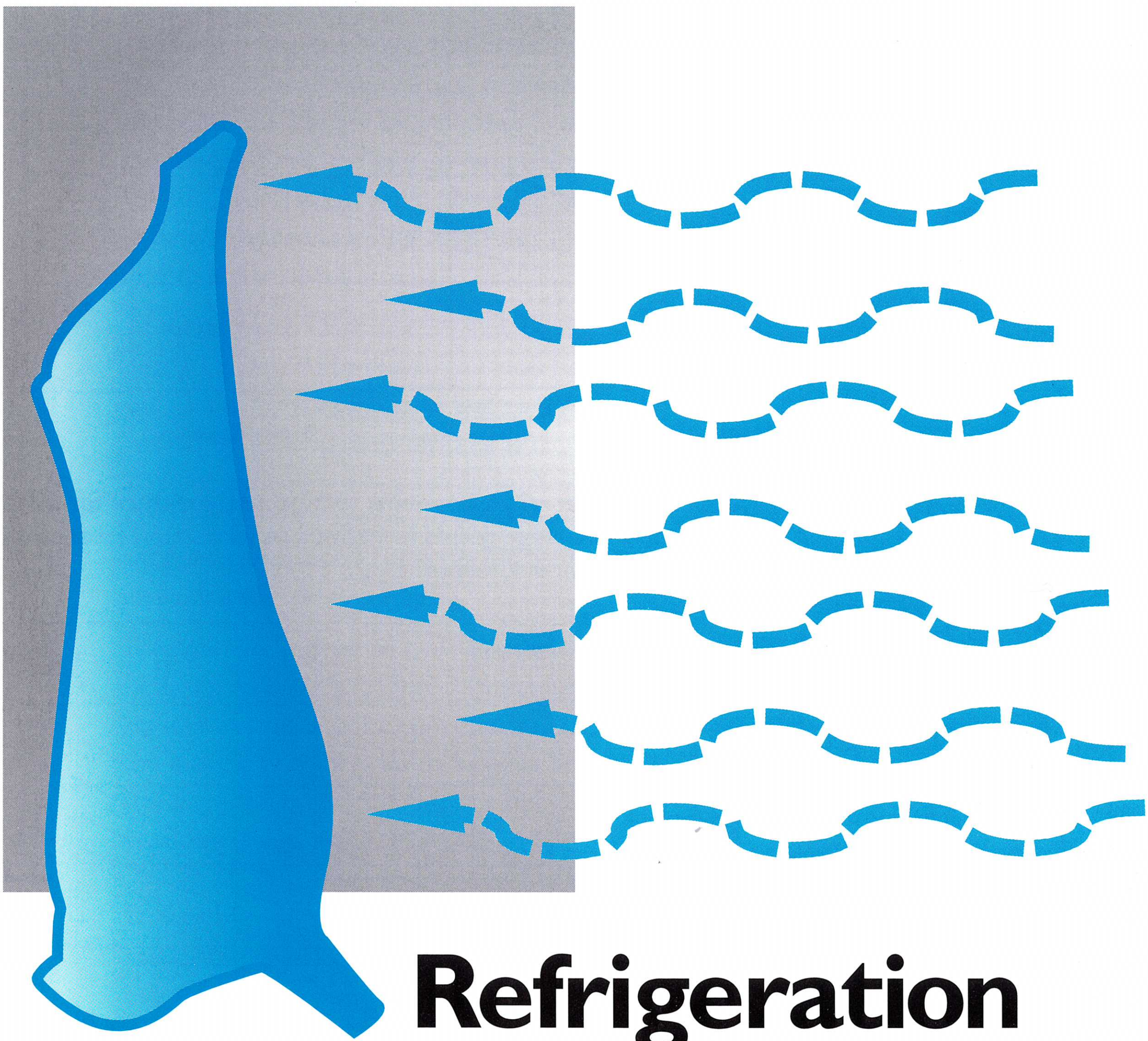


Refrigeration Energy Strategies

1997

Meat Research Corporation

AMT
AUSTRALIAN MEAT TECHNOLOGY

The refrigeration system is the major user of electrical power in most abattoirs, accounting for between 60% and 75% of total power use. It has been estimated that the cost of power use by the refrigeration system contributes between $14 and $17 per tonne of dressed carcase weight (DCW). More efficient use of refrigeration can reduce production costs but this should never be at the expense of food safety.

