Pre-cooling Milk

Tom Ryan, Teagasc, Kildalton

Refrigerating milk on the farm has two main aims, to inhibit bacterial spoilage and to extend storage on the farm so as to minimise milk transport cost.

While good hygiene in all aspects of milk production is essential to the production of quality milk the growth of bacteria during the storage interval must also be curtailed. At body temperature bacteria in milk increase very quickly and even milk with a low initial count will sour rapidly. When cooled by well water to between 15^{O}C and 20^{o}C the growth rate is restricted and milk produced under hygienic conditions will retain good quality for a period of up to 15 to 20 hours. However, when the storage period exceeds this limit further cooling by refrigeration is necessary. Now not only the storage temperature but also the cooling time to reach the storage temperature, which is normally 4^{o}C, is important. Hence refrigerated bulk milk coolers must be designed and selected to cool the milk to 4^{o}C within a specified time. This cooling period is such that when the tank is filled to capacity by the addition of the final milking – usually the fourth at a peak, the total cooling period (including the usual milking period) should not exceed 3 hours.

Effective pre-cooling of milk can make savings and enhance the keeping quality of the milk.

Pre-cooling

Pre-cooling of milk in-line by well or mains water before it enters the tank has a number of advantages. These include:

1. Economy – cooling costs can be reduced by up to 50% depending on the temperature and supply of water and the operational efficiency of the cooler, e.g. water to milk flow.

2. Milk quality – pre-cooling ensures a lower milk blend temperature, which helps to curtail the growth of bacteria.

3. The tepid water from the pre-cooler can be used for udder washing, yard washing and for stock.

4. Condensing unit size can be reduced, provided pre-cooling to less than 18^{o}C can be consistently achieved. This is advantageous where power supply is limited.

5. Back up cooling – a pre-cooling system provides a useful auxiliary system in the event of condensing unit failure.

6. Pre-cooling milk will reduce cooling times when comparing equivalent systems

Some of the benefits of pre-cooling will be undone if the bulk tank cooling unit isn't installed and maintained properly. It is important to ensure a good airflow to and from the condensing unit (radiator). Anything that restricts the supply of fresh air and /or causes the recirculation of warm air will increase running costs and reduce compressor life. It is very common to see condensing units on farms that are damaged, partially blocked and recalculating warm air.

Plate Coolers

A plate cooler fitted to the discharge side of the milk pump is the most popular pre-cooling system mainly due to its high efficiency and compactness. The plate cooler consists of a sandwiched arrangement of stainless steel plates with the milk and cooling water flowing in opposite directions through spaces between alternate plates. The spaces between the plates are small and the milk should be filtered before entering the cooler to prevent debris from accumulating. A water filter(s) may be necessary if foreign matter or minerals are present in the water supply.

For optimum efficiency in milk cooling the water flow rate should be adjusted to about double the measured milk flow rate, thereby reducing the milk temperature to within 3-5^{o}C of the inlet cooling water (Table 1). At a higher water flow rate only a marginal reduction in milk outlet temperature is achieved. At a lower water flow rate, a reduction of milk temperature to within 5-10^{o}C of the inlet water temperature could be expected.

TABLE 1: Plate cooler, milk and water outlet temperature (^{O}C) as affected by water inlet temperature and water to milk flow ratio. Milk inlet temperature 35^{O}C

Water Inlet (^{O}C)	**Water/milk 1:1**		**Water/milk 2:1**		**Water/milk 3:1**	
	Milk ^{O}C	**Water ^{O}C**	**Milk ^{O}C**	**Water ^{O}C**	**Milk ^{O}C**	**Water ^{O}C**
10	**20**	**27**	**15**	**20**	**14**	**17**
15	**22**	**28**	**19**	**23**	**18**	**21**
20	**25**	**30**	**23**	**27**	**22**	**25**

Source: M.G. Fleming and J. O'Keeffe, Teagasc, Moorepark Research Centre

Plate Cooler Size

As well as water temperature and water to milk flow rate the size of the plate cooler is also important. Under sizing the plate cooler will result in reduced cooling efficiency. The plate cooler should be sized according to the milk flow rate. For a single stage plate cooler the number of plates generally required is given in Table 2.

