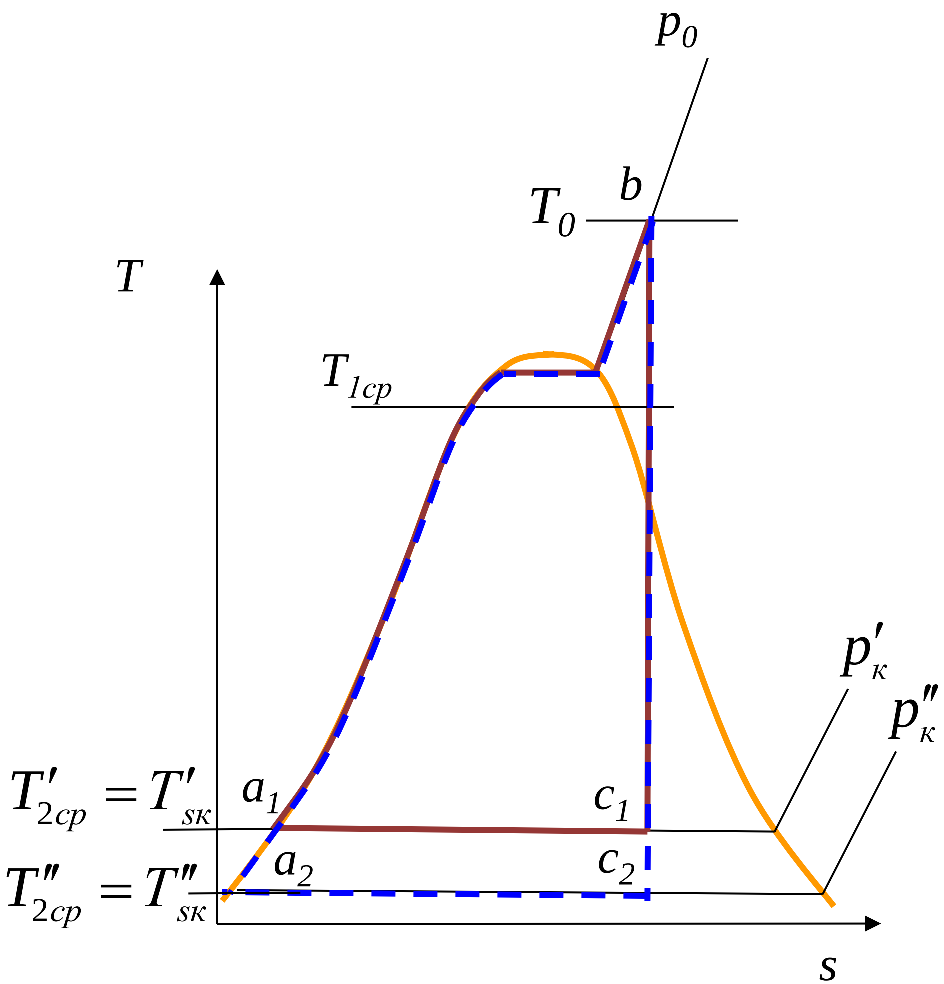
2.4. Impact of final pressure on EF of ST

2.4.1. Impact of final pressure on thermal EF of ST



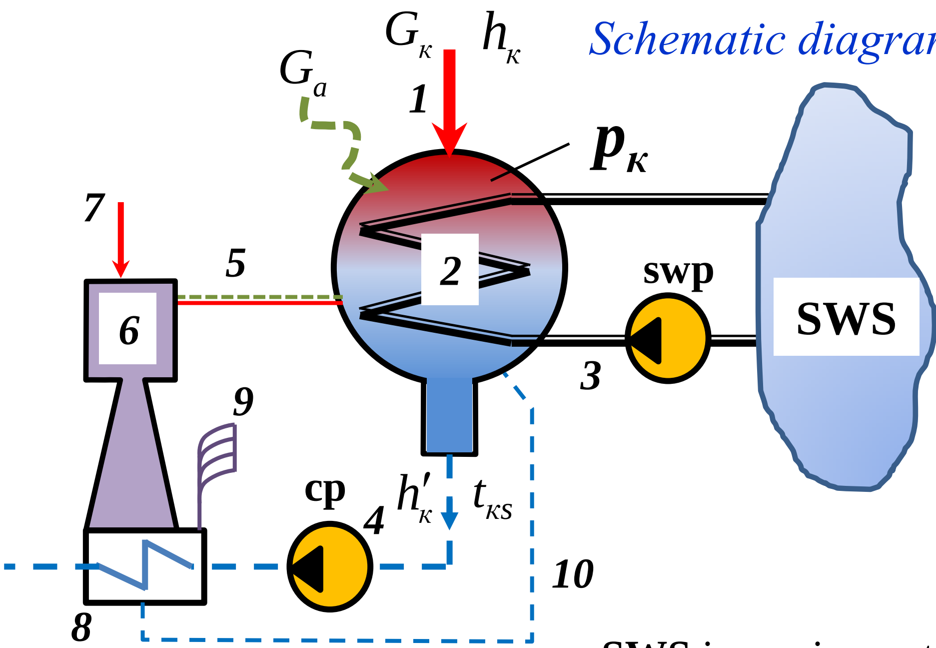
$$\eta = 1 - \frac{q_К}{q_{ТУ}} = 1 - \frac{T_{2cp}}{T_{1cp}}.$$

