

An Absorption Refrigeration System Used for Exploiting Mid-low Temperature Geothermal Resource

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ABSTRACT

An absorption refrigeration system used for exploiting mid-low temperature geothermal resources is described, in which a two-stage LiBr/H₂O absorption chiller driven by hot water is the core technique. The refrigeration system is driven by a low-temperature hot source and consists of an evaporator, a low-pressure absorber, a low-pressure generator, a high-pressure absorber, a high-pressure generator, a condenser, a low-pressure heat exchanger, and a high-pressure heat exchanger.

This refrigeration system can reduce the geothermal water of above 70°C to 60°C. Experimental data indicated that the COP of this chiller ranges from 0.38 to 0.42 with heat source temperature of 63-65°C. Compared to the traditional air-conditioner, implementation of this system reduces power consumption by 62%, and the payback period of the investment is less than four years. This system has a high value of practice and a great deal of market prospect.

1. INTRODUCTION

Geothermal energy has many advantages over other renewable forms of energy, such as a large heat flow density, ease of collection and transport, parameter stability (flux, temperature), and convenience of use. Geothermal energy is not only a mineral resource but also a valued water resource of the tourist villages, and has already become a focus for development and utilization.

In China, utilization of mid-low temperature geothermal resources in local regions has had favorable effects, such as those in Beijing [1] and Tianjin [2]. These two cities make use of geothermal water for heating in winter, which reduces the use of fossil fuels and helps to ameliorate the atmosphere and environment. However, China has lagged behind some other developed countries in the level of utilization of geothermal resources. In addition to using high temperature resources to generate electricity, most direct uses of mid-low temperature geothermal resources are still in a state where simple and original methods of utilization are adopted.

In recent years, a lot of tourist villages with geothermal resources have been built in Guangdong, because investors are interested in the sustainable development. To improve tourist villages, two-stage LiBr/H₂O absorption chillers driven by hot water are used to supply cooling capacity to the buildings, which makes full use of the geothermal

resource of more than 70°C^{[3][4]}. Geothermal water at about 60°C from the chiller outlet can be used in the drying of agricultural products, bathing, aquaculture and so on, which allows the realization of comprehensive utilization of the geothermal resource and simultaneously promotes development of tourism and agriculture in the local region.

2. REFRIGERATING PRINCIPLE OF TWO-STAGE LIBR/H₂O ABSORPTION CHILLER DRIVEN BY HOT WATER

The cycle system of a two-stage LiBr/H₂O absorption chiller consists of an evaporator, a low pressure absorber, a high pressure absorber, a low pressure generator, a high pressure generator, a condenser, a low pressure liquid heat exchanger, a high pressure liquid heat exchanger, and a liquid circulation pump and refrigerant pump, as shown in Figure 1.

The refrigeration process can be divided into three parts: 1) refrigerant circulation; 2) low pressure liquid circulation; and 3) high pressure liquid circulation. Low pressure refrigerant steam from the evaporator (E) is absorbed by liquid in the low pressure absorber (Al), and refrigerant steam is generated in the low pressure generator (Gl) through low pressure level circulation, circulation. This steam is later absorbed by liquid in the high pressure absorber (Ah). Then, high pressure refrigerant steam is generated in the high pressure generator (Gh) through high pressure level circulation. Next, the steam enters the condenser (C) to output its heat, and the temperature and pressure decrease when it passes the throttle valve or U shaped tube. Finally, it enters the evaporator (E) to supply cooling load (air-conditioning) to the building.

Compared to one-stage absorption chillers, two-stage LiBr/H₂O absorption chillers use two extra pieces of equipment: a high pressure absorber and a low pressure generator, which makes use of lower temperature geothermal water more effectively.

3. COP OF TWO-STAGE LIBR/H₂O ABSORPTION CHILLER DRIVEN BY HOT WATER

By definition, the cooling capacity of a two-stage LiBr/H₂O absorption chiller is Q_o , the heat capacity from geothermal water in the high pressure generator is Q_{hg} , and the heat capacity from the low pressure generator is Q_{lg} . Thus, the Coefficient of Performance (COP) of the chiller is defined by Equation 1:

