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Cigarette Factory Steam System Modeling Simulation and Energy Consumption Distribution Analysis

Shuo Xu *, Hongyu Gu, Bo Zhang, Yujie Yang, Zhantao An, Jian Liu

Baoding Cigarette Factory of Hebei Baisha Tobacco Co., Ltd. Baoding Hebei, 071000, China

*** Corresponding author:** Shuo Xu (Email: 280933673@qq.com)

Abstract: During the production process of a certain cigarette factory, the production wastewater cannot be recycled, resulting in a waste of resources and energy. To solve this problem, the steam system of the cigarette factory was modified to recycle the production wastewater. After the system is put into operation, the production wastewater is recycled and the water quality is adjusted before being reused, which increases the system water replenishment temperature, reduces the system energy consumption and production unit consumption, and achieves significant economic and environmental benefits.

Keywords: Cigarette Factory; Energy Saving; Production Wastewater; Recycling.

1. Introduction

Tobacco companies consume a lot of energy. According to statistics, the total energy consumed by the tobacco product industry every year is equivalent to 2.3 million tons of standard coal, of which coal consumption is 970,000 tons and electricity consumption is 3.7 billion kW·h., To fully realize low-carbon targets, energy conservation and emission reduction in the tobacco industry are imperative.

At present, some scientific research institutions and cigarette manufacturing companies have successively carried out the formulation of energy consumption evaluation and analysis standards and research on technologies to reduce energy consumption in cigarette production. According to preliminary calculations, if cigarette companies in the industry can reduce building energy consumption by 10%, the national cigarette industry will be the company can save energy consumption of 35,000 tons of standard coal, which is equivalent to the annual energy consumption of a company with an annual output of 1.5 million boxes of cigarettes. However, regarding the overall energy utilization status of the industry and the current status of energy-saving research, there is still a lack of energy-saving technology solutions that are cost-effective and can be promoted and implemented in the industry.

Fu Bo et al[1]. took a cigarette factory in a hot summer and cold winter area as the research object. They divided the entire factory area into six different functional areas that remained relatively complete and independent under the premise of organic combination. They used simulation software to analyze different energy-saving technologies. A comprehensive energy consumption analysis was conducted, and the results showed that after adopting various energy-saving measures, the comprehensive energy-saving rate of the joint workshop target building was 12.65%.

Cao Yong et al[2]. established an energy management system for a cigarette factory. Through real-time monitoring, analysis and prediction of energy consumption, they achieved centralized management, accurate measurement and reasonable dispatch of energy in the cigarette factory, making energy dispatch more timely and reasonable, reducing energy consumption and energy costs.

Bai Changjun [3][3] proposed that cigarette factories should effectively control the details of each work in the factory, effectively ensure the cooperation between equipment operations, and achieve energy saving and consumption reduction through lean management of electrical appliances and water in the cigarette factory.

Hao Wei et al[4]. improved the operating performance and power quality of distribution equipment through scientific transformation and application of power distribution equipment in a power plant.

Deng Shaopo et al[5]. established a water resource and heat recovery system in the tobacco factory to recycle the wastewater and waste heat with better quality and higher temperature produced by the silk making workshop and air conditioning system. The wastewater recovery rate can reach more than 75%, and the waste heat recovery and utilization rate in winter can reach more than 90%, with significant economic and environmental benefits.

Dong Aiguo et al[6]. proposed a variety of control strategies for the air-conditioning system with high energy consumption in tobacco factories. By using the variable air volume operation technology of the air-conditioning box and the year-round multi-condition control technology of the control system, operating costs were greatly saved.

Chen Luyao et al[7]. proposed an air-conditioning energy consumption prediction model based on GRU neural network. They were familiar with short-term and long-term predictions of the energy consumption of the air-conditioning system in the execution workshop of a tobacco factory. The results showed that the model prediction performance was good.

It can provide theoretical support for the operation control strategy and energy saving of the air conditioning system in cigarette factories.

To sum up, many scholars have conducted in-depth research and achieved results in terms of energy saving and consumption reduction in cigarette factories, including waste heat recovery from cigarette factory wastewater, energy-saving renovation of cigarette factory workshops, air conditioning operation strategies, and energy consumption prediction of cigarette factories.

2. System Introduction and Mode

2.1. System Specification

The steam thermal system of the cigarette factory consists of four Creden boilers, separate cylinders, iron removers, deaerators, resin tanks, hot water tanks, heat users, heat exchangers, pumps, etc.

