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Cascade Utilization of Low Enthalpy Geothermal Water from the Geothermal Power Plant in Fengshun, Guangdong

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ABSTRACT

The Fengshun geothermal power plant is a single-flash experimental geothermal power plant located in Fengshun County, China. After power generation, the geothermal water is still 72ºC with a mass flow rate of 230t/h. To improve the utilization efficiency of the geothermal water, an integrated cascade utilization system is designed to recovery the geothermal tail water from the geothermal power plant for cooling, agriculture drying and spa&bathing. The test data shows that the utilization ratio of geothermal resource is higher than 70%, which includes geothermal bathing of 40.6%, geothermal refrigeration of 23% and geothermal drying of 7.1%.

1. INTRODUCTION

Geothermal energy is one of the renewable and stable sources with no CO_2 emission and can be used for power generation, cooling and heat generation, spa and so on. Geothermal resources can be classified as hydrothermal systems, conductive systems and deep aquifers. According to the temperature, hydrothermal systems can be distinguished as high, medium and low enthalpy resources. When the geothermal fluid is above 150ºC, it can be classified as a high enthalpy resource. When the geothermal fluid is between 90ºC and 150ºC, it is categorized as a medium enthalpy resource. When the temperature of the geothermal fluid is below 90 ºC, it is a low enthalpy resource.

The utilization methods of geothermal energy include power generation, direct utilization and ground source heat pump. Generally, geothermal resources of high enthalpy is used for power generation and medium and low enthalpy resources geothermal resources is used for direct utilization or heat pump. Cascaded utilization is an efficient way to effectively utilize geothermal energy. The concept of cascade utilization can be basically described as the harnessing of geothermal heat at different thermal levels in sequential processes. Around the world, United America, Iceland, Poland, New Zealand, Austria, Italy, Albania, Greece, Macedonia, Kenya, Turkey, Romania, Mexico, Slovenia, Hungary, Thailand, China and so on have built cascade utilization projects of geothermal energy and show great benefits include social, economic and environmental benefits.

Guangdong province is one of the areas with most abundant low and medium temperature geothermal resources in China and Fengshun county is located in eastern part of Guangdong province. In Fengshun county, there are 24 hydrothermal activity areas, 15 of which is hot springs and the temperature of some hot springs reaches 92℃. It's been estimated that the exploitable quantity of geothermal water in these hydrothermal areas is about 20000ton a day. Among these 24 hydrothermal areas, Tangkeng, Dengwu and Fengliang are located in the county city or town, which can be utilized by local residents with short distances. For a long time, most of geothermal water is only used for spa, which causes lots of exergy loss. So, in 2015 a cascade utilization system of low enthalpy geothermal water from the geothermal power plant was built to show the benefits of geothermal energy utilization in cascade.

2. FENGSHUN GEOTHERMAL POWER PLANT

Figure 1: geothermal tail water after power generation

Fengshun geothermal power plant(FSGPP) was built in 1970 and it was the first geothermal power station in China and the installed capacity was 86kW. After twice rebuilding, the installed capacity of geothermal plant reached 300kW in 1984, shown in Fig.2. The geothermal water is pumped from a geothermal well with depth of 800m. The temperature of geothermal water at the wellhead is 91ºC and the flow rate is 60kg/s. The FSGPP has operated for approximately 8000h annually for several decades. Only a temperature difference of 19°C is obtained when geothermal water used for power generation and the flashed underutilized geothermal water with a mass flow rate of 57kg/s, temperature of 72°C is generated. A high amount of available energy can be further utilized or recovered from the flashed underutilized geothermal water to improve the utilization efficiency of the geothermal water.

