Study on operation scheme of absorption heat pump of cogeneration units in non-heating season

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Abstract. This article research into cogeneration power plants’ absorption heat pump operation scheme in the non-heating season. Two technical routes for supplying domestic hot water and heating condensate water have been proposed. By analysis and calculation, concluded as follow: Schemes for supplying domestic hot water has good economic benefits; For Scheme to heat condensate water, energy-saving condition depends on the heat source of heat pumps. Using turbine extraction steam as heat source is inefficient, while use other heat sources can reduce the turbine heat rate by approximately 60kJ/kW-h.

1. Introduction
Thermal power plants can only use about 35% of the energy in the input fuel, and most of the heat not used is taken away by the circulating cooling water[1]. In order to make use of this part of energy, some cogeneration units choose to use absorption heat pump to extract the circulating water waste heat supply heat supply network. In the non-heating season, due to the user has no heating demand, the waste heat extracted by the heat pump has nowhere to be utilized. Regarding the operation of the heat pump in the non-heating season, Xiaohong He[2] et al. and Zhenqi Zhou[3] respectively studied the use of waste heat for domestic hot water and preheated condensate. On this basis, this paper takes a 300MW heating unit as an example to study the operation scheme of its absorption heat pump in the non-heating season.

2. Research object basic parameters
Taking a 2×300MW subcritical coal-fired heating unit in Northeast China as the research object. Its steam turbine nameplate is C250/N300-16.7/537/537, designed and manufactured by Harbin Steam Turbine Works Co Ltd. Its feed water heating system has 8 heaters, rated back pressure 4.9kPa. To extract waste heat to supply heat network, seven 35MW absorption heat pumps has been established, main parameters are shown in Table 1.

| Items                          | Numerical value |
|-------------------------------|-----------------|
| Driving steam pressure (MPa)  | 0.26            |
| Driving steam enthalpy(kJ/kg) | 2953.6          |
| Drainage enthalpy(kJ/kg)      | 377.07          |
| Circulating water temperature(℃) | 30/38          |
| Heating network water temperature(℃) | 80/60          |
| Circulating water flow (t/h)  | 1719.7          |
| Heating network water flow (m³/h) | 1428.6         |
3. Analysis of producing domestic hot water by heat pump

The cogeneration unit can provide 70~80°C domestic hot water for users in the non-heating season by adding water storage tank, plate heat exchangers, hot water circulation pumps and other facilities. The system diagram is shown in Figure 1.

![Fig. 1 Heat pump heating water system](image)

### 3.1. Plan for providing 70°C domestic hot water

The cogeneration unit has a hot water demand of 2,000 tons/day, which is transported by trucks to the user side, and not returned after being sent out. In this plan, 15°C tap water is heated to 70°C then stored in a water storage tank.

It can be seen from the data in Table 1 that only one heat pump needs to be put into operation to meet the requirements, and it is unnecessary to start the heat network heater.

Considering that the supply water flow is small at this time, there is a large heat loss in the supply pipe. Moreover, there will also be considerable heat loss when hot water is loaded and transported. Therefore, the supply water temperature is set to 75°C.

The tap water temperature is about 15°C, which is quite different from the rated return water temperature of the heat pump. Therefore, a part of produced hot water is sent back to the tap water inlet by the hot water circulation pump. After mixing the two, they reach about 40°C and then enter the heat exchanger. This method prevents the return water temperature from being too low to affect the heat pump.

### 3.2. Plan for providing 80°C domestic hot water

When producing hot water at 80 °C, the hot water supply temperature needs to reach 85 °C, which exceeds the limit of the hot water temperature at the outlet of the lithium bromide absorption heat pump. At this point, it is necessary to turn on the heat network heater, heat the hot water from 75 °C to 85 °C, and then enter the heat exchanger.

### 3.3. Technical and economic analysis

Through the establishment of models, analysis and calculation, the technical and economic indicators of the unit in the production of hot water at 70 °C and 80 °C are obtained, as shown in Table 2.

In the calculation, the heat source of the heat pump and the heat network heater is regarded as the fifth section of steam turbine extraction, its enthalpy value is 3019.9kJ/kg. Ignore the effect of running the heat pump on the turbine back pressure. The price of cold water is 5 yuan / ton; the price of standard coal is 800 yuan / ton.

| Tab.2 Main parameters comparison of heating water scheme |  |  |
|---|---|---|
| | Driving steam flow(t/h) | 30.71 |

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**Note:** The driving steam flow is 30.71 t/h.
According to the data in the table, the unit has good economic benefits in the production of domestic hot water in the non-heating season. For 70°C and 80°C hot water, the profit for 80°C hot water is higher.

