ECO-MAX

adsorption chillers

...for global cooling

www.eco-maxchillers.com

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Table of Contents

Why adsorption chillers?

Capturing and using waste heat could be one of the largest conservation and green house gas reduction opportunities. Heat recovery is an opportunity to recycle energy that is typically wasted. According to the EPA, In the United States alone it is estimated that the potential for waste heat recovery could substitute approximately 9% of the total US energy usage, or 1.4 quadrillion BTU. [1]

Adsorption chillers are a unique approach to achieving air conditioning and process cooling. Adsorption chillers are driven by hot water rather than from large amounts of electricity like conventional air conditioners. This hot water may come from any number of industrial sources including waste heat from industrial processes, prime heat from solar thermal installations or from the exhaust or water jacket heat of a piston engine or turbine. The process and industrial sources could include food and beverage processing, chemical, plastic rubber, paper and cement manufacturing as well as the waste heat from steam boilers or sterilizers used in hospitals, hotels and campuses.

The heat extracted from the chilled water and the heat consumed from the hot water is directed into a cooling water system used to dissipate this energy. This heat dissipation may occur in a water system; water heat exchanger, a dry water tower or an evaporative (wet) water tower.

Very little electric power is consumed running the chiller, generally about the same amount of electricity as a handful of old-fashioned incandescent light bulbs. The electric power used drives the internal process computer, a PLC, (programmable logic controller) and the intermittent running of a fractional horsepower vacuum pump.

Why recover waste heat?

Industrial operations represent a significant source of greenhouse gas emissions and most of the waste heat is simply rejected via cooling towers to the atmosphere. It can be thought of as “dumped” heat.

Waste heat is the by-product of system inefficiencies found in industrial and commercial process and represents a waste of resources, opportunities, and money. Waste heat is commonly generated by:

- Steam generation;
- Power generation;
- Process heating;
- Heating and cooling fluids and gases;
- Shaft or drivetrain work.

[1] http://www.eceee.org/conference_proceedings/ACEEE_industry/2007

Greenhouse gas reduction

Consensus is emerging among scientists that the global climate is warming and that a significant effort to stabilize and even reduce the amount of greenhouse gases in the atmosphere is needed. It will take a combination of technologies and process changes to meet the emerging greenhouse gas reduction targets.

Manufacturing activities account for the contribution of energy-related carbon dioxide emissions in the U.S. industrial sector, which also includes agriculture, forestry, fisheries, mining, and construction. Manufacturing accounted for approximately 84 percent of energy-related carbon dioxide emissions and 90 percent of the energy consumption in the industrial sector in 2002.[2]

By installing an ECO-MAX™ adsorption chiller, tons of CO_2 emissions will be prevented from entering the atmosphere. An adsorption chiller consumes very little electricity to operate, especially in comparison to conventional chilling systems, and avoids the greenhouse gases that would have been produced by an electric-driven chiller. Additionally, installing an ECO-MAX™ chiller, as part of a renewable energy system will provide even greater greenhouse gas reductions.

Southwest Region Example

If a typical office building in Phoenix, AZ replaced their 250-ton electric powered chiller with an ECO-MAX™ system supplied by solar hot water, approximately one million lbs. of CO_2 emissions per year would be prevented. This reduction is equivalent to the emissions from burning 55,000 gallons of gasoline or taking more than 83 cars per year off the highway.

[2] http://www.eia.doe.gov/oiaf/1605/ggrpt/pdf/industry_mecs.pdf

Adsorption versus absorption – why *adsorption* is a better choice

Previous thermally driven chillers have been effective but have been burdened with significant maintenance and upkeep. Absorption chiller systems often depend on a corrosive solution of lithium bromide salt that tends to corrode the internal copper tubing and steel shell of the unit. Additionally, absorption chillers produce hydrogen gas as a by-product, requiring an expensive palladium cell inside the chiller unit to remove the hydrogen.

The lithium bromide solution in absorption chillers also has phase state challenges and has a tendency to solidify within the system while operating. If the regeneration temperature becomes too hot or too cold, or the conditions change too rapidly for the system to adapt, the liquid salt will solidify and crystallize inside the chiller unit. Many installations of absorption units require a dedicated caretaker to maintain.

Conversely, ECO-MAX™ adsorption chillers use municipal water as the refrigerant and solid silica gel as the desiccant. There are no CFCs or freons, no Li-Br, and no ammonia. Not using these chemicals equates to no potential for hazardous material leaks, no aggressive corrosion, no chemical testing required, and no damage to upper-level atmospheric ozone.

An ECO-MAX™ chiller significantly reduces the maintenance and upkeep costs by substituting the corrosive salt desiccant with a benign silica gel. Reliability and machine availability are significantly improved. Adsorption chillers have very few moving parts and do not require the maintenance and attention that the absorption chiller systems require.

