Section 1. Machinery construction

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USING OF EVAPORATIVE CONDENSERS FOR COMBINED POWER PLANT

Abstract. An evaporative condenser is used to remove excess heat from a cooling system when the heat cannot be utilised for other purposes. The excess heat is removed by evaporating water. The evaporative condenser has a cabinet with a water-sprayed condenser, and it usually has one or more fans.

Keywords: Evaporative condensers, Combined power plant, Cooled condenser, Condenser, Steam Condenser.

Introduction

One of the factors affecting on the production and development of energy is the amount of water used in equipment in power plant. Especially if it is combined power plants, which the heat of the exhaust gas is used to generate steam for operating of steam turbines.

In a number of Iraqi regions, there are certain problems with water [1], which a large extent hinders of development the energy industry.

One of the ways to solve the problem of water shortage for the operation of combined power plants is to use the air cooled condenser in power plants. However, air condenser are less efficient than water one [2].

It is possible to increase the efficiency of the air cooled condenser by using (evaporative condensers with atomizing spray nozzles) with water on the heat exchanger surface [3]. But the use of water from natural reservoirs has disadvantages. Water from natural reservoirs has some salinity, which negatively effects on the surface of the heat exchanger.

At the same time, the main units of combined power plants use fuel which made up of mostly carbon and hydrogen atoms. The combustion of hydrogen produces water in a fairly large amount.

The object of the research is to evaluate the possibility of using an evaporative steam condenser with atomizing spray nozzles for combined power plants in the climatic conditions of Iraq.

Combined power plant

In the power generation method characterized by the standalone operation of a gas turbine, known as the simple or open cycle, releases exhaust gas at temperatures of around 600 °C into the atmosphere.

Combined cycle power generation improves the general thermal efficiency of the plant by recovering this high temperature exhaust gas. Many combined cycle power generation plants adopt a waste heat recovery cycle in which exhaust gas from the gas turbine is led to the waste heat recovery boiler to generate steam using recovered heat to drive the steam turbine [4].

One of the important components in power plants is the condenser

Steam Condenser

A steam condenser is a closed vessel in which steam is condensed by abstracting the heat by cooling it with water and where the pressure is maintained below atmospheric pressure.

