Simulation Study on Geothermal Direct Supply Combined with Water Source Heat Pump

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Abstract. This paper uses heat pump technology to study a novel thermal energy efficient utilization system for geothermal water. It is a comprehensive utilization of heating system that high temperature geothermal water directly supplies heat stage by stage with combining two-stage water source heat pumps. Results indicate that the temperature of discharged water is below 5°C after the novel system taking advantage of heat energy deeply, which achieves the maximum utilization for geothermal water.

Introduction

Geothermal water is an important material and source for heat supply. The existing high temperature geothermal water heating directly to buildings has good effect on the use of geothermal resources [1][2]. But the heat utilization rate and economy are not high due to the high discharge temperature of geothermal tail water (usually beyond 40°C) [3][4][5].

In addition, common building heating methods mainly contain heat sink heating, floor heating and central air-conditioning heating. Supply water temperature of heat sink heating is high (usually over 70°C, and the difference of inlet and outlet temperatures is about 20-25°C). While the supply water temperature of floor heating and central air-conditioning heating are lower (usually at 45-55°C, and have a small temperature difference of inlet and outlet, about 5°C).

System with Geothermal Direct Supply Combined with Water Source Heat Pump

Against the deficiency of the technology in existence, this paper develops a novel heating system which combines high temperature users (example of heat sink heating) with middle temperature users (examples of floor heating and central air-conditioning heating), and couples two-stage water source heat pumps, that makes geothermal tail water discharge temperature is the lowest after high temperature geothermal water having been used by two-stage heat utilization and two-stage heat pump heat recovery.

A novel geothermal energy cascade depth utilization system combining with water source pump is show in Fig.1. The system includes high-temperature geothermal well 1 within the setting of immersible pump 2. Immersible pump 2 links to the pipeline of high-temperature main pipe 3. High-temperature circulating pumps 4 are installed on the pipeline between high-temperature main pipe 3 and high-temperature users 5. Middle-temperature main pipe 6 connects with high-temperature users 5. Middle-temperature circulating pumps 7 are installed on the pipeline between middle-temperature main pipe 6 and middle-temperature users 8, which link to low-temperature main pipe 9. There is the first outlet pipe 91 connecting with high-temperature evaporator 101 of absorption water source heat pump 10, and regulating valve V1 is mounted on it. The second outlet pipe 92 connects with high-temperature condenser 102 of absorption water source heat pump10 and valve V2 is used for flow rate regulation. Between high-temperature evaporator 101 and water segregator 12, booster pump 11 is installed on the pipe. High-temperature condenser 102 links to high-temperature main pipe 3. One outlet pipe 121 of water segregator 12 connects with low-temperature evaporator 131 of compression water source heat pump 13, and there is regulating valve V3 on it. Another outlet pipe 122 of water segregator 12 connects with low-temperature condenser 132 of compression water source heat pump 13, and there is regulating valve V4 on it. Middle-temperature main pipe 6 connects with low-temperature condenser 132, and low-temperature evaporator 131 links to recharge well 14.

