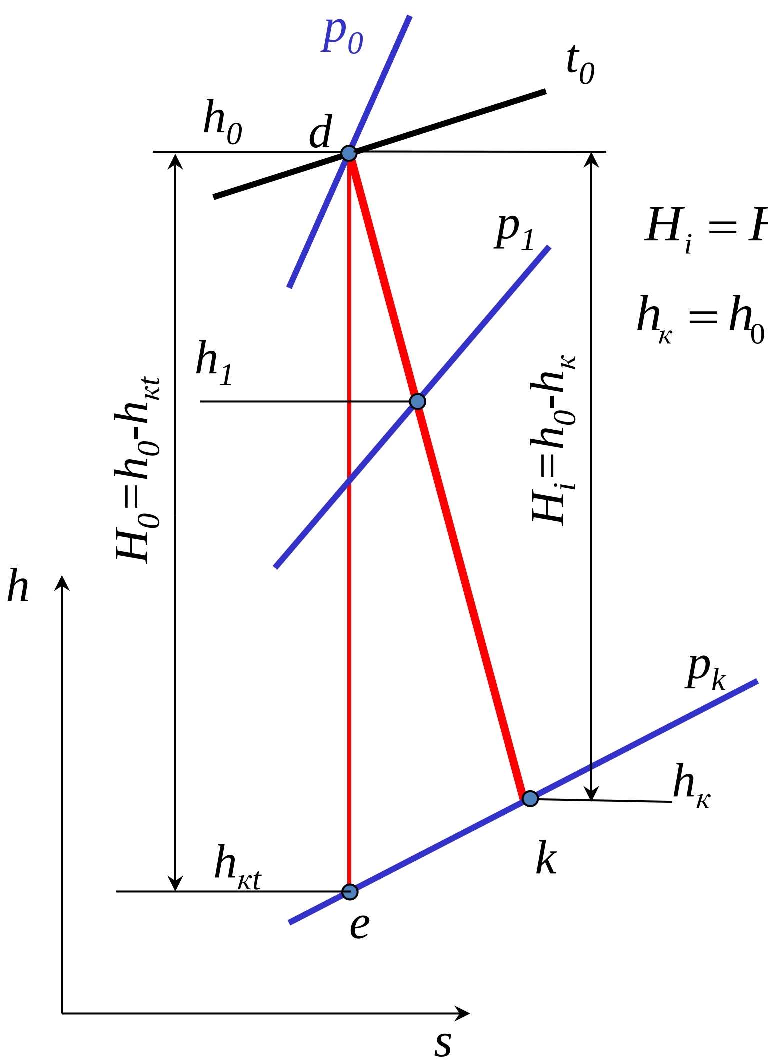
2.5. Regenerative feedwater heating (RFWH)

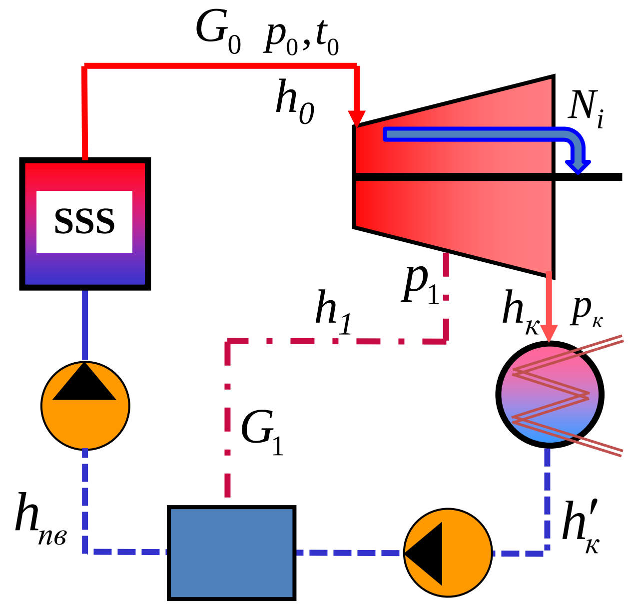
2.5.1. Impact of RFWH on the efficiency of ST