$$COP_s = \frac{Q_o}{Q_{hg} + Q_{lg}} \quad (1)$$

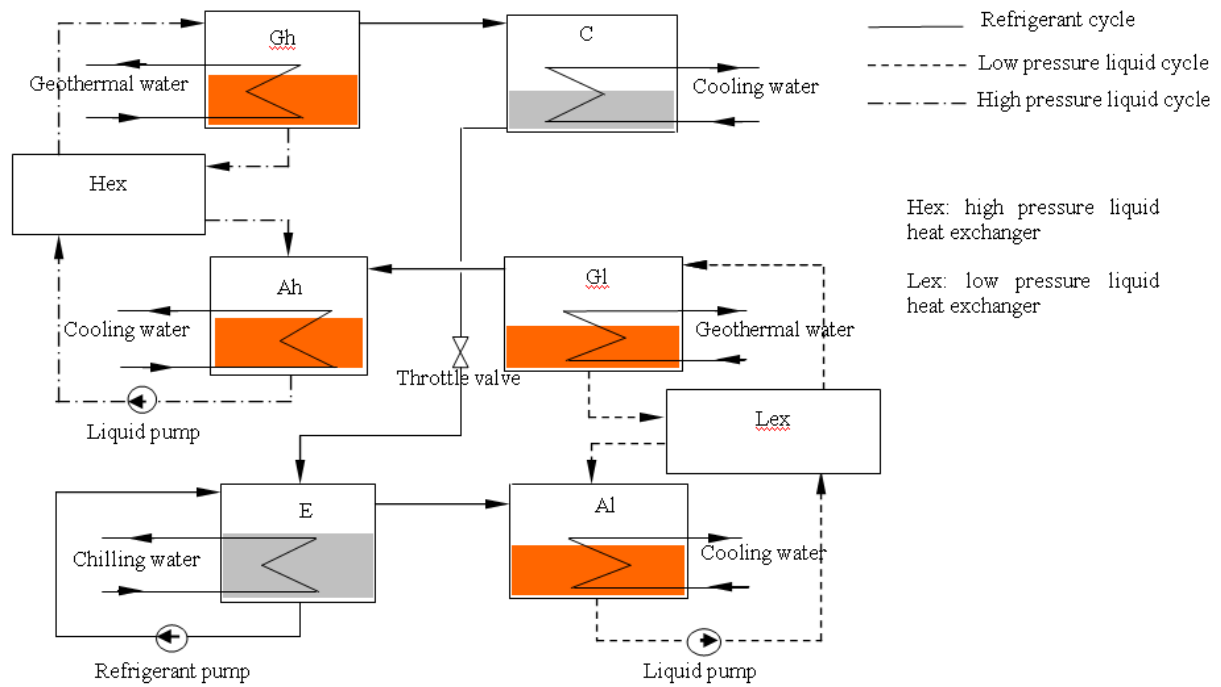


Figure 1. Refrigeration principle of the two-stage LiBr/H₂O absorption chiller

As shown above, two-stage LiBr/H₂O absorption chillers need twice the heat capacity of one-stage chillers in order to obtain the same cooling capacity, so COPs of two-stage LiBr/H₂O absorption chillers are around 0.4.

4. APPLICATION OF GEOTHERMAL REFRIGERATING SYSTEM

The first geothermal refrigerating system in China was completed by the Guangzhou Institute of Energy Conversion, CAS in 2002 and operated in the same year. This system lies in a tourist village in Wuhua, Meizhou, Guangdong, which uses geothermal water of 70°C as a heat source to obtain chilling water of 9°C, which is supplied to a coffee house and a lobby.

4.1 Parts of geothermal refrigeration system

The system mainly consists of two-stage LiBr/H₂O absorption chiller driven by hot water, a deep well pump, a heat exchanger, a cooling tower, several water pumps, a control box, and an air conditioning terminal unit. As shown in Figure 2, geothermal water of 70°C is pumped from the well and enters the heat exchanger to supply the heat flux to the chiller. It is then routed through the refrigeration circulation, and chilling water of 9°C is pumped to a coffee house and a lobby. The capacity of this system is 100 kW, and the overall power consumption is less than 17 kW.

4.2 Main parameters of the system

The main parameters of the geothermal refrigerating system are shown in Table 1. The overall power consumption is less than the cooling capacity of the system. The chilling water can provide adequate cooling capacity for the coffee house and lobby.

4.3 Data analysis of the system

Hot water, cooling water and chilling water are three mediums between the absorption chiller and the

surrounding environment, so the parameters of these three mediums directly influence the cooling capability of the system. The system is tested and analyzed in detail in order to determine the operating status of two-stage LiBr/H₂O absorption chillers driven by low temperature geothermal water.

Table 1. The main parameters of geothermal refrigerating system

Parameter	Value	Parameter	Value
Cooling capacity	100kW	Power consumption of chiller	1.85 kW
Power consumption of geothermal water pump	2.2 kW	Power consumption of hot water pump	2.2 kW
Power consumption of chilling water pump	3 kW	Power consumption of cooling water	5.5 kW
Power consumption of cooling tower	2.2 kW	Overall power consumption of system	16.95 kW
Chilling water temperature	9-12°C	Geothermal water inlet temperature	70°C
Geothermal water outlet temperature	55-60°C	Cooling water temperature	24-32°C
Geothermal water flux	20 t/h	Cooling water flux	60 t/h

