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

Part 1: Absorption chilling process, types, and comparison to compression chilling

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Absorption chillers use heat to generate chilled water for cooling. If the source of heat is inexpensive or even “free”, such as recovered waste heat from a biogas-fueled engine-generator set, absorption chillers can cost significantly less to operate and maintain than conventional electric compression chillers. The technology has been in use for over 60 years, emerging commercially in the 1950s. Absorption chillers use a solution of refrigerant and absorbent that separates when heated, causing the refrigerant to evaporate (see Figure 1). Cooling water causes the refrigerant to condense and enter a low-pressure evaporator/absorber chamber, where it boils at low temperature to cool a chilled water loop. One of two refrigerant/absorbent solutions is used, water/lithium bromide (LiBr) or ammonia (NH_3)/water. LiBr is most common in the United States while the use of NH_3 as a refrigerant for all types of chillers is widespread in Europe.

Lithium bromide absorption chiller

LiBr absorption chillers use water as the refrigerant, producing chilled water at a minimum output temperature of 40°F. These chillers are typically used for space cooling and dehumidification purposes, ranging from 5 to 3,000 refrigerated tons. [1] LiBr is a salt in liquid form and is safe and non-toxic.

Ammonia absorption chiller

An NH_3 absorption chiller uses NH_3 as the refrigerant. The low freezing point of NH_3 allows these chillers to generate chilled water at much lower temperatures, even below minus 15°F. NH_3 absorption chillers are typically used for cold storage applications, such as rapidly cooling and storing foods. NH_3 is toxic at concentrations of 35 to 50 ppm; human detection threshold is 5 ppm. NH_3 is also flammable in a narrow range of concentrations mixed with air in the presence of open flames.

Absorption chiller process: basic principals

- Water boils at a lower temperature when below atmospheric pressure.
- Water is attracted to LiBr; NH_3 is attracted to water.
- While water and LiBr easily mix at certain conditions, heating the mixture causes molecules to separate and the water will evaporate while the LiBr sinks.

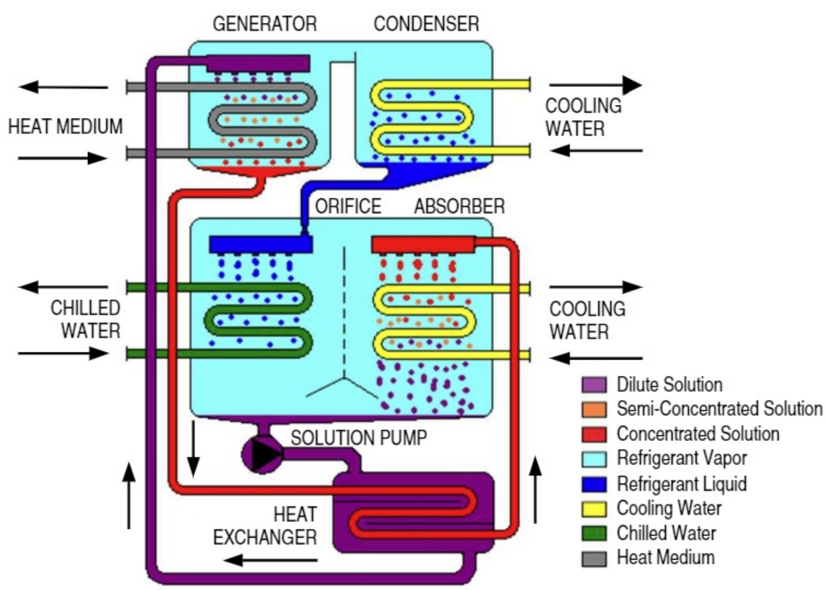

Figure 1. Basic single-effect absorption chiller process (LiBr and water solution). [2]

Absorption chiller process: components

A single-effect absorption chiller consists of two chambers and one heat exchanger. One chamber consists of the condenser and the generator. The other chamber consists of the evaporator and the absorber. The heat exchanger improves the efficiency of the system. The evaporator/absorber chamber is kept at near vacuum conditions (0.12 psia) for the water/LiBr solution, allowing water to boil at 40°F. NH_3 chillers operate at pressures much higher than atmospheric and use a rectifier to separate water from the NH_3.

Single-effect, double-effect, triple-effect

An absorption chiller that employs one heat exchanger and one generator is called a single-effect design. This design uses lower-grade heat input such as high temperature hot water at approximately 190°F or low-pressure steam. A double-effect design utilizes two heat exchange-generator stages and requires a higher-grade heat input, such as pressurized hot water or engine exhaust air. Triple-effect designs released early in the 21st century employ three stages of heat exchangers and corresponding generator chambers, requiring even higher-grade heat input.

Energy use comparison with conventional chillers

The coefficient of performance (COP) indicates the efficiency of a chiller. For an absorption chiller the COP is the cooling output divided by the heat energy input, whereas for a conventional electric chiller the COP is the cooling output divided by the electricity input. It does not make sense to compare the COP values among these two different types of chillers. Instead, compare their operating cost (the cost of the energy input per unit of cooling output). The typical COP of absorption chillers is 0.7 for single-effect and 1.35 for double-effect. Triple-effect designs can reach a COP of 1.8. Conventional electric chillers have COPs between 3.0 and 7.0. Air-cooled electric chillers have lower COPs of around 3.0 and water-cooled electric chillers have higher COPs (5.0 to 7.0). Absorption chillers employ at least one solution circulation pump that uses a small amount of electricity.

Refrigerant type comparison with conventional chillers

Absorption chillers do not use ozone-depleting or greenhouse gas-emitting refrigerants like electric chillers continue to use today. The most common refrigerant used in electric cooling systems is hydrofluorocarbon-134a (or, R-134a) that has a very high global warming potential (GWP) of 1,430. [3] R-134a is odorless and leaks are difficult to detect. Absorption chillers use either NH_3 (R-717) or water as the refrigerant, both of which are environmentally advantageous.

Water-cooled vs. air-cooled

All absorption chillers are water-cooled and require the use of a cooling tower to provide cooling water. The cooling water required for an absorption chiller is typically 1.5 to 2 times as much as that required for the same capacity water-cooled electric chiller, so the cooling tower must be larger. There are electric chillers and refrigeration systems available that are air-cooled, avoiding the need for a cooling tower.

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] Yazaki Energy Systems, Inc. http://www.yazakienergy.com/waterfired.htm.
[3] U.S. EPA, Transitioning to Low-GWP Alternatives in Commercial Refrigeration, EPA-430-F-16-073, December 2016.