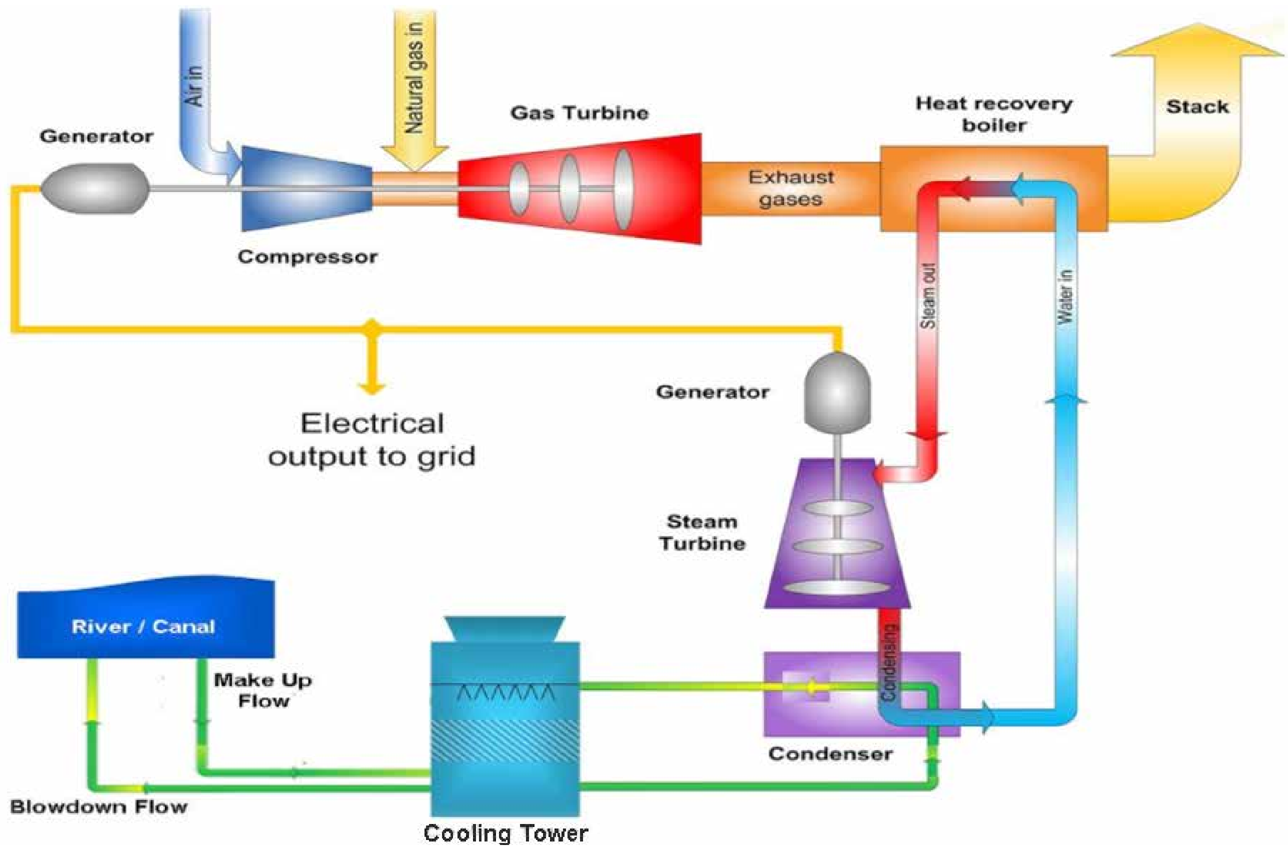


Figure 1. Combined power plant

The condensed steam is known as condensate. The efficiency of the steam power plant is increased by the use of a condenser. The steam condenser is an essential component of all modern steam power plants.

Objectives of the Steam Condenser

A steam condenser has the following two objectives:

1. The primary objective is to maintain a low pressure (below atmospheric pressure) so as to obtain the maximum possible energy from steam and thus to secure a high efficiency.

The secondary objective is to supply pure feed water to the hot well, from where it is pumped back to the boiler.

Types of Steam Condenser

There are two main types of steam condenser:

1. Jet condensers (mixing type condensers)

1. Parallel flow jet condenser
2. Counterflow or Low-level jet condenser

3. Barometric or High-level jet condenser
4. Ejector Condenser

2. Surface condensers (non-mixing type condensers)

1. Downflow surface condenser
2. Central flow condenser
3. Regenerative condenser
4. Evaporative condenser [5].

On this article we will focus on evaporative condenser

Evaporative condenser

An evaporative condenser is used to remove excess heat from a cooling system when the heat cannot be utilised for other purposes. The excess heat is removed by evaporating water.

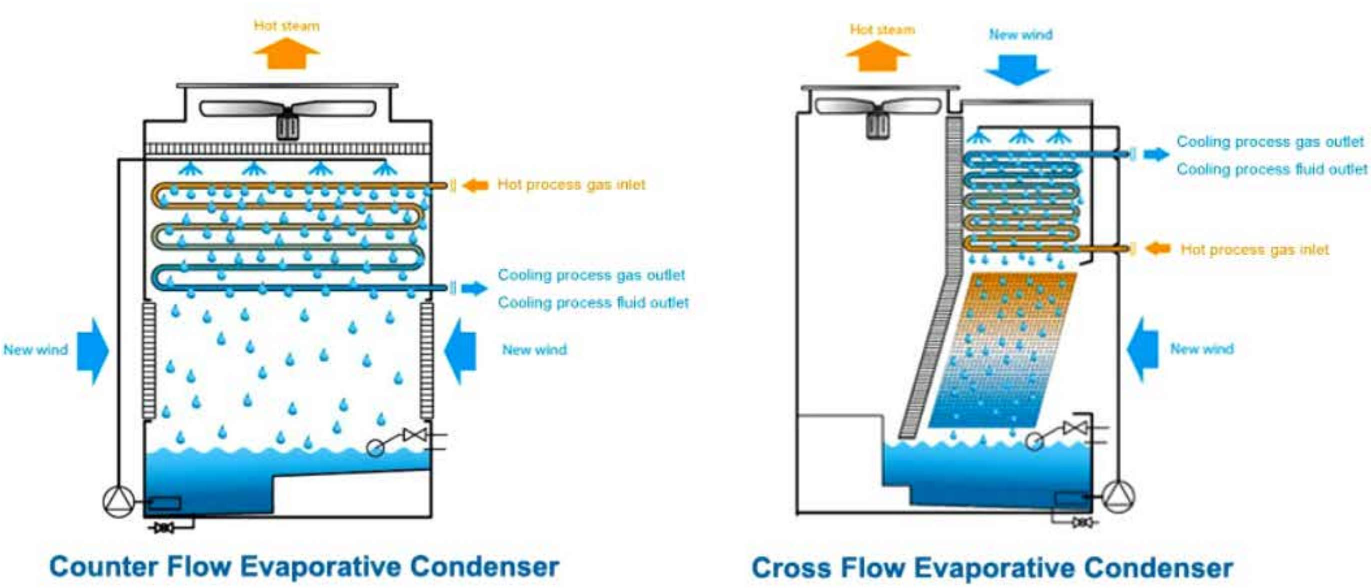
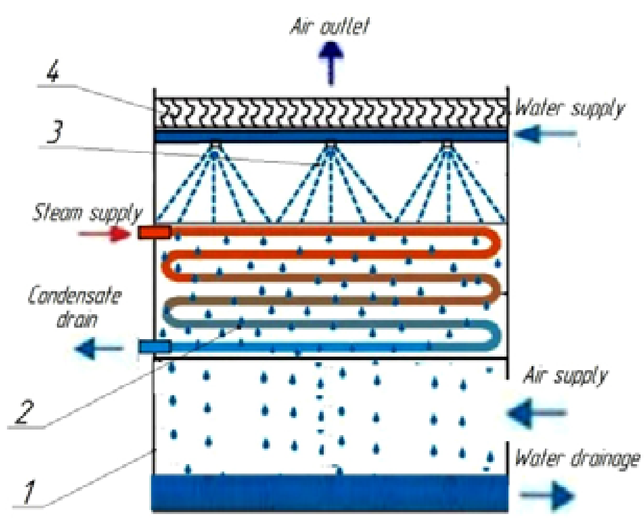