The energy cost of operating a plant can only be reduced by:

- reducing the refrigeration heat load;
- reducing the related refrigeration electricity use (fans, lights etc.); or
- improving the plant coefficient of performance (COP).

The majority of electrical energy required to operate the refrigeration plant is consumed by the compressors and therefore the greatest potential for savings exists in this area. The energy required to operate the compressors, known as Coefficient of Performance (COP), is dependent on the efficiency of the whole plant.

$$\text{COP} = \frac{\text{Total Heat Load (kW)}}{\text{Compressor Energy (kW)}}$$

The COP can vary greatly between plants as it is dependent on compressor type, condenser performance and plant design. Figures 1 and 2 show typical plant COPs for various suction and condenser temperatures. These show clearly that, as the difference between suction and condenser temperatures increases, the COP reduces (i.e. more energy is required per unit of refrigeration).

FIGURE 1 **Plot of COP versus suction temperature for a single-stage plant at various condensation temperatures (Cleland, A.C. & Cleland, D. J., 1992)**

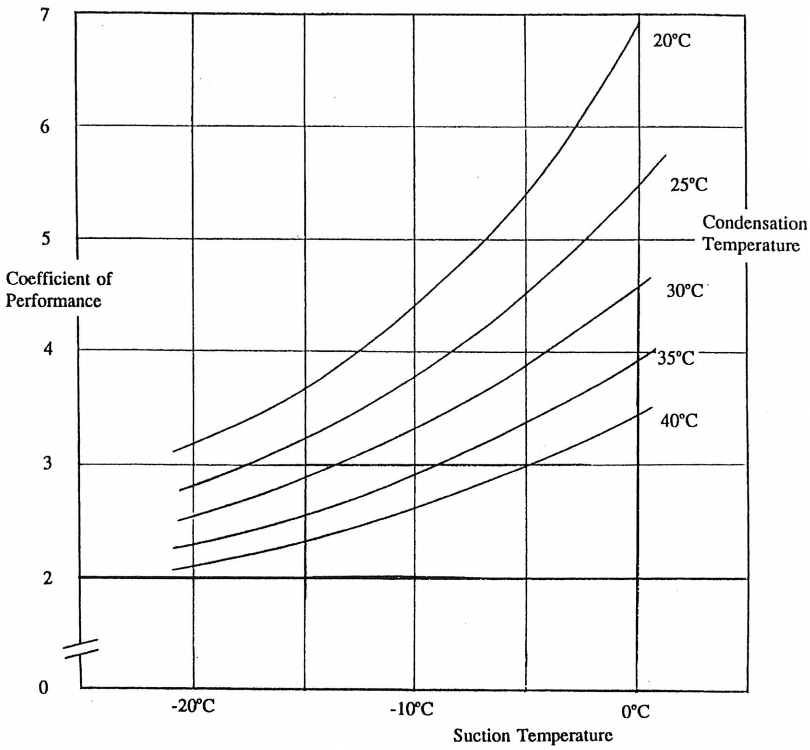


FIGURE 2 **Plot of COP versus suction temperature for single-stage and two-stage plants at various condensation temperatures (Cleland, A.C. & Cleland, D. J., 1992)**

