

2. Milk Cooling

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Purpose and Cooling Standards – Milk Cooling

The cooling process of milk produced on California dairy farms consumes the largest portion (30%) of total electrical energy used. The cooling of milk immediately after milking is vital to maintaining high quality levels until processed for fluid consumption or used to manufacture other dairy products.

The Grade “A” Pasteurized Milk Ordinance, 2001 Revision states:

Raw milk for pasteurization shall be cooled to 10°C (50°F) or less within 4 hour or less, of the commencement of the first milking, and to 7°C (45°F) or less within two (2) hours after the completion of milking. Provided, that the blend temperature after the first milk and subsequent milkings does not exceed 10°C (50°F). [www.cfsan.fda.gov/~ear/pmo01-3.html]

The 3-A Sanitary Standards for Farm Milk Cooling and Holding Tanks, Number 13-10 is a second standard that deals with cooling milk on dairy farms. Section E1.1 deals with cooling. This standard states:

Cool the product to 50°F (10°C) or less within 4 hours or less of the commencement of the first milking and to 40 F (4.4 C) or less within 2 hours after the completion of milking. Provided, that the blend temperature after the first milking and subsequent milkings does not exceed 50 °F (10 °C).

In California the milk temperature must be cooled to 50°F prior to pickup. However, milk that is shipped out of state must be cooled to 45°F. Since there is some uncertainty about final destination of the milk that leaves the farm, most CA dairy farmers cool their milk to 45°F. For the purposes in this Dairy Farm Guidebook, the assumption will be made that milk will be cooled to 45°F and the blend temperature, where applicable, will not exceed 50°F

Since milk harvested from the dairy cow is typically 99° F and will be stored at 45° F, the temperature must be reduced 54 F°. To reach this temperature roughly 50 Btu of heat must be removed per pound of milk. [Assumes the specific heat of milk to be 0.93 Btu/lb, F] Some of this heat may be lost as the milk travels from the cow to the cooling system. The amount of heat lost will depend on the milking system and the ambient air temperature. Because there is a possibility that no heat may be lost due to high ambient air temperatures, the cooling system should be designed to remove all this heat.

Two types of milk cooling systems are used on California dairy farms. They are: “Direct expansion” refers to a system where the evaporator plates are incorporated in the lower portion of the storage tank in direct contact with the milk. Liquid refrigerant boils [expanding] inside the evaporator thus the name “direct expansion”. Milk cooling takes place within the tank. One or more agitators move the milk over the evaporator plates for cooling. There is a limit to the size of refrigerated milk cooling and storage tanks due to structural issues. There is also a limit to the refrigerated surface area. The ability to remove heat from the milk fast enough [Btu/hr] to meet cooling requirements with high milk loading rates is not possible without reducing evaporator surface temperature to the point where freezing of milk may occur. This is particularly challenging when milk temperatures approach 38 °F. Agitating warm milk for long periods of time can also be detrimental to milk quality.

Generally, this milk cooling system cannot cool the milk as fast as the milk enters the tank. There must be time between milkings such that the cooling system can catch-up and cool the milk to 45 °F. With cows being milked up to 22 hours per day, this cooling system cannot be used.

“Instant” cooling is where the milk cooling is completed external to the storage tank or silo and then pumped into storage. An intermediate cooling fluid, such as chilled water from an ice builder or a glycol-water mixture from a chiller is used to cool milk rapidly in a heat exchanger rather than direct expansion. Theoretically there is no limit to the surface area in a heat exchanger, only economical and practical limits.

The trend towards larger milking herds, greater milk production per cow and larger more efficient milking parlors [cows per hours] has increased milk flow rate [gal/hr], with large volumes of milk to be cooled within a 24-hour period. The “instant” cooling system is not limited by the amount of surface cooling area in the storage tank or silo. This is the most common cooling system on larger California farms in spite of slightly less efficiency due to lower evaporator temperatures and pumping energy required to move the intermediary fluid thru the heat exchangers.

Refrigeration Cycle

A mechanical refrigeration cycle is nearly always used to either cool the milk directly or indirectly via an intermediate cooling fluid. The basic mechanical refrigeration system is shown in Figure 2-1. The system consists of a motor driven compressor that compresses the cold refrigerant gas returning from the evaporator so that the refrigerant can be condensed at high temperature. The high pressure - high temperature gas from the compressor flows to the condenser where the refrigerant is de-superheated and condensed by transferring heat to a cooling medium, usually air and/or water. The high- pressure liquid from the condenser will be a few degrees warmer than the cooling medium. This liquid is then metered thru a thermostatic expansion valve into the low- pressure evaporator that is in contact with milk (direct expansion), water (ice builder) or glycol-water solution in a chiller. Here the liquid refrigerant boils at low pressure and temperature absorbing heat from the milk, water or glycol-water. The low-pressure vapor is removed from the evaporator by the compressor where the vapor is again compressed and the cycle is completed.

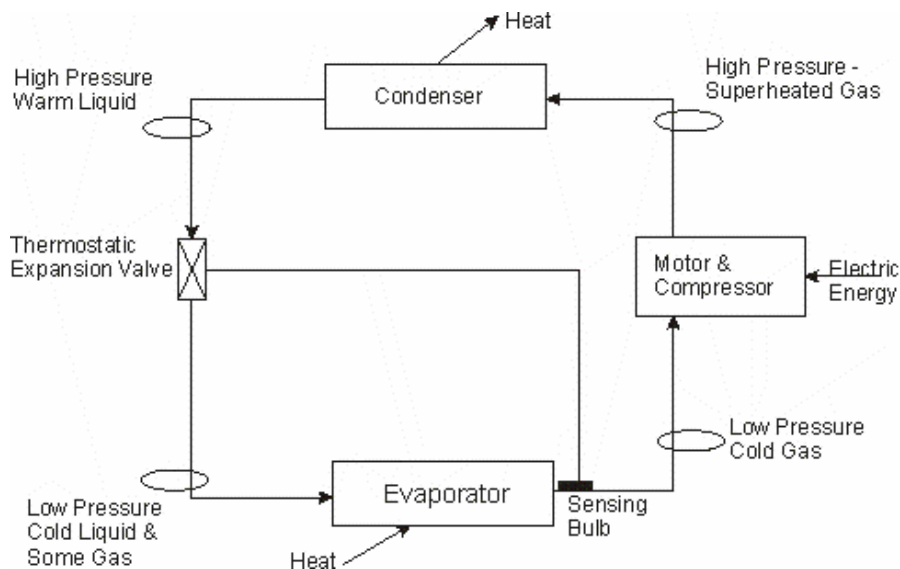


Figure 2-1. Schematic of a Mechanical Refrigeration System

The efficiency of a refrigeration system is given in terms of an EER [Energy Efficiency Ratio] where the units are Btu (cooling effect) per Watthour of energy input. There are many factors that impact EER. One factor deals with the relationship between the high side and low side pressure. EER will decrease as the difference between these two pressures increases. To maximize EER the low side pressure needs to be kept as high as possible and the high side pressure kept at low as possible. These factors need to be considered when selecting the refrigeration equipment. Other factors will be discussed later.

An assortment of energy conserving measures exists to improve the overall efficiency of milk cooling systems. More discussion of their application will be presented later.

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Equipment – Milk Cooling

Compressors

The most common refrigeration compressor found on dairy farms today is the reciprocating. 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 seal is generally a weld. See Figure 2-2. The motor operates in a low- pressure atmosphere of the refrigerant.



