Energy Recycling With 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 percent of the total US energy usage, or 1.4 quadrillion BTU.

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 thewaste 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 iscommonly generated by:

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

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 changesto 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 inthe industrial sector in 2002.

By installing an ECO-MAX™ adsorption chiller, tons of CO2 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 CO2 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.

Adsorption versus absorption 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 thehydrogen.

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. Manyinstallations of absorption units require a dedicated caretaker to maintain.

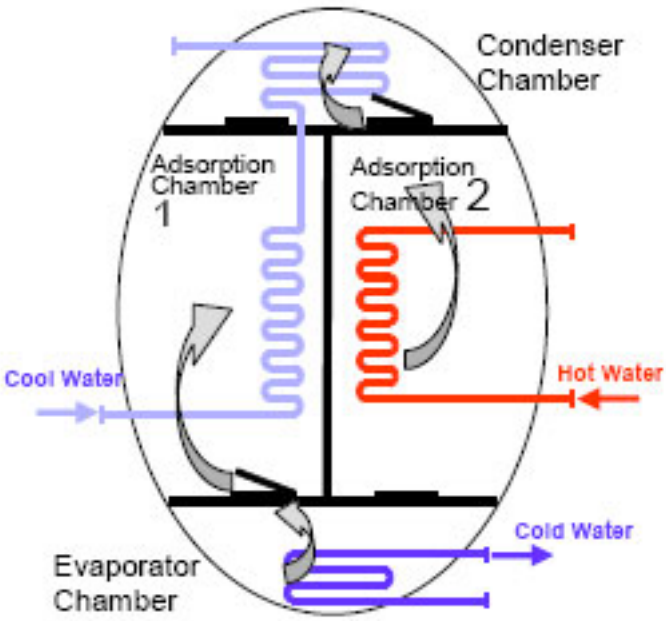
Conversely, ECO-MAX™ adsorption chillers use municipal water as the refrigerant and solid silica gel as the desiccant. There are no CFCs or freons, no Li-Br, and no ammonia. Not using these chemicals equates to no potential for hazardous material leaks, no aggressive corrosion, no chemical testing required,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

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
Operating Life	The silica gel lasts up to 30 years	7-9 year with normal use; the heat exchanger may need to be replaced sooner due to the caustic operating environment
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 40°F. Lower temperatures increase capacity of the system.	Must be between 65°F and 85°F using a control valve
Chilled water output	37°-48°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 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 a99 percent reduction in the chiller's electrical usage.

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 40°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



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, 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 lowtemperature.

As the water evaporates in the evaporator, it cools the chilled water. The adsorption chiller has four chambers; an evaporator, a condenser and two adsorption chambers. All four chambers are operatedat 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 toremove 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 thebottom 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 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 andreturns 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 thedesorption 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 and the outputcold water between 38° and 40°F.

Case study: Frito Lay In 2005, the Frito-Lay plant in Charlotte, NC, installed an adsorption chiller when 150 tons of cooling were needed in the processing area, to offset the 150 tons of a mechanical unit and save on electricity cost. The Charlotte plant utilized an existing hot water loop heated to 194°F with waste heat from a

cooking process to power the adsorption chiller. After ~10,000hours, the downtime due to mechanical issues was 0 as well as 0 repair parts. According to Frito-Lay the observed annual electrical savings have been$27,000.

Installation opportunities ECO-MAX™ chillers can be sized from 10 to 1,000 tons of Refrigeration. Adsorption Chillers are effective as a stand-alone system either as an enhancement to acurrent HVAC system or a replacement technology to a current chiller system.

Waste heat stream Preferred applications have a steady stream of waste heat as well as a demand for either chilledair 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 byCO_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 percent, more than double the standard fuel utilization rates at most coal-fired power plants. For further information, visit www.eco-maxchillers.com [1].

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[1] http://www.eco-maxchillers.com