Sector Focus

Milk Cooling

	Sector	GWh/y
1	Retail display	9,233
2	Catering – kitchen refrigeration	4,380
3	Transport	4,822
4	Frozen storage – generic	900
5	Blast chilling – (hot) ready meals, pies	425
6	Blast freezing – (hot) prepared products	316
7	Dairy processing – milk/cheese	250
8	Milk cooling – raw milk on farm	207
9	Potato storage – bulk raw potatoes	165
10	Primary chilling – meat carcasses	129

Mean estimated annual UK energy usage

Technology

The prevailing pattern of milk collection systems includes milk chilling directly after milking and tanker collection from the farm gate using tanker-mounted meters for measuring milk quantity. Several cooling systems are in use. The milk may be cooled in a bulk tank by a chilled water jacket containing an icebank or by a direct expansion refrigeration system. It may be precooled in a plate heat exchanger using mains water and chilled water or glycol, and then stored in bulk with or without direct expansion refrigeration to counter subsequent heat gains.

Energy used in sector

Refrigerated systems used in the cooling of milk on farms in the UK are estimated to use 207 GWh of energy per year.

Systems in use

A number of systems are available for cooling milk on farms.

Direct expansion (DX)

In a direct expansion system the evaporator coil is contained within the cooling vessel comes into direct contact milk. It is one of the most popular methods of milk cooling on small and medium size dairy farms.

A horizontal construction is claimed to be space saving and the efficient evaporator ensures quick trouble free milk cooling, coupled with the agitator the milk is evenly stirred ensuring optimal heat exchange and prevention of freezing.

Typical systems range from 5000 - 40000 Ltr.

Indirect or Instant Cooling

Here an intermediary fluid, such as water or a water-glycol solution, is employed to transport heat from the milk to the evaporator. The chiller generally works in conjunction with a dual stage plate cooler. Well water is often used in the first stage of the plate cooler to reduce milk temperature to within 3°C of the input water temperature. The chiller provides -2 to +1°C water/propylene glycol solution to the second stage of the plate cooler. When milk enters the second stage of the plate cooler, the water/glycol solution rapidly cools the milk to 3°C before it enters the bulk storage tank.

Generally, instant chilled water/glycol cooling systems are considered slightly less efficient than direct expansion systems. The reason for the lower efficiency is the lower suction pressure to achieve lower evaporator temperatures inherent to instant cooling systems and the pumping energy required to move the water/glycol through the heat exchanger. The lower temperatures and short heat transfer period along with pumping energy cause the instant cooling system to use more energy per litre than a direct expansion system.

Instant cooling systems are most often used on large dairy farms where large quantities of milk are harvested quickly, and fast cooling is necessary to maintain milk quality.

Using an ice bank is claimed to improve energy efficiency. Milk cooling with ice water from an ice bank is claimed to has advantages over the Direct Expansion (DX) cooling system:

- Cooling from 35°C to 10°C is claimed to be 50% **faster and cheaper** than Direct Expansion method (DX).
- The ice water cools the milk without any risk of freezing, even with small volumes in the tank.

Typical systems range from 5,000 to 40,000 ltr capacity.

Direct Chilling (DIB)
This method uses an external ice maker and runs the iced water through the cooling jacket of the vat. Systems only cool the milk that comes into contact with the area of the tank that is actually below the top of the milk with inbuilt sensors to accurately detect the level.

Using a DIB system is claimed to have the following advantages over the Direct Expansion (DX) cooling system:

Advantages
- Fast and efficient cooling - increased milk quality - as milk is cooled instantaneously.
- Cooling from 35°C (entry temp. of milk) to 10°C occurs 50% faster and cheaper than Direct Expansion method (DX).
- The ice water cools the milk without any risk of freezing, even with small volumes in the tank.
- Electrical power requirement is low since small compressors operating at full power and therefore high efficiencies can replenish the ice supply.
- Running costs are low due to the use of cheap night rates.

Typical systems range from 5,000 to 40,000 ltr capacity.