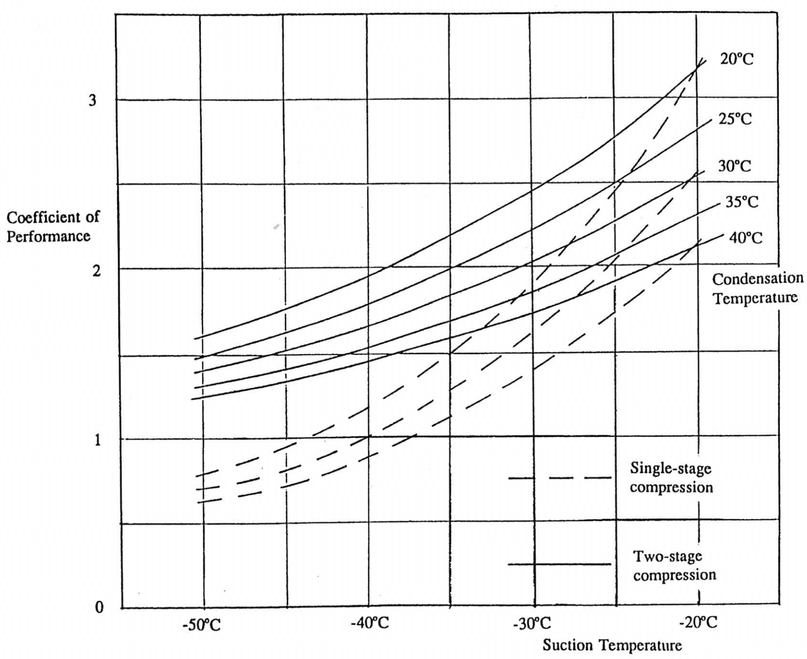


Figure 2 shows the effect of two-stage compared with single-stage compression on COP, demonstrating that most freezing installations benefit from two-stage compression.

As the COP is dependent on the difference between suction and condensing temperatures, it follows that the suction temperature should be as high as possible commensurate with maintaining the desired product temperature, and condensing temperature should be as low as possible. Optimum temperatures can be maintained by ensuring that losses in condensers and evaporators are minimised. If suction pressures can be maintained above atmospheric pressure, air ingress to the system can be minimised and the need for air purging reduced.

Evaporator fin surfaces should be maintained in a clean condition and oil should not be allowed to accumulate in the evaporator. A build-up of material on the fins not only reduces heat transfer but can restrict air flow.

Most larger installations utilise evaporative condensers, whereas smaller packaged plants use air-cooled condensers. As water is continuously being evaporated from the cooling surfaces of evaporative condensers, a scale will form unless a supply of good quality water is available. If scale is allowed to build up, heat transfer will be affected resulting in an increase in condensing temperature and higher operating costs.

Air-cooled condensers are used mainly with packaged systems in smaller installations. Condensing temperatures can become elevated if the heat exchange surfaces are fouled with dirt and dust or if the condenser is located in an area of high ambient temperature. It is essential that the condenser be kept clean, located so as to provide a free air flow and not be sited adjacent to other heat sources.

Run refrigeration compressors efficiently. Do not run screw compressors part-loaded for long periods. Run the most efficient compressors first.

Chiller Operation

The heat load during carcase chilling can be divided essentially into two components – product load and other heat loads. The product load is typically 80% of the total heat load and can only be lowered by loading fewer bodies into the room or loading at a slower rate, both of which could be counter-productive to the overall efficiency of the meat plant.

We are therefore left with reducing the other heat loads which include fans, lights, people, air infiltration and conduction through the walls, floor and ceiling. Electrically-powered equipment, such as fans and lights, in refrigerated areas contributes to the heat load, so there is cost incurred in its operation and in the removal of the heat it creates.

Fans

For a chiller holding 80 bodies, typically the total rated fan capacity to provide an air velocity over the carcases of 1 m/s would be 16 kW. There is little to be gained in increased cooling rate by operating at higher air velocities. The power required by the fans increases with the cube of the velocity, therefore a doubling in air velocity would require an eight-fold increase in fan power.

Fans operating at full speed for the complete chilling cycle of (say) 20 hours would consume 320 kWh of electricity and add 16 kW to the heat load. The use of speed controllers or two-speed fans has the potential to reduce energy usage. When the majority of the heat has been removed (about 10 hours after the commencement of chilling) the fan speed could be reduced by 50% or more. There will be a saving of the 80 kWh of electricity used to operate the fans and a reduced heat load.

