



Multi-effect Solar Absorption Chiller

Triple effect solar energy VAM installation in Solar Energy Centre, Gurgaon

By P. Babu and **Vikas Tripathi**
 Head – Innovation Head – Marketing (Cooling Business)
 Thermax Ltd., Pune Thermax Ltd., Pune

Introduction

The world has seen tremendous growth over the last decade, and energy requirements have soared consequently. Since energy sources are depleting fast, the increased demand is pushing up the prices of available energy sources, especially fossil fuel. It is only a matter of time before the world will have to resort to alternative, non-depletable energy sources. At the same time, environmental concerns are gaining importance. Thankfully, we have an unlimited source of energy, our Sun. Though there are developments in other alternative energy options as well, solar energy looks to be the most promising and sustainable solution to our future needs.

Solar Energy

Solar energy is now widely used for producing electricity using a variety of technologies. However, the cost of production is still not viable in many

parts of the world for various reasons. For one, the cost of this technology is high. Transmission and distribution losses add to the cost, which makes it unviable especially for regions where fossil fuel-based power prices are subsidized.

Since a major portion of global energy production is used for cooling and heating purposes, direct conversion of solar energy for these applications is more viable than producing electricity and converting it to cooling or heating. Though solar heating is a relatively simple concept and has gained popularity, direct use of solar energy for cooling is a more recent development. Solar cooling using absorption chillers is a fairly widespread concept in Europe, and increased efficiency of solar collectors has facilitated high-efficiency solar cooling in the recent past.

However, solar energy is highly unreliable. Higher temperatures can easily

be achieved in clear skies, but the temperature of water heated during overcast conditions falls drastically. Temperatures vary substantially according to the time of day and month, and result in varied tem-

About the Author

P. Babu is a mechanical engineer from College of Engineering, Guindy and Anna University. He has been working for the past 16 years in Cooling Business in Thermax as Head – Innovation for absorption chillers and heat pumps. He has worked on improvement in COP of licensed products and has introduced the world's first Lithium Bromide double-effect chiller working at OOC, and several other products for Thermax. He has applied for 10 patents including 4 international patents in the field of absorption chillers. His paper on "Development of Advanced & Customized Absorption Chillers" was presented in ASME International Engineering Congress, Chicago in 2006.

Vikas Tripathi is working with Thermax as Head – Marketing (Cooling Business). He specializes in Strategic Marketing and Business Development.

continued on page 74

continued from page 72

Table 1: Operating temperature ranges for different types of solar collectors

Motion	Collector type	Absorber type	Concentration ratio	Indicative temperature range (°C)
Stationary	Flat plate collector (FPC)	Flat	1	30-80
	Evacuated tube collector (ETC)	Flat	1	50-140
	Compound parabolic collector (CPC)	Tubular	1-5	60-240
Single-axis tracking	Compound parabolic collector (CPC)	Tubular	5-15	60-300
	Linear Fresnel reflector (LFR)	Tubular	10-40	60-250
	Parabolic trough collector (PTC)	Tubular	15-45	60-300
	Cylindrical trough collector (CTC)	Tubular	10-50	60-300
Two-axes tracking	Parabolic dish reflector (PDR)	Point	100-1000	100-500
	Heliostat field collector (HFC)	Point	100-1500	150-1500

Note: Concentration ratio is defined as the aperture area divided by the receiver/ absorber area of the collector.

perature output from solar collectors. Typically, the temperature varies from 90 to 170°C.

Table 1 shows various types of solar collectors and their temperature ranges.

Single and Double Effect Solar Absorption Chillers

Conventionally, absorption chillers available in the market are single effect or double effect. Single effect chillers can work on energy available at lower temperatures; however, COP achieved by them is also low. Double effect chillers can produce refrigeration with substantially lower energy consumption; however, they require higher temperature heat sources and cannot work with lower temperature heat sources.

Table 2 shows the comparison between refrigeration produced from one unit of heat energy and the temperature level required.

