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Solar Absorption Cooling for Commercial Buildings

Background

Building air conditioning systems conventionally use electrically driven compression chillers to deliver cooling. These systems run on electricity that can be expensive and also contribute to the network peak demand during summer months.

Thermal cooling can be a lower cost alternative to electrical cooling. Thermal cooling systems utilise solar thermal energy or waste heat to deliver cooling with minimal electricity usage. When solar heat or waste heat is not available, they can operate with natural gas.

The use of solar energy for cooling makes intuitive sense due to the high alignment of solar radiation availability with typical building cooling requirements. Moreover, these systems aid in the decrease of carbon emissions due to reducing fossil fuel based electricity and gas usage.

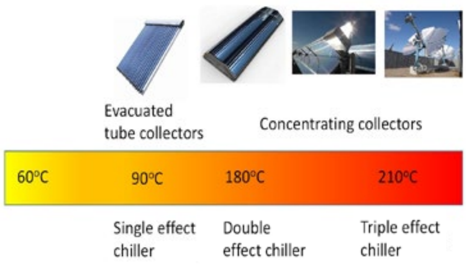
The main components of an absorption chiller based solar thermal cooling system include: the solar collectors, the thermal chiller and often thermal storage.

Solar Collectors

Solar collectors convert incident sunlight into heat. There are various types of liquid collectors that are primarily used for solar cooling applications. Depending on the design, these collectors are capable of delivering heat at various temperature ranges suitable for solar cooling applications.

Thermal Chiller

Absorption chillers are the pre-dominant thermal cooling system used for solar cooling applications. They have a combination of refrigerant and a sorbent in a closed cycle. Typical refrigerant/sorbent combinations used in absorption chillers include water–lithium bromide and ammonia–water.



Solar collectors and absorption chiller mapping based on temperature

Absorption chillers are divided into three categories, single effect, double effect and triple effect based on the temperature of heat input required to drive them. The above figure shows the mapping of solar collectors and absorption chillers based on the temperature range.

Single effect absorption chillers are the most common solar cooling systems in operation, due to their lower initial cost and low grade heat requirement below 100°C. However, operational energy savings and carbon reduction potential are even greater with high temperature (high efficiency) thermal chillers.

Thermal Storage

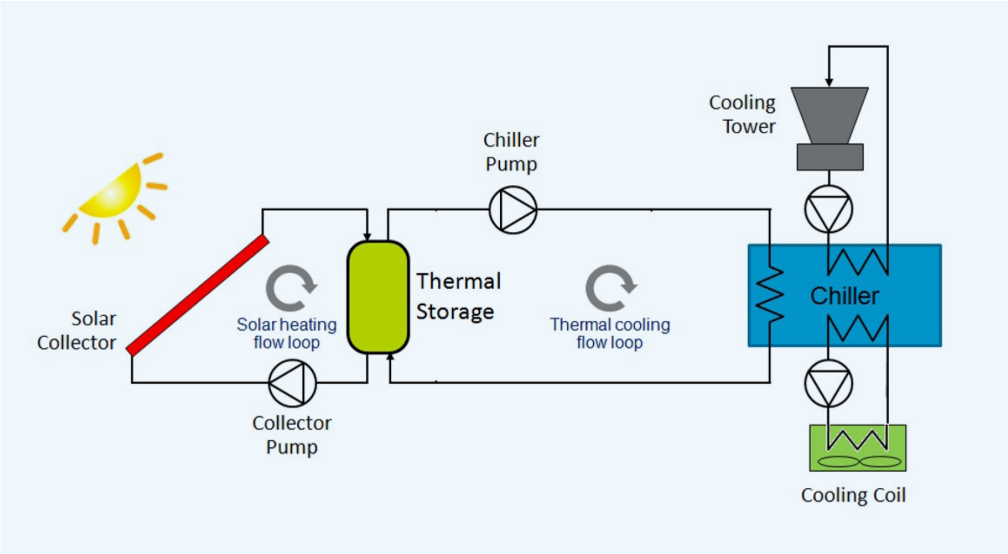
Thermal energy storage systems are often used in solar cooling systems to improve cost savings by reducing fossil fuel backup energy usage.