The schematic diagram of the steam system is shown in Figure 1. First, the tap water is purified by the resin tank and divided into two streams. One stream flow to the flue gas waste heat exchanger to recover the waste heat of the flue gas and then mixes with the other stream and enters the hot water tank. The water effluent from the hot water tank is divided into two streams. One stream flow to the sewage heat exchanger to recover the waste heat of the boiler sewage and returns to the hot water tank. The other part is used as boiler feed water and enters the boiler after being pressurized by the pump. Part of the feed water absorbs heat and evaporates into steam in the boiler, part of the saturated water enters the deaerator as a heat source, and the remaining small part is lost as boiler wastewater. The steam enters the low-pressure sub-cylinder of the thermal station, the bathroom of the joint workshop, the vacuum resurgence of the joint workshop, and the high-pressure sub-cylinder of the thermal station. The steam in the high-pressure sub-cylinder of the thermal station enters the spice kitchen, silk making workshop, silk making workshop gas storage tank, and air conditioner respectively. The green dotted line indicates that the condensate is not recovered, and the solid line indicates that it is recovered.

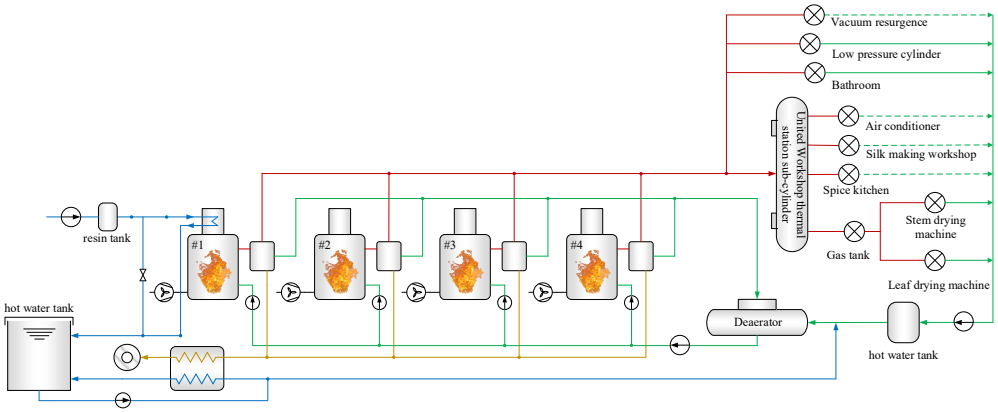


Figure 1. Steam system flow chart

2.2. System Problems and Improvements

The temperature of the condensate water in the bathroom and air conditioner of the joint workshop is relatively low, while the temperature of the condensate water in the other steam-consuming units is relatively high. When the two water tanks are mixed, the temperature difference is too large and vibration occurs, which affects the normal operation of the system. Therefore, the current system only recycles the cooling of the lower temperature part. water, resulting in a large amount of waste of energy, so a modification plan was proposed for the system to add a heat exchanger to allow the high-temperature condensed water to heat the low-temperature condensed water and then mix and recycle the two.

2.3. Steam System Energy Consumption and Unit Consumption Calculation Model

2.3.1. Energy Consumption Calculation Model of Each Unit of Steam System

(1) Boiler energy consumption I_b is calculated by formula (1):

$$I_b = (Q_b e_f)/(h_b Q_{net,ar,CH_4}) - D_0(e_0 - e_{fw}) - D_S(e_s - e_e) \quad (1)$$

In the formula: Q_b is the useful energy input into the system (boiler heat absorption); h_b is the boiler efficiency; Q_{net,ar,CH_4} are the low calorific value of natural gas; e_f is the chemical exergy of the natural gas used; D_0 is the main steam flow rate; e_0 is Main steam ratio exergy; e_{fw} boiler feed water ratio exergy; D_S is the boiler drain flow rate; e_s is the boiler drain ratio exergy.

(2) The energy consumption calculation model Ih of the steam consuming unit is calculated by formula (2):

$$I_h = D_i(e_0 - e_i) - D_e(e_0 - e_e) \quad (2)$$

In the formula: D_i is the flow rate of condensed water recovered by each steam consuming unit, e_i is the specific exergy of condensed water recovered by each steam consuming unit, D_e is the amount of condensed water discharged into the environment by each steam consuming unit, e_e is the discharge amount of each steam consuming unit The ratio of the amount of condensed water entering the environment.

(3) The energy consumption Io of the deaerator is calculated by formula (3)

$$I_h = D_{s,in}(e_s - e_{out}) + D_{i,all}(e_l - e_{out}) + D_b(e_b - e_{out}) \quad (3)$$

In the formula: $D_{s,in}$ is the boiler drain flow entering the deaerator, e_{out} is the deaerator outlet specific exergy, $D_{i,all}$ is the recycled condensate water flow, e_l is the condensate water specific exergy, D_b is the water replenishment amount, e_b is the replenishment water specific exergy.

