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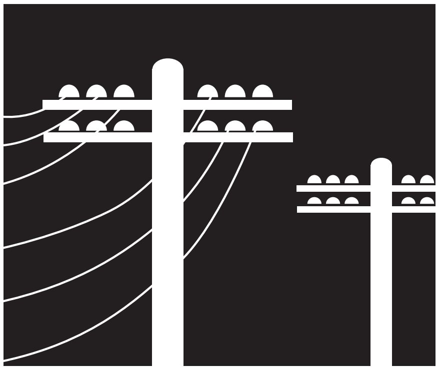


Energy Conservation in Agriculture

Refrigeration systems

Scott Sanford

Milk must be cooled to storage temperature, typically about 38˚F, to preserve its quality. The cooling process involves removing 56 BTUs of energy from each pound of milk.

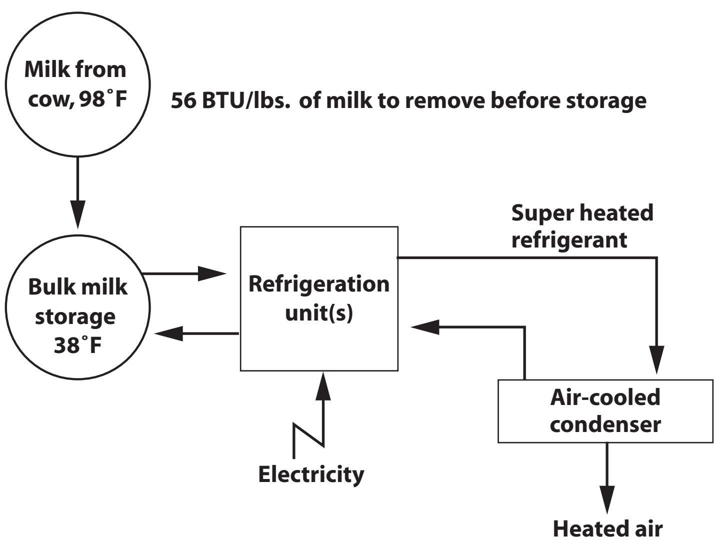
The basic refrigeration system is made up of a refrigerated bulk tank, a refrigeration compressor unit and an air-cooled condenser unit (see figure 1). There are several technologies that can be added to the milk cooling systems on dairy farms to reduce the refrigeration requirements or to capture waste heat for pre-heating water. They include refrigeration heat recovery units, well water precoolers and scroll compressors. This publication discusses refrigeration heat recovery units.

Refrigeration heat recovery units (RHR)

Refrigeration heat recovery (RHR) units are very popular and efficient at capturing heat from the refrigerant that would otherwise be discharged directly into the air. Some of the brand names for these devices include: Therma-Stor, Heat-Bank, Fre-Heater, Century-Therm and SuperHeater.

Refrigeration heat recovery units can capture 20–60% of BTUs in the milk for pre-heating water. The water temperature rises depending on: 1) the amount of hot water used while the refrigeration system is running; 2) the ambient air temperature surrounding the condensing units; and 3) the amount of milk being cooled. The maximum water temperature is about 140˚F, but varies greatly depending on farm conditions.

Figure 1. Milk cooling energy flows: Basic refrigeration system.



How do they work?

An RHR unit captures heat from the system refrigerant that would otherwise be discharged to the air and transfers it to the water, in effect preheating the water before it enters the water heater.

The RHR unit is made up of a water storage tank and a heat exchanger. The heat exchanger can be separate from the water tank or jacketed to the outside of the storage tank and covered with insulation and a protective shell.

The jacketed storage tank, which is available in 50-, 80- and 120-gallon size tanks (see figure 2) is the most popular. Heat is transferred to the water as the hot refrigerant gas leaving the compressor unit is piped through the RHR heat exchanger and cooled (figure 3).

Depending on ambient conditions, the refrigerant gas can reach temperatures in excess of 200˚F when entering the RHR heat exchanger and 75–85˚F lower exiting the tank after the refrigerant heat is transferred to the water. An air-cooled (sometimes water-cooled) condenser unit is plumbed in series with the RHR heat exchanger to remove any remaining heat from the refrigerant before it passes through the evaporator to start the cycle over (see figure 4).

Some RHR tanks are available with electrical heating elements so they can be used as a water heater/RHR combined unit. These are advantageous where space is limited and water usage is low but at the expense of reduced heat recovery.

