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COMPARATIVE THE EFFICIENCY ANALYSIS OF DIFFERENT STEAM GENERATORS TYPES FOR A POWER UNIT WITH A VVER-700 REACTOR

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A steam generator (SG) is a heat exchange device that generates non-radioactive steam in the second (third) circuit due to the heat of the coolant. The steam generator is a crucial component of a nuclear power plant because it creates the steam required to power the steam turbines, which in turn power the electric generators, which create the electricity required for different aspects of daily living. In pressurized water reactor (PWR or VVER) nuclear power facilities, there are two different types of SG: horizontal SGs with VVER are used in Russia, and vertical SGs with PWR are used in America.

The vertical SG has a vertical housing, two horizontal tube sheets, and a vertical U-shaped tube. Two-step separation facilities are located on the housing's top. The tube bank's whole height is covered by a shell that organizes the circulation loop (figure 1).

The horizontal SG has a horizontal cylindrical housing and horizontal U-shaped tubes of the heat exchange surface which are installed in two vertical collectors. Gravitational separation is used to dry the steam at the top of the housing (figure 2) [4].

This article briefly discusses the various types of steam generators. The calculated parameters, thermal and hydraulic characteristics are compared and analyzed at different coolant velocities. The calculations were done in the traditional method [1–3].

The main differences between the methods for calculating these steam generators:

- the need to take into account the economizer section in the vertical steam generator;
- various formulas for calculating the heat transfer coefficient when the working fluid boils in a large volume.

Table 1 provides the basic data that was used in the calculations.

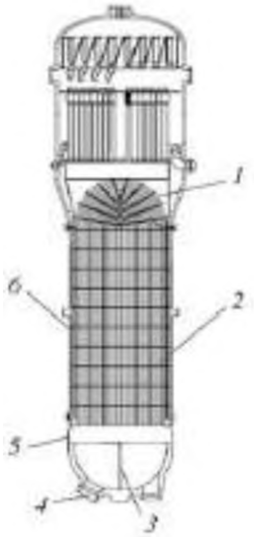

Fig. 1. Vertical SG:
1 – tube bundle; 2 – tube bundle supports;
3 – partition; 4 – coolant inlet and outlet stub pipes;
5 – tube sheet; 6 – house [4]

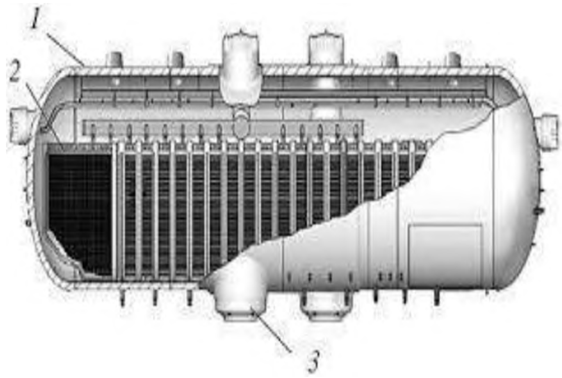

Fig. 2. Horizontal SG:
1 – housing; 2 – tube bank;
3 – coolant inlet and outlet collector [4]

Table 1. Basic data for SG calculations

Parameter	Value	Units	Parameter	Value	Units
Thermal power	2015	*MW*	Coolant inlet temperature	330	°C
Steam pressure	7	*MPa*	Coolant outlet temperature	300	°C
Coolant pressure	16,53	*MPa*	Feedwater temperature	230	°C

1. Thermal Calculation for SG

The purpose of the thermal calculation of the SG is to determine the main dimensions of the SG (heat exchange area, number and average length of pipes). To carry out variant thermal calculations of steam generators, an original program was developed in the Excel working environment. Features of the algorithm of this program are shown below.