Figure 2-2. Hermetically sealed reciprocating compressor (Copeland)

The accessible hermetic unit is similar except the housing is bolted together in a single unit rather than welded. The motor and compressor are accessible. See Figure 2-3. In some cases the low pressure - low temperature refrigerant passes over the motor.

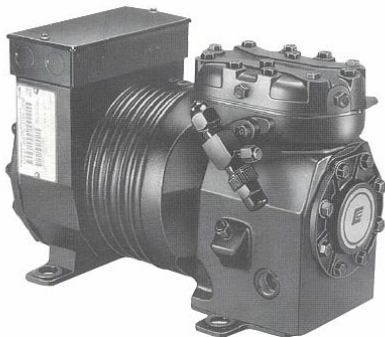


Figure 2-3. Accessible reciprocating compressor (Copeland)

Condensers, Air- and Water-Cooled

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 remote. An example of a remote air-cooled condenser is shown in Figure 2-4 as installed on a dairy farm.



Figure 2-4. Remote air-cooled condenser

A water-cooled condenser operates under the same principles as an air-cooled condenser except water is the coolant. Water-cooled condensers are generally smaller in size and offer a higher EER than air-cooled condensers. There are several reasons.

The heat transfer coefficient [Btu/ft², F, hr] between the metal surface of the exchanger and water is greater than that for air. This coefficient describes the heat transfer [Btu/hr] for each square foot of surface area and the mean temperature difference [F°] between the refrigerant gas and the cooling media. This means that for the same temperature difference, the surface area of a water-cooled condenser will be smaller than the air-cooled condenser. This generally means the size or footprint is less. This also means that the temperature difference can be smaller with the same surface area, which helps maintain a higher EER.

Water is a better carrier of heat than air. On an equal volume basis, water will absorb 3,500 times as much heat (Btu) for the same rise in temperature. This means that a much greater volume of air is required than water to remove the same amount of heat from the condensing refrigerant.

The airflow in an air-cooled condenser is perpendicular to the flow of refrigerant. This reduces the contact time between the air and the condenser surface thus requiring greater face area. This is not true in a 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 in Figure 2-5 along with a complete unit. 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 passes with baffles in the shell to reduce short-circuiting and increase turbulence of the refrigerant. Condensed refrigerant collects in the bottom of the shell.

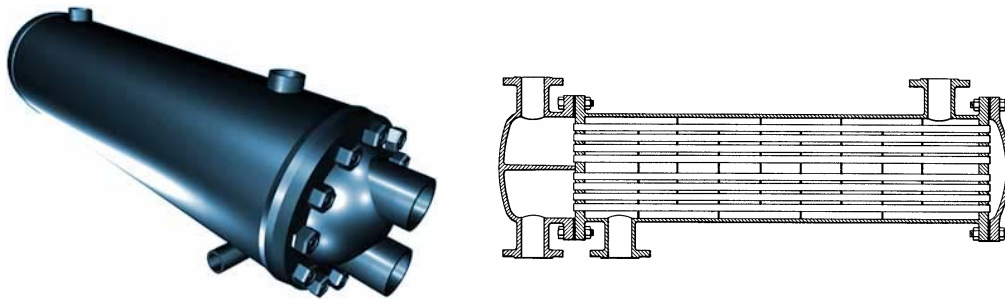


Figure 2-5. Example of a shell and tube water-cooled condenser (Standard Refrigeration)

An assembly of a compressor and condenser plus associated controls and equipment is called a condensing unit. Three condensing units are shown in Figure 2-6. These units have a water-cooled condenser mounted underneath an accessible hermetic compressor. The water pipe connections can be seen on the end of the condenser. The flow of water through the water-cooled condenser is generally controlled by pressure controlled water valve.



Figure 2-6. Water-cooled condensing units with accessible hermetic compressors

The flow control valve can be seen between the right end of the water cooled condenser and the galvanized water pipe. The control is connected to the high-pressure side of the compressor. The purpose is to maintain a constant head pressure.

Thermostatic Expansion Valve [TEV]

This type of expansion device is often used on refrigeration system for milk cooling. The device functions as a restrictor and flow regulator. There is considerable pressure drop across this restriction separating the high-pressure side condenser from the low side evaporator. The refrigerant flow through the TEV is controlled such that the refrigerant gas leaving the evaporator will have a few degrees of superheat. This insures that no liquid refrigerant enters the compressor. [The sensing bulb for the TEV is identified in Figure 2-1.] The sensing bulb contains a small amount of refrigerant, the same refrigerant as in the cooling system, so the pressure in the bulb is the same as the pressure in the return pipe from the evaporator. The sensing tube provides feedback to the TEV.

Evaporator

The evaporator is that section of the refrigeration system where the liquid refrigerant evaporates or boils at low pressure and temperature, absorbing heat from the surroundings space. For milk cooling, the evaporator may be a part of the bottom of the milk cooling/storage tank [direct expansion] or a chiller, where an intermediary fluid, such as water or a water-glycol solution, is employed to transport heat from the milk in a plate heat exchanger to the evaporator of the mechanical refrigeration system.

Direct Expansion

This system cools the milk directly in the milk storage tank. The lower section of the tank is the evaporator. There is a chance that the milk can be frozen at the evaporator if the evaporator temperature is too low and there is insufficient mixing of the milk that allows the milk to remain in contact with the evaporator too long.

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 used in the first stage of the plate cooler to reduce milk temperature to within 5°F of input water temperature. The chiller provides 28-34° F water – propylene glycol solution to the second stage of the plate cooler. When milk enters the second stage of the plate cooler, chilled solution from the chiller “instantly” cools the milk to 38° F. The milk enters the bulk tank or silo completely cooled.

Generally, instant chilled water/glycol cooling systems are 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 thru 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 hundredweight than a direct expansion system.

A schematic diagram of an instant cooling system using a one-pump (coupled) system is shown in Figure 2-7.

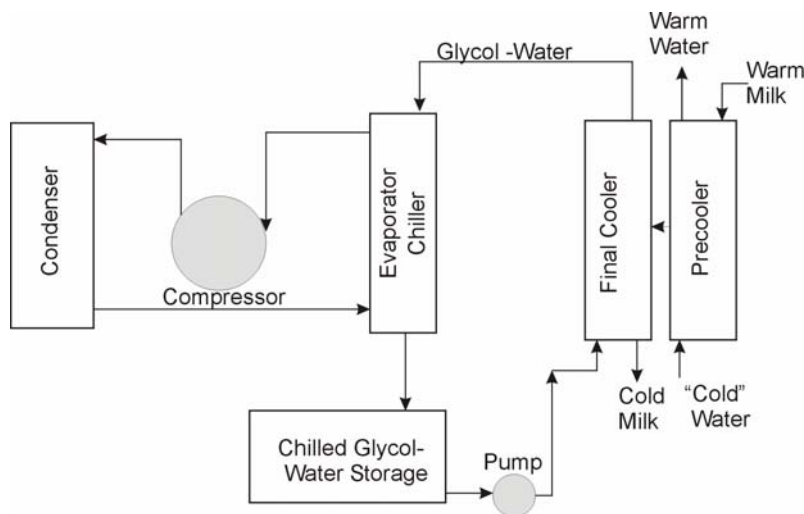


Figure 2-7. Instant milk cooling system with a coupled, one pump system

Having a single circulation pump requires careful sizing of the evaporator chiller and milk plate heat exchanger because each will have the same flow rate [gpm]. The two heat exchangers [evaporator and milk cooler] are coupled. Manufacturers of plate heat exchangers usually recommend that the coolant flow rate be 2 to 3 times the flow rate of product being cooled.