A. Regenerative heating



$$H_i = H_0 \eta_{oi};$$

$$h_\kappa = h_0 - H_i.$$



Internal turbine power without RFWH:

$$N_i = G_0 H_i = G_0 \left(h_0 - h_\kappa \right),$$

Heat supplied to the turbine without RFWH :

$$q_{TE} = h_0 - h'_\kappa$$

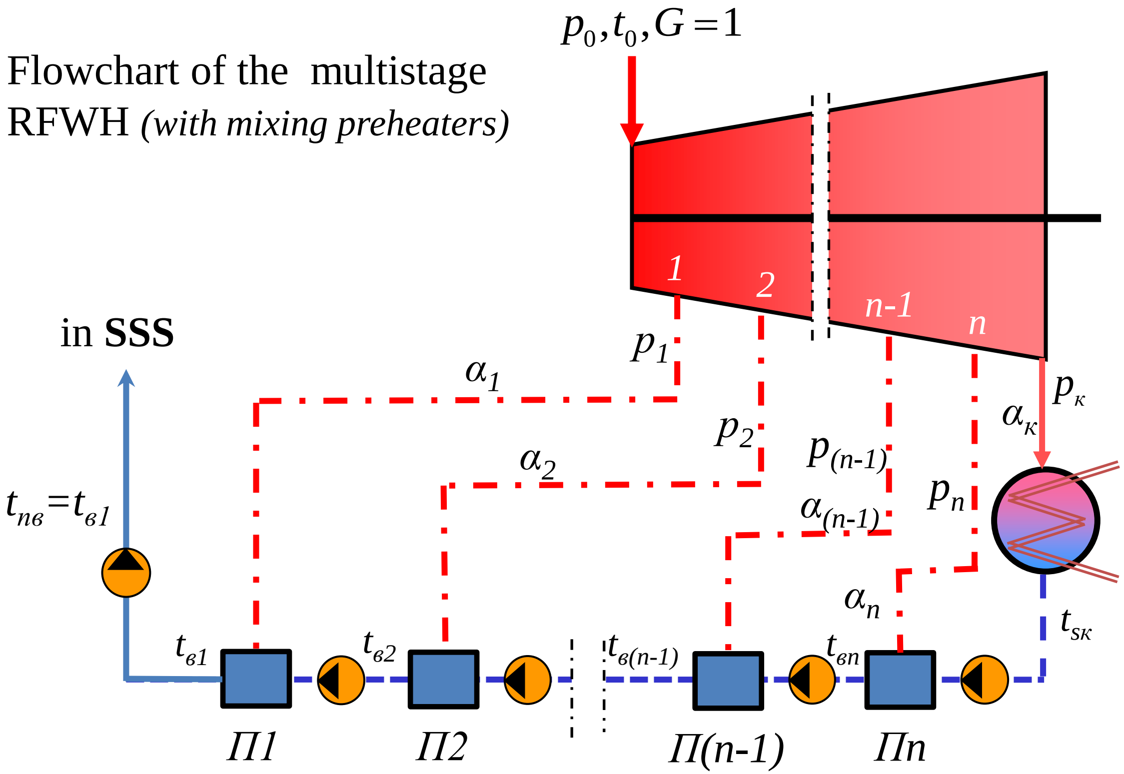
Internal turbine power with RFWH:

$$N_i^R = G_0 \left(h_0 - h_1 \right) + \left(G_0 - G_1 \right)\left(h_1 - h_\kappa \right) =$$
$$= G_0 \left(h_0 - h_\kappa \right) - G_1 \left(h_1 - h_\kappa \right).$$

Heat supplied to the turbine with RFWH:

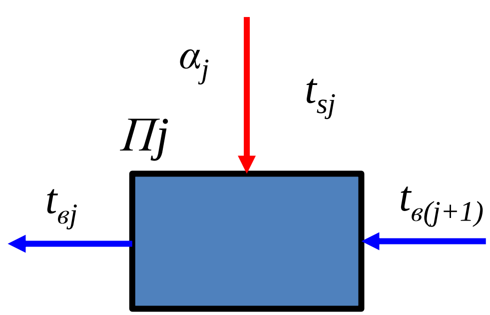
$$q_{TE}^R = h_0 - h_{пв}$$

Flowchart of the multistage RFWH *(with mixing preheaters)*



Why does steam flow into the preheater?

