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BULK MILK COOLERS

This bulletin includes technical information based on latest development on products, systems, techniques etc. reported in journals, companies' leaflets and books and based on studies and experience. The technical information on different issues is on different areas of plant operation. It is hoped that the information contained herein will be useful to readers.

The theme of information in this issue is **Bulk Milk Coolers**. It may be understood that the information given here is by no means complete.

In this issue:

1. INTRODUCTION

Milk production in India is characterized by smallholder dairy farmers spread over vast and far-flung areas away from the markets. A dairy farmer usually owns 1-3 milking animals, each producing only a few litres of milk per day. The small quantity of milk produced by each farmer is delivered at the village milk collection centre for pooling with other producers' milk. This milk may be chilled here and transported to a processing plant, or un-chilled milk may be transported to a chilling centre, at pre-decided times, usually once in the morning and once in the evening during a day. Processing plants are generally located away from the collection centers. Therefore, the whole activity right from milking by a producer to delivery of pooled raw milk at a processing plant might take up to around 4-6 hours.

Raw milk generally has a low microbial load as it comes out of the animal's udder. However, the temperature of raw milk at the time of milking, generally about 30-35˚C, is most conducive for the growth of microorganisms. Subsequent holding of raw milk at ambient temperatures for longer periods (4-6 hours), till it reaches a processing plant, provides conducive environment and enough time for microorganisms to proliferate extensively. Thus, by the time raw milk is received at a dairy plant the number of bacteria has already increased manifold, resulting in souring and other quality deterioration.

Therefore, if milk cannot be delivered to the processing plant within 2-3 hours of milking, it is necessary to chill it to around 4˚C, at which temperature microbial growth is greatly retarded.

Other means of milk preservation-by adding chemical preservatives- are not permitted in our Food Laws.

Milk could be chilled at farms at the village collection centre itself or at the raw milk chilling centres which receive raw milk from a number of village collection centres located nearby. However, chilling milk at collection centers results in much superior quality of milk than chilling it at the chilling centers, as in the former case the waiting time at the collection centers and transportation time are saved.

Moreover, small milk chilling units operationalized at the village collection centres are easier to handle and effective in ensuring chilling and preservation of milk soon after milking by a producer. The most commonly used system of chilling milk at collection centers is to use bulk milk coolers.

This issue of the *Technews* provides useful information on bulk milk coolers (BMCs).

2. ADVANTAGES OF BULK MILK CHILLING SYSTEM

The main advantages of a bulk milk cooler are summarized below:

- It is an easy system and can be handled by one person after training.
- With chilling of raw milk commencing immediately after reception at collection centre, exposure of milk to ambient temperatures for longer periods is avoided and, thereby, microbial deterioration, including souring, of milk can be prevented.
- Standard Plate Count (SPC) of raw milk chilled in bulk milk coolers is found in some cases – with a very good overall hygiene system - to be as low as 100,000 cfu (colony forming units) per ml of milk with MBR (methylene blue reduction) time of up to 4 hrs. Raw un-chilled milk received in cans generally has an MBR time of a few minutes to 1.5 hours and SPC of several million cfu per ml of milk.
- Since raw milk can be safely stored at low temperatures (less than 7˚C) for longer periods, it is possible to chill, pool and store raw milk of more than one collection before transporting the whole quantity to a processing plant. This could result in substantial reduction of transportation cost.
- Sourage of raw milk due to failure of transportation system or vehicle breakdown en route could be eliminated.
- Use of cans can be reduced and bulk quantities of chilled raw milk can instead be transported in insulated tankers. Costs related with cans such as purchase cost, repair and maintenance, and replacement costs could be eliminated.

- Due to high bacteriological counts in raw milk, a general practice in the industry has been to pasteurize milk at temperatures as high as 80 to 85˚C. Low bacteriological count in raw milk on account of use of chilling at collection level makes it possible to effectively pasteurize milk at lower temperatures i.e., 72 to 75˚C. This prevents frequent fouling of pasteurizer and also results in savings on account of less steam consumption.
- Load on chilling system in a dairy processing plant is substantially reduced.
- Availability of chilling system at milk collection point removes dependence on truck schedule and inherent constraints of milk collection. Thus BMCs are more flexible leading to the satisfaction of the staff and members of a village milk collection centre.