A better practice may be a decoupled system where two pumps are used, one for the evaporator and a second for the plate heat exchanger. Such a system is shown in Figure 2-8. Here the two pumps can be sized individually to optimize the performance

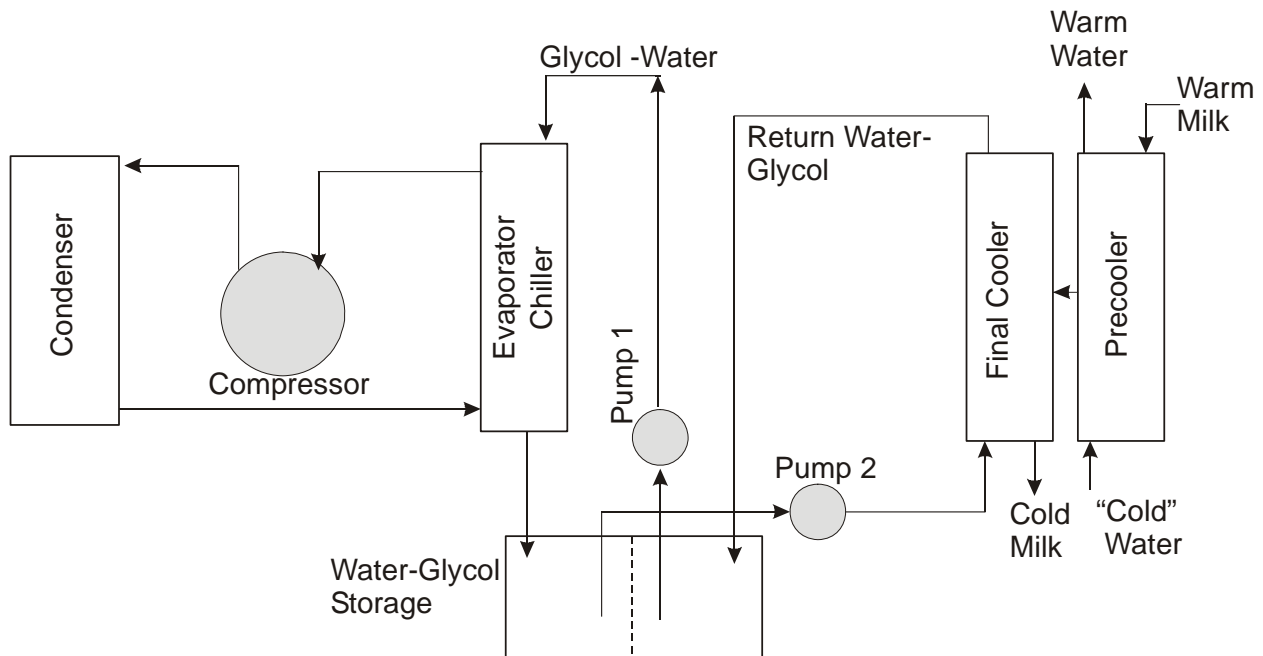
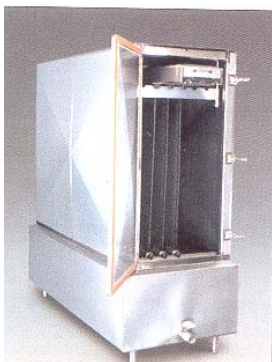


Figure 2-8. Instant milk cooling system with decoupled, two pump, system

of the evaporator/chiller section and the final plate heat exchanger. With this system there is also an opportunity to have two feedback control loops; one to maintain the correct temperature of the water-glycol storage and second to achieve proper temperature of the cooled milk.

The evaporator on a cooling system could be the cooling plates in a falling film chiller. Examples of a falling film chiller and a single plate are shown in Figures 2-9 and 2-10. The falling film chiller consists of a series of plates arranged vertically, the number of plates being determined by the required cooling capacity. These plates can be seen in Figure 2-9.



(Photo courtesy of DeLaval)



Figure 2-9. Falling film chiller showing vertical plates and a view of a plate

The warmed water/glycol solution from the plate cooler enters the top of the chiller cabinet and empties into a distribution pan, which is suppose to evenly disperses the solution over the vertical cooling plates. Achieving this can be a challenge. A thin layer (film) of solution cascades (falls), thus the name “falling film” chiller, down each side of the refrigerated plate and falls into an insulated reservoir located the base of the unit, where it will be returned to the plate heat exchanger. Falling film chillers are generally associated with coupled systems, one circulating pump.

Generally two plates would be connected to a single condensing unit. Referring to Figure 2-10, the six white (frost covered) pipes are attached to six vertical plates. Each pipe is served by a thermostatic expansion valve with the sensing bulb attached to the exit pipe from that same plate [liquid refrigerant enters at the bottom and gas exits at the top of the plate]. The three drier/filters each serve one condensing unit and two plates.

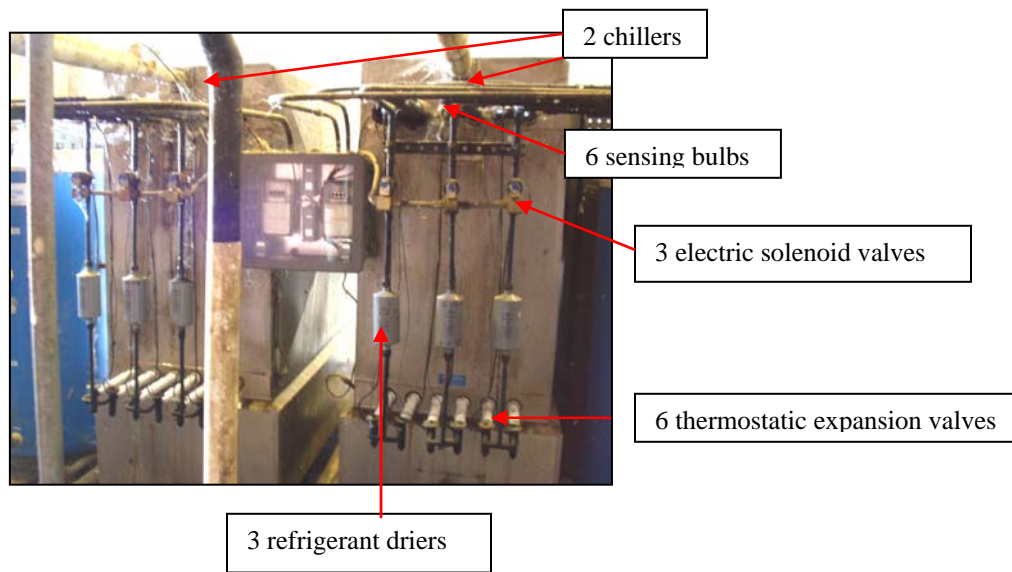


Figure 2-10. Falling film chillers showing refrigerant connections

There are alternative evaporators that generally associated with a decoupled cooling system. For this arrangement the water-glycol would be stored in a separate tank. Two types will be presented. These units have a much smaller foot print that the falling film chiller

The first is a chiller barrels. A chiller barrel can be different shapes and sizes. An example is shown in Figure 2-11.



