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A technology review on recovering waste heat from the condensers of large turbine units in China

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ABSTRACT

Through recovering waste heat from condensers of large turbine units, both the heating capacity of the plant and the energy efficiency of the cogeneration system can be significantly increased. This paper presents a technology review on waste heat recovery from the condensers of large turbine units. The review covers detailed process and application of the technologies. These technologies are discussed and compared through the analyses of the heating capacity of the plant, the energy efficiency of the cogeneration system and the transportation capacity of the heat network. Taking the waste heat recovery as core task, the "Clean-heating project covering the whole city" is being implemented in many cities. As the key technology in this project, DH system with cogeneration based on absorption heat exchange (Co-ah system) has been widely used. This project will bring social, environmental and economic benefits to China significantly.

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Nomenclature

COP_h	the coefficient of performance of heat pump.
Q	heat output (MW).
w	power consumption or power generation reduction caused by heating (MW).
COP_{eq}	the equivalent coefficient of heating performance.
$COP_{h,t}$	the total coefficient of performance of system.
AHP	

1. Introduction

1.1. The development of the DH system with cogeneration

The DH system with cogeneration has always been the concern of the world, due to its significant advantages on energy saving and emission reduction [1–4]. In China, more than 70% of thermal power units are coal-fired, which consume about a half of the coal output [5]. Hence, the Chinese government has devoted to developing large capacity coal-fired cogeneration units (300 MW, 600 MW and even 1000 MW) in recent years. The total installed capacity of cogeneration units had exceeded 180 million kW until 2010, accounting for above 80% of the industrial heating load and nearly 30% of the building heating load [6,7].

The corresponding construction of large scale heating pipe network will be essential. For instance, for a 2 × 300 MW CHP plant, the building heating area can reach about 15 million m^2, and the transportation distance generally exceeds 20 km. In the indirect connection system, the design temperature of the primary heat network is 130 °C/70 °C or 120 °C/60 °C, the secondary heat network is 70 °C/50 °C (conventional radiator) or 50 °C/ 40°C (radiant floor heating terminal) [8].

1.2. The current problem of the DH system with cogeneration

Although DH system with cogeneration has developed rapidly since the 1990s in China, its proportion is falling in northern China. The main reasons are as following:

1.2.1. The heating capacity of the plant is limited. Meanwhile, enormous waste heat has not been fully used

With the accelerated urbanization, the heating capability of central heat source has been becoming insufficient generally in northern China. It is very difficult to develop more number of large capacity units (CHP plants, etc.) due to financial and environmental factors.

Besides, there is huge energy saving potential in the large cogeneration units. As shown in Fig. 1, to ensure the safe operation of the cogeneration units, the mass flow rate of the exhausted steam from the low-pressure cylinder cannot be less than the minimum design value. The exhausted steam waste heat is discharged by the cooling tower (or air cooled condenser). This waste heat accounts for more than 20% of heat output of the boiler. If it can be recovered, both the heating capacity and energy efficiency can be significantly improved, and the greatest energy saving and emission reduction can be achieved.

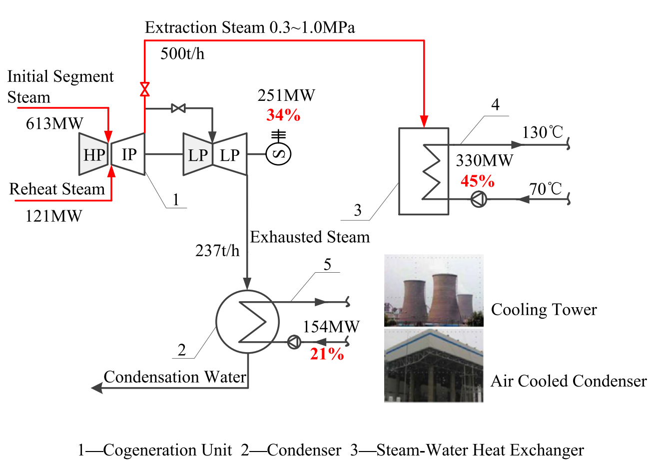

Fig. 1. The heat balance of a 300 MW cogeneration turbine unit.

According to statistics analysis, the waste heat from the condensers is equivalent to about 610 million tons of standard coal annually in northern China. If a third could be used in depth, the demand of building heating in northern towns (about 200 million tons of standard coal annually) can be satisfied. Above all, the waste heat recovery is the research focus to improve the energy efficiency of the cogeneration system and is of great importance to the society.

1.2.2. The transportation capacity of the heat network is limited

In recent years, the transportation capacity of the heat network has been seriously insufficient in many cities. Take Beijing City for example: the design transportation capacity of the present heat network is only 140 million m^2, nevertheless, the demand of building heating is more than 300 million m^2 in the region covered by the heat network. Enlarging the pipe diameter of the heat network needs a huge investment, and in view of the complex status of ground and underground space, it is very difficult in construction.

Besides, many large capacity plants are usually far from the central area of a city for environmental protection, so the transportation distance is longer. Therefore, both the investment of the pipe network and the power consumption of the circulating water pump are very large. That will influence the economy of CHP projects in some extent and limit the development of the DH system with cogeneration [9].

2. Current situations of the technologies about waste heat recovery of turbine units

Scholars have done plenty of researches about using the waste heat to improve the heating capacity of the plant and the energy efficiency of the cogeneration system.

It is undeniable that the energy grade (temperature) of waste heat from the condenser is very low. In winter operating condition, the back pressures of wet-cooling and air-cooling turbine units are 3–5 kPa and 10–20 kPa respectively, and the corresponding saturation temperatures of the exhausted steam are 24–33 °C and 45–60 °C. Obviously, the temperature of the exhausted steam is too low to heat the return water of the heat network directly.

There are usually three conventional methods to solve the above problems:

1) Change the structure of the cylinder and blade, and improve the back pressure of turbine units. Then the return water of the heat network can be heated directly by the exhausted steam, namely the low vacuum operation technology.
2) Use the heat pump technologies, including the electric heat pump and the absorption heat pump (AHP).