3. COMPONENTS OF BULK MILK CHILLING SYSTEM

The farm level bulk milk chilling system consists of the following components:

a) Bulk Milk Tank: It is a horizontal tank of rectangular or cylindrical shape and made of AISI 304 Grade stainless steel. The tank is also fitted with accessories such as inlet and outlet connections, agitator and calibrated stick etc., all made of AISI 304 Grade stainless steel. The tank is provided with a thick insulation, generally polyurethane foam, between the inner and the outer jacket to prevent refrigeration loss.

Bulk milk cooling tank could be either 'Direct Expansion' or 'Ice Bank' type.

Direct expansion type of bulk milk coolers are made in various shapes and sizes (Figs 1 and 2). Smaller capacity tanks (250 to 1000 litres) are usually cylindrical in shape while bigger capacity tanks (1500 to 2500 litres) are usually rectangular in shape. The tank has a built-in double walled plate evaporator at the bottom, through which the refrigerant passes. Heat from milk is transferred directly into the refrigerant in the surrounding evaporator area. Agitation of milk and convection currents developed in milk due to temperature difference enables total mass of milk to get cooled to the desired temperature.

Fig. 1: Open type direct expansion cylindrical bulk milk cooler

As there is no means of storing refrigeration, the compressor operates only when milk cooling is required. Therefore, to be able to satisfy the high speed cooling of milk in a short duration, larger refrigeration compressors are required.

Farm bulk coolers of 'Ice Bank' type usually are 'self contained' and consist of three tanks placed inside each other. Insulating material is provided between outer and the middle tanks. Between the middle tank and the inner tank, an evaporator coil (copper pipes), through which the refrigerant passes, is placed, which acts as an ice builder and is always surrounded by water for heat transfer from milk to ice. Another design consists of two separate tanks: one for holding and cooling milk and the other for building and storing ice (Fig 3). An ice bank tank works by using a small compressor to build up a reserve of refrigeration in the form of ice over a long period of time (7-14 hours a day).

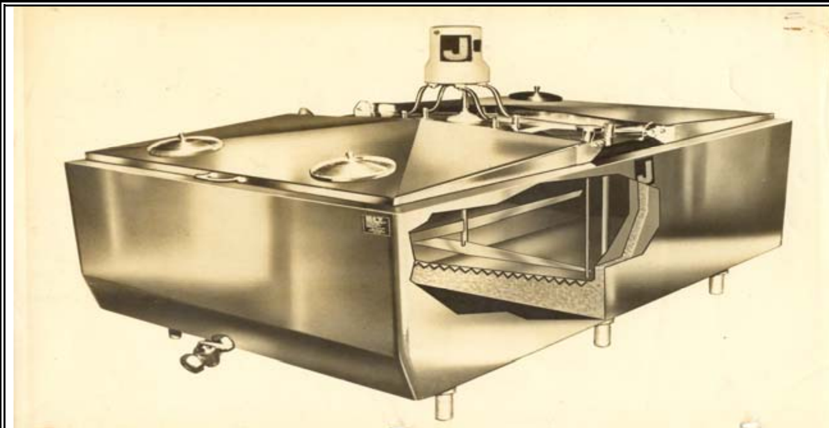

Fig. 2: Direct expansion rectangular bulk milk cooler

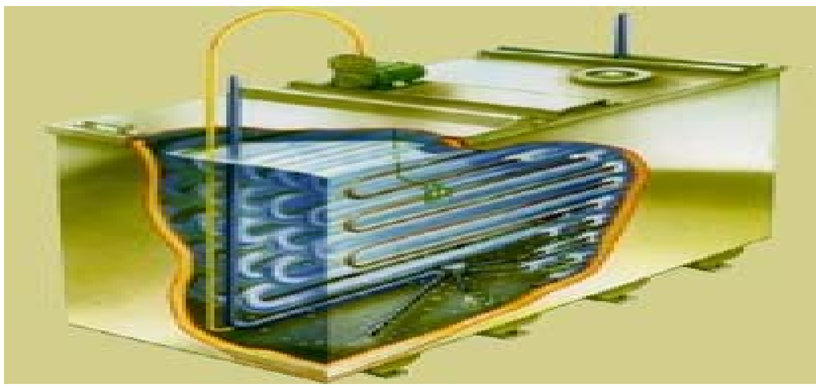

Fig. 3: Ice bank tank

b) Refrigeration Unit: It consists of a refrigeration compressor, air cooled condenser, condenser fan, receiver and expansion device.

