# Energy Conservation in Cold Storage and Cooling Operations

Jim Thompson, Department of Biological & Agricultural Engineering, UC Davis

**Storage**

Energy use in a cold storage facility is affected by the amount of heat the refrigeration equipment must remove and the efficiency of the equipment. The main sources of heat in a facility for long-term storage are transmission through walls, evaporator coil fans, lights, air leakage, and respiration of the stored commodity.

Heat entering a cold storage facility through walls can be minimized by increasing the insulation and by painting the exterior a light color. Doubling the insulation (as measured by R value) reduces transmitted heat by half. Newer facilities use insulation levels as high as R40 in walls and R60 in ceilings. In general, it is advisable to build with more insulation than utility costs may presently warrant, because energy costs are difficult to predict and it is much cheaper to install insulation during construction than after construction is completed.

Sun shining on walls and roof dramatically increases the effective outside temperature, increasing heat flow into a storage facility. A dark, flat roof can be 75°F (42°C) warmer than the outside air temperature. Painting a south-facing wall a light color can reduce the effective wall temperature by 20°F (11°C) compared with a dark wall. Walls and roof of a cold storage facility should be painted a light color or shaded from the direct sun.

Fans are used in cold storage facilities to move air through the evaporator coils and to uniformly circulate cooled air around stored commodities. During the initial filling of a storage facility, 100 cfm per ton of product (0.3 m3.m-1 per tonne) stored is needed to remove the residual field heat of the product. However, after the commodity has reached the desired temperature, air movement can be reduced by 60 to 80%. Also during the winter months, the outside air temperature drops and less heat enters through the walls compared to summer or fall conditions.

Lights in the cold storage room should be turned off when not needed. Use plastic flap doors to reduce infiltration of warm outside air during loading and unloading. Seal around openings for pipes and electrical conduits. Heat produced by respiration of the stored commodity can be minimized by keeping the commodity minimum recommended storage temperatures.

Refrigeration system design has a great effect on energy use. The temperature of the refrigerant fluid after it is cooled in the condenser should be as low as possible. For example, a facility maintaining 32°F (0°C) and a condensing temperature of 125°F (52°C) requires 50 percent more power than one that operates at a condensing temperature of 95°F (35°C). In warm areas, evaporative condensers should be selected over air-cooled units. Utilities often offer rebates to install extra heat exchange surface for the condenser in order to further reduce refrigerant condensing temperature. Maintaining highest possible suction pressure also reduces compressor energy use. Use large evaporator coils and a control system that increases suction pressure as demand on the refrigeration system is reduced. Use a compressor system that operates efficiently over the required range of refrigerant flows. Screw compressors operate efficiently only at flow rates near their maximum capacity. Use several in parallel, shutting down those that are not needed, or consider using reciprocating compressors for peak loads. They operate efficiently over a large range of refrigerant flows.

**Initial Cooling Systems**

Table 1 compares the energy efficiency of three systems based on a number called an energy coefficient. The coefficient equals the cooling work done divided by the energy purchased to operate the cooler. High values represent high efficiency. Vacuum cooling is the most energy efficient followed by hydrocooling and forced air cooling. Part of the reason for the high efficiency of vacuum cooling is that it removes heat only from the product being cooled. The other types of coolers remove heat from fans, pumps, infiltration of outside air, heat conducted through exterior walls, lights, forklifts, and people working in the cooler. Table 2 shows a distribution of heat loads for the three types of coolers. Nearly all forced air coolers are used for some short-term product storage. This contributes to their particularly low energy coefficient numbers but it is not possible to separate energy use for storage from the total.

The data in Table 1 show a great difference between the most efficient and least efficient coolers of a given type. For example, a well-operated hydrocooler can operate more efficiently than most vacuum coolers. However, a poorly operated hydrocooler can have nearly as low an energy efficiency as a forced-air cooler. The difference in efficiency between a given cooler and the best cooler of its type represents the potential for energy savings.