Figure 2. Evaporative condensers

The evaporative condenser has a cabinet with a water-sprayed condenser, and it usually has one or more fans. The excess heat is removed by evaporating water. In an evaporative condenser the primary coolant of the cooling system is cooled, which is the opposite of a cooling tower. Evaporator condensers are more expensive than dry coolers and are primarily used in large cooling systems or systems where the outdoor temperature is high. In many locations around the world, regulations limit the physical size of a cooling system and this in turn limits the use of evaporative condensers [6].

Spraying a condenser with water exploits the fact that the dew point temperature is lower than the air temperature and that a wet surface transfers heat more efficiently.



(a)

Figure 3. Technological scheme of evaporative condenser: 1 – Body; 2 – Heat exchanger; 3 – Nozzles; 4 – Drop separator;

The technological scheme in which the atomization water is collected in the sump of the condenser and is again returned to the system of nozzles, then for the upper rows and as a result of the relatively high cooling water temperature and air enthalpy, part of the heat lost by the cooling water is stored in the sprayed water [7].

The temperature of the spray water varies significantly with the height of the evaporative condenser, for outdoor air temperature range 10…45 °C, the temperature of the cooling water is in the range from 18 to 55 °C, this significantly affects the process of condensation of water vapor inside the tube.

The useful power of the steam turbine in a combined power plant depends significantly on the ambient temperature and the steam condensation pressure, we estimate the change in the specific power of a steam turbine in a combined power plant depending on the indicated parameters in the climatic conditions of Iraq.

In the calculations, it was assumed that the ambient air temperature varied from 10 to 45 °C. Change of water vapor condensation pressure from 8 to 25 kPa. The calculation data are shown in (Fig. 4).

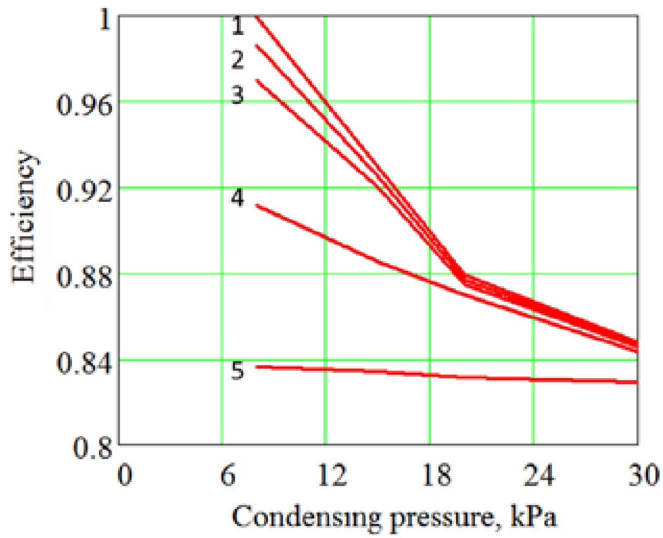


Figure 4. The specific power of a steam turbine in a combined power plant depending on the ambient temperature and the pressure of condensation of water vapor for the climatic conditions of Iraq

For the temperature of the outside air used as the cooler in the evaporative condenser, 10…45 °C, the average temperature of spray water 18…55 °C Evaporative condenser efficiency does not exceed 80% of the nominal value.