Figure 2-11. Chiller Barrels (TX from Standard Refrigeration Co.)

This chiller barrel is similar in constructed to a shell & tube heat exchanger discussed earlier as a water cooled condenser. This chiller does not have to be coupled to the milk plate heat exchanger so that both units need not be sized to function at the rated capacity with the same coolant flow rate (gpm).

A second alternative is the brazed heat exchanger. These units are similar in function to the single pass plate heat exchangers used to cool milk that will be discussed next. However, these units do not have gaskets between the plates and they cannot be opened, the unit is welded shut. An example of a brazed heat exchanger is shown in Figure 2-12.

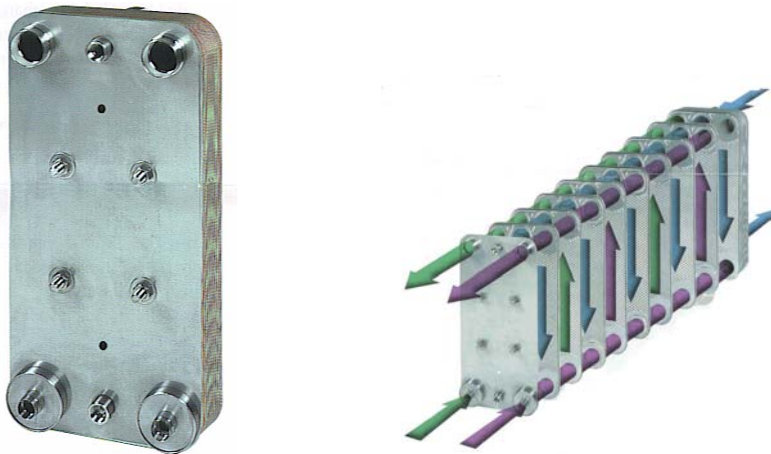


Figure 2-12. Brazed plate heat exchanger; a complete unit and an expanded view (Flat Plate)

Because of their design these units are more compact and have a smaller foot print than either falling film or chiller barrels. These units can be used for direct expansion. The barrel chillers and the brazen heat exchangers are more likely to be used on the decoupled system. The system pictured in Figure 2-13 is a decoupled system with barrel chillers and scroll compressors. The diagram in Figure 2-14 shows the decoupled - two pumps system.



Figure 2-13. Decoupled or two pump system (Kool Way® by Westfalia-Surge™)

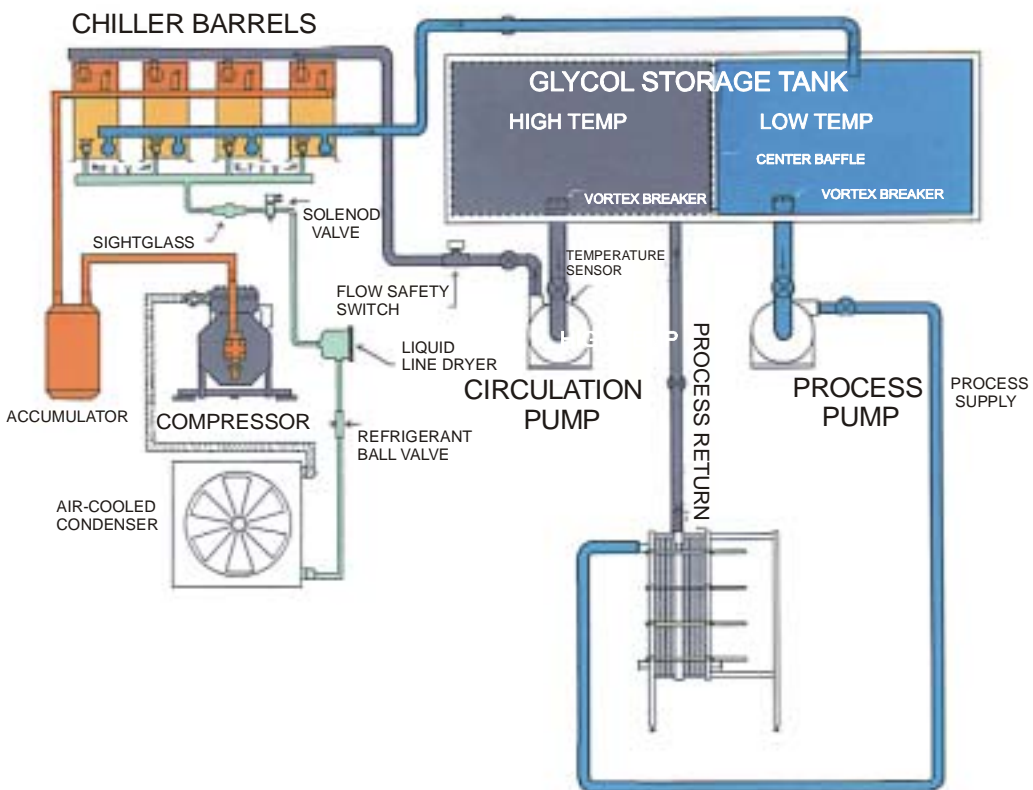


Figure 2-14. Flow diagram for Kool Way® by Westfalia-Surge™

The circulation pump operates whenever the refrigeration system is operating. The refrigeration system is controlled by the temperature of the Low-Temp tank. The process pump runs continuously with no feedback control.

Milk Cooling Heat Exchangers

The heat exchangers used for cooling milk are made of stainless steel and are designed to be opened for cleaning. A well-water-cooled heat exchanger that partially cools the milk prior to entering a direct expansion cooling system or an instant cooler has been available for over 20 years. Today this energy conservation measure [ECM] is standard equipment on larger farms. For instant milk cooling systems this pre-cooler is the first section of a larger plate heat exchanger with final cooling occurring in the second section.

Well Water Partial Cooling

The use of a well water-cooled plate or shell & tube heat exchanger to pre-cool milk prior to the milk entering a refrigerated milk tank or a final plate heat exchanger is common. Earlier, shell & tube or double tube heat exchangers were commonly used. More recently plate type heat exchangers have become dominant.

There are three major configurations of a plate heat exchanger. The configuration shown in Figure 2-15 is a single pass unit. Here the two fluids are in contact [on either side of a plate] as the fluids make one pass between the plates.

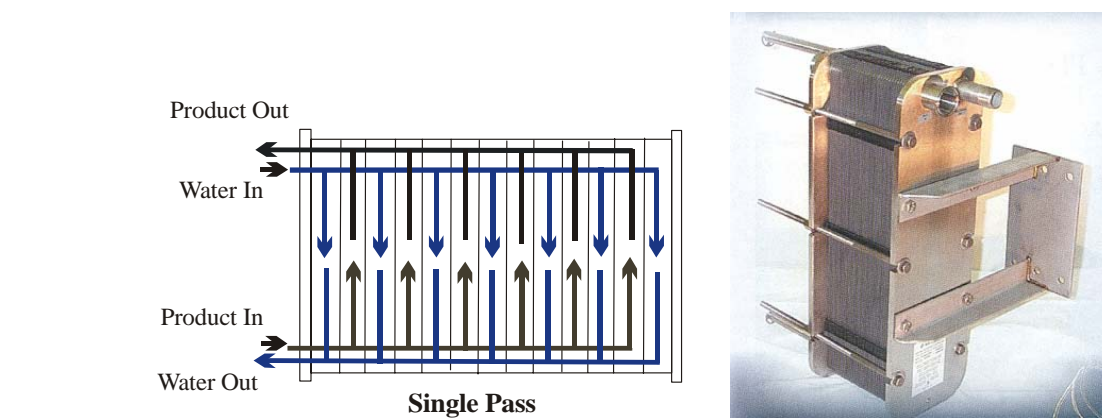
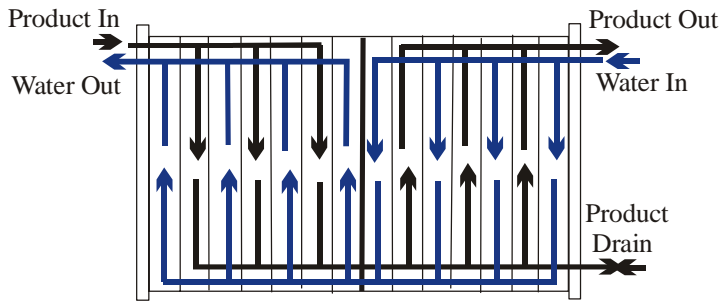