Adsorption versus absorption comparison

Attribute	Adsorption Chiller	Absorption Chiller
First cost	Similar	Similar
Continuous operation	Over 8,000 hours per year continuous operation possible	Daily shut-down maintenance for the dilution of lithium bromide solution
Start-up / Shut-Down Time	No special procedures. Full capacity reached in 8 minutes maximum. No adverse effects from loss of power.	Dilution cycle required. Start-up and Shut-down time varies with manufacturer.

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Maintenance	Replace vacuum pump oil as needed (recommended every 5 years) Annual cleaning of condenser tubes. Approximately $5,000/year (or less depending on labor costs)	Needs continuous monitoring and maintenance including: 1.Liquid analysis (replacement indication) 2. Pumps 3. Controls 4. Back Up Boiler 5. Air Leakage 6. Li-Br exchange 7. Heat exchanger replacement (corrosion) Full maintenance contracts are approximately $20,000-$30,000 per year.
Chemistry	Municipal water and silica gel	Distilled water and lithium-bromide
Hot water requirements	Continuously variable, 122°-205°F or higher; simple automatic shutdown at 122°F	Variation must be tightly controlled between 180° and 212°F or higher; backup heat required if hot water is below 175° F to prevent crystallization
Cooling water requirements	85°F to 50°F. Lower temperatures increase capacity of the system.	Must be between 65°F and 85°F using a control valve
Chilled water output	40°-55°F is normal	48°F or warmer
Frequency of desiccant replacement	Not necessary	Every 4-5 years
End-of-life	No special disposal requirements	Hazardous materials concerns and disposal procedures required.

Adsorption versus conventional mechanical chillers – Why an ECO-MAX™ adsorption chiller is a better choice

Adsorption chillers eliminate noisy compressors, high-pressure refrigerant systems, high amperage electrical connections, refrigerant monitoring and alarm systems, and high maintenance costs. Adsorption chillers, specifically ECO-MAX™ chillers, will provide a 99% reduction in the chiller's electrical usage.

Adsorption versus mechanical chiller comparison

Attribute	Adsorption Chiller	Mechanical Chiller
Sound Pressure Level	Very low <50 db (A)	Loud > 80db (A)
Operating Cost	~$320/year[3]	$100,000 or greater for continuous operation
Maintenance	Replace vacuum pump oil as needed (recommended every 5 years) Annual cleaning of condenser tubes Approximately $5,000/year (or less depending on labor costs)	Seasonal maintenance required ~ $10,000 per year or greater Annual oil analysis Replace oil every 5 years Periodic teardown and rebuild required Annual cleaning of condenser tubes Replacement of bearings every 15 years
Chemistry	Municipal water and silica gel	HFC and HCFC refrigerant with synthetic oils
Energy Requirements	Hot water- 122°F to 205 °F	Electricity – 208/230,480 or 4,160 volts
Cooling water requirements	85°F to 50°F. Lower temperatures increase capacity of the system	85°F to 65°F minimum temperature -- unstable at low temperatures
End-of-life	No special disposal requirements	Certified technician required to reclaim all refrigerant at risk of $25,000 fine (and 5 years imprisonment) for release to the atmosphere

[3] **Assumed: 0.4kw operation for controls and two pumps for 100 ton model. 8000 hours/year continuous operation, $.10 kilowatt hour electricity costs**

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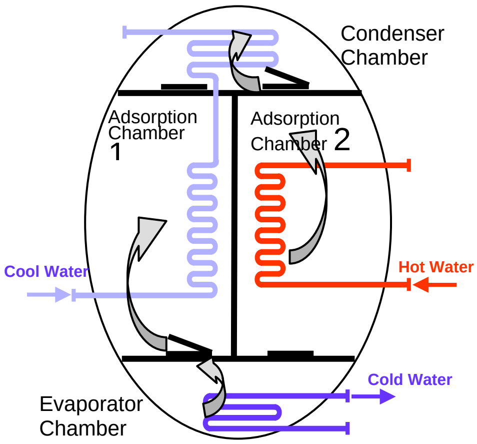
How our adsorption chiller works



The principle of adsorption works with the interaction of gases and solids. With adsorption chilling, the molecular interaction between the solid and the gas allow the gas to be adsorbed into the solid. The adsorption chamber of the chiller is filled with solid material, silica gel[4], eliminating the need for moving parts and eliminating the noise associated with those moving parts. The silica gel creates an extremely low humidity condition that causes the water refrigerant to evaporate at a low temperature.

As the water evaporates in the evaporator, it cools the chilled water.[5]

The adsorption chiller has four chambers; an evaporator, a condenser and two adsorption chambers. All four chambers are operated at nearly a full vacuum.