Sizing refrigeration heat recovery units

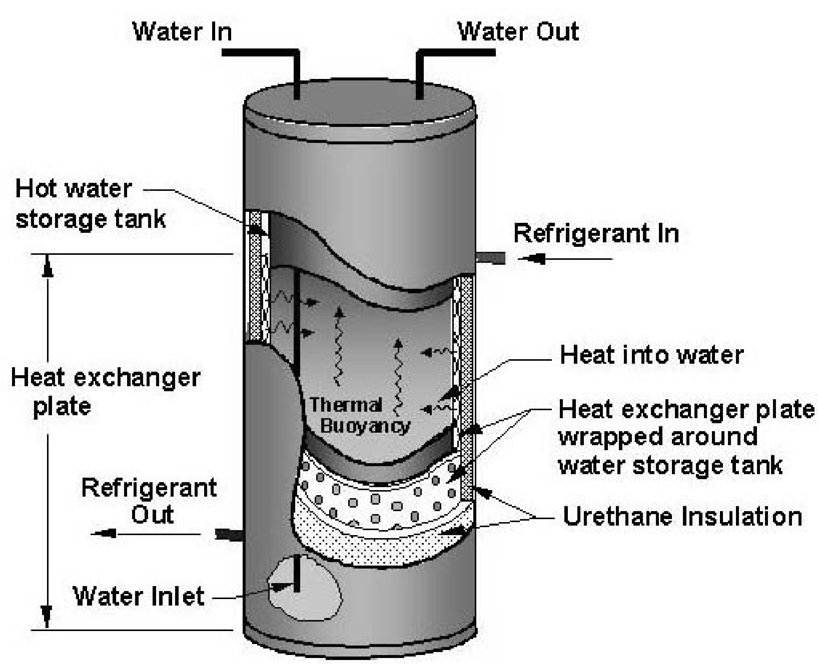
To maximize the recovery of waste heat, the RHR storage tank should be large enough to provide all of the hot water requirements for one milking. If it takes 50 gallons per cycle for washing the milking system and 46 gallons per cycle to wash the bulk tank every other day, then it will typically require 75 gallons of hot water to clean the milking system and 69 gallons for the bulk tank.

In an ideal world, we would like 144 gallons of RHR storage but since the bulk tank is only washed every other day, we would typically only provide storage for 110 gallons (75 gallons plus half of 69 gallons) so the RHR unit would be sized to a 120-gallon tank.

Large farms may benefit by having two or more RHR storage tanks. Another option for farms needing additional storage volume is to install an insulated storage tank next to the RHR unit and plumb the tank drains

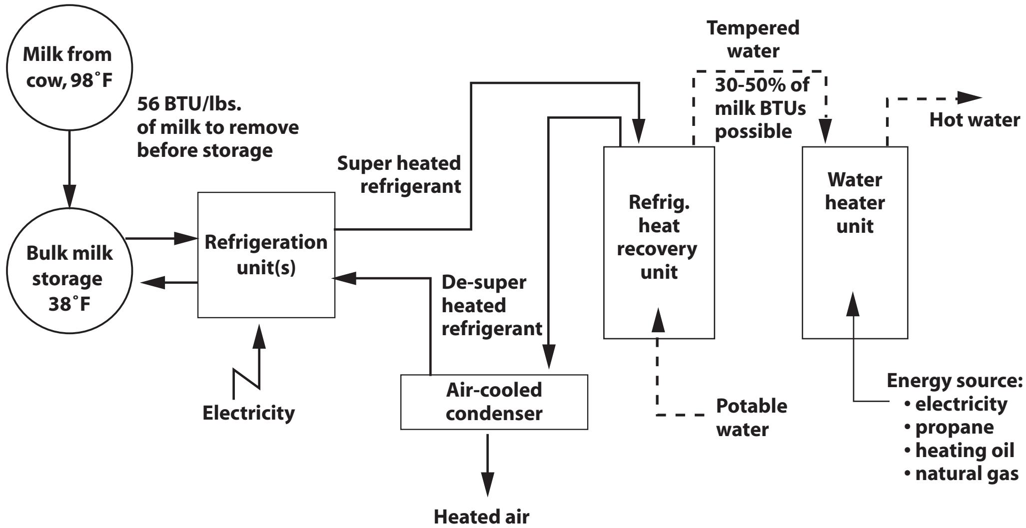
Figure 2. Typical refrigeration heat recovery installation next to water heater.

Figure 3. Cut-away view of a refrigeration heat recovery unit.



together and the tank outlets at the top together (see figure 5). Thermal buoyancy will move warm water into the storage tank as it is heated. If increased efficiency is desired, a small circulator pump can be installed so that water is continuously being circulated whenever the refrigeration compressors are running.

