MEAT TECHNOLOGY UPDATE
Cutting edge technology for the meat processing industry

# Meat technology update

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# Refrigeration Principles

Refrigeration is the most commonly used method of preserving meat and meat products. Since the effectiveness of any refrigeration system is influenced by component selection and application, it is essential to have an understanding of the process and its various components.

## The Refrigeration System

The basic components of the refrigeration system are the refrigerant, compressor, condenser and receiver, refrigerant expansion device and the evaporator (Figure 1).

The theoretical refrigeration cycle can be depicted on a pressure-enthalpy diagram (Figure 2). (Enthalpy is the heat content of a substance.)

Commencing at 1, refrigerant vapour at low pressure and temperature is drawn into the compressor which, under operation, increases the pressure and temperature of the vapour.

The refrigerant vapour at high pressure and temperature then passes to the condenser (2) where it is cooled (giving up its latent heat), condenses to its liquid form, and is stored in a receiver.

The high-pressure refrigerant liquid is then expanded through an expansion device (3). At this point, the refrigerant is at a low pressure and is mostly liquid. It has a low boiling point, due to the low pressure.

When the liquid refrigerant enters the evaporator (4), it boils, absorbing the necessary latent heat for its evaporation from the surroundings of the evaporator. The resultant refrigerant vapour at low pressure and temperature then passes to the suction side of the compressor (1), completing the cycle.

**FIGURE 1 Elements of a simple refrigeration system**

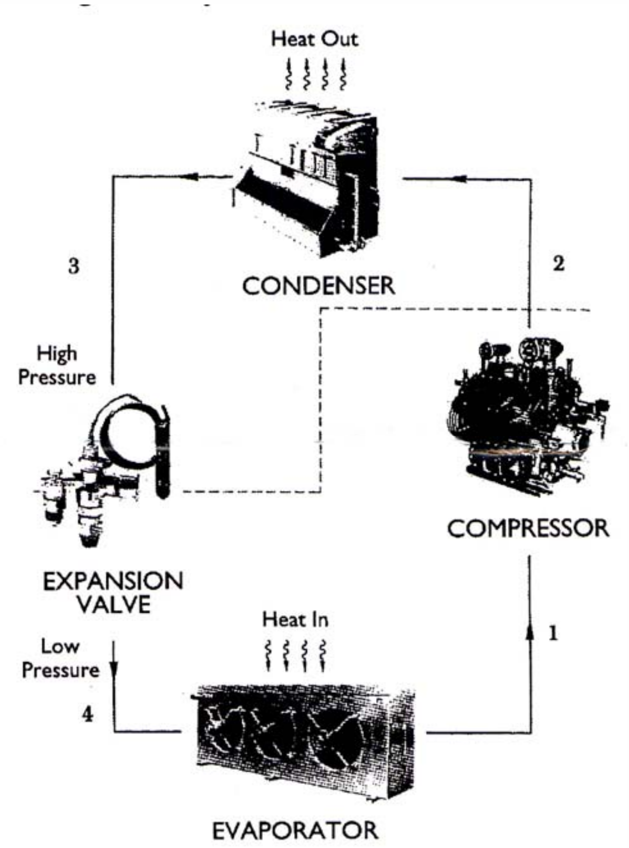


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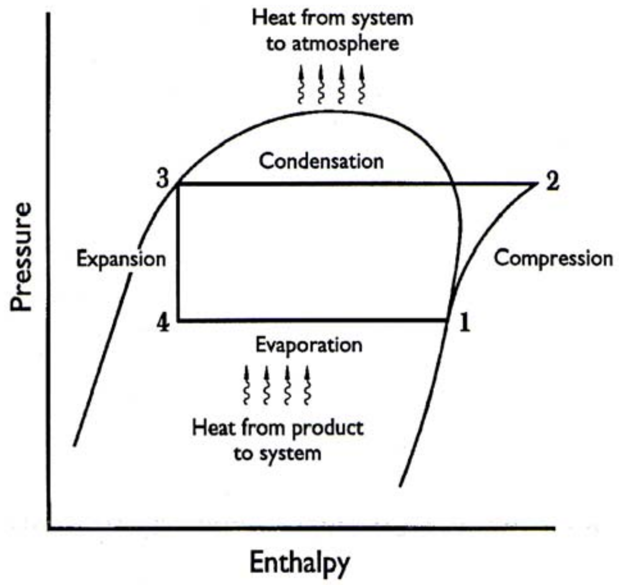
**FIGURE 2 Pressure/enthalpy diagram for a theoretical refrigeration cycle**




The diagram shows the behaviour of a theoretical system. Real systems behave slightly differently in that some superheating (i.e. heating above its evaporating temperature) and some sub-cooling of the refrigerant vapour and liquid will occur within the cycle. However, the effects are relatively minor in the real system.