$$\eta'' > \eta', \quad \text{т.к.} \; T''_{2cp} < T'_{2cp}.$$

2.4.2. Factors which affect the final pressure

The final pressure built by the **condensing unit.**

Schematic diagram of the condensing unit:



1 – steam from the turbine;
2 – condenser;
3 – cooling water supply;
4 – condenser pump;
5 – extraction of gas-vapor mixture from the condenser;
6 – steam jet ejectors;
7 – motive-steam supply to the ejector;
8 – aftercondensertor;
9 – non-condensable gas extraction;
10 – aftercondenser condensate.

SWS is service water system

The mission of the condensing unit

1. Thermodynamic mission: Heat extraction in the cold source.

2. Thermodynamic mission: Building low pressure (vacuum) – increase η_t
3. Possibility to use the operating substance in a closed cycle.

Vacuum in the condenser is created due to sharply reduced volume during steam condensation (by 25 – 30 thousand times).

Heat is extracted from steam through circulating cooling water, its temperature being close to the ambient temperature, inside the capacitor piping.

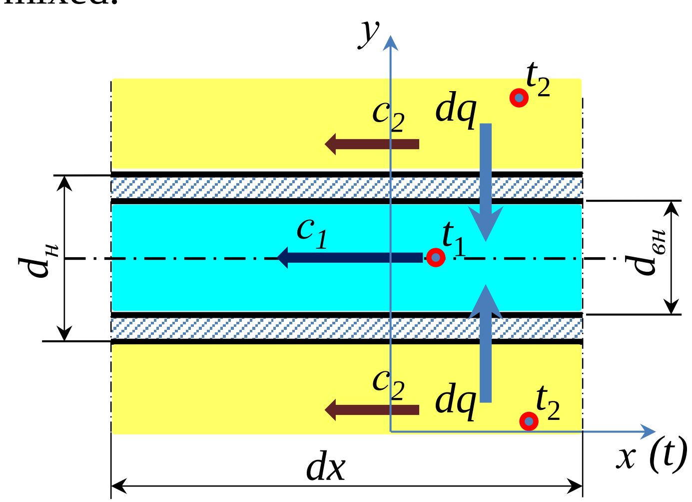
<u>Excursus</u> Consider heat transfer

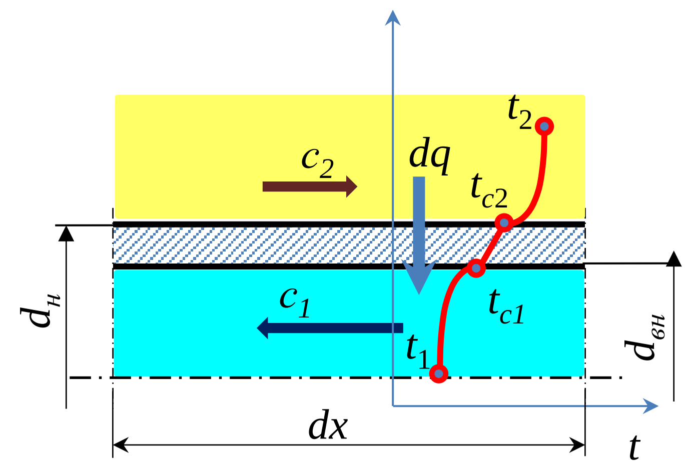
<u>Heat exchangers</u> are devices used to transfer heat from one heat-conducting medium to another one.