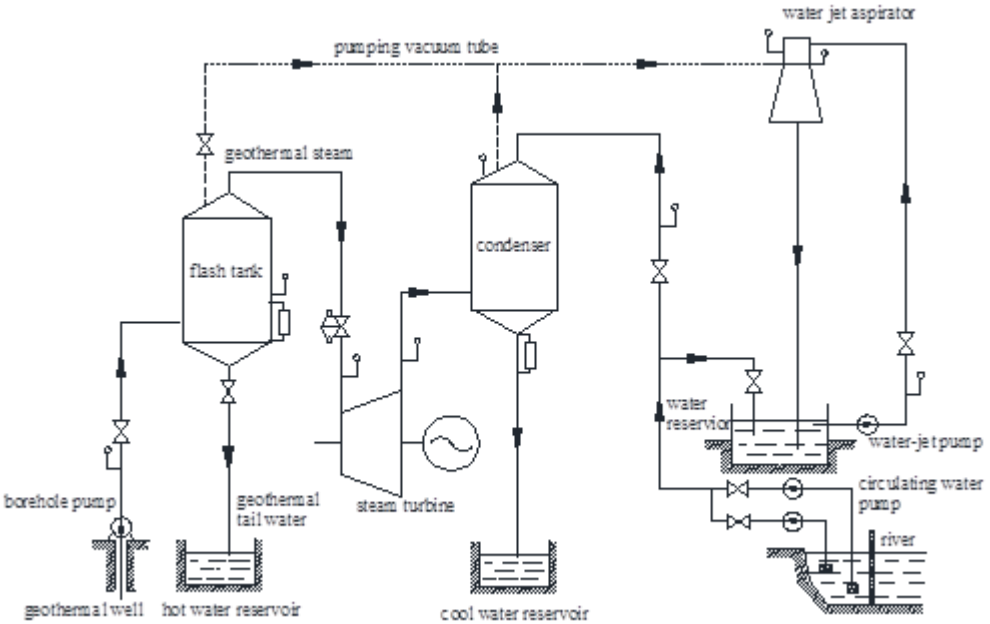

Figure 2: Schematic diagram of Fengshun geothermal power plant

3. CASCADE UTILIZATION DEMONSTRATION SYSTEM

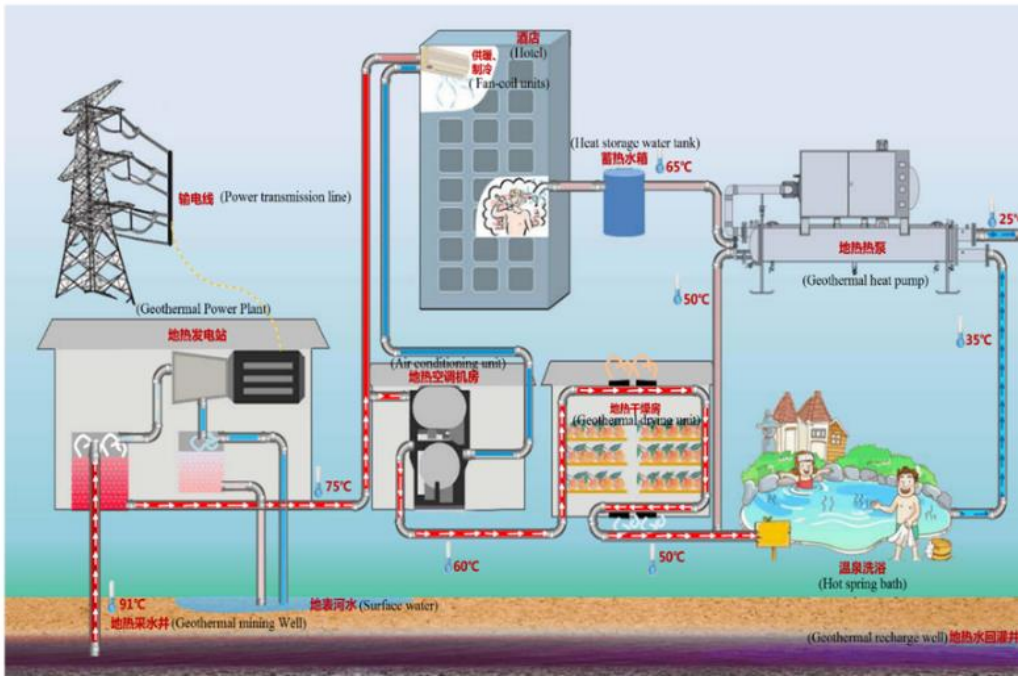

Figure 3: Schematic diagram of cascade utilization demonstration system

The designed flow chart of integrated cascade utilization system of waste geothermal water is shown in Fig.3. The integrated cascade utilization system includes four stages: geothermal cooling or geothermal heating, geothermal drying, geothermal bathing, geothermal heat pump. There are two running modes of geothermal comprehensive and cascade utilization demonstration system: running mode in summer and running mode in winter. In summer, the geothermal water at the temperature of 75ºC after power generation firstly flows into the absorption refrigerator to produce cooling water and temperature of the geothermal water drop to