Compressors could be of hermetic, semi-hermetic or scroll type. Hermetic compressors are least efficient and normally the cheapest. These compressors are 'sealed for life' and cannot be taken apart for repairs. Semi-hermetic compressors are more expensive but more efficient than a hermetic compressor. The compressor can be taken apart and repaired.

Scroll compressors are most efficient type, up to 10% better than a hermetic compressor, but are more expensive. The compressor is 'sealed for life'. (1)

Most of the chilling systems generally operate on hydrochlorofluorocarbon (HCFC) refrigerant - R22 - which is more ozone friendly than conventional chlorofluorocarbons (CFCs). However, the production of R22 will be phased out by the year 2015 and the most likely replacement for R22 will be a total ozone benign refrigerant R407c which is a mixture of hydrofluorocarbons (HFC) - namely, R32, R125 and R134a in the ratio of 23:25:52. All new compressors should be able to operate with R407c without the need for major alterations. (1)

c) Tanker Loading Pump: An electrical pump to transfer chilled milk from bulk milk tank to road milk tanker.

d) Control Panel: An easy to operate control panel and a digital temperature indicator with a battery back-up to keep a check on the temperature of milk.

e) Balance Tank (Optional): A stainless steel tank with SS pump for transferring milk to bulk milk tank.

f) Diesel Generator Set: A DG set of appropriate capacity to operate the system in the event of non-existent electric supply in the village or a temporary breakdown of electric supply. This removes dependence of the chilling system on state operated electricity distribution systems.

4. DIRECT EXPANSION AND ICE BANK TYPES OF BULK MILK COOLERS

Comparative advantages and disadvantages of direct expansion type bulk coolers and ice bank type bulk coolers are presented in the Table 1 below:

Table 1: Comparative advantages / disadvantages of direct expansion type bulk coolers and ice bank type bulk coolers

Direct Expansion Type Milk Coolers	**Ice Bank Type Milk Coolers**
Direct expansion tanks need comparatively bigger refrigeration units costing more than twice the cost of a refrigeration unit for ice-bank type coolers.	Ice-bank system offers the advantage of smaller and less expensive refrigeration unit.
Refrigeration can immediately be started as soon as milk reception has started.	Refrigeration unit needs to be operated for 4 to 5 hrs prior to milk collection for building reserve refrigeration in the form of ice.
Milk cooling is directly achieved by circulation of refrigerant around the milk tank and hence no separate pump is required.	While milk cooling is in progress the refrigeration unit and water circulation pump have to be operated for effective water turbulence to maintain the water at appropriate temperature for effective heat transfer.
The refrigerant in the evaporator is at lower temperature, and as the temperature difference between the milk and refrigerant is greater, the system offers speedy cooling even at lower milk temperatures.	The final milk temperature of 4˚C is hardly achieved in a reasonable time as the temperature difference between chilled water, maintained at 2 to 4˚C, and desired temperature of milk is small.
The temperature of the refrigerant in the jacket generally being lower than the freezing point of milk, freezing of milk on the heat exchange surfaces could be encountered.	No such problem encountered as the temperature of water used for heat transfer seldom drops to 0˚C.
Cooling of milk stops as soon as refrigeration unit is switched off.	Bulk milk coolers with an ice bank in the jacket continue to cool the milk even when the refrigeration unit is not operating.
Since water is not used for heat transfer no scale formation takes place on evaporator coils.	Scale formation due to hard water on outer surface of the milk tank and evaporator coils reduces the overall heat transfer coefficient. Thereby time for cooling of the milk to desired temperature is increased.

Direct Expansion Type Milk Coolers	Ice Bank Type Milk Coolers
With refrigeration system off and no stored refrigeration available in the form of ice, the empty tank can be rinsed with hot water for effective cleaning.	In case of 'self contained' ice bank bulk cooler, once empty, if the tank is rinsed with hot water, the reserve ice left on the evaporator coil surrounding the inner milk tank tends to melt, thus resulting in refrigeration loss.
One person with little training can handle the BMC efficiently.	Skilled operator is required all the time to operate and monitor the refrigeration unit etc.