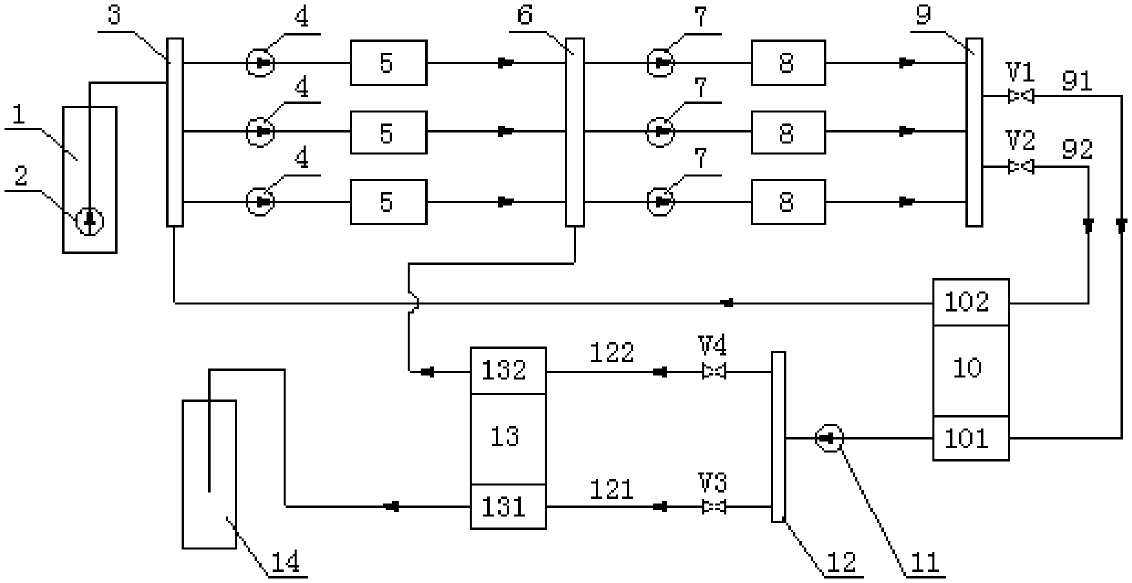

Fig.1. The system chart of a cascade depth utilization of geothermal water

The development of geothermal cascade depth utilization system of this research supplies high temperature geothermal water to high-temperature users first and then to middle-temperature users. After that part of the water supplies to the evaporator of an absorption water source heat pump and the other part supplies to the condenser of the absorption water source heat pump, from which the hot water is sent to high-temperature main pipe, while part of cool water from the evaporator of absorption water source heat pump is sent to the evaporator of a compression water source heat pump and another part is sent to the condenser of the compression water source heat pump, from which the middle-temperature water is sent to middle-temperature main pipe.

Simulation Study

Simulation is based on the above proposed solution of geothermal cascade depth use, applying thermodynamic theory, flow and heat transfer theory, computer software technology and other knowledge to make models to perform the simulation of operating conditions about this geothermal cascade depth utilization solution. Then the effectiveness of the program will be evaluated.

Simulation calculation modules include mixer/ shunt units, fluid transfer pump, and heat exchanger [6]. All units and relevant material as well as work steam constitute the simulate system process.

Input stream of mixer unit can be any quantity, via a simple material balance mixing to become one material flow. The input stream of mixer also can be heat flow and work flow. Shunt can mix one or several flows having been known (like temperature, pressure, flow rate, and constituent, etc.) and divides them into random outlet stream in the same state. All the material flows have the same constituents and conditions with inlet stream after being mixed.

The pump unit mainly calculates the needed power when raises fluid pressure to a specify number. This module is usually used to deal with single-phase liquid, and for some special calculations, it can also deal with two or three phases. Accuracy of simulation calculation depends on the effective phase state, compressibility of fluid, the required efficiency, and so on.

Heat exchanger can calculate one or more inlet stream, and make it become a single flow under the specific temperature, pressure, or phase state. Thermodynamic state of flow constituent having been known can be solved by setting conditions. For the heat exchanger unit, one stream can provides thermal load to change the thermodynamic state of flow within it, and directly heat exchanger setting also can change the state.

①Heating system without heat pump

Water from high-temperature geothermal well 1 enters into high-temperature main pipe B3 through immersible pump B2. After heating the high-temperature user B5, it goes into middle-temperature main pipe B6 and heating the middle-temperature user B8. Finally it passes low-temperature main pipe B9 and turns into recharge well. Software simulation flow chart is shown in Fig.2.