1.1.Building a tQ-diagram

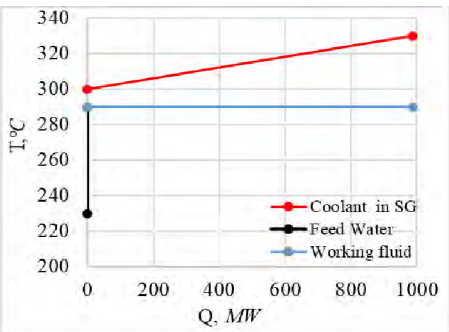

Fig. 1. tQ–diagram for horizontal SG

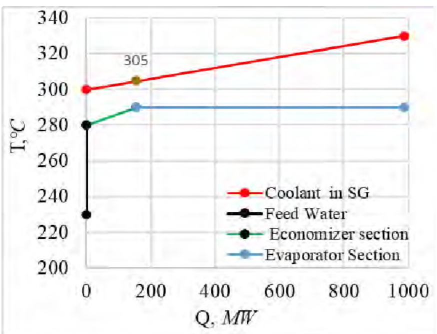

Fig. 2. tQ –diagram for vertical SG

1.2. Calculation of heat transfer inside tubes

In both cases, the known standards equation was applied to determine the amount of heat transfer that would flow from the coolant to the tubes.

$$\alpha_{1avr} = 0{,}021 \cdot \left(\frac{\lambda_{1avr}}{d_{in}}\right) \cdot (Re_{avr})^{0,8} \cdot (Pr_{avr})^{0,43}, \frac{W}{m^2 \cdot {}^\circ C}, \quad (1)$$

where ν_{1avr} – kinematic viscosity of the coolant, m²/s; Pr_{avr} – Prandtl criterion for coolant parameters; λ_{1avr} – thermal conductivity of the coolant, W/(m·°C); Re_{avr} – Reynold's criterion for coolant parameters.

1.3. To calculate the heat transfer from pipes to the working fluid in different steam generators (horizontal/vertical), different equations were used:

➢ For horizontal SG [1],

$$\alpha_2 = \frac{10.45}{3.3-0.0113\cdot(t_s-100)} \cdot q_{in}{}^{0,7}, \frac{W}{m^2\cdot°C}; \quad (2)$$

➢ For vertical SG [5],

$$\alpha_2 = 1.26 \cdot q_{in}{}^{0,75} \cdot e^{\frac{p_2}{6.2}}, \frac{W}{m^2\cdot°C}. \quad (3)$$

Where q_{in}-initial value of the heat flux, W/m²; p_2- pressure of the working fluid, MPa.

2. Thermal calculation results of SGs

The results of thermal-hydraulic calculation of horizontal SG and vertical SG are shown in figure 3–5.

Figure 3 illustrates how the speed of the coolant inside the tubes affects the overall heat transfer coefficient. The graph shows that when the velocity of the coolant velocity increases, it also increases.