Figure 2-15. Single Pass plate heat exchanger

The flow pattern in Figure 2-15 is a counterflow configuration, the coolant and milk flow in opposite directions, the cold water input is next to the cool milk out. All heat plate exchanger should be installed with counterflow. This flow pattern has a higher mean temperature difference and a greater effectiveness than parallel flow.

A dual or double pass heat exchanger is more effective than a single pass unit. Here the product makes two passes so that the product is in contact with the coolant twice as long, assuming all other factors are equal. See Figure 2-16.



Dual Pass

Figure 2-16. Dual pass plate heat exchanger

The comparison between single and dual pass plate heat exchangers is shown in Figure 2-17. The graph shows the relationship between the number of plates and the expected temperature drop in the milk with single and dual pass plate heat exchangers. The ratio of low rate between the milk and cooling water was 1:1. There are three data points for the single pass unit. A linear projection of those three data points was made to estimate the temperature drop for a single pass exchanger unit with more plates. Two data points are plotted for a dual pass unit. If both types had 32 plates, the expected drop in temperature for the single pass unit would be 25 F° and slightly over number of plates and temperature drop 28 F° for a dual pass unit. For the same number of plates, a dual pass is more effective than a single pass.

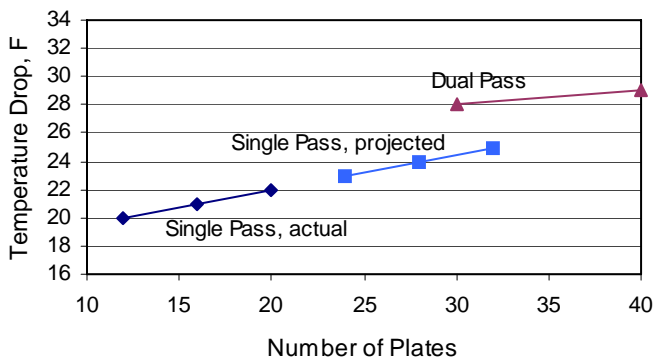


Figure 2-17. Relationship between number of plates and temperature drop

The third configuration for a plate heat exchanger is the two-stage. Figure 2-18 shows the flow configuration for this unit. This unit is equivalent to two single pass units joined together. One section is used for precooling with well water and the second section is for final cooling with chilled water or glycol-water solution. This unit is common on California dairy farms.

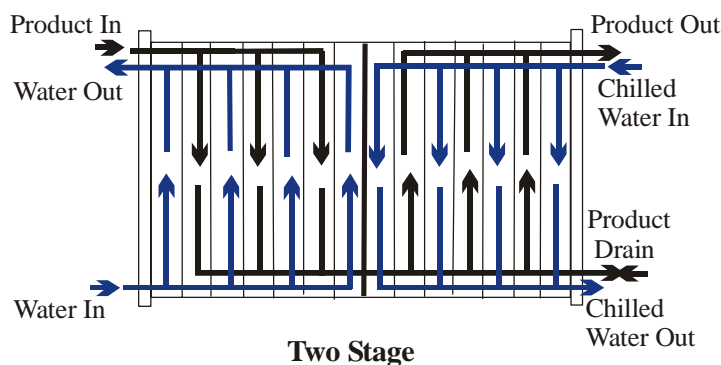


Figure 2-18. Two stage; well water precooler and chilled water or water-glycol final cooling)

The effectiveness of a heat exchanger is also dependent on the ratio of flow [gpm] between the product and the cooling media. A higher coolant flow rate provides a greater mean temperature difference between the milk and coolant and a higher coolant velocity between the plates that increases the heat transfer coefficient. Most manufacturers recommend at least a ratio of 2, water flow twice the milk flow.

The data for the graphs shown in Figure 2-19 were taken from manufacturer's literature to demonstrate the impact of coolant flow on the exit milk temperature. The milk flow from the milk pump on a receiver is intermittent. When the level of milk in the receiver reaches the upper probe, the pump starts. The milk flow could be at least 25 gpm for a few seconds and then stop for perhaps a minute. Tests on two conventional receiver pumps in a double parlor showed that the average milk flow rate during milking was about 12 gpm. Both receiver pumps operated 26 percent of the time, meaning that the average flow rate of milk when a pump was operating was 44 gpm. To achieve a recommended flow ratio of 2, the chilled coolant flow rate while the milk pump was operating must be 88 gpm which difficult to achieve on a dairy farm.

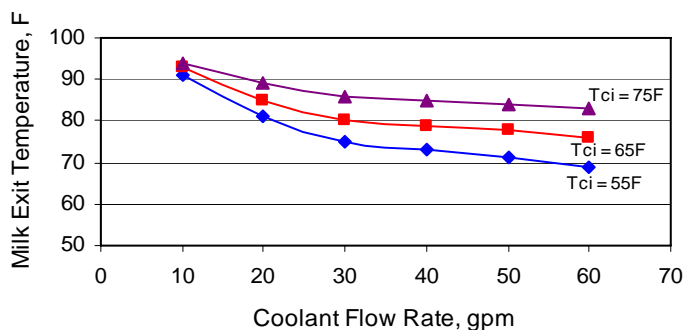


Figure 2-19. Impact of coolant flow rate on exit milk temperature for three coolant temperatures (T_{ci}), inlet milk temperature = 98°F, intermittent milk flow = 35 gpm, coolant flow while milk pump is operating, low flow between cycles.

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Milk Cooling Energy Utilization Indices (EUIs)

The EUI for milk cooling with a well maintained cooling system and no energy conservation measures averages between 0.8 and 1.2 kWh/cwt [hundred weight] of milk cooled. There are two EMCs that can be employed. They will be described in the next section. As ECMs are added, the EUI will decrease. Partial cooling the milk with a well water “precooler” will save 0.2 to 0.3 kWh per cwt milk cooled. Installing a variable frequency drive will lower the EUI an additional 0.2 kWh per cwt milk cooled. The actual reduction in energy use will be dependent on well water temperature, water flow and the effectiveness of the VFD to reduce the milk flow through the heat exchanger.

To calculate the savings of well water precoolers and VFDs on receiver pumps click on the following link: [Calculators](#)

Milk cooling system	EUI, kWh/cwt cooled
Conventional	1.2 – 0.8
Well water precooler	0.9 – 0.6
Well water precooler with VFD on receiver pump	0.7 – 0.4

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Milk Cooling Energy Conservation Measures (ECMs)

There are several measures that can be implemented that will reduce the energy consumed to cool milk. Some of these were mentioned above.