2.3.2. Steam System Unit Consumption Calculation Model

System unit consumption b is defined as the amount of

coal consumed to produce 10,000 cigarettes, and is calculated by equation 4:

$$b = m_c / a \tag{4}$$

In the formula, m_c is the mass of coal consumed, and a is the amount of smoke produced.

Coal consumption mc can be calculated by formula (5):

$$m_c = m_{CH_4} Q_{net,ar,CH_4} / Q_{net,ar} \tag{5}$$

In the formula, m_{CH_4} is the consumption of natural gas, $Q_{net,ar}$ is the low calorific value of coal

3. Steam System Energy Consumption Analysis

3.1. Steam System Energy Consumption Distribution and Analysis

During the operation of the steam system of the tobacco factory, there are various irreversible factors that cause energy loss in the system. When the steam system is running, only two boilers are started. Calculate and visualize the energy consumption distribution of each unit of the entire system, as shown in Figure 2. The specific energy consumption of each unit and the proportion of each unit's energy consumption to the total energy consumption of the steam system,

It can be seen from the figure that the No. 1 boiler has the largest energy consumption, which is 3643.6kW, accounting for 52.4%; the energy consumption of the No. 2 boiler, air conditioner and silk workshop is second, which is 1059.2kW and 863kW, accounting for 15.2% and 12.4% respectively. %, 7.4%; the energy consumption of other units is smaller. This is because Boiler No. 1 has a larger load and produces more steam, resulting in greater energy consumption, while Boiler No. 2 produces less steam and consumes less energy. Most of the total steam generated by the two boilers is used for the air conditioning system and the silk making workshop, so the energy consumption of the air conditioning and silk making workshops is relatively large. Only a smaller amount of steam is used in other process plants, so the remaining units consume less energy

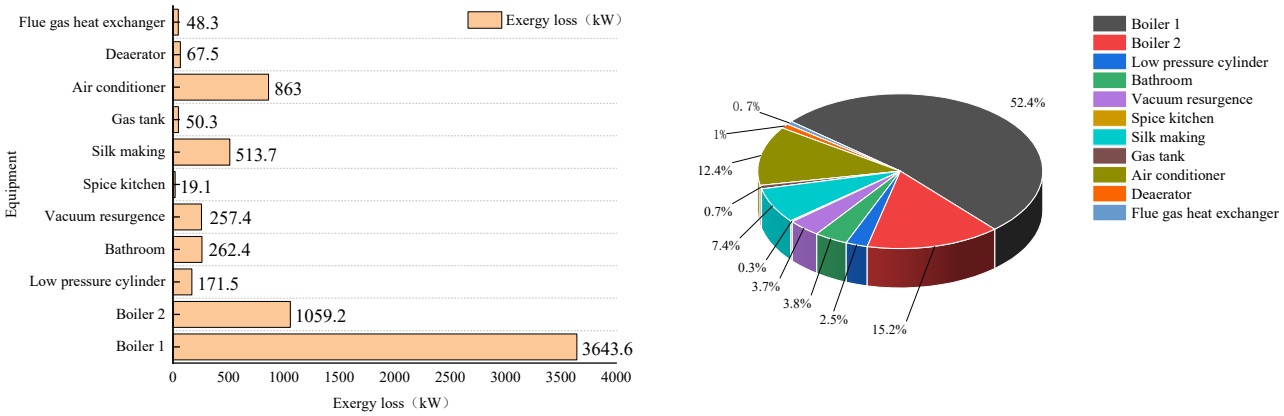


Figure 2. Energy consumption of each unit of the system before transformation and proportion of energy consumption of each unit of the system

3.2. Analysis of Energy Consumption and Unit Consumption of Steam System after Renovation

It can be seen from the previous section that the energy consumption distribution and proportion of the steam system in the factory area before the transformation are met. When the conditions required for tobacco factory production during this period are met, when the load of each boiler remains unchanged and the amount of steam required by each process workshop remains unchanged, changes the system's return water parameters will have a great impact on the system's energy consumption distribution and unit consumption (coal consumption per 10,000 cigarettes produced, unit kg/10,000 cigarettes).

3.2.1. The Impact of Water Return Rate on System Energy Consumption and Unit Consumption

In the steam system, the water return rate is defined as the ratio of the condensed water recovery amount to the total steam amount, and is an important parameter.