Table 2: Comparison between single and double effect solar absorption chillers

Mode	Heat source temperature (°C)	COP
Single effect	80-90	0.7-0.75
Double effect	150-170	1.2-1.45

This puts the solar system engineer in a dilemma. If he selects a single effect chiller to utilize longer hours of solar cooling available, he has to provide double the energy and a large solar field, increasing the capital cost and space required. Selection of double effect chiller brings down solar field space and cost. But this will be at the cost of shorter utilization hours, as during lower solar radiation the desired higher temperature level cannot be achieved.



Photo 1: Office premises cooled by a double effect solar absorption chiller receiving high temperature hot water through solar dishes

Normally, when a concentric collector is working at its full capacity, the losses in the system due to convection and radiation form a small percentage of the heat generation capacity. Based on the temperature of the fluid to be heated, the absolute heat loss (kW) remains the same for a given system. When there is cloud cover and substantial diffused radiation, the heating capacity reduces drastically; the percentage loss may exceed more than 50%. In such cases, a double effect chiller with double the COP of a single effect will deliver lesser refrigeration output than the single effect chiller. In such a scenario, it is advisable to reduce the system temperature to reduce the losses and operate the system in single effect mode.

Most of the time the solar system is backed up with fossil or biomass fuel energy. Since the COP of a single effect chiller is low, its heat demand for refrigeration is nearly double than



Photo 2: Comfort cooling through a single effect solar absorption machine in Spain

a double effect chiller. Utilizing the fossil or biomass fuels for driving a single effect machine will, in fact, increase carbon emission more than conventional refrigeration cycles and defeat the basic purpose of deploying solar energy.

Multi-effect Solar Chillers

A special design of absorption chiller has solved this challenge. This absorption chiller works in single effect mode when low temperature levels are achieved, works both in single as well as double effect mode in series when medium temperature levels are achieved, and works purely as a double effect chiller when sufficiently higher temperature levels are available. This new invention is called a multi-effect solar absorption chiller.

Salient features

1. The machine is designed in such a way that a single unit is capable of running in the whole range of heat source temperatures.
2. Single-double cycle in a multi-effect solar chiller operates in single effect mode when the hot water temperature is below 110°C, single-double effect mode when the hot water temperature is in the range of 110-150°C, and double effect mode if the temperature available is more than 150°C.
3. Conventionally, the single-double effect chillers are used to cater to two different heat sources at different temperatures, for exam-

continued on page 76

continued from page 74

ple, DG (diesel generator) set hot water at 90°C and exhaust gas above 200°C. The construction and cycle of operation is different as two heat sources at two different temperatures are used, while in case of solar chiller only, single heat source is available.

4. The chiller can work from 90°C to 180°C and can enhance its COP automatically as the available solar heat source temperature rises.
5. When the machine operates in single effect mode due to lower temperature from solar energy, the capacity achieved is less due to lower COP. The balance capacity is arranged by means of additional heat sources (steam/ firing/ any other heat source) with double effect COP.

Table 3 gives the operating parameters of such a solar chiller.

Table 3: Multi-effect solar absorption chiller

Mode	Heat source temperature (°C)	COP
Single effect	90-115	0.7-0.75
Single-double effect	115-150	1.0-1.2
Double effect	more than 150	1.2-1.45

Technical challenges faced

1. To design a single-double cycle with single heat source with fluctuating temperatures. Conventional cycles use two different heat source temperatures.
2. To devise a control system to automatically enhance the COP of the chiller when the available solar heat source temperature is rising.
3. To design the cycle with double effect COP for the balance



Photo 3: A single-double effect absorption chiller installation in Germany

capacity with additional heat source when the solar cycle is running in single effect mode.

Conclusion

Triple effect solar absorption chillers offer the following benefits:

- The space required for solar panels for the same capacity is reduced by 30% compared to conventional systems
- They can deliver 40% higher TR in a day compared to a chiller designed for a specific narrow temperature band.
- The average COP of the system is increased by 30%

Currently, triple effect chillers suitable for solar air conditioning are available with COP of 1.75. ❖