Absorption Chilling: Turning Biogas-Fueled Engine Waste Heat into Chilled Water

Part 4: Economic feasibility of milk cooling with lithium bromide absorption chiller

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A 5-year payback was calculated for a 3,000 cow dairy to use excess waste heat from its biogas-fueled combined heat and power system in a lithium bromide absorption chiller for pre-cooling harvested milk from 100°F to 45°F, offsetting load on an existing electric cooling system. When a potable water-to-milk pre-cooling system is in use, the payback extends to 10 years.

Capital cost

The capital cost of an absorption chiller per refrigerated ton (RT) of chilled water output exceeds that of a conventional electric compression-condenser chiller. However, the economic feasibility of the absorption chiller versus a conventional chiller should be evaluated to compare the net present value and return on investment since absorption chillers often have significantly lower operating costs. According to data from the US Department of Energy (DOE) [1], a 50 RT single-effect LiBr absorption chiller with an associated cooling tower has an equipment cost of $2,010 per RT or approximately $100,500. A 440 RT single-effect LiBr system is estimated at $930 per RT, indicating that cost per RT decreases with increasing capacity size. Double-effect absorption chillers have a higher price point, but their gains in efficiency over single-effect units may overcome this depending on the application.

Operation and maintenance (O&M) cost and life expectancy

Absorption chillers have very few moving parts and require infrequent preventive maintenance (usually 2 times per year). Identical to conventional water-cooled electric chillers, preventive maintenance includes monitoring the water quality of both the chilled closed loop and the cooling closed loop. In addition, sample analysis of the LiBr solution should be done to determine the quantity of corrosion inhibitor. Modern LiBr absorption chillers have an automatic purge system to maintain the vacuum conditions. In the past, issues with crystallization in LiBr absorption chillers occurred when the concentration of LiBr in the solution was high and there was air leakage from a vacuum loss.

While absorption chillers have minimal maintenance activities, a good understanding of the process cycle will help onsite staff confirm the equipment is operating as it should and prevent any major upsets. The O&M cost of LiBr chillers ranges from 0.1 to 0.6 ¢/ton-hour depending on the size and manufacturer. [1] Absorption chillers are expected to operate for 20 to 25 years with proper maintenance and operation.

Incentives

Absorption chillers can be used to offset the use of existing electric chillers or refrigeration systems, thus reducing farm electricity usage and associated demand charges. Utility and state incentives for energy efficiency and demand reduction measures can often apply to implementing absorption cooling systems.

Economic feasibility of milk cooling

While it may be possible to use the readily available LiBr absorption chiller technology to cool milk from 100°F to as low as 40°F, it is most realistic to consider the opportunity to pre-cool harvested milk to 45°F. This is because the typical chilled water supply temperature from a LiBr chiller that uses water as a refrigerant is 42 to 44°F. The economic feasibility analysis of using a LiBr absorption chiller for milk cooling on a 3,000 milking cow dairy, with and without the use of a potable water pre-cooler, is summarized in Table 1. In both cases, the assumption is that an air-cooled scroll compressor refrigeration system with a coefficient of performance (COP) of 3.1 is in use at the dairy for cooling milk to a temperature below 38°F. Another key assumption is that the absorption chiller is a single-effect design (COP = 0.7) with a hot water input from an existing on-farm anaerobic digester gas fueled CHP system. The analysis shows that if the farm is not using a potable water-to-milk pre-cooling system, the simple payback on implementing absorption chilling to pre-cool harvested milk to 45°F is 5 years. If a well or municipal water pre-cooling system is in use, the simple payback lengthens to 10 years.

Table 1. Economic feasibility analysis of using a LiBr absorption chiller for milk pre-cooling as applied to a 3,000 milking cow dairy farm.

	No potable water pre-cooler	Potable water pre-cooler in use
Initial milk temperature before absorption chiller	100°F	62°F
Final milk temperature before conventional electric chiller system	45°F	45°F
Absorption chiller cooling capacity	55 RT	17 RT
Absorption chiller power use	4 kW	3 kW
Capital equipment cost (estimated)	$110,000	$50,000
Installation cost (estimated)	$33,000	$30,000
Annual maintenance cost (estimated) [1]	$2,000	$1,000
Annual operating cost (estimated) [2]	$2,145	$1,600
Conventional chiller avoided power per hour	62.5 kW	19.5 kW
Conventional chiller avoided operating cost [2]	$33,500	$10,450
Simple payback period	4.9 years	10.2 years

A smaller dairy farm with less than 1,500 milking cows would likely see a longer payback period due to the increased capital and operating cost per cooling capacity ($ per RT) that occurs with decreasing system size. For example, a 400 milking cow dairy would need approximately 7.5 RT of absorption chilling capacity to pre-cool milk from 100°F to 45°F, requiring the smallest commercially available chiller. This application is likely to be technically feasible but unlikely to be economically feasible.

Greenhouse gas (GHG) emission avoidance

GHG emissions can be avoided by using an absorption chiller that utilizes the excess waste heat from a biogas-to-electricity system to produce chilled water for pre-cooling milk, offsetting the electricity consumption of a conventional compressor-driven milk cooling system. In the case of a 3,000 milking cow dairy farm that does not have a water-to-milk pre-cooling system, the estimated electricity offset is 500,000 kWh per year. Applying the US national weighted average emission rate for grid electricity reductions, [3] the estimated GHG emission avoidance is 353.5 MT of CO_2 per year (0.12 MT of CO_2 per cow-year).

FACT SHEET SERIES: Absorption Chilling: Turning Biogas-Fueled Engine Waste Heat into Chilled Water

Part 1: Absorption chilling process, types, and comparison to compression chilling
Part 2: Applications and practical considerations of absorption chilling for dairy farms
Part 3: Technical feasibility of dairy farm applications of absorption chillers
Part 4: Economic feasibility of milk cooling with lithium bromide absorption chiller

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[1] U.S. DOE, Combined Heat and Power Technology Fact Sheet Series: Absorption Chillers for CHP Systems, May 2017.

[2] Assumes the system operates 8,000 hours/year and the utility electric rate is 5.5¢ per kWh (usage charges) and $8 per kW-peak per month (demand charges).

[3] U.S. EPA (2019) AVERT, U.S. national weighted average CO_2 marginal emission rate, year 2018 data.