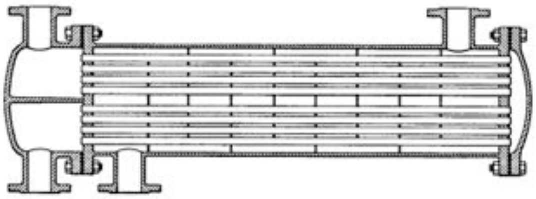
Components

Hermetically sealed reciprocating compressor

The most common refrigeration compressor found on dairy farms today is of the reciprocating type. Reciprocating compressors can be either open type, hermetic or accessible hermetic. The open type has the drive unit external to the compressor. Power would generally be transmitted from the drive unit [motor] to the compressor by V-belts. The hermetic type has the compressor and motor in a common sealed housing. The purpose of the condenser is to desuperheat and condense the refrigerant gas by removing the sensible superheat, the latent heat of condensation and sensible heat to subcool the liquid.

There are two major types of condensers; air-cooled and water-cooled. If the condenser is an integral part with the compressor on a common platform, the unit is called a condensing unit. Condensers may also be mounted remote of the compressor.

The air-cooled units are similar to a car radiator. The refrigerant gas flows through finned tubing and air is moved over the fins perpendicular to the tubing to remove heat from the gas. The contact time between the air and the fins is short. The capacity of an air-cooled condenser is determined by the area of the fins, the velocity of the air across the fins, and a mean temperature difference between the air and refrigerant. Air-cooled condensers can be either an integral part with the compressor on a common platform or remove.



Shell and tube water-cooled condenser

Water-cooled shell and tube condensers are commonly used on dairy farms. A cross section of such a heat exchanger is shown below together. The unit shown has a removable core for cleaning. Generally the cooling water flows through the tubes and the condensing refrigerant gas is in the shell. The unit shown is a 2 tube pass system with baffles in the shell to reduce short-circuiting and increase turbulence of the refrigerant.

Example of a remote air-cooled condenser on dairy farm

A compact integrated ice bank system is space saving and ergonomic. The use of chilled water generally increases the total energy required in kWh/t but decreases the demand in kW and so is usually preferred for larger installations. Water requirements for cleaning are small and can be estimated at about 0.15 m^3t^{-1} of chilled milk or less. For bulk tanks cold in-place cleaning is often used and is particularly suitable for icebank chilling systems.

The total energy requirements for milk chilling prior to transportation to milk plants can be estimated at 25 to 30 kWh.t^{-1} net or 85 to 105 kWh.t^{-1} gross respectively.

Energy saving options

There are several measures that can be implemented that will reduce the energy consumed to cool milk.

- Pre coolers - Well water-cooled heat exchangers partially cool milk prior to the milk entering
- Variable frequency drives - The flow of milk during milking from the milk pump will vary from vary from zero to 220 ltr per m. In a milking parlor with two milk pumps, there may be no milk flowing through the heat exchanger 75 to 90 percent of the time and the flow during the other 10 to 20% of the time is high. This is not an efficient way to operate a heat exchanger. To help alleviate this problem, a variable frequency drive can be applied to the milk pump. This slows down the flow of milk from the receiver so that the milk pump operates a higher percentage of the time. The flow of milk through the heat exchanger will be lower and more continuous. Both factors improve the effectiveness of the heat exchanger.
- New compressors - Scroll compressors are now being introduced for milk cooling on dairy farms. Because the scroll compressors operate in a circular motion, have fewer moving parts and no intake or discharge valves, there is less vibration and less noise. A study comparing a scroll compressor with a reciprocating hermetically sealed compressor on a direct expansion cooling system showed a 20 percent reduction in energy use. The reduction in energy use was caused primarily by a reduction in the electrical demand.

Energy saving potential of future technologies

A number of technologies are under development for use in the near future. Some of the most promising include:

- Greater use of renewable energy sources such as solar electricity (PV), solar thermal, wind energy, biomass, geothermal heating and cooling.
- Greater system integration by use of heat pumps, Combined Heat and Power (CHP) and Trigeneration.

Fostering the Development of Technologies and Practices to Reduce the Energy Inputs into the Refrigeration of Food

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For further information on saving energy see: www.grimsby.ac.uk/What-We-Offer/DEFRA-Energy