The ECO-MAX™ chiller uses a simple refrigeration process

The chiller cycles the adsorption chambers 1 and 2 between the processes of adsorbing and desorbing. In the figure above, the water vapor flashes off the surface of the tubes in the evaporator, creating the chilling effect captured in the output of chilled water. The water vapor enters Chamber 1 through the open ports in the bottom of the chamber and is adsorbed into the silica gel in Chamber 1. Cool water is circulated in this chamber to remove the heat deposited in Chamber 1 by the adsorption process.

Hot water enters Chamber 2 to regenerate, or desorb, the silica gel while Chamber 1 is in the adsorption process. The water vapor is driven from the silica gel by the hot water. The refrigerant water vapor rises to the condenser portion of the ECO-MAX™ where it is then condensed to a liquid state. The condenser water is recycled in a closed-loop to the bottom of the machine where it is immediately available for re-use.

As the machine cycles, the pressure in Chamber 1 is slightly lower than in the evaporator chamber. A portion of the water refrigerant evaporates and moves to Chamber 1. Simultaneously, the pressure in Chamber 2 elevates slightly as the water

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4 Silica gel is a granular, porous form of silica made synthetically from sodium silicate. Despite the name, silica gel is a solid. Silica gel is most commonly encountered in everyday life as beads packed in a semi-permeable plastic. In this form, it is used as a desiccant to control local humidity in order to avoid spoilage of some goods. Silica gel's high surface area (around 800 m^2/g) allows it to adsorb water readily, making it useful as a desiccant (drying agent).

5 The water is cooled at a rate of almost 1,000 Btu/lb of water evaporated.

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Power Partners, Inc. is an EPA CHP Partner. The CHP Partnership is a voluntary program seeking to reduce the environmental impact of power generation by promoting the use of CHP. The Partnership works closely with energy users, the CHP industry, state and local governments, and other clean energy stakeholders to facilitate the development of new projects and to promote their environmental and economic benefits.

vapor is driven from the silica gel. The water vapor is then pushed to the condenser chamber where it is condensed back to the liquid state and returns to the evaporator chamber.

When the silica gel in Chamber 1 is saturated with water and the silica gel in Chamber 2 is dry, the machine's process reverses. The first step is the opening of a valve between the two chambers, allowing the pressure to equalize. Then, cool water is sent through Chamber 2 to transfer any residual heat to Chamber 1, which begins the heating process. The reversal is completed and the adsorption in Chamber 2 commences while Chamber 1 is dried by the desorption heating.

The ECO-MAX™ adsorption chiller is capable of operating within a wide range of temperatures. The machine self-regulates and balances the performance of the system by the control programs, shifting to the program best suited for the system conditions. For optimal performance of ECO-MAX™ chillers, the hot water should be 194°F, the cool water about 75°F to 95°F and the output cold water 45°F to 55°F.

Installation opportunities

ECO-MAX™ chillers can be sized from 30 to 250 tons of refrigeration.

Adsorption Chillers are effective as a stand-alone system either as an enhancement to a current HVAC system or a replacement technology to a current chiller system.

Waste heat streams

Preferred applications have a steady stream of waste heat as well as a demand for either chilled air or water. Examples include:

- Food processing
- Beverage processing
- Hospitals
- Chemical processing
- Manufacturing

Renewable energy systems

ECO-MAX™ chillers can easily be integrated to utilize solar hot water collectors and concentrators to produce the source heat for the chiller. The energy to run the chillers is obtained by solar hot water collectors on the roof and is stored in a large hot water tank for continuous use. Since the chiller can operate on input hot water temperatures as low as 130°F, the adsorption chiller works well with solar thermal systems.

Tri-generation or CCHP

Building owners and facility managers are installing electricity generation systems that run on natural gas and have the potential to use the waste heat from the water jacket and exhaust gases to operate a waste heat recovery system. Natural gas systems have the advantage of producing half the CO_2 emissions per kilowatt when compared to electricity generated from a coal-fired power plant. By integrating a waste heat recovery system with on-site generation, the system has the potential to further reduce by CO_2 emissions eliminating the chilling system's electricity consumption as well as eliminating additional heating requirements in winter. Tri-generation systems can have fuel efficiency rates of 85-95%, more than double the standard fuel utilization rates at most coal-fired power plants.

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Power Partners, Inc., a company dedicated to sustainable manufacturing practices, manufactures ECO-MAX™ chillers in Athens, Georgia. Power Partners is one of the ten largest women-owned businesses in the United States as certified by the Women's Business Enterprise National Council (WBENC).

For further information, visit **www.eco-maxchillers.com** or contact:

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