The influence of water return rate on the change of system energy consumption in four typical days in spring, summer, autumn and winter under the conditions of tobacco factory production is shown in Figures 3 and 4 (a), (b), (c), and (d), when the water return rate gradually increases, the hot water tank and iron remover release more energy to the outside world, and the energy consumption increases. The energy consumption of other units in the system gradually decreases. This is because the minimum temperature of the condensate water is higher than the environment. When the temperature and condensate recovery rate increase, the amount of additional water replenishment will decrease, and the amount of boiler water required for the deaerator will decrease. Under the condition that the amount of steam generated remains unchanged, the boiler feed water amount will decrease, the heat of the boiler system will decrease, and the energy consumption will decrease; deaeration the average heat exchange temperature difference of the device is reduced, the energy consumption is reduced, the heat released by the heat users to the environment is reduced, and the energy consumption of each heat user is reduced.

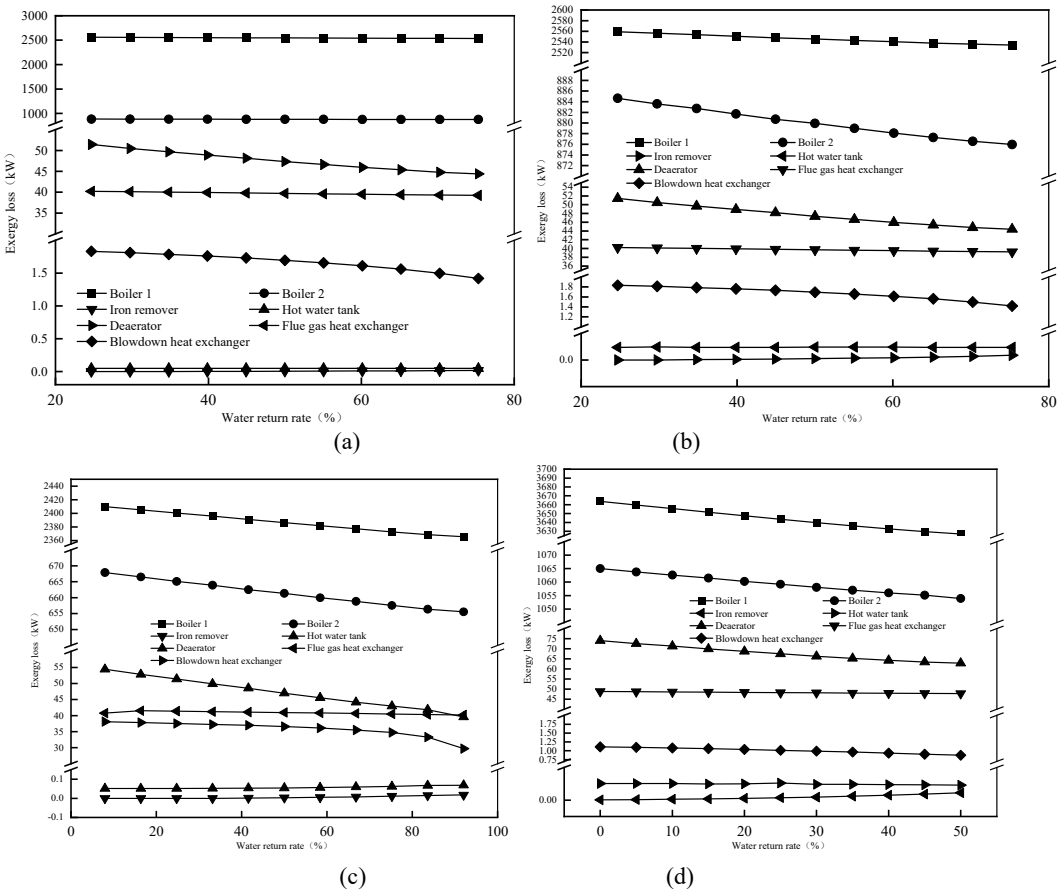


Figure 3. The impact of water return rate on energy consumption of non-steam consuming units