Precoolers

Well water-cooled heat exchangers partially cool milk prior to the milk entering the refrigerated storage tank or a second heat exchanger for instant cooling. This practice was discussed earlier because the practice has been widely accepted and in many areas has achieved 100 percent market penetration.

Variable Frequency Drives [VFD] For Milk Pumps

As stated earlier, under conventional practice, the flow rate (gpm) of milk from a receiver is not uniform. The flow of milk during milking from the milk pump will vary from zero to 25 - 50 gpm. In a milking parlor with two milk pumps, the pumps may operate 10 to 25 percent of the time while the cows on one side of a parlor are being milked. This means that there is no milk flowing through the heat exchanger 75 to 90 percent of the time and the flow during the other 10 to 20 percent of the time will be high. This is not an efficient way to operate a heat exchanger. On the well water or chilled water-glycol side of the heat exchanger the flow needs to be 50 to 100 gpm for that 10 to 20 percent of the time. This is difficult.

To help alleviate this problem, a variable frequency drive can be applied to the milk pump. The concept here is to slow down the flow of milk from the receiver so that the milk pump operates a higher percentage of the time. This means the flow of milk through the heat exchanger will be lower and more continuous. Both factors improve the effectiveness of the heat exchanger.

Control for the variable frequency drive is generally a series of magnetic reed switches mounted inside a hollow stainless steel pipe [probe] mounted vertically near the center of the receiver through the Plexiglas cover. Depending on the length of the probe, two to four reed switches are positioned along the probe at appropriate locations. Stainless steel floats that hold a magnet fit around the probe and are held positioned along the probe at the same location as the reed switches. The floats are held in place by clips on either side of the float. When the float with a magnet floats up to the reed switch the switch either closes or opens depending on the logic being used. When the float leaves the switch the switch returns to its initial position.

Using a binary code, the frequency output from the VFD and thus the speed [rpm] of the receiver pump can be controlled by which reed switches are closed [one] and which ones are open [zero]. The VFD can be programmed to provide different speeds depending on the position of the floats. When the top reed switch is activated the VFD generally goes to 60 Hz for full speed of the milk pump. When the lowest switch is activated as the milk rises in the receiver, the pump will start at the lowest preset speed giving the lowest milk flow. The goal is to have the pump operate at the lowest speed for the greatest percentage of the time.

One needs to be careful when setting this lowest speed. Nearly all receiver milk pumps are centrifugal [variable delivery, delivery varies with total head and rpm] as opposed to positive displacement pumps where delivery is nearly linear with speed and within reason unaffected by discharge pressure. Centrifugal pumps experience shut-off head. At a certain combination of total head [pressure] and pump rpm, the flow from the pump stops. The total head is the sum of the suction head, between 12 and 15 inches of Hg, and discharge head that includes the vertical height to the discharge point or height of milk in a silo, the pressure loss in the filter, the friction of the heat exchanger and piping.

The curves shown in Figure 2-20 illustrate the performance of a 4-blade impeller milk receiver pump driven at different speed with a VFD. A vacuum of 13 inch Hg was maintained in the receiver. The pump had considerably different characteristics during speeding up and slowing down. With 13 inch of vacuum the shut off head occurred at 42 Hz, or 2,400 rpm for a motor rated at 3,450 rpm.

The first seven data points in Figure 2-20 are plotted on the graph in Figure 2-21. The sensitivity of the pumping rate to pump speed is significant. When speeding up, a change in pump speed of 10 Hz or about 600 rpm made little difference in flow rate. However, when the pump was being slowed down by the VFD, the flow rate decreased from 14 to 0.6 gpm for the same change of 600 rpm. Setting the preset speeds on a VFD for any milk pump must be done with care.

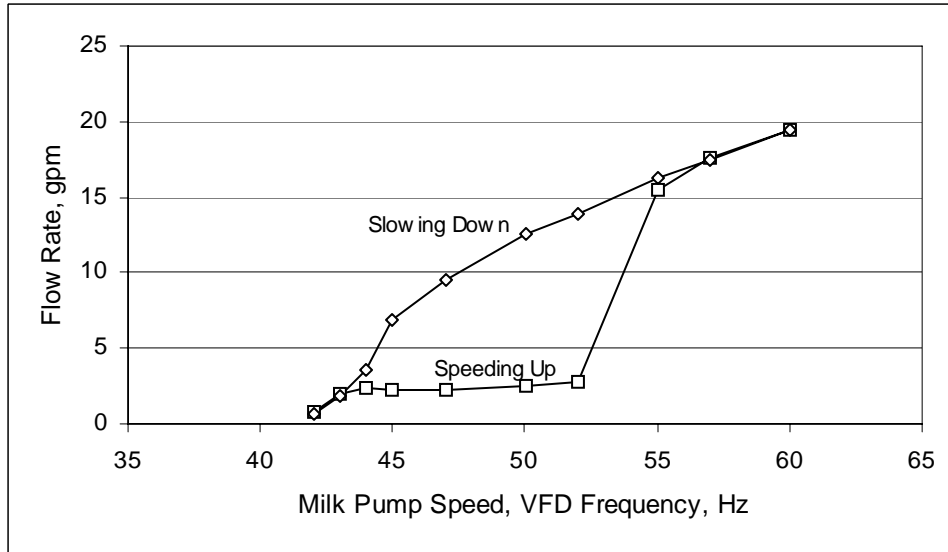


Figure 2-20 Characteristics of a 4 Blade Impeller Milk Pump with a VFD

Another issue that should be considered is the agitation of the milk inside the milk pump at lower speeds. When the pump is operating at full speed (the impeller was turning at 3,450 rpm) the delivery rate was about 20 gpm. For every gallon of milk delivered the impeller turned 172 times. At low speed the delivery was less than 4 gpm but the speed was 2,400 rpm. Now the impeller turned 600 times per gallon or more that three times the agitation. The impact of this additional agitation has never been studied.

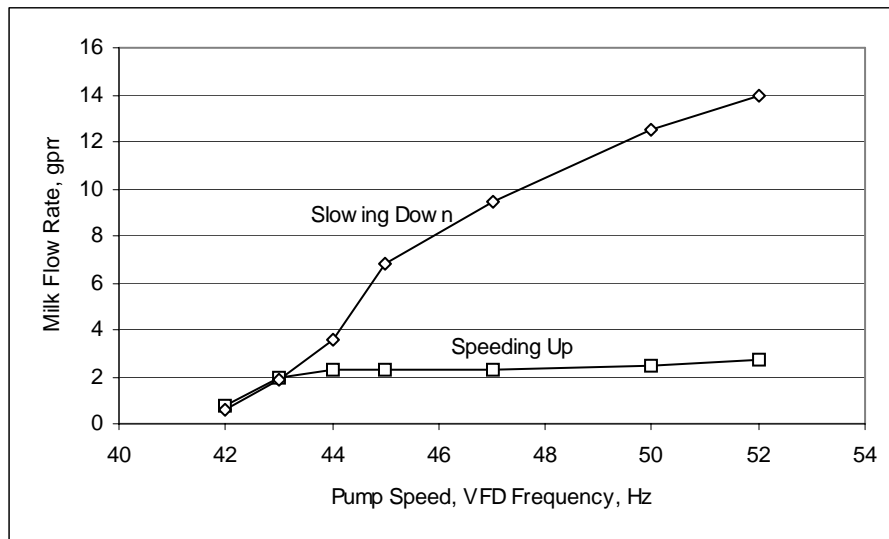


Figure 2-21 Enlargement of a Portion of Figure 2-20

Scroll Compressors

Two new classes of compressors, the scroll and discus are now being introduced for milk cooling on dairy farms. These new compressors are both more efficient. The scroll compressor utilizes two identical scrolls, one fixed and the second rotating within the fixed scroll. 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.