## The Refrigerant

The refrigerant is the working fluid of the cycle. It absorbs heat as it vaporises at a low temperature and gives up heat by condensing at a high temperature and pressure. There is no ideal refrigerant, but different refrigerants are more suited to specific applications.

Ammonia (R717) is environmentally friendly and meets many of the listed requirements - but it is toxic. Its pungent odour at low concentrations ensures that personnel are repulsed long before exposure becomes dangerous. There is little risk in its use where proper precautions in design and installation are observed. Ammonia is predominantly used in large industrial installations where trained operators are available.

The halocarbon refrigerants R12 and R22 were widely used in domestic refrigerators, display cabinets, butchers' shops and small abattoirs where unattended operation is essential. Because R12 is a chlorofluorocarbon (CFC) and is implicated in the depletion of ozone in the atmosphere, its use is being phased out. Manufacture of R12 ceased at the beginning of 1996 and is being progressively replaced in existing installations. R22 is a hydro-chlorofluorocarbon (HCFC) and has a lesser effect on ozone. However, its production is being progressively phased out, with total phase-out (except for a small amount to service existing equipment) being planned for 2020.

## The Compressor

The energy input in the refrigeration cycle is provided by the compressor. The amount of energy required is determined by the volume of refrigerant being circulated, its properties and the increase in pressure from the evaporator to the condenser.

Lowering the temperature (pressure) in the evaporator or increasing the temperature (pressure) in the condenser increases the power requirement of the compressor and hence the running costs of the refrigeration system.

In a large plant using an ammonia system, the compressors and ancillary equipment are normally located in a central engine room. In small plants, butchers' shops and the like, the compressor/condenser unit is often located adjacent to the refrigerated space. In display units it is frequently built into the unit.

Chilling applications require only single-stage compression. When evaporator temperatures below -30°C are required, as in freezing applications, two-stage compression can be justified. Refrigeration compressors operate most efficiently at moderate pressure ratios. By utilising two-stage compression, high overall pressure ratios can be achieved economically.

## The Condenser

Compressing the refrigerant vapour drawn from the evaporator causes its pressure and temperature to increase. The hot, high-pressure vapour is then transferred to the condenser, where its latent heat is removed by cooling, causing the vapour to return to a liquid but remain at high pressure.

In ammonia systems, the evaporative condenser (Figure 3) is the most common type used. Air-cooled condensers and receivers (Figure 4) are used for small packaged plants with halocarbon refrigerants.

In evaporative condensers water sprays are used to aid cooling, which means that the capacity of the evaporative condenser is influenced by the ambient wet-bulb temperature. In most parts of Australia, particularly when ambient temperatures are high, the wet-bulb temperature is significantly lower than the dry-bulb temperature. This lower wet-bulb temperature gives the evaporative condenser its greatest advantage over the air-cooled condenser, whose capacity is influenced by the dry-bulb temperature.

Both types of condenser require free circulation of air over the coils for effective cooling.

**FIGURE 3 Diagrammatic sketch showing arrangement of an evaporative condenser**

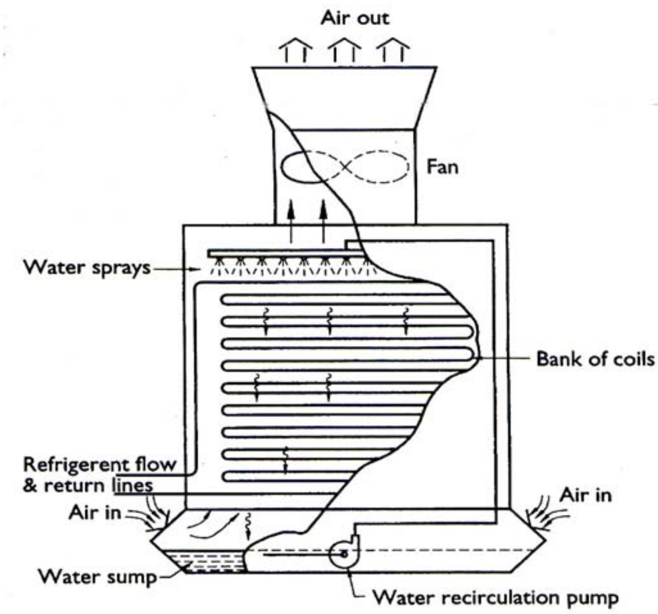
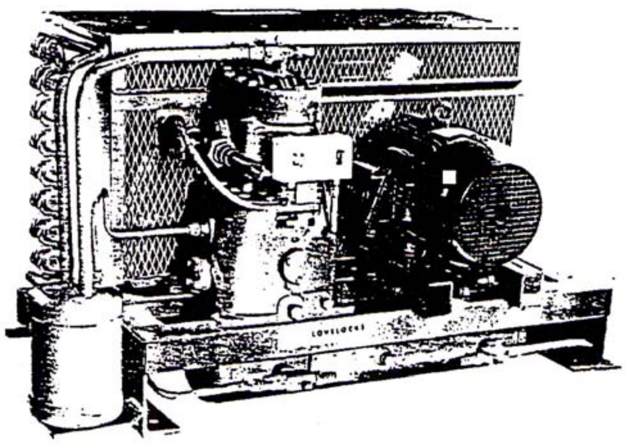