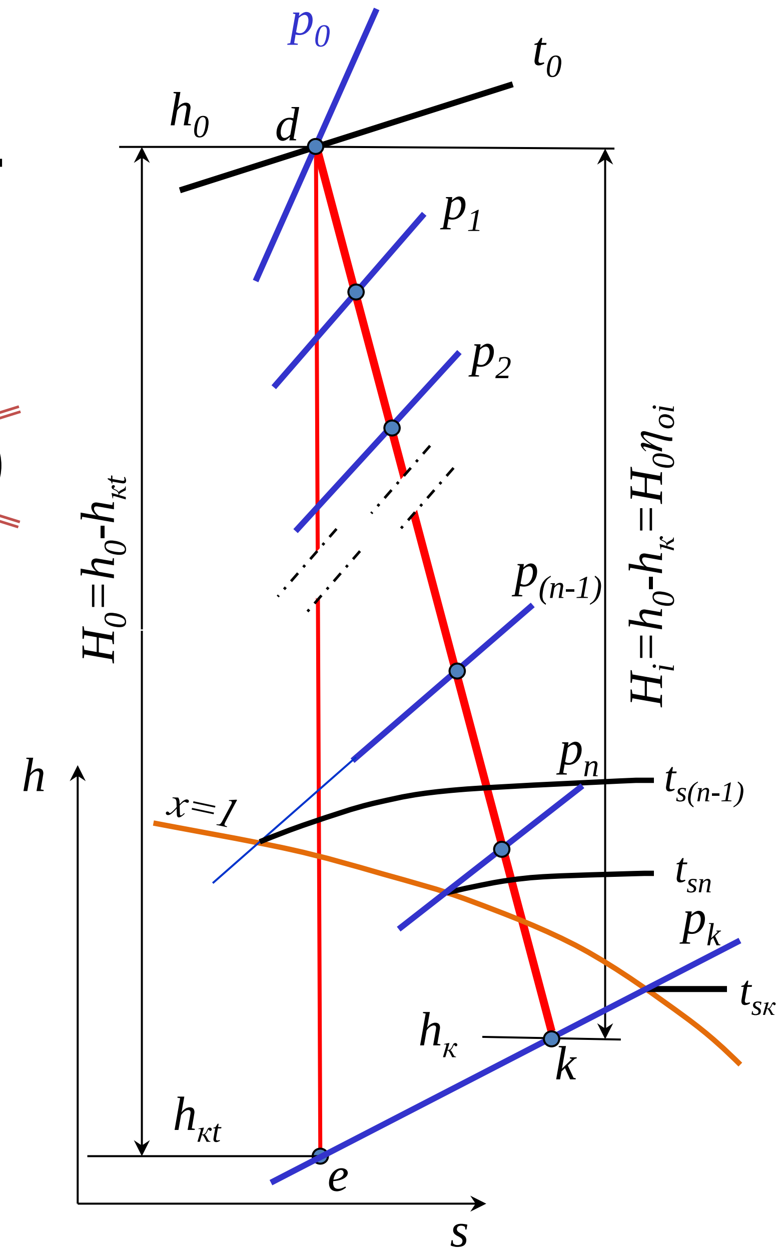
Пn: $t_{sn}>t_{sк}$ → Due to heat transfer steam is condensed to allow space for steam from the turbine → α_n