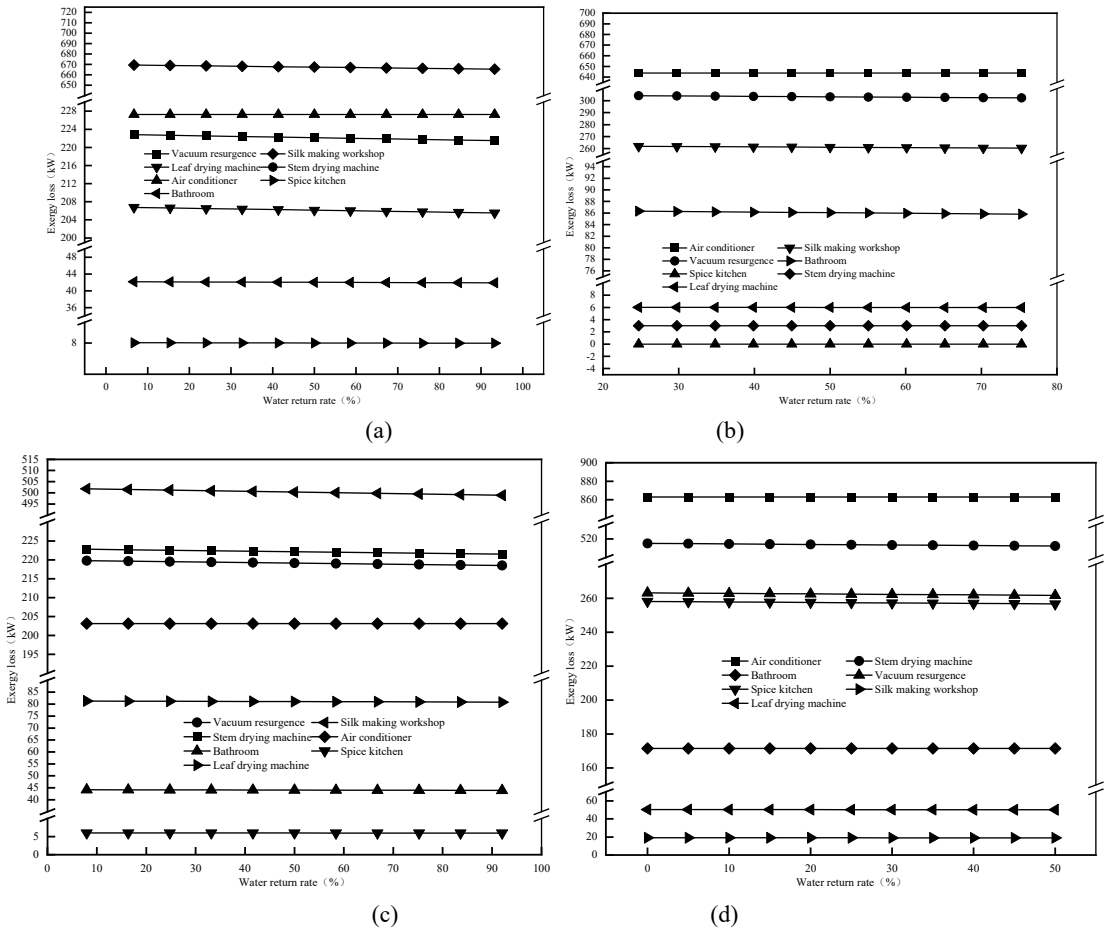


Figure 4. Effect of water return rate on energy consumption of steam consuming units