Lights

Lighting requires a relatively small load of about 2 kW for the above chiller example. Small savings in electricity and heat load can be made by ensuring that lights are switched off after completion of loading.

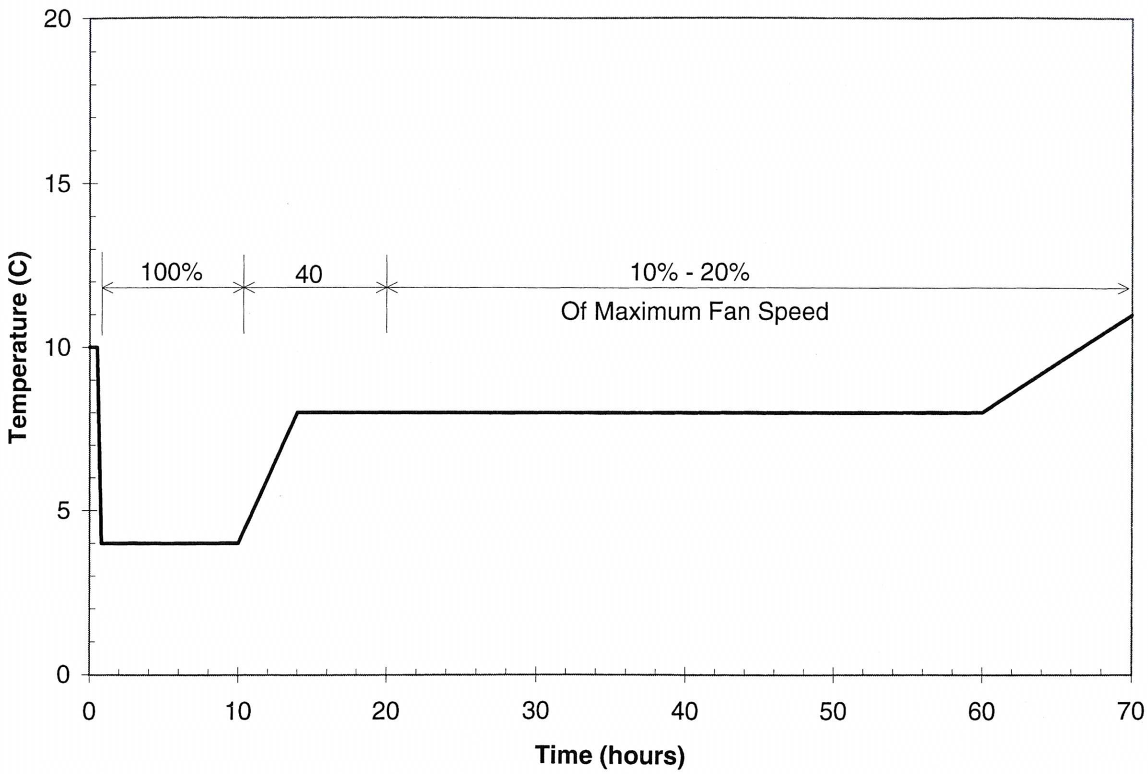
Air Infiltration

A door left wide open to the slaughter floor could add 33 kW to the chiller heat load. Entry of warm, moist air can also lead to condensation problems and a rise in chiller temperature. If the chiller is loaded over a long period, the door should not be left open for the complete loading period. Carcases should be batched outside the room and loaded in a group to reduce door opening time. This is especially relevant if the chiller opens directly off the slaughter floor, as is the case in many small plants and in some larger plants of older design. Doors should slide easily or be mechanically operated to encourage staff to close doors as required. The use of air locks should be considered.

Heat Leakage

The majority of heat leakage will be through ceilings, floors and external walls and is dependent on the building design. The properties of

FIGURE 3 **Recommended chiller air temperature and fan speed**



insulation deteriorate with time and cracks between panels can develop. These increase heat leakage and have the potential to lead to condensation. Cracks can be sealed on outer ceiling surfaces by foam-in-place insulation.