<u>Shell-and-tube heat exchangers</u> – heat is transferred through the separating surface (tube), i.e. heat-conducting media are not mixed.

Alternative

Heat transfer via mixed heat-conducting media.





dq – heat flow through an elementary surface *dF*:

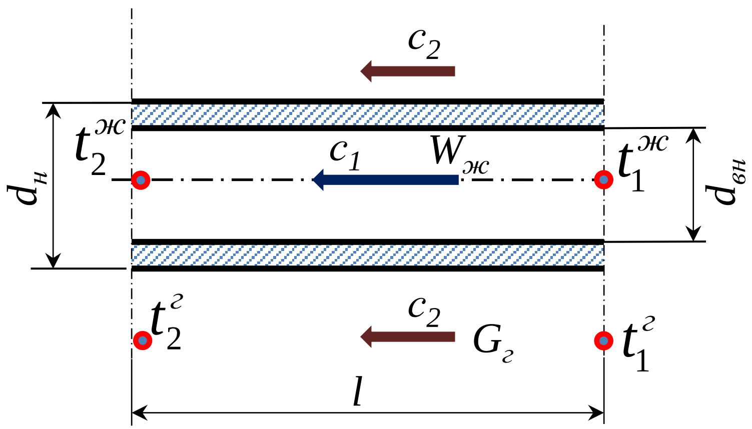
$$\begin{cases} dq = \alpha_1 \cdot (t_1 - t_{c1})\, dF, \\ dq = \dfrac{\lambda}{\delta} \cdot (t_{c1} - t_{c2})\, dF, \\ dq = \alpha_2 \cdot (t_{c2} - t_2)\, dF. \end{cases}$$

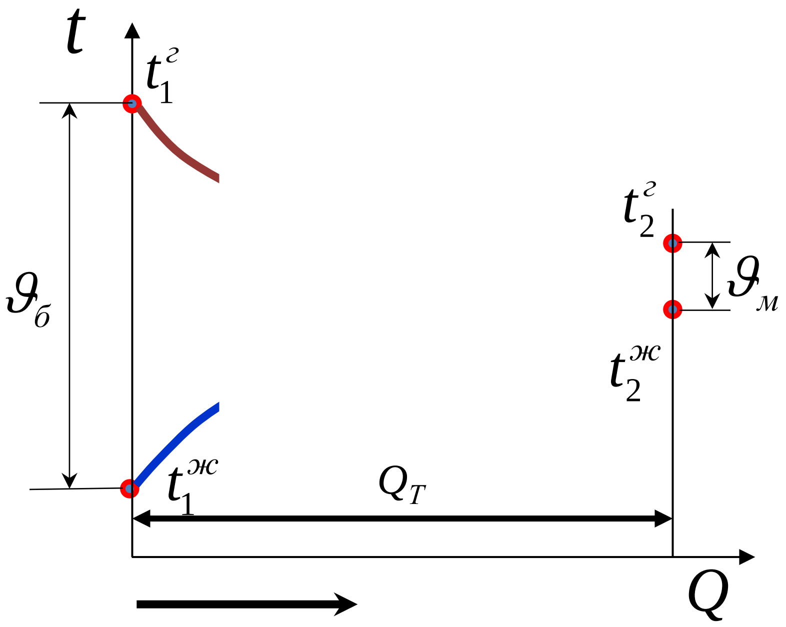
$$dq = k_м \cdot (t_2 - t_1)\, dF,$$

$k_м$ - heat transfer coefficient (local), *[W/m²K]*.

$$k_м = \frac{1}{\dfrac{1}{\alpha_1} + \dfrac{\lambda}{\delta} + \dfrac{1}{\alpha_2}}$$