$t_{sj}>t_{в(j+1)}$

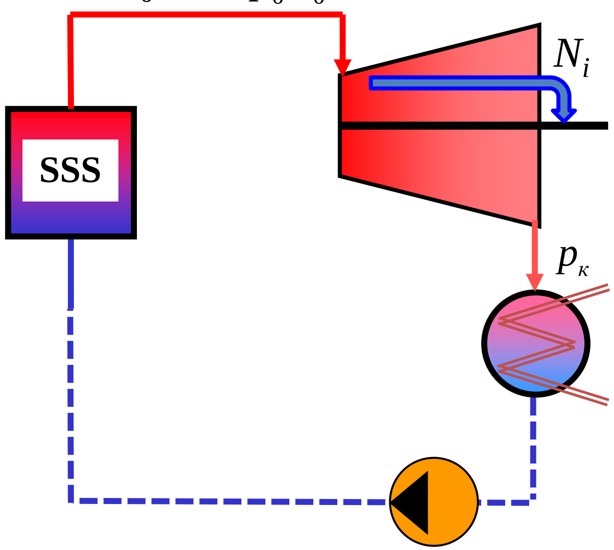
$t_{вj}=t_{sj}-\vartheta_n$

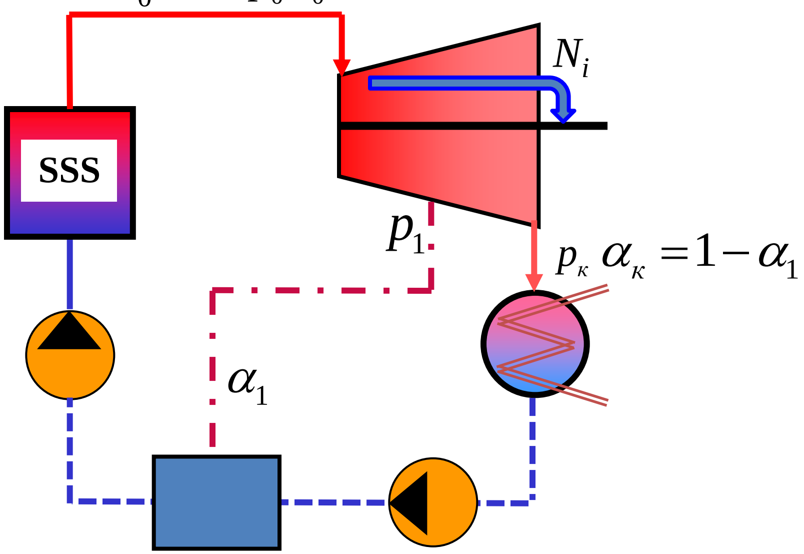
$$\alpha_к = 1 - \sum \alpha_j$$



B. Impact of RFWH on the efficiency of ST

Absolute internal EF is considered to be an indicator of efficiency





$$\eta_i = 1 - \frac{q_K}{q_{TE}} \qquad *$$

$$q_{TE} = h_0 - h'_к$$

$$q_K = h_{кt} - h'_к$$

$$\eta_i^R = 1 - \frac{\alpha_к q_K}{q_{TE}^R} \qquad **$$

$$q_{TE}^R = h_0 - h_{пв}$$

$$q_K = h_{кt} - h'_к$$

The comparison of formulas * and ** does not allow us to determine unambiguously the effect of RHWH on the ST efficiency (*as both the numerator and denominator in formula* ** *are smaller than those in formula* *).

But *if RFWH increases the ST efficiency*, **this is due to the reduced heat loss in the condenser caused by the reduced steam flow to the condenser.**

By definition, an absolute internal EF:

$$\eta_i = \frac{l_i}{q_{TE}}$$

l_i – internal work

For the turbine equipment **with RFWH**:

<u>EF:</u>

$$\eta_i^R = \frac{l_i^R}{q_{TE}^R}$$

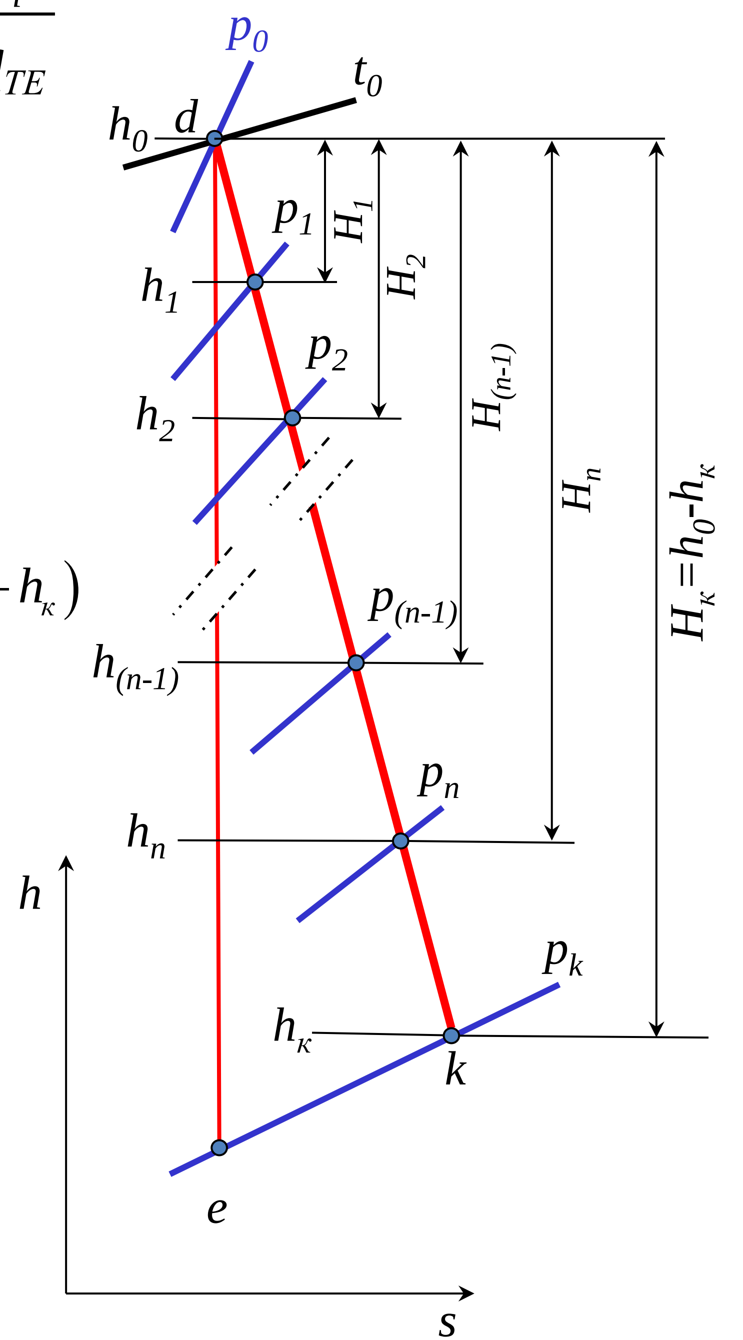
<u>Internal work:</u>

$$l_i^R = \alpha_1(h_0 - h_1) + \alpha_2(h_0 - h_2) + ... + \alpha_n(h_0 - h_n) + \alpha_\kappa(h_0 - h_\kappa)$$