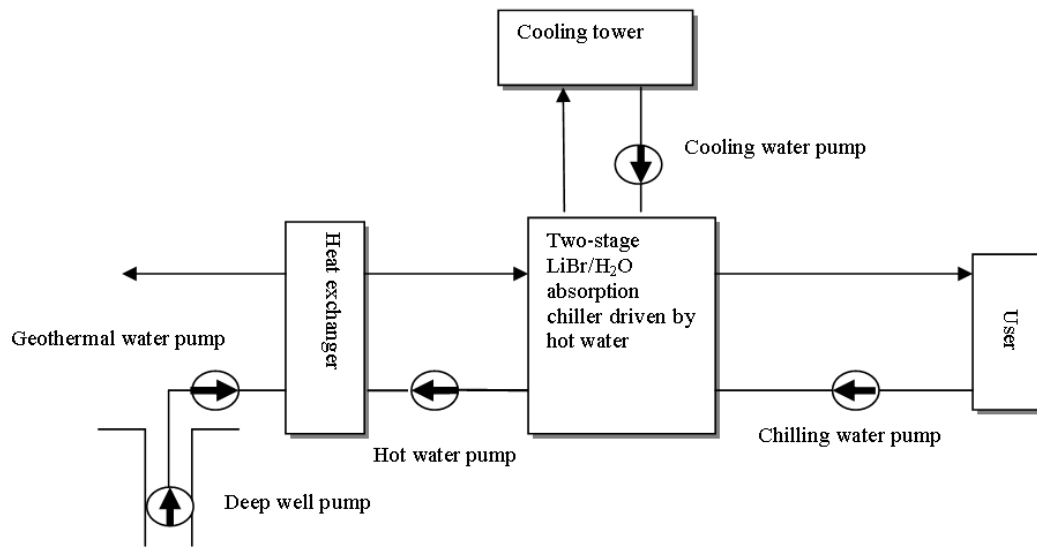


Figure 2. 100kW geothermal refrigerating system

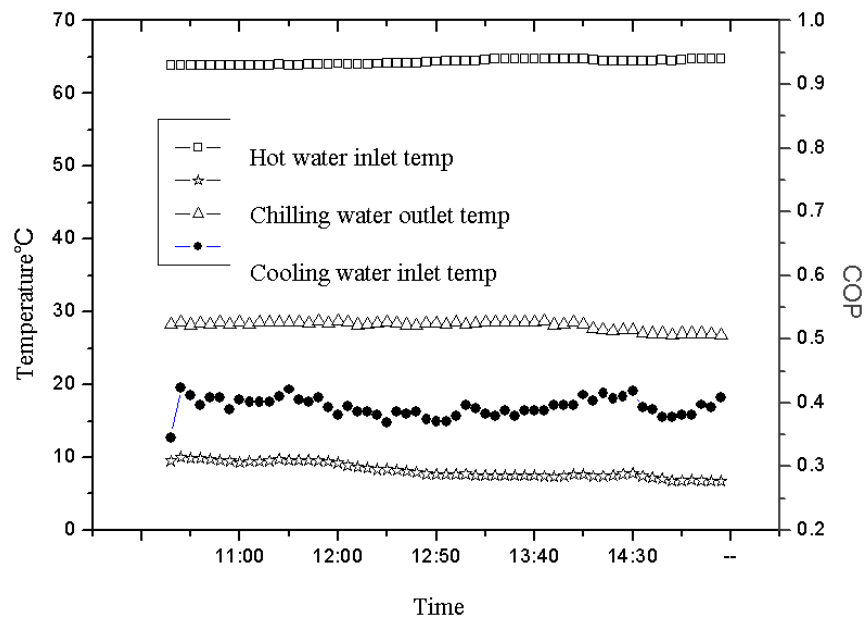


Figure 3. Running curve of geothermal refrigerating system

As shown in Figure 3, the heat source temperature of the chiller mostly stayed at 63 – 65°C. This stability determines the stabilities of chilling water temperature and the performance of the chiller. Although the geothermal water temperature is slightly low, the COP of the chiller still remains at 0.38 – 0.42.

4.4 Economic analysis of the system

A comparison between geothermal refrigeration systems and traditional air conditioning systems is shown in Table 2. The power consumption of a geothermal refrigeration system is 27.35kW less than that of a traditional air conditioning system, and the use of the system saves 55,100 Yuan (RMB) in annual operating costs. Compared to traditional systems, the investment cost is greater by 210,000 Yuan, and the payback period of this system is about 4 years.

5. CONCLUSION

While geothermal resources are very abundant in China, their distribution is not well-proportioned. Most geothermal resources are distributed in remote areas, such as villages and towns, so they have not been utilized very much. The importance of the exploitation of the geothermal energy resource to the development of the local economy and to the acceleration of tourist village growth must be realized.

The technology of two-stage LiBr/H₂O absorption chillers driven by hot water, which use mid-low temperature geothermal resources of 70 – 90°C, has already become a very important part of comprehensive geothermal utilization. With the construction more tourist villages surrounding geothermal resources, this technology will be applied widely.

Table 2 Economic analysis of geothermal refrigerating system

Item	Unit	Former system	Geothermal refrigerating system
Cooling capacity	kW	100	100
Power consumption	kW	44.3	16.95
Investment cost	Yuan(RMB)	160,000	370,000
Annual running cost	Yuan(RMB)	89,300	34,200
Annual saving	Yuan(RMB)		55,100
Payback period	Year		3.8

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