A typical solar thermal cooling system layout with an absorption chiller is shown in the figure. This system consists of a solar loop that delivers heat into a storage tank and a chiller loop that supplies heat from the thermal storage to the absorption chiller.

When the solar heat is insufficient, the thermal chiller can use a backup heat source, typically gas.

System benefits include:

- Reducing peak electricity demand, avoiding expensive network upgrades.
- Protecting end users from fluctuating energy prices.
- Delivering primary energy savings to the host site.



Solar thermal cooling system with absorption chiller and storage

Solar cooling system performance parameters

Thermal energy efficiency (Thermal coefficient of performance COP_{th}):

Heat energy delivered by the collector is dependent on the temperature gain across the collector and the fluid flow rate through the collector. Single effect absorption chillers that use heat in the range of 70–100°C typically operate with a COP_{th} of 0.6 to 0.7. Double effect chillers operating with heat in the range of 150–180°C have a COP_{th} of 1.1 to 1.2. Triple effect chillers use heat in the range of 200–250°C and operate with a COP_{th} of 1.6 to 1.8.

Electrical energy efficiency (Electrical coefficient of performance COP_{el}):

Although solar thermal systems use heat energy to deliver cooling, electricity is still required to operate the fans and pumps in the system. The amount of cooling delivered while using one unit of electricity is used to compare the electricity cost benefit delivered by the solar cooling system to an electrical cooling system. The electrical COP of the solar cooling system is dependent on the system design.

Solar fraction

Solar fraction is the proportion of solar heat used for total cooling. It is expressed as the ratio of solar energy use in the system to the total heat energy use (i.e. sum of solar heat + backup heat). A solar fraction of 1 would indicate that all the heat used by the system is provided by solar. The use of thermal storage, multiple service heat delivery (e.g. hot water and cooling) contribute to an increase in the solar fraction of the system.

Case study

Solar thermal cooling: Echuca hospital

> **"after the solar cooling system installation, we don't switch on the electrical chiller during the daytime"**
>
> **Quote from the facility manager**

Motivation

- Reduce electricity usage during peak electricity tariff periods by shutting down the electric chiller.
- Avoid network upgrades while increasing the air conditioning capacity.
- Reduce emissions.

Project details (phase I)

Evacuated tube collector field at Echuca hospital

Year of installation	2011
Location	Echuca, Victoria
Solar collector details	406m^2 Evacuated tube collectors
Thermal chiller details	Single effect absorption chiller, 500 kW cooling capacity Dry cooling for heat rejection
Backup heating	Gas boiler integrated into chiller solar hot water loop
Storage	Hot water storage for storing excess solar heat for theatre hot water boost. Storage tanks not in the chiller loop

Project details (phase II)

Single axis tracking collector field at Echuca hospital

Year of installation	2017
Location	Echuca, Victoria
Solar collector details	Single axis tracking Fresnel collectors 820m^2
Thermal chiller details	Double effect absorption chiller, 1500 kW cooling capacity Wet cooling for heat rejection
Backup heating	Gas boiler integrated with chiller
Storage	No hot water storage Fire water tanks for storing chilled water

System benefits

Two annual cycles of operation for phase I system provided below.

Mean solar heat delivered	36 600 kWh/month
Mean cooling delivered	41 900 kWh/month
Mean backup energy used	26 200 kWh/month
Mean thermal COP of the system	0.74
Mean electrical COP of the system	8.68
Estimated electrical energy saved per annum[1]	60 300 kWh
Annual mean solar fraction during the day	0.42

Observations

- With current gas and electricity tariffs, the operation of the thermal chiller with gas delivers energy cost savings to the facility.
- Opportunities exist to improve thermal losses, solar fraction.

1 Electrical chiller COP of 3.5 used in the estimates.

More details of the case study, installed site pictures and the energy saving calculator can be found at: https://www.airah.org.au/PUSCH

The performance and cost numbers provided in the brochure are indicative. Actual values may vary depending upon location, type of collector etc. This work is supported by the Australian Renewable Energy Agency (ARENA).

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