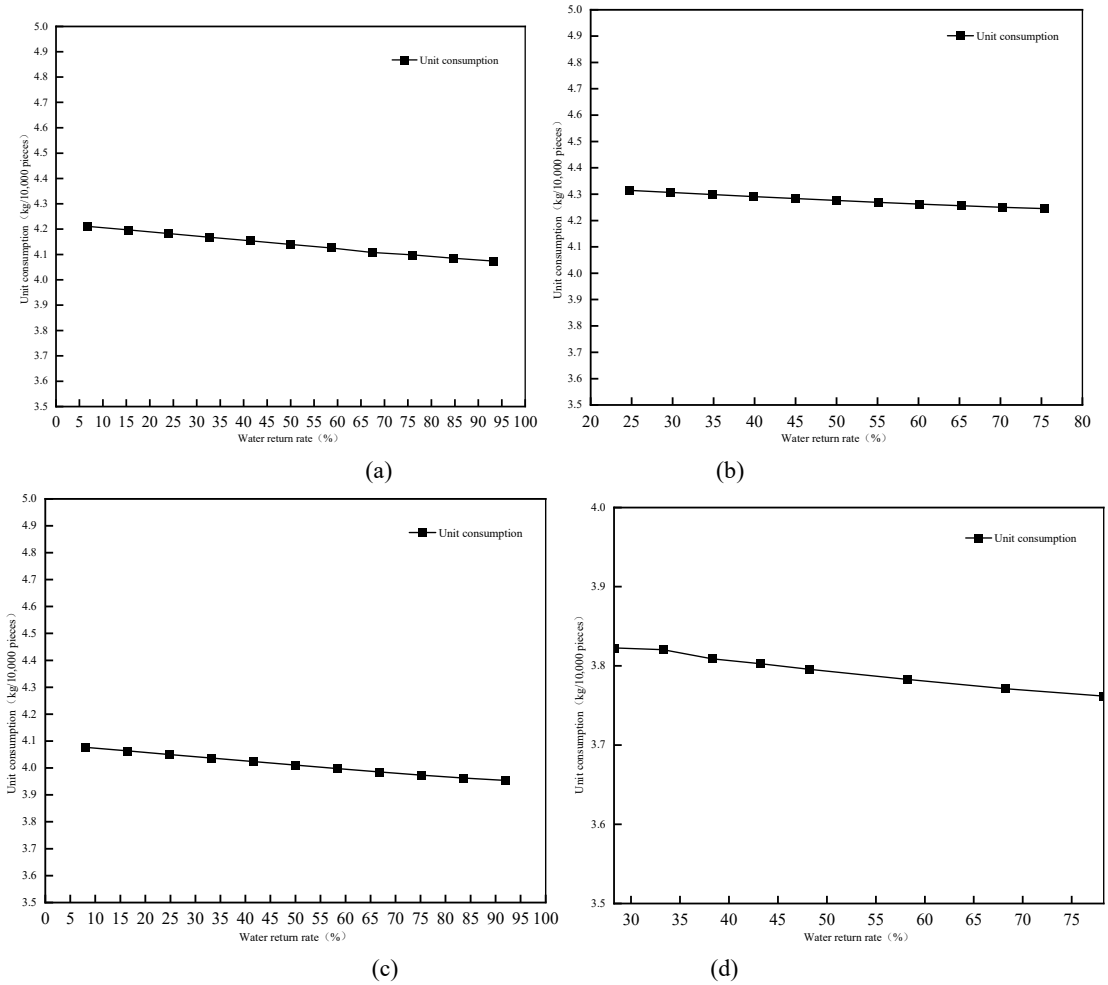


Figure 5. The impact of water return rate on unit consumption

It can be seen from Figures 3 and 4 that the increase in water return rate has a positive impact on the energy consumption of each unit of the system, and will inevitably affect the unit consumption of the cigarette factory.

The impact of return water rate on typical daily unit consumption in spring, summer, autumn and winter is shown in (a), (b), (c), and (d) in Figure 4. When the return water temperature remains unchanged at 35°C, As the water return rate increases, the amount of natural gas consumed by the steam system decreases while the cigarette output remains unchanged, thus reducing the unit consumption of the system.

3.2.2. The Impact of Return Water Temperature on System Energy Consumption and Unit Consumption

The influence of the return water temperature in the steam system on the system energy consumption changes in four typical days in spring, summer, autumn and winter is shown in (a), (b), (c), and (d) in Figures 6 and 7, when the return water temperature rises, the energy consumption of each unit of the system decreases. This is because the energy consumption of each steam consuming unit released to the environment decreases as the return water temperature increases. Therefore, the energy consumption of each steam consuming unit decreases. As the return water temperature increases, the energy consumption of each steam consuming unit decreases. As the temperature increases, the average heat exchange temperature difference of the deaerator decreases, so the energy consumption decreases, and the heat required for deaeration by the deaerator decreases, resulting in a decrease in boiler hydrophobicity, a decrease in boiler system heat, and a decrease in energy consumption.

The influence of return water temperature on system unit consumption changes in four typical days in spring, summer, autumn and winter is shown in (a), (b), (c), and (d) in Figure 8. It can be seen from the figure that when the return water rate is different When the temperature changes, as the return water temperature increases, the system unit consumption gradually decreases. This is because the return water temperature increases, causing the total heat absorption of the boiler to decrease, thereby reducing the natural gas consumption, while the smoke production remains unchanged, so the system unit consumption decreases. When the return water temperature increases from 35°C to 75°C, energy consumption decreases in all four seasons.

4. Conclusion

In view of the problem that the condensate water recovery system of a certain cigarette factory cannot recover condensate water normally, a modification plan was proposed. The main conclusions are as follows:

(1) Improving the water return rate of the system through system transformation can reduce the energy consumption and unit consumption of each unit and improve the efficiency of the cigarette factory.

(2) The two streams of condensed water with a large temperature difference are mixed and recycled after

passing through the heat exchanger, which increases the return water temperature of the current system and reduces the system energy consumption and unit consumption.