Figure 2-22. Scroll Compressor (Copeland)

A study comparing a scroll compressor with a 13-year-old 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 by a reduction in the electrical demand (6.7 to 5.7 kW) and hours of operation per day (7.2 to 6.1). These units are quieter and operate with less vibration.

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Operator Level Checks – Milk Cooling

Air Circulation For Air-Cooled Condensers

Place condensers in an area where air temperatures will be the lowest possible. Providing air-cooled condensers with air that is as close to outside air temperature as possible will give the best possible performance. Locating condensers in a utility room with poor air circulation causes the condensers to operate at an elevated temperature that results in a higher head pressure, higher energy use and reduced refrigerating capacity. Locate condenser in shady areas, not in the direct sun or on the roof. Condensing units are not placed on roof tops because that is the coolest place but because this is the cheapest “floor space”, there is no available space inside and reduces noise.

The liquid refrigerant leaving a condenser will hopefully be 5 to 10 F° warmer than the ambient air temperature. The closeness of the refrigerant temperature to the ambient air is a good indication of the effectiveness of the condenser.

Water-Cooled Condensers

Be sure ample cooling water is available for all condensers. Remember that the compressor head pressure generally controls the water flow rate via a pressure-controlled water valve. Maximum water flow will occur when the compressors are working under full loaded and/or when the cooling water is warm.

Check the temperature of the water entering and leaving the condenser. The entering water should be close to the temperature of ground/well water. The temperature of the exit water will be warmer than the inlet temperature but the water should not be hot. As mentioned above, compare the temperature of the liquid refrigerant leaving the condenser and the inlet and exit water temperatures. Again the exiting liquid refrigerant temperature should be a few degrees warmer than the exit water temperature.

Sight Glass and Moisture Indicator

All refrigeration systems [condensing units] should have a sight glass and moisture indicator, usually in one unit. The unit is mounted in the liquid line ahead of the thermostatic expansion valve. When the system is operating there should not be any bubbles visible in the sight glass. Bubbles indicates low refrigerant. While the systems are starting up and when they are shutting down there may be bubbles. This is to be expected and does not indicate low refrigerant.

Built into the center of the sight glass is a chemical that changes color when exposed to water/moisture. The housing for the sight glass will show the color when the system is “dry” and the color when the system is “wet”. These chemicals are temperature sensitive. Temperatures near 75 °F give the best results.

Refrigerant Leak Detection

Oil

Refrigerant leaks are associated with oil leaks. Oil and accumulated dirt appearing at pipe joints [solder or compression], surfaces around compressor particularly where there is high-pressure refrigerant is a sure indicator of a leak. If oil accumulates there is a refrigerant leak. This is not a scientific detector but an operator can observe oil accumulating and report this to the equipment dealer.

Electronic Detection

These instruments measure variation in current flow caused by ionization of decomposed refrigerant between two oppositely charged platinum electrodes. The electronic detector is the most sensitive and common of the various leak detection methods. They are capable

of sensing a leak as small as 1/100 oz of R-12 per year.

Dye Method

Uses fluorescent dyes and an ultraviolet light to pinpoint leaks. A pre-measured amount of dye is injected into the refrigeration system at a service port and allowed to circulate. The refrigeration lines, valves, fittings, tubing, coils, compressors and seals are scanned with a hand held ultraviolet light. Any leaks present will glow brightly, revealing their precise location. Can reveal leaks as low a 1/8 oz. per year.

Halide Torch

The halide torch is a fast, reliable, economical method of detecting chlorinated [R 12 and R 22 for instance] refrigerant leaks. Air is drawn over a copper element heated by propane flame. If halogenated vapors are present, they decompose, and the color of the flame changes to bluish-green. Although not as sensitive as electronic detectors, this method is suitable for most purposes.

Field Tests & Maintenance Measures

Milk Cooling

- Periodically check that the precooling solenoid functions properly. Mineral deposits accumulated over time can prevent the solenoid from opening fully and water flow through precooling is reduced. Likewise, the solenoid valve can leak causing high water use and cooling of the wash water.
- Check the temperature of the milk leaving the precooling. Most instant cooled systems have both precooling and final cooling in the same plate cooling so this cannot be checked. If the precooling is a separate unit, the exit temperature of the milk should be within about 5 to 10 degrees of the incoming water temperature. The closer to the incoming water temperature, the better.
- Check the milk tank temperature. Overcooling the milk results in a much higher energy use.
- Condensing unit operating time:
 - Direct expansion cooling systems: the condensing unit will operate after milking is complete because the milk in the tank will not be cooled to the desired level by the end of milking. How long the compressor runs after each milking depends on the relationship between the flow rate of milk into the tank and the cooling capacity. Note the usual running time for the condensing unit. If the operating times become gradually longer this would indicate a problem with the efficiency or effectiveness of the chilling system as long as the amount of milk being cooled remains constant. The problem could be at the precooling; flow rate of water, water temperature, fouling of

the heat exchanger. The problem could be at the condensing unit – perhaps a loss of refrigerant or the condensers are becoming dirty and less effective.

- Direct or instant cooling systems: the condensing unit should turn off shortly after the end of milking. Problems with the cooling system would be indicated by a gradual rise in milk temperatures entering the silo. Problem would be similar to those mentioned above.
- Check compressor, condenser and motor temperatures.

Table 2-1. Refrigeration Troubleshooting Chart

Symptom	Problem	Solution
Slow cooling (low – Btu/hr capacity)	<ol style="list-style-type: none"> 1. Inadequate refrigerant charge 2. Plugged suction line filter 3. Plugged suction screen 	<ol style="list-style-type: none"> 1. Replace refrig. charge 2. Replace filter 3. Clean screen
Low suction Pressure	<ol style="list-style-type: none"> 1. Plugged orifice 2. Partially pierced aeroquip fitting 3. Low head pressure (below 200 psi) 4. Restricted liquid or suction line 5. Plate iced up, thermostat cutout too low 6. Plugged evaporator inlet 	<ol style="list-style-type: none"> 1. Clean orifice 2. Remove and repierce 3. Adjust head pressure control 4. Remove restriction 5. Readjust thermostat above 36°F
High head Pressure	<ol style="list-style-type: none"> 1. Dirty air condenser 2. Defective fan motor 3. Inadequate ventilation 4. Restricted airflow 5. Defective fan motor switch 6. Misadjusted fan motor switch 7. Limed up TS 8. Plugged high side (liquid line) filter/drier 9. Restricted or too small orifice (metering) 10. Restricted or kinked liquid line 11. Partially pierced aeroquip fitting on high side 12. Plugged evaporator inlet 13. High suction pressure caused by tank filled with refrigerant 14. Overcharge of freon combined with evaporator covered with hot milk and 100° F ambient 	<ol style="list-style-type: none"> 1. Clean condenser 2. Replace fan motor 3. Improve ventilation 4. Relocate condenser 5. Replace fan control 6. Readjust fan control 7. Delime 8. Replace Filter/Drier 9. Clean or replace with correct size 10. Locate and remove restriction 11. Disassemble and remove seal 12. Blow backward 13. Spray water on condenser 14. Correct refrigerant charge and spray water on the condenser
Compressor cut-outs on internal thermal overload	<ol style="list-style-type: none"> 1. Internal thermal faulty 2. Compressor heating up: start relay defective 3. Compressor heating up: system low on refrigerant 4. Compressor heating up, high head or low suction pressure 5. Low capacity compressor body 	<ol style="list-style-type: none"> 1. Replace overload or compressor 2. Replace start relay 3. Charge refrigeration system 4. Remove restricted lines or improve system charge 5. Replace compressor body
Intermittent Agitator	<ol style="list-style-type: none"> 1. Motor overheating 2. Defective internal thermal on motor 3. Motor failing 	<ol style="list-style-type: none"> 1. No lubricant in gear box Too heavy lubricant in gear box 2. Replace thermal overload 3. Replace or repair motor
Defective or misadjusted thermometer	<ol style="list-style-type: none"> 1. Milk too warm 	<ol style="list-style-type: none"> 1. Replace or adjust

