valve packing when systems are open (for repair, coil-cleaning or when oil or refrigerant is added) can create an insulating barrier. This barrier reduces the effective size of the condenser and heat transfer efficiency. By purging the system of air this barrier can be minimised.

2 Cleland, A, 1997, Energy efficient processing – Plant Organisation and Logistics, 43rd ICOMST Congress Processing’s, Auckland, New Zealand
3 Energy Efficiency Best Practice Program (EEBPP), 2000, Energy efficient refrigeration — the fundamentals, UK, Good Practice Guide 280, www.envirowise.gov.uk
4 Energy Centre of Wisconsin, 1999, Fact Sheet - Cutting Energy Waste in Large Refrigeration Systems www.irc.wisc.edu/file.php?id=33



Each 1.8 kg of excess head pressure caused by air in the system reduces the compressor capacity by one per cent.[5]

Purging can be manual or automatic. Manual purging does not totally eliminate the air and can be dangerous as refrigerants may be flammable and are discharged to the atmosphere.

Reducing compressor losses

Compressors are the work horses of refrigeration systems and consume between 80-100 per cent of the system's total energy use.

Compressor selection

The efficiency of the system is measured by the co-efficient of performance (COP). This is the ratio of cooling output (kilowatt) compared with energy input (kilowatt), thus the higher the COP, the more efficient the system. The Australian Dairy Processing Engineering Centre has produced software called Coldsoft for plant personnel to review and improve the performance of refrigeration systems.

Compressor load

The most widely used compressor for refrigeration is the screw compressor; its efficiency decreases for partial loads.

Compressor capacity should be matched with cooling load as operating it at partial loads will cause the compressor to stop and start frequently, reducing efficiency. Multiple compressors with a sequencing or capability control can be used to match the load.

Compressors operating in sequence should be reviewed to ensure the time intervals at which individual machines operate at part load ratios is less than 70 per cent.[6]

Compressor location

Compressors should be located in cool and well-ventilated areas as they generate large amounts of waste heat and where possible waste heat should be recovered for reuse.

Insulation on suction lines

Insulating the suction lines reduces energy loss as compressor efficiency is improved with lower suction gas temperature.

Heat recovery

Heat recovery from compressors may be viable if a potential application exists close to the heat source. A plate heat exchanger that recovers heat from the compressor's lubricating oil can heat water up to 90 °C without adversely affecting compressor performance. For example, a 37 kW single-stage, oil-injected, rotary-screw compressor unit attached to a heat recovery unit can produce a 73°C hot water flow of 36 L/min.[7]

Improved refrigerant efficiency

Prevent refrigerant leakage

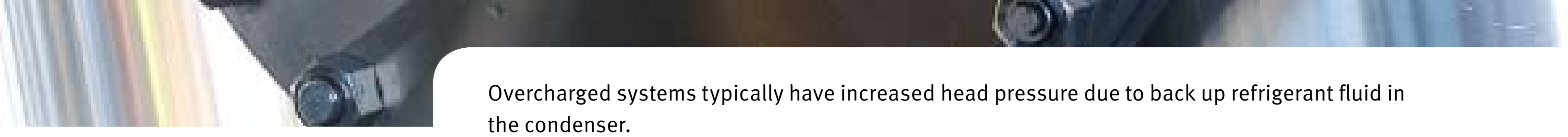
Refrigerant leaks are an important environmental and occupational health and safety issue that can also reduce the efficiency of a refrigeration system. Leaks typically occur at flared joints, flexible hoses and damaged pipes. Low refrigerant charge causes the compressor to work harder, reducing the cooling effect.

Using the correct refrigerator charge can reduce cooling costs by five to 10 per cent. An American study of 74 refrigeration systems found incorrect refrigerant charge used in over 40 of them.[8]

Typical signs of undercharged systems are:

- frosting on the evaporator entrance
- warm suction lines
- cool liquid line
- warm supply air
- continuously operating compressors.

5 Rockwell, T and Quake, T, 2001, Armstrong International, Improved Refrigeration System Efficiency, www.process-cooling.com/CDA/Archives/6a73f9b7695b7010VgnVCM100000f932a8c0
6 Reindl, D, 2004, 10 Cooler Ideas for Refrigeration System Efficiency, www.plantservices.com/articles/2007/188.html
7 Atlas Copco brochure Energy recovery systems. Atlas Copco Brisbane
8 US Department of Energy, Energy Efficiency and Renewable Energy, 2005, Federal Energy Management Program, Actions you can take to reduce your cooling costs. www1.eere.energy.gov/femp/pdfs/om_cooling.pdf



Overcharged systems typically have increased head pressure due to back up refrigerant fluid in the condenser.

Level indicators show the level of the liquid in the receiver and can quickly alert operators to possible refrigerant loss. For more information on methods to detect refrigerant leaks visit: Methods of Refrigerant Leak Detection www.bacharach-training.com/methods.htm.

Selection and performance of refrigerants

Some substances used as refrigerants include air, carbon dioxide, ammonia, hydrocarbons, hydrofluorocarbons (HFCs) and water. The Australian Institute of Refrigeration Air Conditioning and Heating website provides the Refrigeration Selection Guide, which discusses the environmental impacts of refrigerants and provides a selection guide to fluorinated and natural refrigerants.

Other factors such as the compressor type, operating pressures, age of the plant, the compatibility of materials (seals and gaskets) with the new refrigerant and the heat transfer and transport properties must also be considered. Refrigeration contractors can provide more information.
www.airah.org.au/downloads/AIRAH_RSG2003.pdf

NATURAL REFRIGERANTS AND HEAT RECOVERY[9]

Herb processor, Gourmet Garden designed its refrigeration system (a series of process and chiller rooms and a cold-store) with eco-efficiency in mind.

The company insisted it did not want to use any freon because of its unfavourable global warming potential so ammonia and CO_2 (natural refrigerants with good energy efficiencies) were selected for the new system.

When energy efficiency and possible future expansion were considered, the company chose to go with an ammonia/CO_2 cascade system that uses glycol as a secondary refrigerant to transport cooling to a number of areas in the factory.

The company also considered water efficiency and installed air-cooled condensers, which provide savings in water consumption of 70 per cent over equivalent cooling towers or evaporative condensers, while not compromising the energy efficiency of the plant.

A heat recovery system was incorporated into the refrigeration plant to preheat the hot water services for the factory. (Gourmet Garden is an ecoBiz participant.)

Reduce the load

Once the required temperature has been achieved, refrigeration systems will operate at low load and consequently lower efficiency. If possible, switch off refrigeration plants during non-production periods such as overnight or weekends.

In modern refrigeration systems, temperatures increase slowly when refrigeration is turned off and can be off for up to 15 hours without compromising food safety. Some of these savings may be negated by the need to initially draw the temperature back down after the shut-off period. This should only be undertaken in consultation with the refrigeration service providers.

Refrigeration alternatives

Absorption chillers allow cooling to be produced from heat sources such as low-grade steam or hot water, rather than electricity. However, the COP of absorption refrigeration is very low. They are generally used where there is adequate waste heat such as condensate from a steam system or hot water. While most units are small and used for air conditioning their capacity can be boosted by a standby electrically-driven chiller.

This series of fact sheets provides examples and suggestions to the modern food processor on how to achieve both economic and environmental benefits from eco-efficiency. Visit the project website www.ecoefficiency.com.au for more ideas and case studies.

9 ISECO, 2007, Gourmet Gardens www.iseco.com.au/GourmetGardens.htm

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