5. PERFORMANCE OF BULK MILK CHILLING SYSTEM[2]

The ISO (ISO 5708: First edition–1983-03-15) classifies the bulk milk tanks on the basis of the following performance parameters, and specifies refrigeration ratings (daily capacity, milk cooling rate and storage temperature performance).

a) Classification on the basis of performance: The performance of a tank is specified according to the following classification:

- **Number of collections:** Classification of bulk milk tanks on the basis of the number of milk collections it is designed for is given in Table 2 below:

Table 2: Classification of bulk milk tanks on the basis of the number of milk collections

Classification	Number of milk collections
'2'	Tank designed for two milk collections
'4'	Tank designed for four milk collection

- **Ambient temperatures:** Classification of bulk milk tanks on the basis of the performance temperature (PT) and safe operating temperatures (SOT) is given in Table 3 below:

Table 3: Classification of bulk milk tanks on the basis of the performance temperature and safe operating temperatures

Classification	Performance temperature (PT) ˚C	Safe operating temperature (SOT) ˚C
A	38	43
B	32	38
C	25	32

(Note: For Indian conditions the type 'A' tank is suitable as it can be efficiently operated at higher ambient temperatures).

- **Milk cooling time:** Classification of bulk milk tanks on the basis of time taken for cooling of milk from each collection is given in Table 4 below:

Table 4: Classification of bulk milk tanks on the basis of time taken for cooling of milk

Classification	Cooling time in hours All collections (35 to 4˚C)
I	2.5
II	3.0
III	3.5

Thus, for example, a bulk milk tank which is designed for two collections, operates at a performance temperature of 38˚C and cools milk of each collection within 3.0 hours would be designated as '2AII".

b) Daily capacity: The refrigerating system when operating in ambient temperatures between 5˚C and the specified performance temperature should be of sufficient capacity to cool the rated volume of milk in a tank for two collections, or 50% of the rated volume of milk in a tank of four collections, every 24 hours from 35˚C down to 4˚C and to extract the heat gained by the tank from all other sources.

c) Milk cooling rate: If a tank, designed for two collections, is either empty or contains 50% of its rated volume of milk at 4˚C, and 50% of the rated volume of milk at 35˚C is added in one batch, all of the milk should be cooled to 4˚C in not more than the specified cooling time (see Table 4).

If a tank, designed for four collections, is either empty or contains 25, 50 or 75% of its rated volume of milk at 4˚C, and 25% of the rated volume of milk at 35˚C is added in one batch, all of the milk should be cooled to 4˚C in not more than the specified cooling time (see Table 4).

d) Storage of milk:

- Under normal operating conditions the mean temperature of the milk between cooling periods should not be higher than 4˚C for tanks for four collections and 5˚C for tanks for two collections and none of the milk should exceed a temperature of 9˚C.
- At the specified performance temperature the rate of rise of the mean temperature of milk, initially at about 4˚C, should not exceed 1˚C in 4 hours when the rated volume is allowed to stand undisturbed.

6. CLEANING OPERATIONS AND HYGIENE MAINTENANCE [3, 4, 5]

Bulk tanks must be properly cleaned and sanitized. An improperly cleaned tank would be a major source of bacterial contamination in milk, thereby causing its deterioration and mitigating the advantages of chilling milk at farm level. Prevailing low temperatures of milk in an improperly cleaned tank favour rapid multiplication of psychrophilic bacteria (microorganisms capable of rapid growth at temperatures of 2 to 10°C) and cause serious flavour defects in milk.

a) Cleaning procedure: Tanks may be cleaned manually or with CIP or mechanical systems. A typical example of cleaning cycle for bulk milk tanks is provided in Table 5 below:

Table 5: Cleaning procedures for bulk milk tanks

Step / Cleaning Cycle
Pre-rinse • Rinse the tank manually and flush pipeline with lukewarm (38-43°C) water immediately after use to remove remaining milk residues. Water temperature should not exceed 49°C. • Disassemble all parts that must be hand-washed. Before carrying out routine cleaning of the tank, the thermometer probe and dipstick should also be removed and put aside carefully.