60 °C. Then the geothermal water flows into the drying system and the temperature drops to 50 °C. The geothermal water from the drying system with temperature of 50 °C is used for spa. At last, the waste geothermal water is used as the low-temperature heat source of the heat pump. Through cascade utilization, the discharge temperature reach as low as 25 °C. In winter, the absorption refrigerator is replaced by plate heat exchanger.

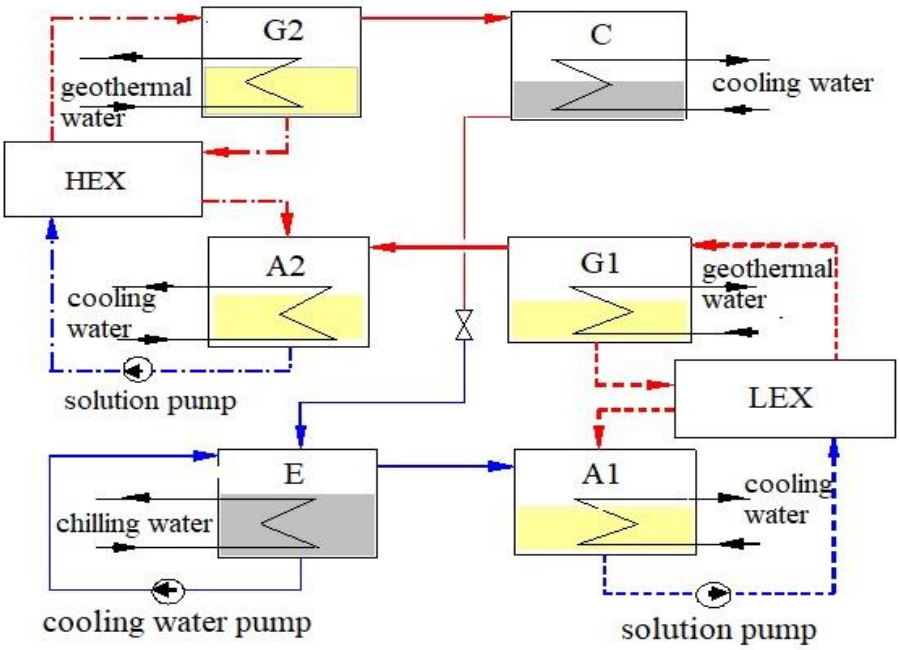

Figure 4: Schematic diagram of absorption cooler

Figure 5: Photo of the absorption cooler

The geothermal absorption chiller is adopted a two-stage-drive solution cycle using H_2O-LiBr as working pair and the performance of the chiller is shown in Fig.4. The two-stage geothermal absorption chiller is a three-pressure-level machine. The high-pressure, low-pressure and intermediate-pressure levels. At the intermediate-pressure level, the low desorber(G1) delivers refrigerant vapor to the high absorber(A2). The high solution circuit transports the refrigerant up to the high desorber(G2), where it is boiled out of solution a second time. The refrigerant then traverses the condenser(C), evaporator(E), and low absorber(A1) as single-stage absorption chiller. The unique feature of the half-effect machine is that the required heat input temperature is lower than that for a single stage with the same chilled water and heat rejection temperatures. The design parameters of the geothermal absorption chiller are shown in table 1.