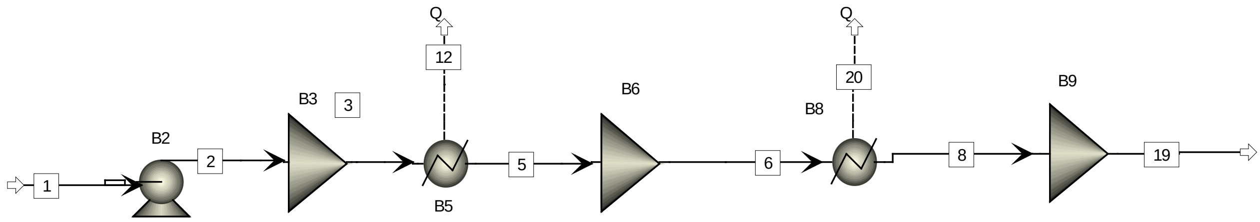

Fig.2. Heating system flow chart without heat pump

②Heating system with one-stage water source heat pump

Water from high-temperature geothermal well 1 enters into high-temperature main pipe B3 through immersible pump B2. After heating the high-temperature user B5, it goes into middle-temperature main pipe B6 and heating the middle-temperature user B8. Then it passes low-temperature main pipe B9. The flow rates of high-temperature evaporator B101 and high-temperature condenser B102 of absorption water source heat pump are adjusted by water segregator B99. The outlet water temperature from B102 is similar to the geothermal water, therefore, it goes back to B3. The water from B101 goes into recharge well. Software simulation flow chart is shown in Fig.3.

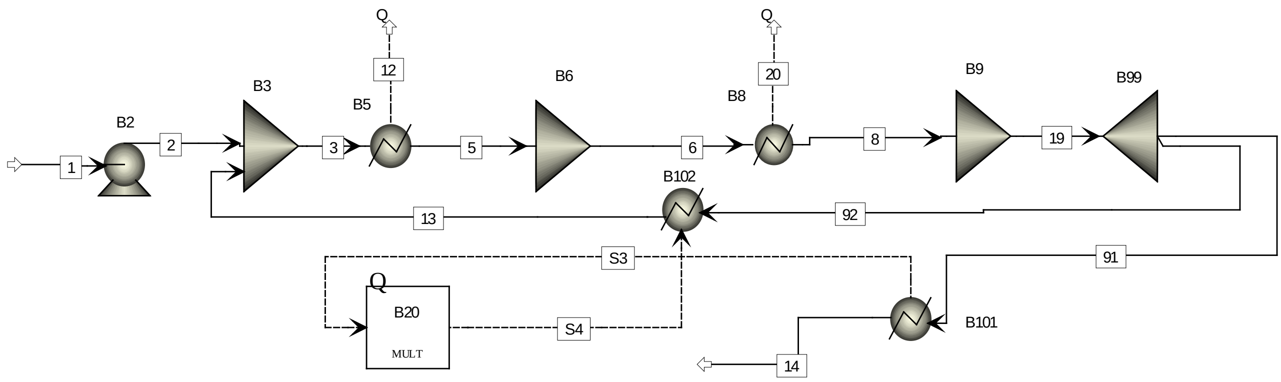

Fig.3. Heating system flow chart with one-stage heat pump

③Heating system with two-stage water source heat pump (A)

Water from high-temperature geothermal well 1 enters into high-temperature main pipe B3 through immersible pump B2. After heating the high-temperature user B5, it goes into middle-temperature main pipe B6 and heating the middle-temperature user B8. Then it passes low-temperature main pipe B9. The flow rates of high-temperature evaporator B101 and high-temperature condenser B102 of absorption water source heat pump, as well as low-temperature condenser B132 of compression heat pump are regulated by water segregator B99. The outlet water temperature of B102 is similar to geothermal water, therefore, it goes back to B3. The outlet water temperature of B132 is similar to the water in middle-temperature main pipe, so it enters to B6. The water from B101 goes into low-temperature evaporator B131, and then flows into recharge well. Software simulation flow chart is shown in Fig.4.