Step / Cleaning Cycle
Detergent Wash • Mix chlorinated alkaline cleaning solution (usually containing basic alkalies, phosphates, wetting agent, and chelating agent) or as specified in manufacturer's recommendations and based on water quality tests. • All detachable parts like tank covers, gaskets, calibration rod etc. should be cleaned manually after disassembling. For hand washing of disassembled parts: - Soak all parts at 49-57°C for at least 5 minutes. - Brush all parts thoroughly. - Drain. • For bulk tanks: - Circulate cleaning solution for 6-10 min. - The wash solution temperature should be above 49°C at the end of the cycle. Start with detergent solution at 77°C. - Brush all parts, including outside of tank and outlet valve, not designed for cleaning by circulation of cleaning solution. - Drain. - Clean the outlet connection and outlet valve manually.
Rinse • Rinse off the detergent solution with tap water before the acid rinse, if required. • Rinse tank thoroughly (inside and outside). • Rinse tank outlet valve.
Acid-rinse (Occasional) • Rinse the bulk tank with lukewarm or cold acidified water (Occasionally, rinsing with an appropriate acid solution is required to remove inorganic soils that build over a period of time). • Do not re-circulate rinse solution. • Circulate for 2-3 minutes and drain. • Visually inspect line, receiver jar, etc., for proper cleaning.
Sanitization Immediately before milking: • Flush pipeline and bulk tank with sanitizer immediately before milking (a cold dilute solution of sodium hypochlorite of 250 ppm can be used as a sanitizer and sprayed on interior surface of the milk tank). • Circulate for 2-3 minutes and drain. **(hypochlorite solution needs to be thoroughly flushed out with clean cold water within five minutes of its use or else serious corrosion of the tank may occur)**. • Sanitize hand-washed parts. Drain.

b) Checkpoints to follow:

- Check cycle times as recommended on the wash chart.
- Check that all solutions drain completely between cycles.
- Check that the pump has sufficient pressure to reach all areas.
- The last action before adding milk to the cooler should be a sanitize cycle.
- Consider an acid wash if no softener is being used in hard water.
- Check outlet valve, gasket and manhole area for cleanliness.
- Check inlet area to cooler and inlet pipe.
- The outside of the bulk tank needs to be kept clean at all times.

7. USEFUL TIPS

- Always keep the tank and the surroundings clean and dry.
- Follow the operating instructions strictly.
- During storage the milk should be periodically stirred at least for a period of 2 minutes every half an hour or so.
- Do not start / stop the unit from the main supply switch. If the main supply is required to be shut down for any reasons, ensure that the pump down operation has been completed prior to switching off the main supply.
- In case of shut down of the system due to power failure during operations, wait for 5-10 minutes before restarting the system.
- Maintain a logbook to be filled up on daily basis to monitor the performance of the tank. Maintain a separate logbook on preventive and breakdown maintenance.
- In case the system is not working, empty the tank by transferring milk into clean cans. Shift the milk to the nearest chilling centre or to the processing plant so as to prevent deterioration of milk.
- Do not try to repair anything locally. Call the service agent in case of any breakdowns of the system.
- Do not keep the junction boxes / control panels open or loosely fitted.
- Do not clean the cooling unit area especially the copper pipes with water. Wipe off the excessive dust or dirt with a dry cloth. Due care should be taken not to disturb the cabling or the thin copper pipes which are very delicate and serve as connections to the control and

safety devices. Do not use sharp objects to clean condenser fins.

- Do not try to start the compressor when it gets tripped due to internal heat sensing relay. Wait for the compressor to cool down by itself and then restart automatically. It may take 30-180 minutes, depending upon the internal heat, for the compressor to restart. If you try to start the compressor in the tripped condition, it may lead to further overheating and result in more delay and compressor failure.
- Do not alter the setting in the control panel with regard to the temperature or agitator time intervals.
- Do not by-pass any safety devices to keep the system operational during failures.
- Do not by-pass the voltage stabilizer / voltage guard, even if faulty. In case of faults call the service agent. In case the agent removes any safety device, get him to sign the maintenance logbook with appropriate entries to the effect.
- Due care should be taken during the operations and cleaning not to pour / spray water on the cooling unit especially the motors, which may result in major failures and hazards.

When operating the DG set, do not shut it off until the pump down operation is complete.

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