Table 1: The design parameters of the geothermal absorption chiller

Parameters	Unit	Value	Parameters	Unit	Value
Inlet temperature of hot water	℃	80	Outlet temperature of hot water	℃	65
Inlet temperature of chilled water	℃	14	Outlet temperature of chilled water	℃	9
Inlet temperature of cooling water	℃	32	Outlet temperature of cooling water	℃	37
Concentration difference at high-pressure level	%	4	Concentration difference at low-pressure level	%	3.5
Cooling capacity	kW	300			

The drying system includes heating system, dehumidification system, automatic measure & control system and drying room. The drying room consists of two drying chambers. The effective volume of every chamber is 30 m^3. The three draught fans with nominal air delivery of 12000m^3/h and four heat exchangers with total heat exchange area of 32m^2 was installed at the top of every drying chamber.

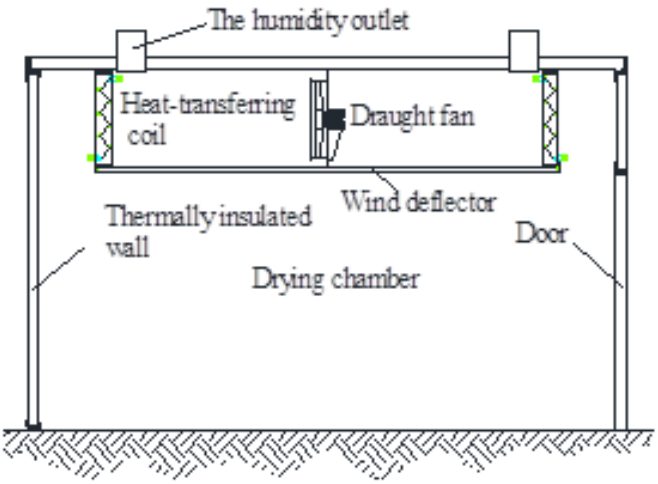

Figure 6: Schematic diagram of the drying room

Figure 7: Indoor scene of the drying room

The geothermal swimming pools are operated and managed by Jindebao Kaiyue International Hot Spring Hotel. There are 5 large sporty pools including thermostatic wave pool, floating pool, massage pool, leisure bar, children's adventure pool and 30 health & wellness pools. The total floor area reaches 18500 square meters. In hot spring pools, the geothermal water is mixed with fresh water in order to decrease the temperature to suitable level.

Figure 8: Geothermal swimming pools

The geothermal heat pump is the last stage of the cascade utilization system. The geothermal heat pump can use the geothermal tail water from hot spring pool with temperature about 35℃ to produce hot water with temperature above 70℃ for meeting the heating or hot water demand of the hotel. ZHR01 prepared by Tianjin University was chosen as the working fluid of the heat pump.

Figure 9: Geothermal heat pump

4. PERFORMANCE OF THE CASCADED SYSTEM

To meet the air conditioning demand of the Jindebao Kaiyue International Hot Spring Hotel, the installed capacity of the geothermal absorption chiller is 300kW and the consumption of geothermal water from the geothermal power plant is 60m^3/h. The performance of the geothermal absorption chiller tested by experiment is shown in table 2.

Table 2: The performance parameters of the geothermal absorption chiller

NO.	Types of water	Inlet temperature(℃)	Outlet temperature(℃)	Mass flow rate (m^3/h)	Heat exchange capacity (kW)	COP
1	Chilled water	12.2	7.1	53.2	316	0.46
	Heat source water	79.2	70	63.4	685	
2	Chilled water	12.3	7.1	53.2	322	0.46
	Heat source water	79.6	70.2	63.4	695	
3	Chilled water	12.6	7.4	53.2	322	0.47
	Heat source water	80.3	71.1	63.4	680	
4	Chilled water	12.2	7.2	53.2	309	0.43
	Heat source water	80.2	70.6	63.4	709	
5	Chilled water	12.5	7.3	53.2	322	0.48
	Heat source water	80.5	71.4	63.4	673	

The operation performance and energy consumption are tested by tested by experiment. In the experiment, inlet temperature range of geothermal water is 60-64℃ and the mass flow rate range is 30-33m^3/h of one drying chamber. The dry base moisture content changed with the time is shown in Fig.10. Drying rate of the whole dryness process is 0.122kg/(kg•h), the total energy consumption factor is 391.2 kJ/kg.