The tube of finite length



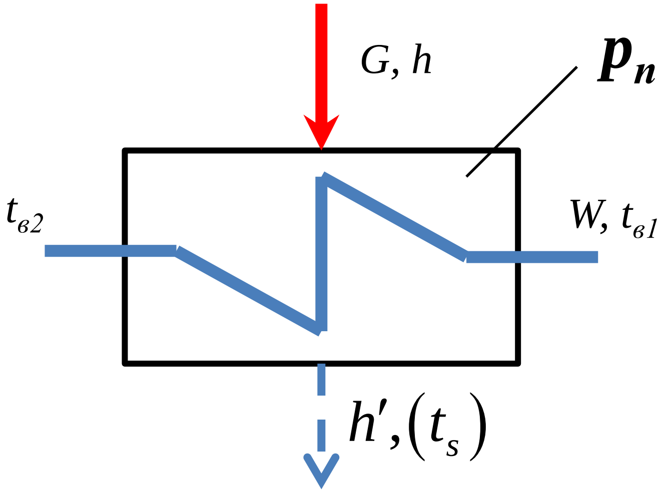


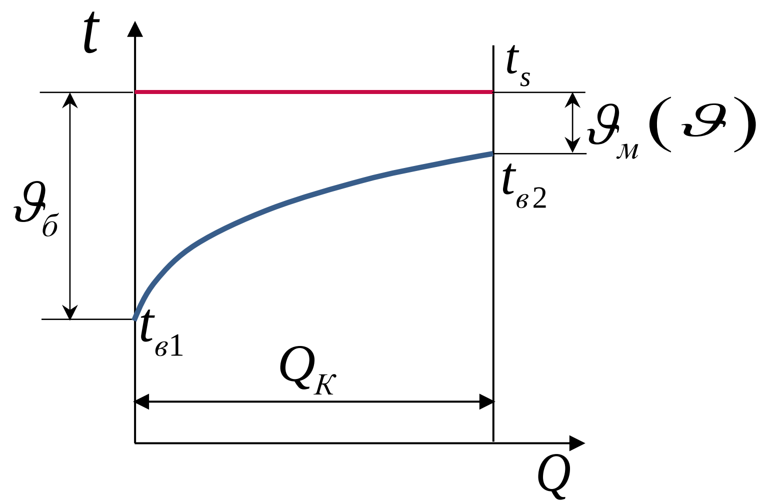
$$Q_T = W_{жс} c_p^{жс} \left(t_2^{жс} - t_1^{жс} \right) = G_г c_p^{г} \left(t_1^{г} - t_2^{г} \right)$$

$$Q_T = k \cdot \Delta t_{сл} \cdot F$$

$$\Delta t_{сл} = \frac{\vartheta_б - \vartheta_м}{\ln \dfrac{\vartheta_б}{\vartheta_м}}$$

Steam-water heat exchanger





$$Q = G\,(h - h') = W\,c_p\,(t_{в2} - t_{в1})$$

$$Q = k \cdot \Delta t_{сл} \cdot F$$

$$\Delta t_{сл} = \frac{\vartheta_б - \vartheta_м}{\ln \frac{\vartheta_б}{\vartheta_м}} = \frac{t_{в2} - t_{в1}}{\ln\left(\frac{\vartheta_б}{\vartheta_м}\right)}$$

$$\vartheta_б = t_s - t_{в1}$$

$$\vartheta_м = t_s - t_{в2}$$

$$p_n = f(t_s)$$

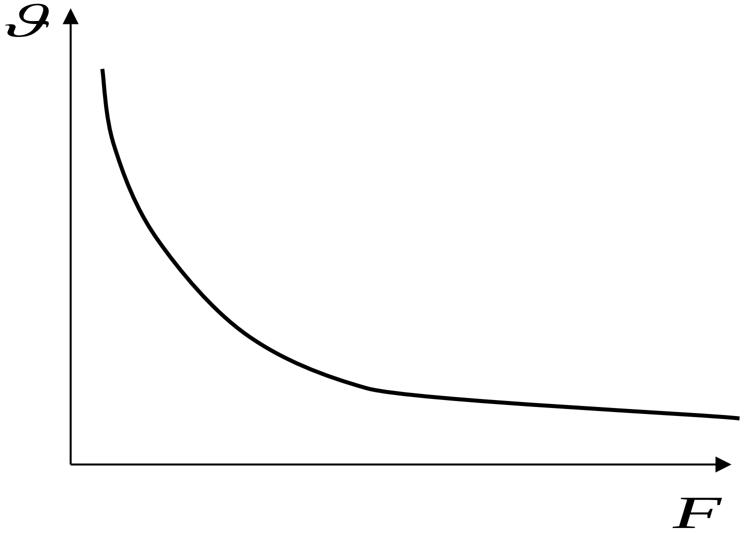
$$W c_p\,\cancel{(t_{в2} - t_{в1})} = k \cdot \frac{\cancel{t_{в2} - t_{в1}}}{\ln\left(\frac{\vartheta_б}{\vartheta_м}\right)} \cdot F$$

$$\ln\left(\frac{\vartheta_б}{\vartheta_м}\right) = \frac{k\,F}{W\,c_p}$$

$$\frac{\vartheta_б}{\vartheta_м} = e^{\frac{k\,F}{W\,c_p}} \qquad \vartheta_м = \vartheta_б\, e^{-\frac{kF}{Wc_p}}$$