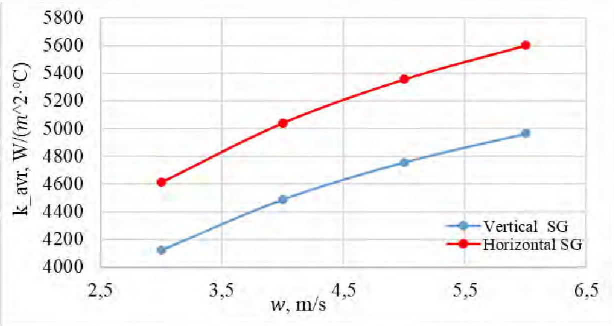

Fig. 3. Dependency of the heat transfer coefficient on the coolant velocity

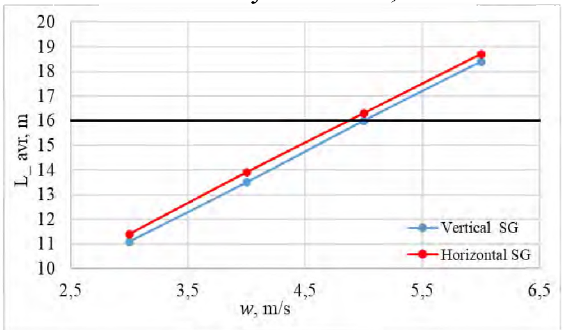

Fig. 4. Dependency of the average length on the coolant velocity

Figure 4 represents the relationship between the average length and the coolant velocity in the tubes. The maximum allowable pipe length for both SGs is 16...17 meters, however, in figure 4 shows that at a speed of 5 m/s, the length of the horizontal SG pipe exceeds 16 meters and is close to 17 meters of the vertical SG. Thus, the coolant velocity of more than 5 m/s is the limit for both steam generators.

Figure 5 depicts how the coolant velocity in the tubes affects the total pressure drops. The graph demonstrates how the total pressure drops rise as coolant velocity rises. In comparison to horizontal SG, vertical SG has greater overall pressure drops.

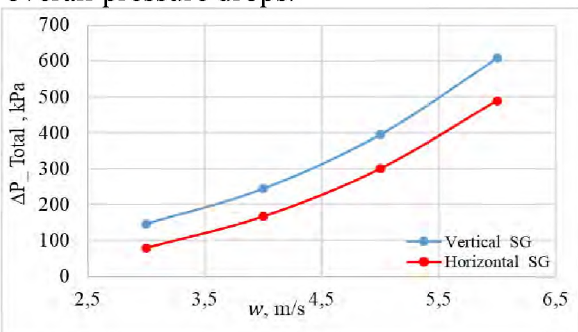

Fig. 5. Distribution of the pressure loss due to change in coolant velocity

Conclusion

A program for thermal calculations of horizontal and vertical SGs of nuclear power plants has been developed. Variant calculations of the main characteristics of these steam generators are performed at different coolant velocities.

According to these calculations, at a heat carrier velocity of more than 5 m/s, the average length of the tubes of both steam generators may exceed the maximum allowable value.

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JUSTIFICATION FOR THE CHOICE OF MATERIAL FOR CONDENSER TUBES FOR STEAM TURBINE PLANTS OF NUCLEAR POWER PLANTS

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Introduction

A condenser is a type of heat exchanger that transfers heat from hot to cold fluid. The condenser condenses or cools the exhaust steam from the last stage of the steam turbine, either directly or indirectly with cooling water via a heat transfer medium.

Each low-pressure turbine typically has one condenser. The condenser is characterized by a large number of small tubes made of admiralty metal, copper, stainless steel, or titanium.

The condenser is essentially a large heat exchanger with horizontally mounted tubes. The tubes can be held up (or staked). In a water box, water from the circulating water system enters the condenser. The water level in the water box must be kept above the uppermost tubes or the condenser will not work properly. In general, the plant is more efficient when the circulating water is cold. When the condenser tubes become fouled, for example, by mud, plugging, or the accumulation of other materials that reduce the ability of the condenser tubes to transfer heat from the steam to the water, power plants become less efficient.

The water boxes are kept full by using an air ejector or other system that keeps the water level in the column above the tubes. Water collects at the bottom of the condenser's steam side in a hot well, which serves as the water source for the condensate pumps' suction.

The pressure within a steam condenser is kept below atmospheric pressure to improve efficiency. It is commonly used to reduce the backpressure of turbine exhaust.

1. Description of the condenser

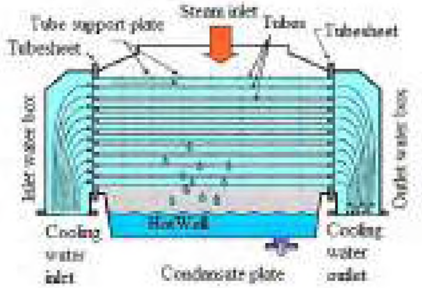

Fig. 1. Condensing unit schematic diagram