Table 2-2. Plate Milk Pre-cooler Troubleshooting Chart

Symptom	Problem	Solution
Reduced milk flow rate through plate milk pre-cooler	Plates have "burn on" milk residue	Disassemble plate cooler and manually clean
	Blockage / obstruction in flow path	
	Pump is leaking before plate	
Reduced coolant (water) flow rate through milk pre-cooler	Filter is restricted / blocked	Install new filter element
	Product viscosity has changed	
	Water pressure too great causing plates to bulge and restrict milk flow	Check inlet & outlet pressures
Milk and/or Coolant leaking	Mineral fouling of plates	Circulate hot acid wash for 30 min.
	General fouling of plates	Disassemble plate cooler and manually clean
	Debris between plates	
Product Temperature Incorrect	Pump is leaking	Filter inlet water
	Output restriction of water flow	Check water outflow lines
	Check condition of gaskets	Replace as necessary
Milk and/or Coolant leaking	Check frame for proper tightening	Retighten to mfg. spec.
	Excessive line pressures	Check inlet & outlet pressures
	Corrosion of stainless steel due to high concentration of chlorine sanitizers.	Consider iodophor or quaternary ammonia sanitizers.
Product Temperature Incorrect	Check flow rates for both sides	Remove obstructions
	Check coolant temperature	
	Check for fouling or deposits	Disassemble plate cooler and manually clean.

Source: Westfalia-Surge

Milk Pumps

All Milk Pumps

Pump Seal:

Leaks in the shaft seals on receiver pumps can go undetected for long periods of time. This is because a leaking pump seal leaks air into the pump rather than leak milk out. The air that enters the pump aerates the milk causing lower milk quality and lower pumping efficiency.

Check valve:

The check valve serves to prevent backflow of milk into the receiver once the pump shuts off. The check valve should close without bouncing or leaking. Bouncing check valves can be heard as thumping or banging after the pump shuts off. Back flow of milk will cause chilled milk to be re-warmed by pre-cooler water in instant cooling systems and milk quality suffers from excessive pumping.

Test for leaking check valves and pump seals:

Check that all clamps and gaskets between the receiver and check valve are secure. Fill the bottom of the receiver with clear, cool water. Apply normal milking vacuum to the receiver. Observe the receiver pump outlet for air bubbles entering the receiver from the pump. If no bubbles are present, then the check valve, pump seal and pipe connections are sound and no leaks exist. If bubbles are present, turn on the milk pump to fill the milk pump line with water and then turn off the milk pump. Observe for air bubbles entering the receiver. If there are no bubbles then the check valve is the cause of the leak. If there are still air bubbles entering the receiver then either the seal is leaking or the connections between the receiver and the check valve are leaking.

Motor temperature:

High motor temperatures on the milk pump may indicate a motor or supply voltage problem.

Variable Speed Milk Pumps

In addition to the checks detailed above, variable speed milk pumps should be checked to confirm that is milk flowing at the lowest speed. One indication that the pump has stalled at the lowest speed is the audible click or thump of the check valve closing when the pump drops to the low speed. A milk pump that continues to run at the low speed, even after a long pause between groups of cows also indicates that the pump is in a stalled condition and is not pumping milk.

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Glossary of Milk Cooling Terms

Blend Temperature: Mass average temperature of milk in the bulk tank as warm milk is added to cool milk.

Bulk Milk Tank: An insulated sanitary container or vat, usually located in the milkroom, used to cool and/or store milk from harvest until pickup.

Chiller: Chilled water system where cooling medium (generally water and propylene glycol) is circulated through a heat exchanger where refrigerant cools the chilled water and then pumps it through an in-line cooler.

Compressor: That part of the refrigeration unit in which the vapor from the evaporator is compressed and delivered to the condenser.

Condenser: That part of the refrigeration unit in which the refrigerant changes from a vapor to a liquid giving up heat. The condenser may be air or water-cooled.

Cooling Capacity: The rate of heat removal in Btu/hour.

Direct Expansion: A single-wall heat exchange method of cooling milk by a direct transfer of heat from the milk to the refrigerant contained in the evaporator.

Evaporator: That part of the refrigeration system in which refrigerant absorbs heat from the milk and changes from a liquid to vapor. In a bulk milk tank, the evaporator is part of the liner of the tank, which holds the milk.

Expansion Valve: Part of a direct expansion refrigeration system between the condenser and evaporator where refrigerant pressure is reduced. In modern systems, the direct expansion valve has been replaced with other flow control devices.

Heat Exchanger: A device providing thermal exchange between two fluids.

Heat Recovery Unit: That part of a refrigeration system that allows recovery of heat from the refrigeration process for a useful purpose.

In-Line Cooler: A cooling device placed in the milk transfer system between the milk receiver and milk tank, which either partially or fully cools milk before it enters the tank.

Plate Heat Exchanger: An in-line heat exchanger that uses plates to separate milk and coolant, which flow through alternate spaces between the series of plates.

Pre-Cooling: Partially or fully cooling the milk before it reaches the bulk tank

Refrigerant: Any substance used in a refrigeration process that transfers heat from the evaporator to the condenser, creating a cooling effect. These fluids generally exhibit a phase change during this process.

3-A Standards: Sanitary standards for farm milk cooling developed by sanitarians, federal administrators and manufacturers.

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Milk Cooling Web Page References

Milking Equipment Manufacturers

- Dairy Equipment Company
Bou-Matic – www.Bou-Matic.com
- Alfa Laval Agri
Delaval – www.delaval-us.com
Germania Dairy Automation – www.germaniadairy.com
Universal Dairy Equipment – www.universaldairy.com
Nu-Pulse Inc.
- Westfalia-Surge – www.westfaliasurge.com
- The Coburn Company, Inc. – www.coburnco.com
- BECO Dairy Automation Inc. - www.becoknows.com
- The Schlueter Company - www.schlueterco.com
- Paul Mueller Company – www.muel.com
- Ross-Holm, Inc. – www.ross-holm.com

Refrigeration Equipment Manufacturers

- Copeland Corporation – www.copeland-corp.com
- Tecumseh Products Corporation – www.tpc-nacq.com
- Heatcraft Refrigeration Products, LLC – www.heatcraftRPD.com
- Standard Refrigeration – www.stanref.com
- Westfalia-Surge – www.westfaliasurge.com

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