Although oversizing is not usually the case, oversizing the plate cooler where continuously operating diaphragm pumps are used should be avoided because air coming from the diaphragm pump passing through the residual milk in the cooler can cause milkfat damage and cleaning difficulties. This may crop up with older plants, but present day milking machine standards insist that all types of milk pumps are operated intermittently. Centrifugal pumps are always operated intermittently to prevent them from running dry and damaging seals.

Table 2: Number of plates required in a single bank model M plate cooler (each plate is 120 mm x 632 mm)

No. of plates	Plate cooler capacity (milk flow rate)	
	Gal/hr	**Litres/hr**
18	**200**	**900**
20	**250**	**1,140**
24	**300**	**1,360**
30	**400**	**1, 820**
36	**500**	**2 ,270**
42	**600**	**2,730**
48	**700**	**3,180**
54	**800**	**3,640**

Source: M.G. Fleming and J. O'Keeffe, Teagasc, Moorepark Research Centre

Two- stage Plate Coolers

Three methods of pre-cooling can be used. These are; well/mains water, chilled water on its own, and a combination of well/mains water and chilled water. For pre-cooling the best option is to use a two-stage plate cooler with two water supplies, one from a bored well or group/mains supply and the other from an ice builder - i.e. chilled water. The ice builder should ideally be able to cope with two milkings to make the best use of night rate electricity. This arrangement can be used with a smaller condenser on the bulk tank, just to keep the milk at the correct temperature.

Well water is more suitable than water from the public supply because it is generally much cooler and is usually cheaper where water rates are based on consumption. A properly installed setup like this can pre-cool the milk to within 1-3^{0}C of the recommended storage temperature.

Where extra investment is needed to allow more effective pre-cooling, e.g. to install a water chiller, this should follow careful cost/benefit analysis. Where someone is buying a new bulk tank the savings made with a smaller condenser should be balanced with the costs of providing for pre-cooling.

Milk Pumps

There are many options to choose from when it comes to deciding on a milk pump. A common choice is to use a centrifugal, operated by a liquid level controller. These have high flow rates that are very suitable for circulation cleaning but flow rates are excessive for effective pre-cooling. For centrifugal pumps to be effective for pre-cooling they need to be matched with a very high capacity plate cooler. This plate cooler would, in turn need a high water flow rate. In addition, a solenoid valve may be fitted in the water line to the cooler. This solenoid valve is wired to the liquid level controller on the milk pump and ensures that water flows only when the milk pump operates and thus helps to conserve water. The solenoid should have a time delay feature which will allow the water to continue to flow for a short time after the milk pump has stopped. This will improve the performance of the plate cooler. The time delay should be no longer than 20-30 seconds. Anything in excess of this carries out little useful cooling as the milk within the plate cooler will have been cooled very close to the temperature of the water entering it.

Inserting a restrictor between the pump and the filter will reduce the flow rate through the filter and plate cooler but it will also cause milk fat damage and possibly froth in the milk. Using a restrictor is not a solution and should not be considered.

Variable speed centrifugal pumps will allow reduced flow rates during milking. Their output is still fairly high, because if they are run too slowly they can have problems starting and producing enough pressure to overcome the vacuum pressure. Some argue that at these slow speeds there is some milk damage. As well as this, there is a considerable price difference between a variable speed centrifugal and a single speed one.

Diaphragm Pumps

From the point of view of milk pre-cooling, a direct-to-line milking system (without recording jars) with an intermittently operating diaphragm milk pump is a good arrangement. Typical output of diaphragm milk pumps under full flow is 1300 - 1800 l/hr (290 - 400 gal/hr) for a single and 2600 - 3600 l/hr (580 - 800 gal/hr) for a double. Within these ranges the output of diaphragm pumps can be set by using different combinations of pulley sizes. Where froth is a problem, diaphragm pumps can clear froth from the milk receiver jar, but to do this the pump must be switched over to continuous pumping, at least until the froth is gone. Rigid impeller centrifugal pumps will not pump froth.