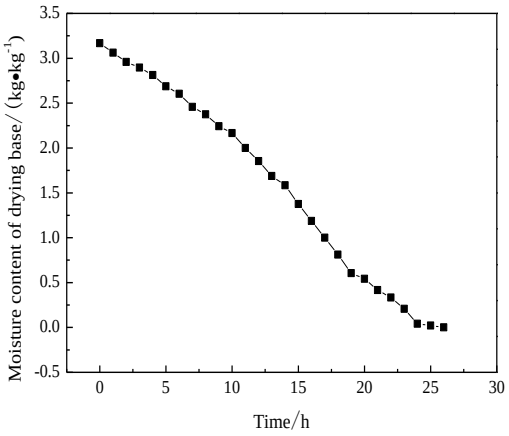

Figure 10: The changing curve of moisture content with drying time

The performance is shown in table 3. The operation conditions are 40℃ of evaporator inlet temperature and 70℃ of condenser outlet temperature. At these operation conditions, COP of the geothermal heat pump is higher than 4.

Table 3: Performance parameters of the geothermal heat pump

Parameters	Unit	NO.1	NO.2	NO.3	NO.4	NO.5	NO.6	NO.7	Average
Heat capacity	kW	318.68	319.23	319.22	318.87	318.56	318.38	319.79	318.96
Input power	kW	75.44	75.95	75.87	75.55	75.38	75.27	76.00	75.64
COP	kW/kW	4.22	4.20	4.21	4.22	4.23	4.23	4.21	4.22

Being restricted by geothermal water demand of the hotel, the cascaded system utilizes 60 t/h geothermal tail water from the geothermal power plant. Among this 60 t/h geothermal tail water, the utilization ratio of geothermal resource is higher than 70%, which includes geothermal bathing of 40.6%(including geothermal heat pump), geothermal refrigeration of 23% and geothermal drying of 7.1%, as shown in Fig.11. Corresponding with this, the whole cascaded system can utilize 55310GJ/year geothermal energy from geothermal tail water.

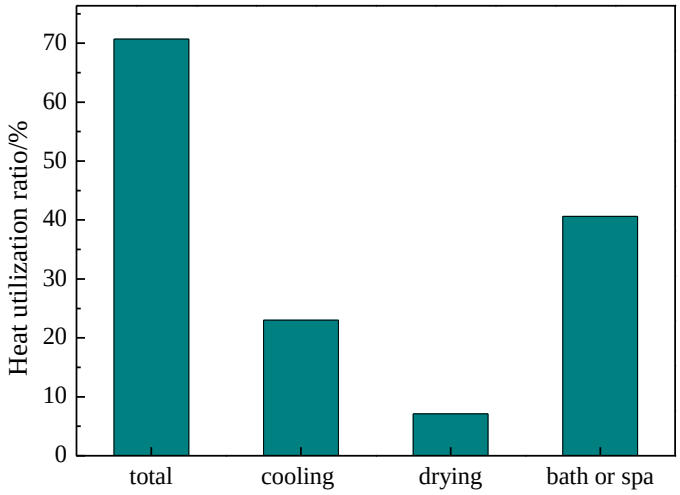

Figure 11: Heat utilization ratio of the cascaded system

5. CONCLUSIONS

Based on the geothermal resource characteristics in south China and the current situation of geothermal resource utilization in Fengshun County. A geothermal comprehensive and cascade utilization demonstration system is built to utilize the geothermal water of 70-80 ℃ from Fengshun geothermal power plant.

Four-stage cascade utilization system included geothermal refrigeration, geothermal drying, geothermal bathing, geothermal heat pump is chosen as the core running mode. The test data shows that the utilization ratio of geothermal resource is higher than 70%, which includes geothermal bathing of 40.6%, geothermal refrigeration of 23% and geothermal drying of 7.1%.

With the completion of the cascade utilization system, hot spring travel industry has developed rapidly and become a hot spot in Guangdong tourism. Nowadays, the geothermal utilization methods in Fengshun County include geothermal power generation, geothermal cooling, geothermal heating, geothermal drying, spas or balneology, geothermal aquaculture, et al. and become a distinctive Fengshun model of geothermal utilization in south China.

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