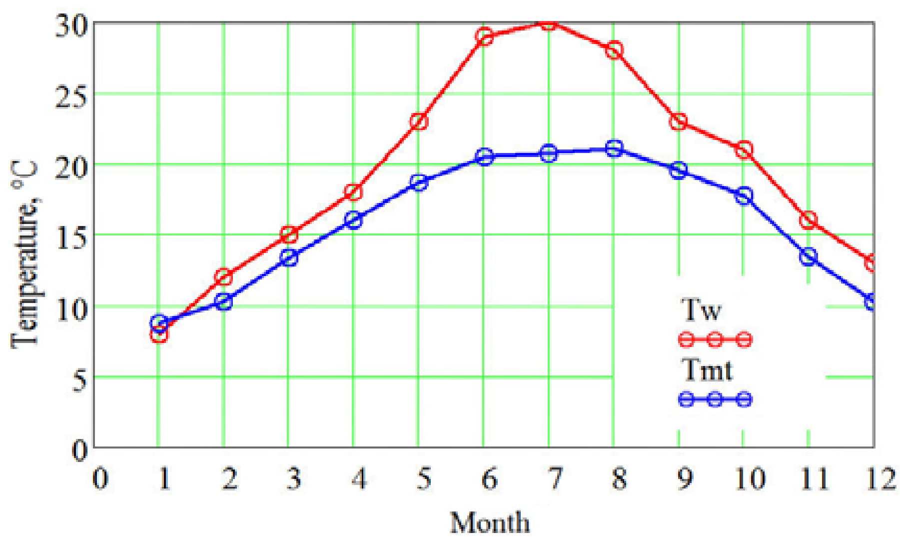


Figure 5. Change in water temperature in reservoirs in the middle part of Iraq (*Tw*) and wet bulb temperature (*Tmt*) during the year

(Ambient temperature: 1–5 °C; 2–15 °C; 3–25 °C; 4–35 °C; 5–45 °C).

In connection with the above, it is necessary to search for technical solutions that could improve the efficiency of the evaporative condenser in the climatic conditions of the central part of Iraq.

The efficiency of the evaporative condenser of combined power plants depends on the average water temperature, atomizing on the heat exchanger surface, comparison of water temperatures in the middle region of Iraq (Tw) and wet-bulb temperature (Tmt) according to [9; 10] is shown in (Fig. 5).

Calculation data show that the temperature of the wet bulb is below the average water temperature in open reservoirs in the central region of Iraq, this is due to the low humidity of the air in the area, the low temperature value of the wet bulb is a important for a significant increase in the efficiency of the condenser, temperature close to (Ttm).

It is possible to achieve an atomization water temperature that is close to the temperature of the "wet" bulb if there is a source of water with low salinity.

Gas turbines generally use excess air values to $\alpha = 6$. But most gas turbines are designed for an excess air ratio of $\alpha = 3$ [11]. Excess air ratio in high power internal combustion engines is in the range of $\alpha = 2.6 \ldots 3$ [12]. For a preliminary estimate, we take the redundancy factor in the main engines of combined-cycle power plants to be $\alpha = 3$.

The hydrogen content in fuels: gaseous – up to 16%, in heavy – up to 11% [13].

According to [14], the amount of water vapor during fuel combustion can be determined in the first approximation using the following equation.

$$V^0_{H_2O} = 0.111H^p + 0.0124W^p + 1.6dV^0_B \rho^0_B$$

Where H^p – hydrogen content in fuel; W^p – water content in the fuel; $1.6dV^0_B \rho^0_B$ – is the water content in the air.