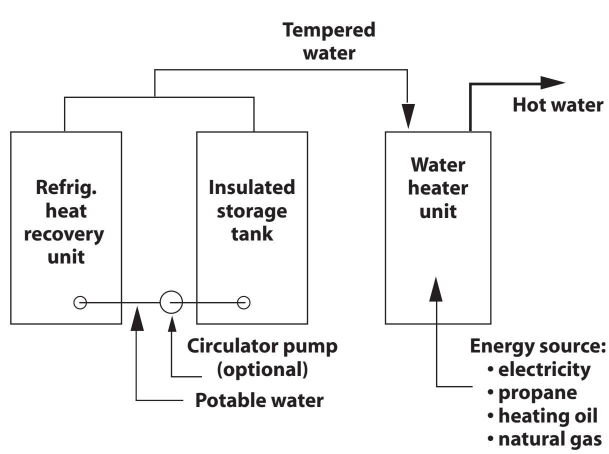
Figure 4. Milk cooling energy flows refrigeration system with refrigeration heat recovery.



Economic justification

The payback for the purchase of an RHR unit is based on a reduction in water heating costs. If the water is heated from 55˚F–100˚F with an RHR unit and then heated to 165˚F with the water heater, the estimated water heating cost savings would be (100˚F - 55˚F)/(165˚F -55˚F) x 100 = 40% savings. Actual savings will vary greatly depending on individual farm conditions.

Figure 5. Refrigeration heat recovery unit with extra storage tank.



Precooler and refrigeration heat recovery unit interactions

The precooler and refrigeration heat recovery units are competing technologies. The precooler removes heat from milk that could be used to preheat water for washing. Conduct an energy analysis to ensure that if both technologies are used, energy costs will not actually increase. Figure 6 is a schematic of a typical milk cooling system with a precooler and refrigeration heat recovery unit.

An RHR unit can recover 20–60% of the 56 BTUs that must be removed from the milk to cool it to storage temperature. Depending on the dairy's hot water usage, only a portion or all of the available energy may be usable for preheating water.

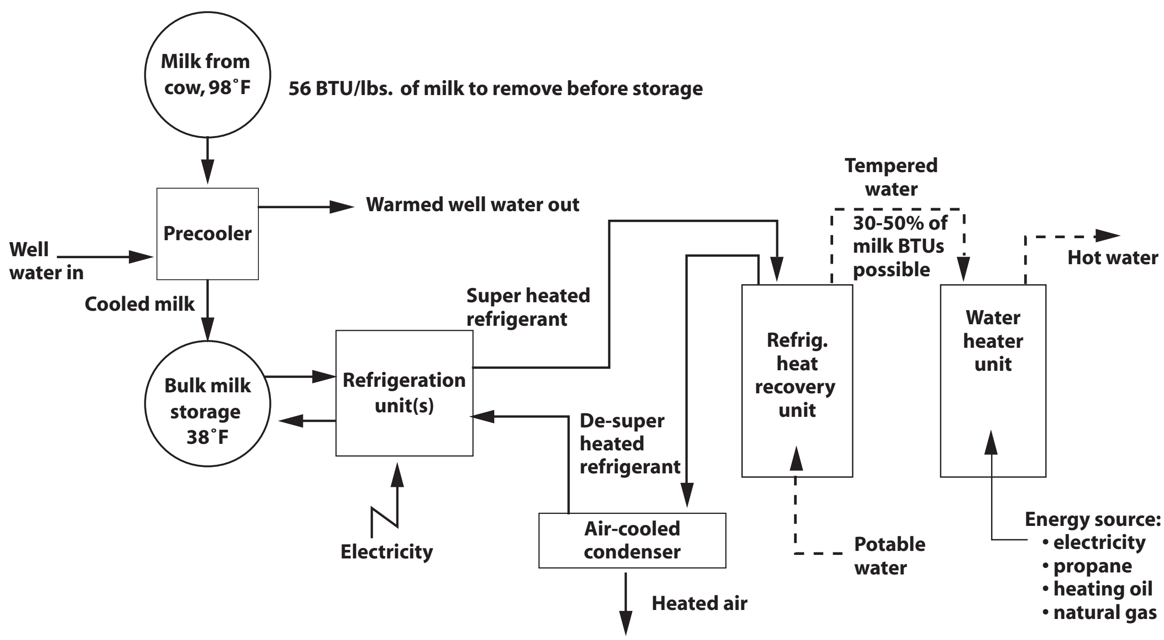
If all of the energy captured by the RHR can be used for preheating water, then installing a precooler will increase overall energy costs because some of the 56 BTUs of energy will be transferred to well water as opposed to preheating water that must eventually be heated to a high temperature.

If an RHR unit is not being used and is not economical, then maximum cooling of the milk (within 3˚F of the well water temperature) with a precooler should be considered. If an RHR unit is being used and it is economical to use a precooler, the temperature decrease by the precooler may be only a portion of the maximum cooling possible.

For more information

Information on different technologies and energy conservation opportunities are contained in the *Energy Conservation in Agriculture* publication series, available from Cooperative Extension Publications at http://cecommerce.uwex.edu.

Figure 6. MIlk cooling energy flows refrigeration system with refrigeration heat recovery and precooler.



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