Where a milk diversion line (“dump line”) is installed a good arrangement is to install a diaphragm pump for the milk and an ordinary centrifugal for the diversion line. Both pumps are switched over to continuous pumping during washing.

In a situation of up-grading, extending or even building a new parlour effective use can be made of an existing single or double diaphragm pump in conjunction with a centrifugal for circulation cleaning with or without a diversion line.

If an existing diaphragm pump output is inadequate for the increased milk flow rate of the extra units, say when cows are at peak, the centrifugal pump is installed in parallel with the diaphragm pump. There are two sets of probes in the receiver jar. The set near the bottom of the receiver controls the diaphragm pump and the set near the top controls the centrifugal pump. The diaphragm pump pumps milk for most of the time, but if the milk level in the receiver reaches the upper probes the centrifugal pump cuts in to lower the level quickly. When the level drops below the upper probes the centrifugal cuts out again. Both pumps are running continuously during washing. Installing a diversion line with this arrangement requires an additional centrifugal milk pump.

Matching up the Components

Take an example of an 8-unit plant. The throughput is likely to be about 8 cows per unit per hour with an average changeover interval of about 7.5 minutes. If we assume that the absolute maximum throughput is 10 cows /unit/ hour (initial attachment plus 9 changeovers) averaging 6 minutes per line. Therefore, 80 cows /hr is theoretically the maximum achievable. If each cow, say milks an average of 18 litres (4 gals) at the a.m. milking, the maximum flow rate is 1440 litres per hour (320 gal/hr). To choose a milk pump and plate cooler to match the flow rate in this scenario a single diaphragm milk pump at about 50 strokes/min can be used. This will give an output of 1570 lit/hr (345 gals/hr). A centrifugal pump can be used for assisting the diaphragm pump in washing and/or for use with a milk diversion line. To matching a plate cooler and filter sock to this flow rate, a realistic choice is to use a 1365 litre per hour (300 gal/hr) plate cooler with a 430 x 75mm (17" x 3") filter sock.

Milk Filtering

An inline milk filter should be fitted in all milking installations. Where a plate cooler is fitted the filter should be fitted between the milk pump and and the plate cooler. Milk filters should be mounted vertically with the drain/cap at the base. The filter should be plumbed so that any sediment is collected on the outside of the filter sock.

For trouble free operations it is essential to match filter sock sizes to milk pump sizes, types and flow rates. The density of material that manufactures use in in-line filter socks varies from 60-155 grams per square metre. The most common one used is 75 grams per square metre. The 75-gram material will filter particles as small as 70 microns (one fourteenth of a millimetre).The flow rate of each filter will vary depending on the:

- fat content of the milk
- pumping pressure of the milk pump
- weight of material per square metre used in the sock.

As an example of the resistance in the filter material a 25mm (1") diameter round disc of 75-gram material with a 10-foot head of pressure (4.3 psi or 0.7 bar) using water, has a flow rate of only 28 litres per minute (8.5 gallons per minute). Table 3 outlines filter sock sizes and milk pump types for different milk flow rates.

Table 3 Filter sock sizes and milk pump types for different milk flow rates

Filter Sock Size	Approx. Flow rate	Milk Pump Type
430mm x 75mm sock (17" x 3")	1500 litres/hour (330 gals/hour)	Single diaphragm pump
600mm x 75mm sock (24" x 3")	3000 litres/hour (660 gals/hour)	Double diaphragm pump
600mm x 100mm sock (24" x 4")	4500 litres/hour (990 gals/hour)	2 x 2D diaphragm or centrifugal pump
*2 x 600mm x 100mm socks positioned in parallel (2 x 24" x 4")	9000 litres/hour (1980 gals/hour)	For use with centrifugal pumps

*Two filter units are needed because the flow rates are very high with a centrifugal pump, so two big filters can cope better with the flow.