Numerical simulation of the process of condensation of water vapor from the exhaust gases of a combined power plant with an excess air coefficient $\alpha = 3$ shows

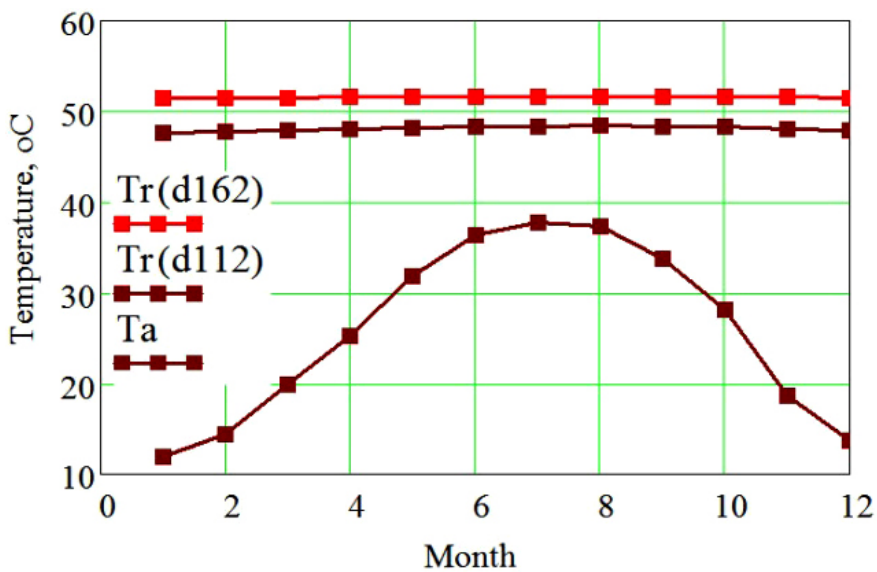


Figure 6.Temperature distribution "dew" of flue gases (exhaust gases) with $\alpha = 3$ by months of the year ($Tr(d162)$ – for gas fuel, $Tr(d112)$ – for heavy fuel, Ta – ambient temperature)

Calculation data show that the achievement of the exhaust gases temperature of combined power plants is 5 °C lower than the "dew" temperature, allows to condense up to 0.02 kg of water from each kg of flue gases. However, the temperature of the condensate will be in the range of 43…46 °C.

Therefore, to use the condensate obtained in the evaporative condenser, it must be cooled. One of the possible technological schemes for cooling condensate obtained from exhaust gases is shown in (fig. 7).

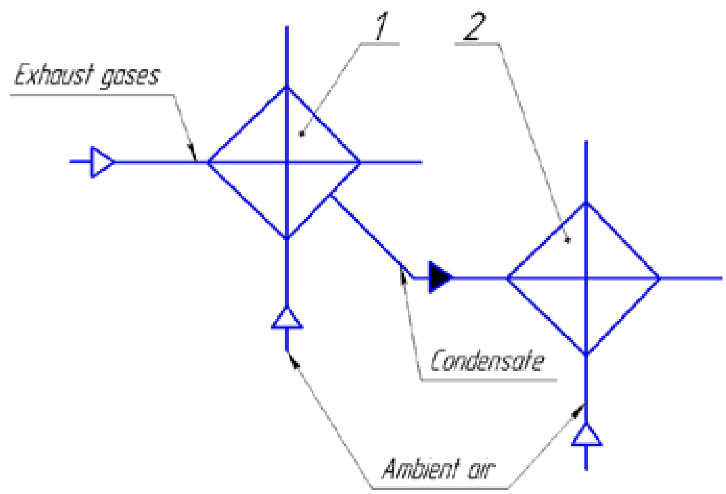


Figure 7. Technological scheme for obtaining and cooling condensate: Surface cooler of flue gases (exhaust gases); Contact condensate cooler

According to the given technological scheme (Fig. 7), the exhaust gases are cooled by ambient air in a surface cooler 1. In this case, up to 0.02 kg of water is condensed out of each kilogram of exhaust gases, the resulting condensate enters the contact cooler 2, where, due to the evaporation of part of the water, the condensate is cooled to the temperature of the "wet" thermoment.

This amount of water can be used as an additional source of water in the evaporative condenser

Conclusion

As a result of mathematical modeling, the possibility of operation of evaporative condensers of combined power plants in the conditions of hot and dry climate of the central part of Iraq is substantiated.

As cooling water in the evaporative condenser, it is advisable to use the condensate of water vapor contained in the exhaust gases of combined power plants.

The temperature of the condensate reaches a sufficiently low temperature of the "wet" thermometer in the contacts of the coolers due to the evaporation of part of the water into the outside air flow with a low moisture content.

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