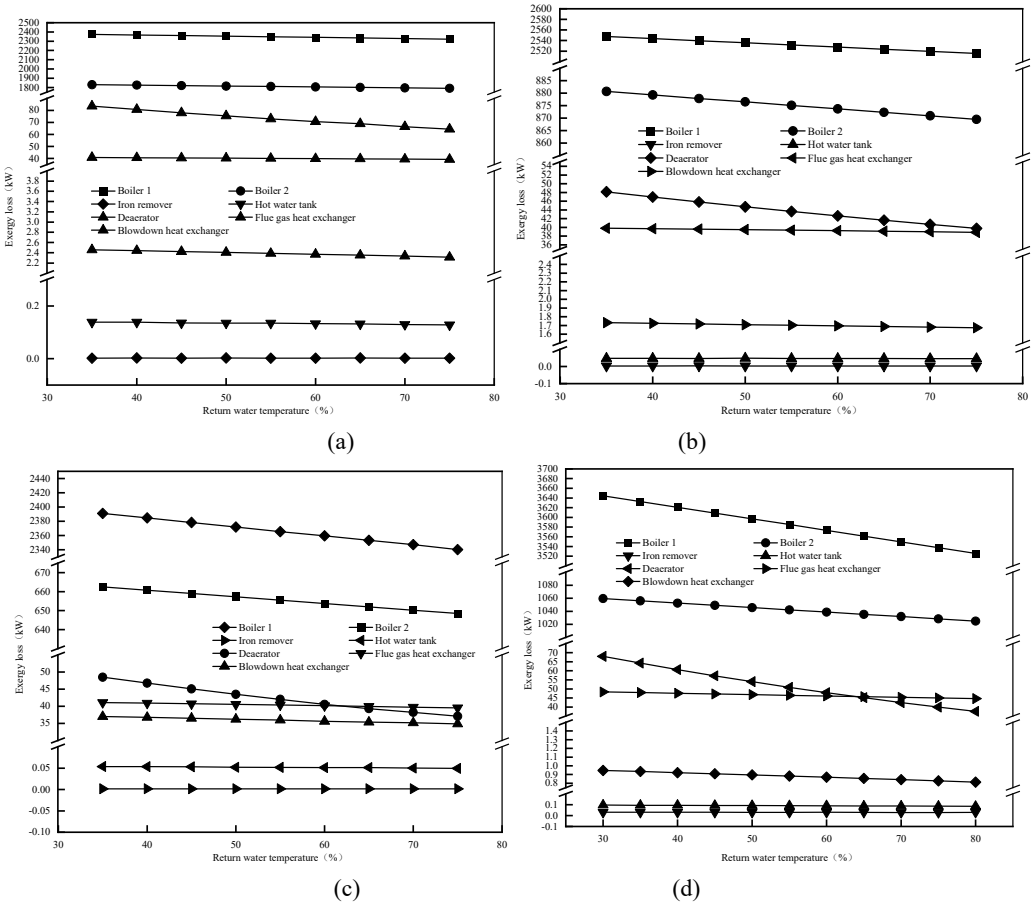


Figure 6. Effect of return water temperature on energy consumption of non-steam consuming units