**FIGURE 4 Air-cooled condenser**



Ideally, condensers should be located well clear of buildings and structures that could restrict air flow. For efficient operation, air-cooled condensers should not be located in areas such as boiler houses where the ambient temperature could be high. Evaporative condensers have been implicated in outbreaks of Legionnaire's disease and should not be sited adjacent to ventilation system intakes.

The evaporative condenser requires a supply of good quality water for its operation. Because water is continuously being evaporated from the cooling coil surfaces, scale will be formed by the precipitation of salts. If this scale is allowed to build up, heat transfer rates will be reduced, causing an increase in refrigerant condensing temperature. Effective cooling can then only be maintained if the compressor operates at higher pressures. This, in turn, will result in greater power usage and higher operating cost.

Both types of condenser must have sufficient cooling capacity to dissipate the sum of the heat extracted by the evaporator and the heat added by the compressor.

## The Expansion Device

The expansion device maintains the pressure differential between the evaporator and condenser necessary for the correct operation of the refrigeration system. It allows the refrigerant to expand from the high-pressure level to the low-pressure side of the system at a controlled rate, depending on the cooling demand.

The thermostatic expansion valve is the most common type of expansion valve and is used almost exclusively in small and medium-sized systems. This valve measures the exit temperature of the refrigerant from the evaporator and controls the refrigerant flow to the evaporator so that the liquid completely changes to a gas before exiting the evaporator. Liquid carry-over is controlled by allowing a small amount of superheat (3°-10°C) in the exiting vapour to the compressor.

Central ammonia systems normally use pumped liquid recirculation systems with flooded evaporators. The liquid-vapour mixture in the ‘wet suction’ line is returned to a surge tank where separation of the liquid-vapour phase occurs. The compressor draws the dry refrigerant vapour from the top of the vessel, and the liquid is pumped from the bottom of the vessel back to the evaporators.

Accurate temperature control and minimum product weight loss can be achieved in liquid recirculation systems by using a modulating back pressure regulating valve at the evaporator. The regulating valve is used to control the flow of refrigerant from the evaporator to the compressor suction. Varying the regulating valve setting varies the pressure and temperature in the evaporator to suit the cooling conditions. The main advantage of this is that the evaporator temperature can be raised as the heat load in the room reduces.

## The Evaporator

After passing through the expansion device, the refrigerant is now at a low pressure and is fed through the evaporator. The evaporator consists of banks of coiled tube, with the surface area increased by the addition of fins. The refrigerant is contained within the tubes, and the air which extracts the heat from the product passes over the finned tubes.

Fans blow air over the tubes in the case of the forced draught cooler (FDC) or draw air through the evaporator in the case of the induced draught cooler (IDC). The fans are selected to provide adequate air circulation at the required velocity over the product to be cooled.

The cooling capacity of the evaporator depends primarily on the surface area of the coils and the temperature difference between the refrigerant and the air being cooled. Finned coil evaporator design is a complex subject, with performance influenced by factors such as tube diameter, tube configuration, fin spacing, number of rows of coils, face area and coil depth. In the case of carcase cooling applications, best results are generally achieved by having a large face area, shallow depth and a small temperature difference between refrigerant and air.

A refrigeration system is most efficient - uses the least power - when the smallest temperature differential exists in the refrigerant between the evaporator and condenser. This can only be achieved when the surface area of the evaporator is sufficient to maintain the smallest possible temperature differential between the refrigerant and the cooling air, and when the cooling capacity of the condensers can dissipate all heat input to the system under the most extreme ambient conditions.

The refrigeration system must have adequate refrigeration capacity to maintain the desired product temperature when widely varying ambient and processing conditions exist.


# Contact us for additional information

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