# A White Paper for Adsorption Chillers

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## Why Adsorption Chillers?

Capturing and using waste heat could be one of the largest conservation and greenhouse gas reduction opportunities. Heat recovery is an opportunity to recycle energy that is typically wasted. Adsorption Chillers save up to minimum 70% in electrical power consumption compared to conventional systems and thereby, help reduce operating costs significantly. No matter which type of waste heat is used to drive chillers, the chillers always operate with utmost efficiency and ease of use.

Adsorption Chillers are a unique approach to save energy cost for air conditioning and process cooling. Low grade waste heat is the driver for Adsorption Chillers rather than from large amounts of electricity like conventional air conditioners. This continuous hot water may come from any number of industrial sources including waste heat from industrial processes, from solar thermal installations or from the exhaust or jacket water heat of an engine or from turbine exhaust. 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.

Very little electric power is consumed running the chiller; the electric power used by chiller drives the internal process computer, a PLC, (programmable logic controller) and the intermittent running of a fractional horsepower vacuum pump. Amount of electricity is same as a handful of old-fashioned incandescent light bulbs. See Figure 1, It's not magic, **It's an advanced green technology using inert "Silica Gel-Water" Pair**


***Figure 1, It's not magic, It's an advanced green technology***

## Why Recover Waste Heat?

According to the EPA in USA., it's estimated that the potential for waste heat recovery could substitute approximately 9% of the total US energy usage. 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 during:

- Steam generation;
- Power generation;
- Process heating;
- Heating and cooling fluids and gases.

## 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.

By installing an Adsorption Chiller, tons of CO 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 Adsorption Chiller, as part of a renewable energy system will provide even greater greenhouse gas reductions.

## 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, 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 Adsorption 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, see Figure 2 Adsorption Chiller.

*Figure 2: Adsorption Chiller 30TR @ 7 °C (45 °F) Chilled water solar application*

# Adsorption versus Absorption - Why Adsorption is a Better Choice? Adsorption versus Absorption Comparison

| **Attribute** | **Adsorption Chiller** | **Absorption Chiller** |
|---|---|---|
| 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. |
| Maintenance | Virtually none | Needs continuous monitoring and maintenance including:<br>1. Liquid analysis (replacement indication)<br>2. Pumps<br>3. Controls<br>4. Back Up Boiler<br>5. Air Leakage<br>6. Li-Br Exchange<br>7. Heat exchanger replacement (corrosion) |
| Internal Material | Municipal water and silica gel, S2 | Distilled water and lithium-bromide |
| Hot water working range | Continuously variable, 50°-96°C (122°-200°F) or higher;<br>simple automatic shutdown at 50°C (122°F) | Variation must be tightly controlled between 180° and 100°C (212°F) or higher;<br>backup heat required if hot water is below 80°C(175° F) to prevent crystallization |
| Cooling water working range | Preferably < 30° C to 10 °C (85°F to 50°F). Lower temperatures increase capacity of the system. | Must be between 18°C (65°F) and 30°C(85°F) using a control valve |
| Chilled water output | 5° - 10°C (40°-55°F) is normal | 9°C (48°F) or warmer |
| Frequency of desiccant replacement | N/A | Every 4-5 years |
| End-of-life | No special disposal requirements | Hazardous materials concerns and disposal procedures required |

## How Adsorption Chiller Work?

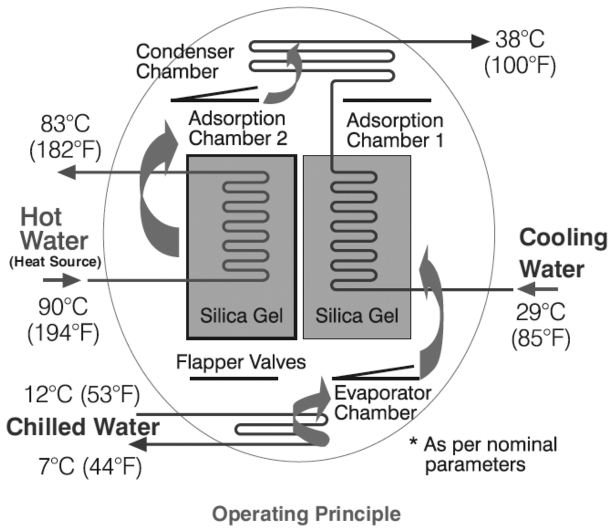


***Figure 3, Cycle of Adsorbing and Desorbing***

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 low temperature. 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 operated at nearly a full vacuum.

## The Adsorption 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 3 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 Adsorption Chillers 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 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 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 the Adsorption Chillers the hot water should be 90 ˚C (194 ˚F), the cool water about 24˚C to 35˚C (75˚F to 95˚F) and the output cold water 7 ˚C to 12 ˚C (45˚F to 55˚F).

## 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 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 | Negligible | High |
| Maintenance | Virtually None | Seasonal maintenance required<br>Annual oil analysis Replace oil every 5 years Periodic tear down and rebuild required Replacement of bearings every 15 years |
| Chemistry | Municipal water and special silica gel-S2 | HFC and HCFC refrigerant with synthetic oils |
| Energy Requirements | Hot water: 50°C to 93°C (122°F to 200 °F) | Electricity – 208/230,480 or 4,160 volts |
| Cooling Water Requirement | Preferably< 30°C to 10°C (85°F to 50°F) Lower temperatures increase capacity of the system | 30°C to 18°C (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 for release to the atmosphere |

## 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:

- Power Plants
- Food and Beverage Industry
- Hospitals
- Chemical Industry
- Petrochemicals and Refineries
- CHP

## Renewable Energy Systems

The Adsorption 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 54.44 ˚C (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 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 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.

## Summary

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, in the present time, the Adsorption Chillers can be ranged from 35kW to 1180kW. Adsorption Chillers are a unique approach to save energy cost for air condition (HVAC) and process cooling. Using the low grade waste heat to produce chilled water, it is saving up to minimum 70% in electrical power consumption compared to conventional systems. Lastly, the author would like to thank you my partners, Power Partners, Inc. USA. (PPI), for sharing this innovation technology, I also would like to personally thank you K.Tavatchai S. from 3V Engineering Solutions Co., Ltd. who compile and well arrange the figures in this white paper.