ϑ – subcooling in the preheater.

$$\vartheta_{м} = \vartheta_{б} e^{-\frac{kF}{Wc_p}}$$



If $F \to \infty,$ hence $\vartheta \to 0.$

1. The greater the *F* value, the higher the cost of the heater.

The lower the ϑ value, the higher the EF of the equipment and the smaller the heat input to generate the desired amount of electric energy. **(?)**

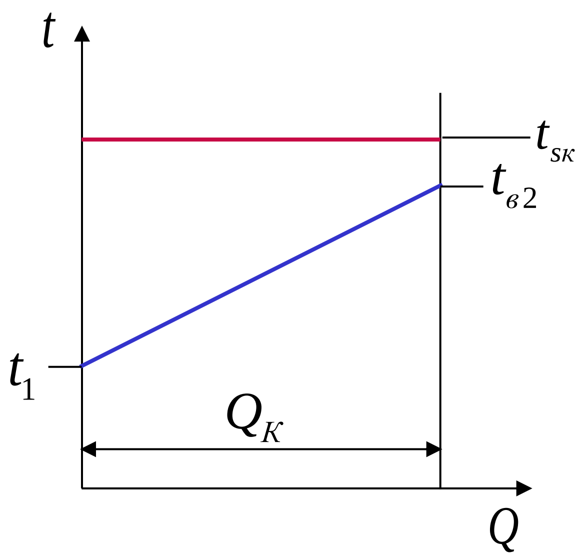
Note 1. If flows of heat-conducting media are mixed correctly in mixing preheaters, $\vartheta \approx 0$.

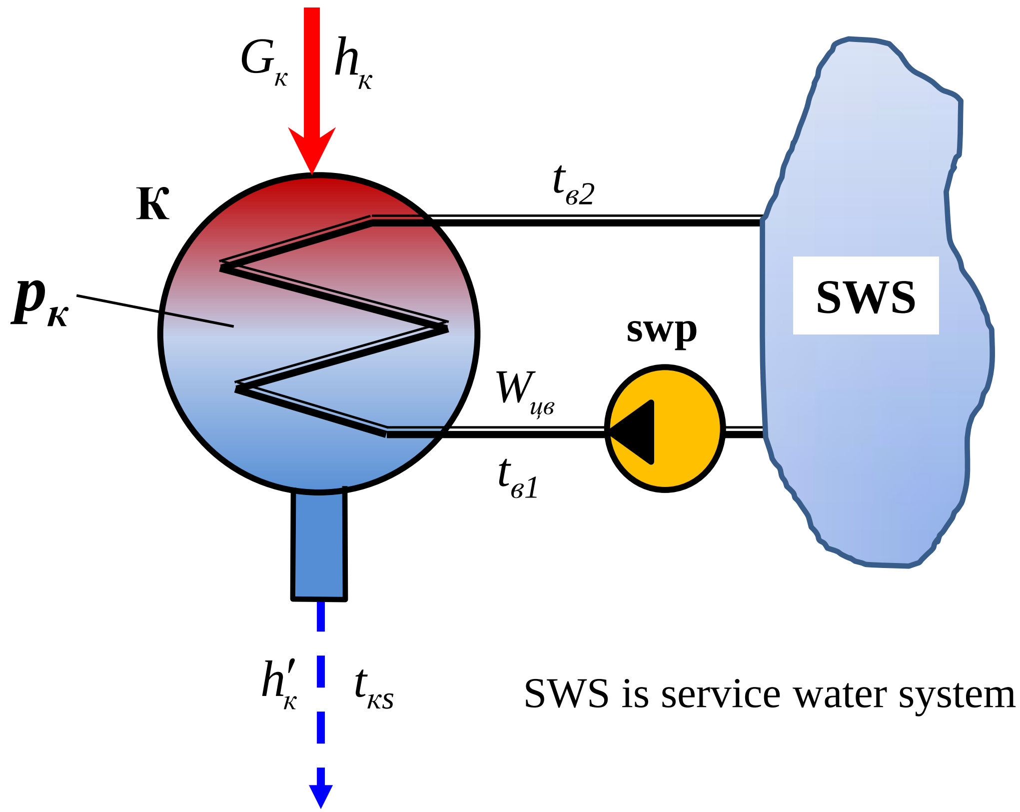
Note 2: in steam-water heaters with steam condensation, pressure in the preheater and water temperature are strongly interrelated:

$$t_{в2} = t_{sn}\left(p_n\right) - \vartheta_n.$$

In currently used closed heaters: $\vartheta_n = \left(2 \div 7\right)^o C.$

ST condensing unit





SWS is service water system

Factors affecting pressure in the condenser

$$t_{s\text{к}} = t_{\text{в}2} + \vartheta_\text{к} = t_{\text{в}1} + \Delta t_\text{в} + \vartheta_\text{к}$$

$\Delta t_\text{в} = t_{\text{в}2} - t_{\text{в}1}$ is water heating in the condenser

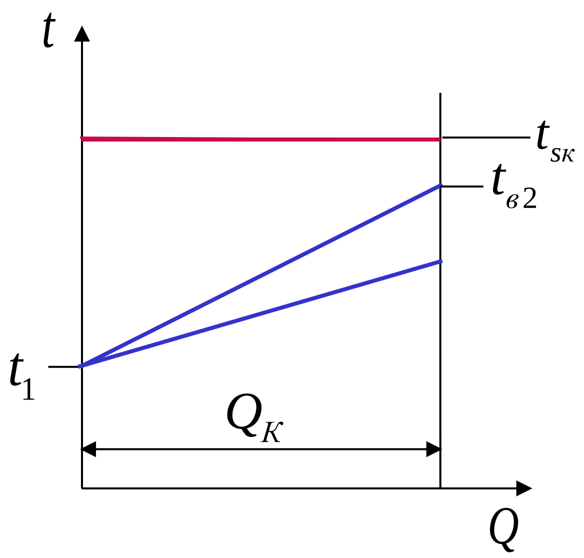
I $t_{\text{в}1}$ depends on the environmental conditions and SWS.

II Water heating in the condenser

$$Q_K = G_K \left(h_\text{к} - h'_\text{к}\right) = W_{\text{цв}} c_p \left(t_2 - t_1\right).$$

$$\Delta t_\text{в} = \frac{G_K \left(h_\text{к} - h'_\text{к}\right)}{W_{\text{цв}} c_p} = \frac{\left(h_\text{к} - h'_\text{к}\right)}{m c_p}$$

$$m = \frac{W_{\text{цв}}}{G_\text{к}}$$ is multiplicity of cooling



$$\Delta t_в = \frac{(h_к - h'_к)}{mc_p}; \qquad m = \frac{W_{цв}}{G_к}$$

Other factors being equal, $G_к$ depends weakly on $p_к$ (in the considered range of $p_к$ variation).

$$W_{цв} \uparrow \Rightarrow (t_2 - t_1) \downarrow_{т.к. Q_K \approx const} \Rightarrow t_2 \downarrow$$

However:

$$dl_{тех} = \upsilon \cdot dp; \qquad l_{тех} = \int_a^b \upsilon \cdot dp = \upsilon_{ср} \cdot (p_b - p_a) = \upsilon_{ср} \cdot \Delta p;$$

$$L_{тех} = N = W \cdot \upsilon_{ср} \cdot \Delta p;$$

Δp – повышение давления в насосе (напор, создаваемый насосом).

For **circulating** pumps: $\Delta p = \Delta p_{гс};$

$\Delta p_{гс}$ – гидравлическое сопротивление тракта, через который насос прокачивает жидкость.

$$\Delta p_{гс} = f(W^2);$$

$$N_{цн} = f(W^3_{цв}).$$

Thus, with regard to the number of water passes in the condenser, ***m*** is within the limit 40÷80.

III $Q_K = k_\kappa F_K \Delta t_{сл}$ $\Longrightarrow$ **....** $\Longrightarrow$ **.... etc.**

In currently used ST condensers: $\vartheta_\kappa = \left(2 \div 5\right)^o C.$

IV Effect of the structure of the outlet section of the turbine.