$(h_0 - h_j) = H_j$ - heat drop of the steam of the *j-th* extraction

$(h_0 - h_\kappa) = H_\kappa$ - heat drop of the steam flowing to the condenser

$$l_i^R = \alpha_\kappa H_\kappa + \sum_{j=1}^{n} \alpha_j H_j$$

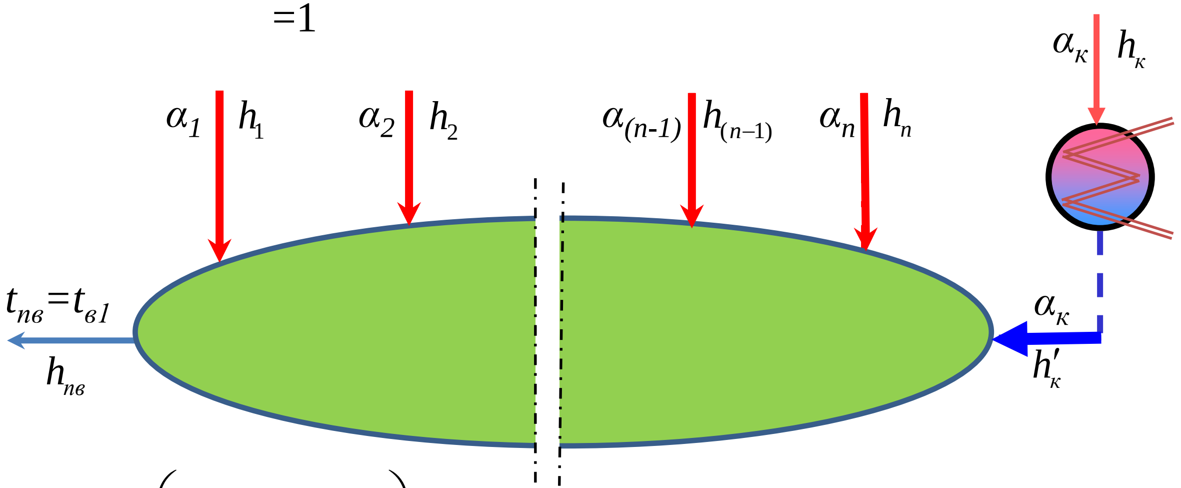


Supplied heat:

$$q_{TE}^{R} = h_0 - h_{пв}$$

$$h_0 = 1 \cdot h_0 \qquad\qquad h_{пв} =$$

$=1$



$$q_{TE}^{R} = \left(\alpha_к + \sum_{j+1}^{n} \alpha_j\right) h_0 - \alpha_к h'_к - \sum_{j+1}^{n} \alpha_j h_j$$

$$\boxed{q_{TE}^{R} = \alpha_к q_{TE} + \sum_{j+1}^{n} \alpha_j H_j}$$

EF:

$$\eta^{R} = \frac{l^{R}}{q_{TУ}^{R}} = \frac{\alpha_к H_к + \sum \alpha_j H_j}{\alpha_к q_{TУ} + \sum \alpha_j H_j} = \frac{\alpha_к H_к}{\alpha_к q_{TУ}} \frac{1 + \dfrac{\sum \alpha_j H_j}{\alpha_к H_к}}{1 + \dfrac{\sum \alpha_j H_j}{\alpha_к q_{TУ}}}$$

$$\eta^R = \frac{\alpha_\kappa H_\kappa}{\alpha_\kappa q_{TY}} \cdot \frac{1+\dfrac{\sum \alpha_j H_j}{\alpha_\kappa H_\kappa}}{1+\dfrac{\sum \alpha_j H_j}{\alpha_\kappa q_{TY}}} = \eta \frac{1+A_{\text{Э}R}}{1+\eta \cdot A_{\text{Э}R}}.$$

$$= \eta; \qquad = A_{\text{Э}R}; \qquad \frac{\alpha_\kappa H_\kappa}{\alpha_\kappa H_\kappa} = \frac{\alpha_\kappa H_\kappa}{\alpha_\kappa q_{TY}} \frac{\sum \alpha_j H_j}{\alpha_\kappa H_\kappa} = \eta \cdot A_{\text{Э}R};$$

$$\eta^R = \eta \frac{1+A_{\text{Э}R}}{1+\eta \cdot A_{\text{Э}R}}.$$

The numerator is greater than the denominator as $\eta<1$.
hence, the fraction is >1.

In this case $\eta^R > \eta$, if $A_{\text{Э}R} > 0$.

Relative change in EF:

$$\delta\eta^R = \frac{\eta^R - \eta}{\eta}$$

$$\delta\eta^R = \frac{1-\eta}{\dfrac{1}{A_{\text{Э}R}} + \eta}$$

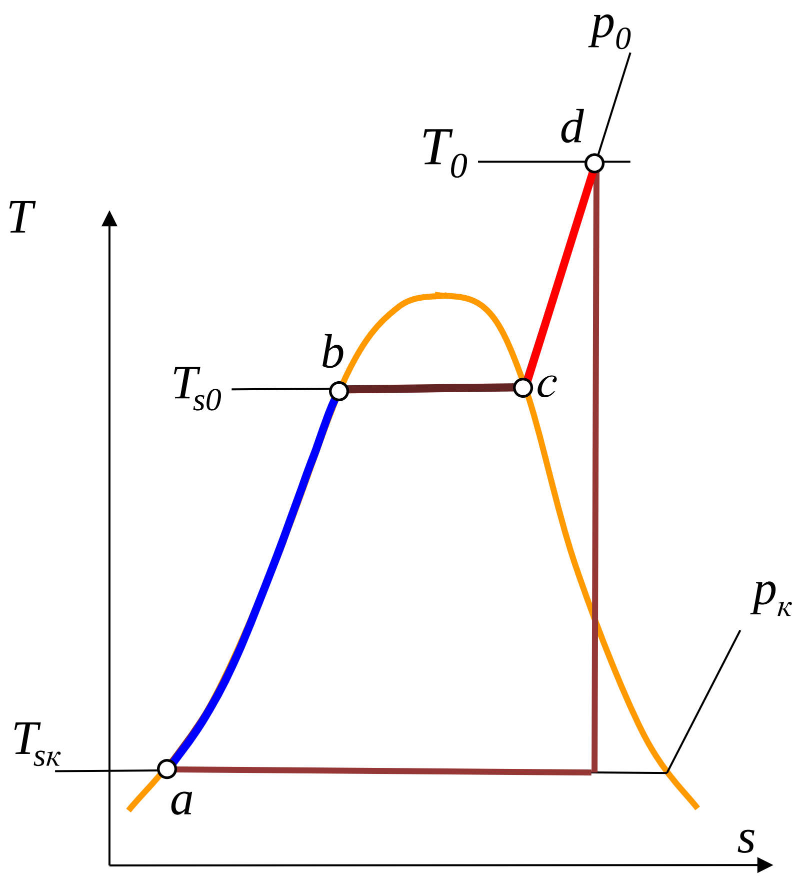
$\delta\eta^R > 0$, as $\eta<1$, if $A_{\text{Э}R} > 0$.

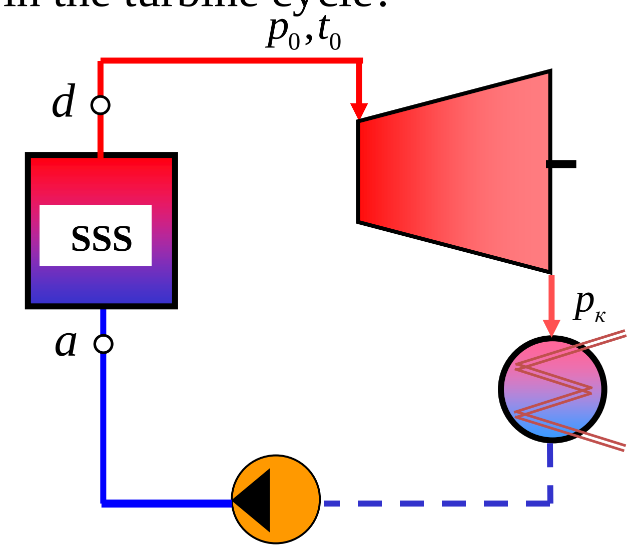
If not (if $A_{\text{Э}R} = 0$) $\delta\eta^R = 0$.

2.5.2. Effect of the feed water temperature and the number of stages on the RFWH effectiveness

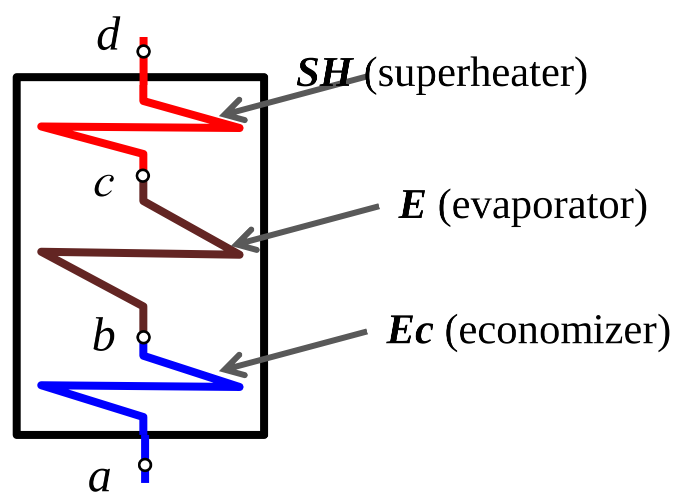
Excursus:

What is the range of temperature variation of **water** in the turbine cycle?





Steam supply system (SSS)



Water temperature in the turbine cycle changes within the range **from** the saturation temperature at the condenser outlet $t_{sк}=f(p_к)$ **to** the saturation temperature at the outlet of the economiser $t_{s0}=f(p_0)$.