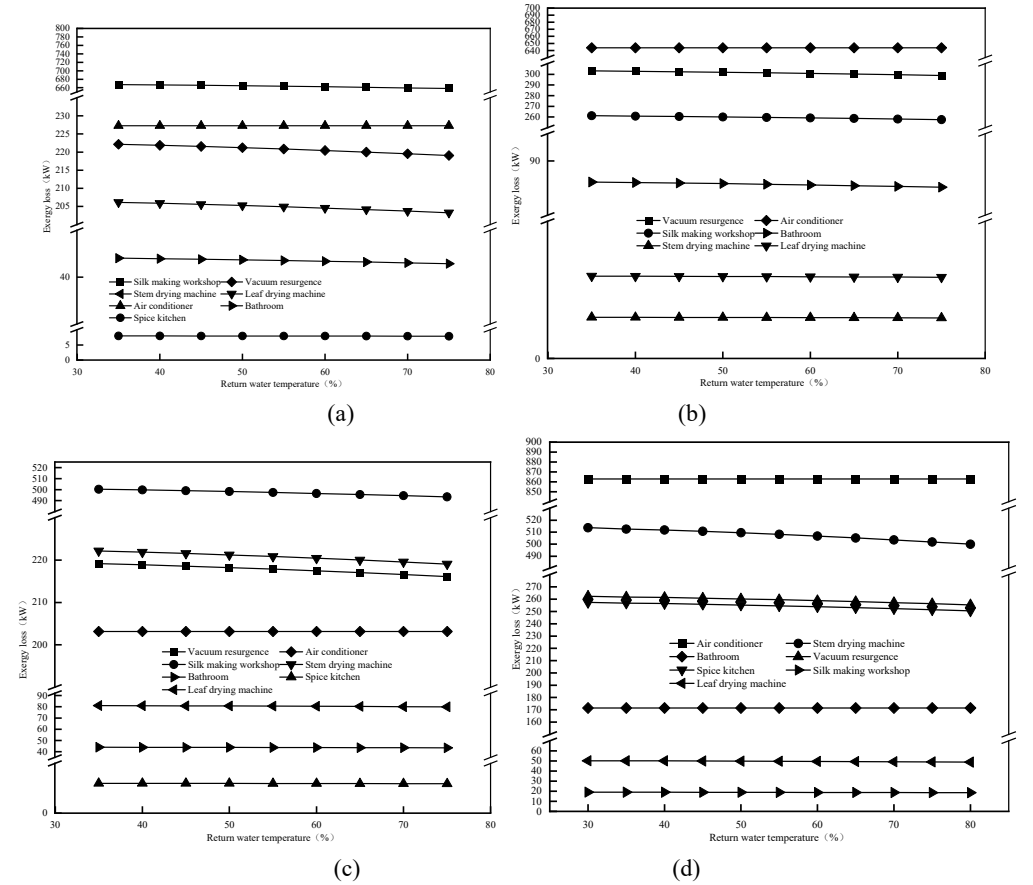


Figure 7. Influence of return water temperature on energy consumption of thermal user units

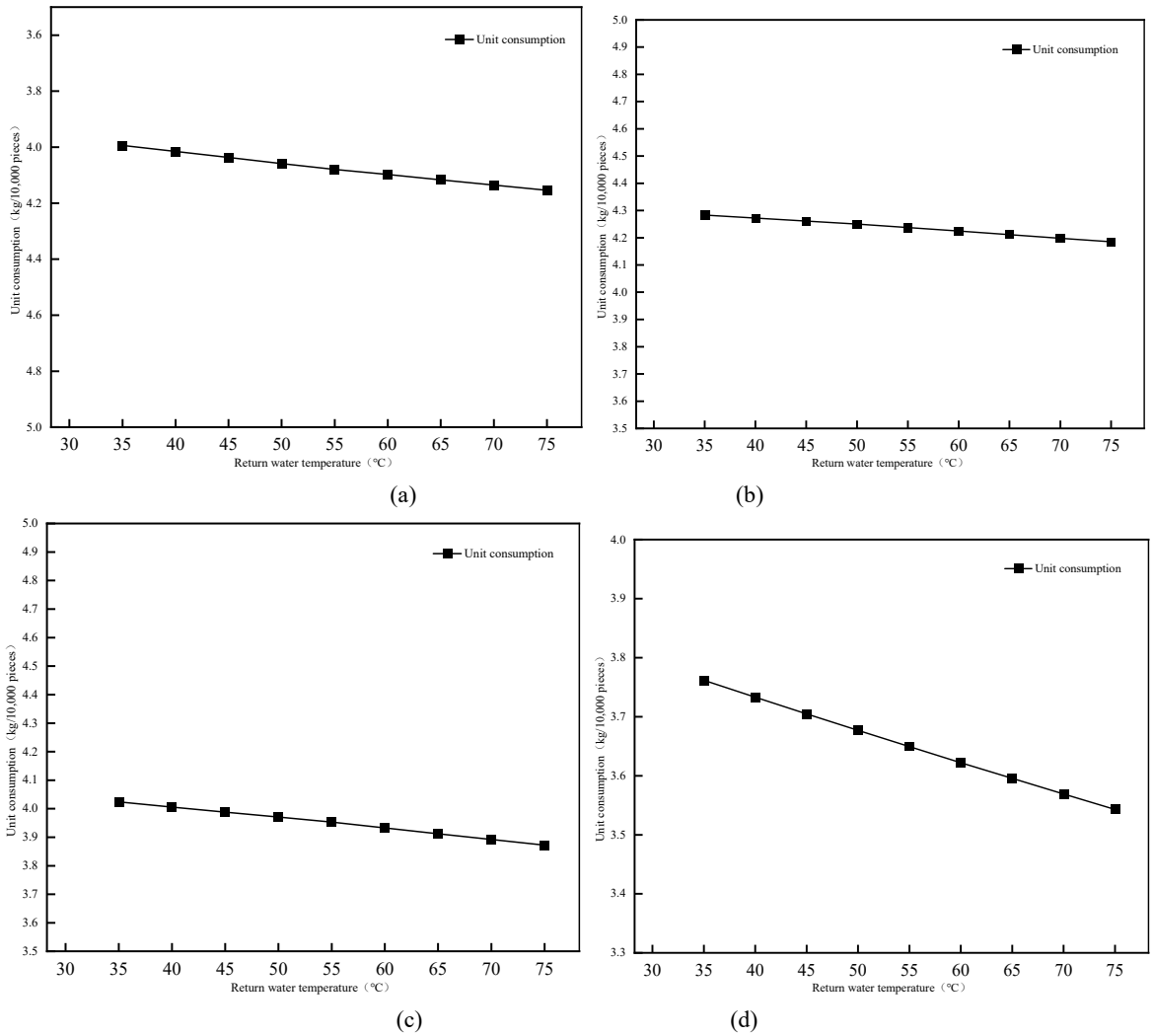


Figure 8. The impact of return water temperature on unit consumption

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