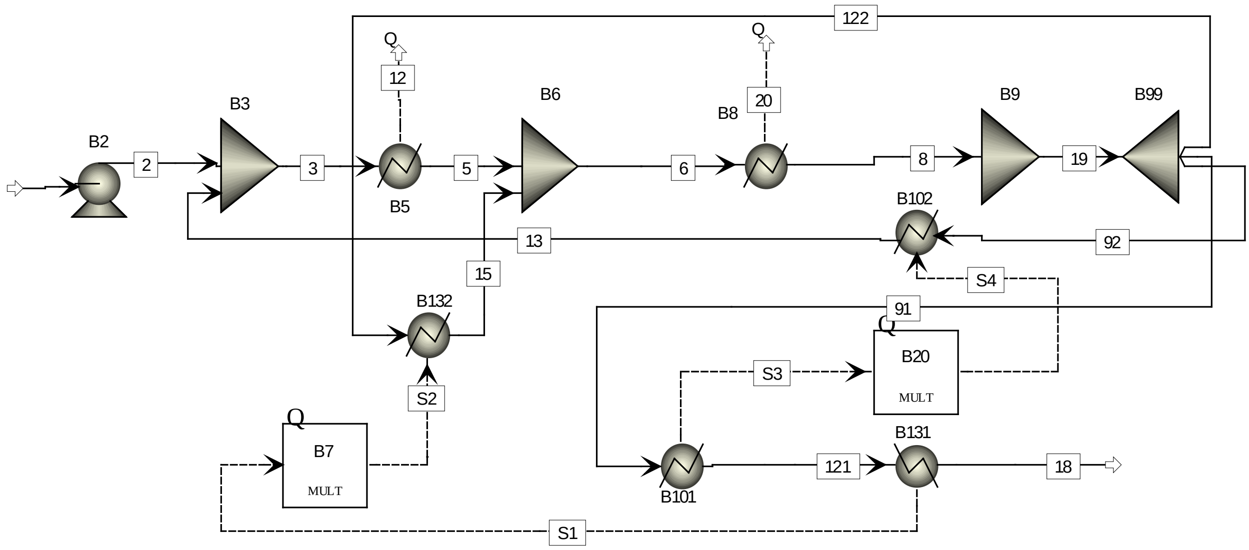

Fig.4. Heating system flow chart with two-stage heat pump (A)

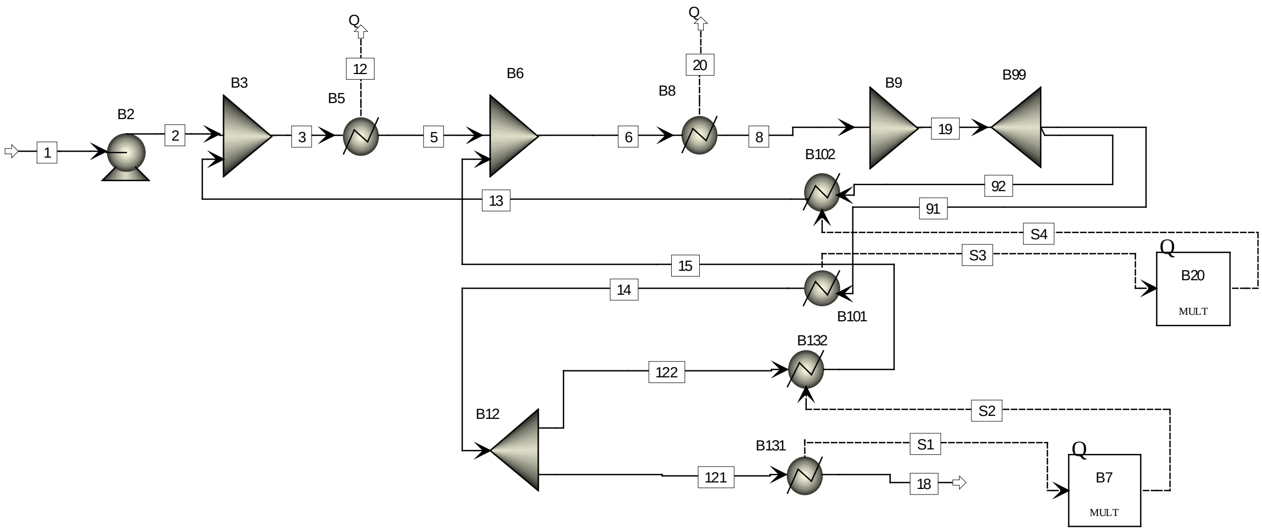

Fig.5. Heating system flow chart with two-stage heat pump (B)