**Vacuum Cooling**

Refrigeration demand varies from zero for the first 10 minutes of a cycle to maximum when product temperature drop actually begins. Many vacuum coolers use one screw compressor, which does not operate efficiently at low refrigerant flows. Vacuum cooler energy use can be reduced and efficiency can be improved by turning off the compressor when no refrigeration is needed (although this reduces motor life). Operating the cooler with a partial load reduces energy efficiency: a half load of lettuce requires 50 percent more energy per carton to cool than a full load. Cooling products that require long cooling times greatly increases energy use. For example, a load of cauliflower, which cools in 2 to 3 hours, takes three times more energy per pound of product cooled than iceberg lettuce that requires only 20 to 30 minutes.

**Hydrocoolers**

Energy use can be reduced by protecting the cooler from exterior heat gain and operating it at maximum capacity. Table 2 indicates that over one-third of the heat input to a hydrocooler is infiltration of warm air, outside heat conducted through walls, and cooling the water reservoir when the cooler is started up each day. Infiltration can be reduced by installing plastic flap doors and by minimizing the distance between the shower pan and the top of the product. Adding insulation and shading the cooler or painting it a light color reduces heat conduction through the walls. Using a smaller water reservoir lowers the amount of start-up cooling needed. Placing the cooler in a refrigerated building reduces all sources of outside heat gain and start-up losses. Energy use per unit cooled associated with pumps and with removing conduction and infiltration heat can also be reduced by operating the cooler at maximum capacity. These energy uses are dependent on the amount of time the cooler is in operation, not on the amount of product cooled. Energy use per pound of product cooled is reduced when more pounds of product are cooled per hour.

**Forced-air coolers**

Energy use in can be reduced by all of the techniques mentioned for storage facilities, but fan energy use is the most significant. In addition to their own energy consumption, fans contribute over one-third (and in some coolers, more than half) of the heat that must be removed from an average forced air cooler. Fan energy use can be minimized by turning fans off when not needed, installing evaporator coils with a minimum airflow resistance, using cartons with adequate venting area, and arranging pallets on the cooler to reduce airflow resistance. Variable frequency controls are commonly used to slow fans at the end of a cooling cycle. This reduces heat input without significantly slowing the cooling process.

**Package ice**

These lose efficiency in two ways.

1. Many operations put about 15 pounds (7 kg) more ice in a box than is needed to cool the product. This allows the product to arrive at destination with about 11 pounds (5 kg ) of ice still in the box, but the extra ice is rarely needed to maintain product quality. In a box of broccoli, this extra represents almost half of the total ice used in the cooling process.
2. Ice systems are often poorly insulated and not shaded from the sun.

**Other options**

Little energy testing has been done with water-spray hydrocooling. All of the recommendations for vacuum coolers should be applicable. Also, consider insulating the cooler, because water in contact with the walls during spraying and water in the reservoir allows outside heat to be transferred into the cooler.

Many cooling facilities are billed for electricity on the basis of not only the amount of energy consumed but the time of day it is consumed. Electricity is usually more expensive during the afternoon hours, which is usually when most electricity is needed for cooling operations. There are ways to shift the energy demand to hours when electricity is cheaper. Slowing the cooling rate and consequently shifting the cooling work to the night is the least expensive option for forced air coolers. This can only be used if there is excess cooling capacity available at night and if products can withstand some delay in cooling. Electric lift trucks reduce refrigeration demand because they produce less heat than propane lifts.

Thermal energy storage is being used by several cooling operations. This equipment stores ice during the night and then uses it the following day for product cooling. Thermal energy storage is very cost effective if it is designed into the initial refrigeration system, creating a less expensive, small system that operates constantly rather than a large system that must operate only when cooling is needed.

**Table 1.** Typical energy efficiency ranges for initial cooling operations. Energy coefficient is the cooling work done divided by energy consumed. High coefficients represent efficient electricity use.

| Type of cooler | Range of Energy Coefficients |
|---|---|
| Vacuum | 2.5 – 1.5 |
| Hydro | 2.3 – 0.7 |
| Forced air | 1.5 – 1.4 |

**Table 2.** Distribution of heat input to three types of fruit and vegetable coolers*

| | Per cent of total heat input | | |
|---|---|---|---|
| | Vacuum | Hydro | Forced air |
| Product | 100 | 54 | 47 |
| Fans or pumps | 0 | 9 | 37 |
| Infiltration, startup, conduction | 0 | 37 | 7 |
| Lift trucks | 0 | 0 | 8 |
| Lights, people, etc | 0 | 0 | 1 |

*Based on measured or calculated heat input for two or three installations of each type of cooler.