### 4. Analysis of heating condensate water by heat pump

The heat pump is used to extract waste thermopower to heat the condensed water, which has the advantages of convenient maintenance, small initial investment, and utilization of waste heat without considering heat users’ demand.

The condensed water at 40°C after the shaft seal heater is taken out, enters the heat pump, and is heated to 80°C and then returned. Because the unit has a condensate temperature of 83°C at the outlet of the No. 7 low-pressure heater under THA condition, the heat pump is equivalent to replacing the No. 7 and No. 8 low-pressure heaters. The system is shown in Figure 2.

![Fig. 2 Heat pump heat condensate water system](image-url)

4.1. Analysis of the fifth stage turbine steam extraction driving heat pump scheme
Taking the fifth stage of steam extraction as the heat pump driving steam, through the establishment of models, analysis and calculation, technical and economic indicators are obtained. The comparison with the THA operating conditions is shown in Table 3.

Tab.3 Main parameters of heat pump heating condensate water driven by the fifth steam extraction scheme

| Items                        | THA condition | Heat pump heating condensate water |
|------------------------------|---------------|-----------------------------------|
| Thermal load (MW)            | --            | 47.14                             |
| Heat pump steam flow (t/h)   | --            | 36.5                              |
| Waste heat power (kW)        | --            | 20369.3                           |
| Main steam flow (t/h)        | 904.68        | 923.37                            |
| Unit steam work (kJ/kg)      | 1211.88       | 1196.33                           |
| Turbine heat rate (kJ/kW·h)  | 8000.82       | 8105.27                           |

It can be seen that the operation of heat pump heating condensate water driven by the fifth stage extraction steam is not energy-saving. The main reason for that is the reduction in the power capacity of the working fluid.

The fifth stage extraction steam is taken as the heat pump drive steam with an enthalpy value of 3019.9 kJ/kg and a mass flow rate of 10.14 kg/s.

If this part of steam is not extracted, it will continue to work in the low pressure cylinder, take the low pressure cylinder exhaust steam enthalpy 2373.1kJ/kg, take the low pressure cylinder efficiency 88%, can do 5763.5kW of work.

After extracting the steam drives the heat pump, the condensed water is heated. That will reduce the steam extraction amount of the No. 7 and No. 8 heaters, so that this part of the steam can continue to work in the low pressure cylinder. No. 7 extraction steam, its enthalpy value is 2641.1kJ/kg, mass flow rate is 6.63kg/s; No. 8 extraction steam, its enthalpy value is 2495.3 kJ/kg, mass flow rate is 5.66kg/s. Under the conditions of the same exhaust steam enthalpy and low pressure cylinder efficiency, the additional work is 2172.27 kW.

The power loss of driving steam into the heat pump is more than the power saved by reducing the low-pressure extraction, which eventually leads to the increase of heat consumption rate of the unit.

4.2. Analysis of the other heat sources driving heat pump scheme

If using driving heat source other than the turbine steam extraction, for example, the steam obtained after the boiler continuous discharge expanded. It can guarantee that the waste heat can be recovered without affecting the work of unit.

Tab.4 Main parameters comparison of heat pump heat condensate water driven by other heat sources

| Items                        | Value |
|------------------------------|-------|
| Thermal load (MW)            | 47.14 |
| Main steam flow (t/h)        | 902.12|
| Unit steam work (kJ/kg)      | 1221  |
| Turbine heat rate (kJ/kW·h)  | 7941.04|

The operation of the unit in this mode can reduce the heat consumption rate by about 60kJ/kW·h, which amounts to reduce the standard coal consumption rate by about 2g/kW·h, which has good economic benefits.

5. Conclusions

1. Aiming at the operation mode of the absorption heat pump of cogeneration units in non-heating season, schemes of supplying 70 °C and 80 °C domestic hot water are proposed. Both schemes have good economic benefits, and the supply of 80 °C water is better.
2. In order to heat condensate water, it is not energy-saving for using turbine extraction steam to drive heat pumps. If other heat sources been used, the operation scheme can reduce the heat rate by 60kJ/kW·h.

References
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