④Heating system with two-stage heat pump (B)

Water from high-temperature geothermal well 1 enters into high-temperature main pipe B3 through immersible pump B2. After heating the high-temperature user B5, it goes into middle-temperature main pipe B6 and heating the middle-temperature user B8. Then it passes low-temperature main pipe B9. The flow rates of high-temperature evaporator B101 and high-temperature condenser B102 of absorption water source heat pump are adjusted by water segregator B99. The outlet water temperature of B102 is similar to geothermal water, so it goes back to B3. The water from the outlet of B101 enters into water segregator B12. The flow rates of low-temperature evaporator B131 and condenser B132 of compression heat pump are controlled by adjusting outlet pipe 121 and 122. The outlet water temperature of B132 is similar to the water in middle-temperature main pipe, so it goes back to B6. The water from B131 goes into recharge well. Software simulation flow chart is shown in Fig.5.

Simulation Results

200t/h is the base of geothermal water consumption. Rated COPs are 1.7 and 4 for absorption water source heat pump and compression water source heat pump respectively. The simulation results of thermal parameter in these four heating systems using 75°C geothermal water are listed in Table 1.

Geothermal water at 75°C supplies directly to high-temperature users, and the temperature decreases to 50°C. After it supplies to middle-temperature users, the temperature decreases to 45°C. Due to the function of one-stage heat pump—absorption water source heat pump—the water temperature decreases to 25°C. Using two-stage heat pump—absorption and compression water source heat pumps at the same time—the geothermal tail water temperature is at 4.8°C. If two-stage heat pump (A) is adopted, the input water of compression water source heat pump condenser is from low-temperature main pipe. If two-stage heat pump (B) is adopted, the input water of compression water source heat pump condenser is from the output water of absorption water source heat pump evaporator, and the output water of compression water source heat pump condenser enters into middle-temperature main pipe.

Table 1. Comparison of thermal parameters in four heating systems

System type	Heating load of high-temperature users (MW)	Heating load of middle-temperature users (MW)	Total heating load (MW)	Input power of absorption water source heat pump (MW)	Input power of compression water source heat pump (MW)
No heat pump	5.82	1.18	7.00	0	0
One-stage heat pump	15.17	3.09	18.26	6.62	0
two-stage heat pump (A)	15.17	9.34	24.51	6.62	1.57
two-stage heat pump (B)	25.25	6.40	31.65	13.76	1.57

Table 1 shows that without heat pump, 200t/h geothermal water at 75℃ can provide 7MW heating supply, discharge tail water temperature is 45°C. When the absorption water source heat pump is applied, the discharge tail water temperature further reduces to 25°C, the heating load achieved is 18.26MW and the input power of absorption heat pump is 6.62MW. When using two-stage heat pump (A), the total heating load is 24.51MW. The increased load comes from compression water source heat pump and it is used for heating the middle-temperature user. When using two-stage heat pump (B), the total heating load is 31.65MW. The increased load is mainly for high-temperature users and seldom for middle-temperature users. It can be adjusted according to the load ratio of high-temperature users to middle-temperature users.

Conclusion

This article establishes a novel thermal energy cascade utilization method for geothermal water, through the software simulation analysis and calculation achieving the operation mode which regulates the two-stage water source heat pump according to the needed heating load. This system realizes the lowest discharge temperature of geothermal tail water. The result of the study has important significance on geothermal water resource efficient utilization.

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