Chilling Cycle

There are limited opportunities to conserve energy during an overnight chilling cycle. Operation on weekends and non-production days presents opportunities to reduce operating costs.

With the availability of relatively inexpensive speed controllers and PLCs, it has become convenient to set a variety of fan speeds for different stages of the chilling cycle. The best strategy is to reduce fan speeds to as low as 10% of full speed to maintain a minimal air flow over product and a constant temperature. In the case of beef carcase chilling, an economic cycle that would cool last few hours of the cycle would increase surface temperature, slightly softening fat for boning. In most cases, these settings would be suitable for both overnight and weekend chilling cycles.

Freezer Operation

Freezing is a more energy-intensive operation than chilling and should be closely studied to ensure that energy is not wasted. The aspects such as air infiltration and heat leakage covered under chilling are even more important in freezing operations, as moisture that leaks into the building will form as ice on the coil and structure, and to remove it will consume energy. Air locks should be provided at door entries and the integrity of the vapour seal on the building insulation must be maintained. If the vapour seal is broken, moisture can migrate into the insulation and eventually freeze, resulting in a breakdown of insulating properties.

contributed by the fans, which can be as much as 20% to 40% of the product load. Blast freezing cycles for cartoned meat should be 48 hours. Twenty-four-hour freezing cycles have been attempted but the cost of achieving the low air temperatures and high velocities required was prohibitive. Air temperatures in blast freezers of -25°C or below and average air velocities of 3 m/s would ensure that conventionally-boned meat in normal-sized cartons would be frozen in a 48-hour cycle. Hot-boned meat may require shallower cartons or lower air temperatures. Higher air velocities in the region of 10 m/s and low air temperatures of -40°C are used in some plants but are generally unnecessary for a 48-hour cycle and costly to operate.

At times, batch blast freezers may be only partly loaded. Performance can suffer as the air can by-pass the stow and energy is wasted by moving more air than is required. In some situations it is possible to divide the freezer with a curtain to direct the air over the cartons and conserve energy by switching off unneeded fans.

If carcase meat, such as beef quarters, is to be frozen on-site, it is more economical to remove as much heat as possible in a chiller (by a two-day chill) prior to bagging and freezing than by placing into the freezer at an earlier stage.

Defrosting

Defrosting of refrigeration evaporators consumes energy and interrupts the cooling cycle. By use of back-pressure control and correct temperature settings, carcase chillers can be operated such that defrosting is not required. Defrosting of freezers can be minimised by restricting the ingress of moist outside air.

Summary

- Set suction temperatures as high as possible
- Maintain condenser surfaces in clean condition
- Reduce fan speeds during holding periods
- Keep doors closed
- Minimise defrosting of cooling coils

Reference

Cleland, A.C. & Cleland, D.J., 1992, 'Cost-effective Refrigeration', Massey University, Palmerston North, NZ, Centre for Postharvest and Refrigeration Research.

Additional Information

'Energy Management for the Meat Industry' in *Proceedings of CSIRO Workshop*, 1983.

'Cost-effective Energy Use in Meat Processing', Energy Authority of NSW, 1995.

'Electricity in Abattoirs, Part One: Surveys, Tarfiffs and Costs; Part Two: Energy Cost Management', (Herbert, L.S.) in *Australian Refrigeration, Air Conditioning and Heating*, Oct. - Nov. 1984.

Additional information

Additional help and advice are available from Food Science Australia, Meat Industry Services Section:

	Phone	Fax
Ian Eustace	(07) 3214 2117	(07) 3214 2103
Neil McPhail	(07) 3214 2119	(07) 3214 2103
Bill Spooncer	(02) 4567 7952	(02) 4567 8952
Chris Sentence	(08) 8370 7466	(08) 8370 7566

Processing and Product Innovation

Meat & Livestock Australia

Tel: (02) 9463 9166
Fax: (02) 9463 9182

Email: ppi@mla.com.au