Impact of initial parameters on EF of the steam turbine equipment
(CONCLUSIONS)

A. Increased initial temperature:

- causes increase in η_t
- effects η_{oi}

(as: - - the final degree of moisture decreases, hence, moisture-related losses in the last stages of the turbine are reduced)

+

However: There is a limit on the initial temperature in terms of mechano-caloric properties of advanced materials and their cost.

B. Increased initial pressure:

- has maximum value η_t
- has a negative effect on η_{oi}

(as: - - the final degree of moisture grows, hence, moisture-related losses in the last stages of the turbine increase)

+?

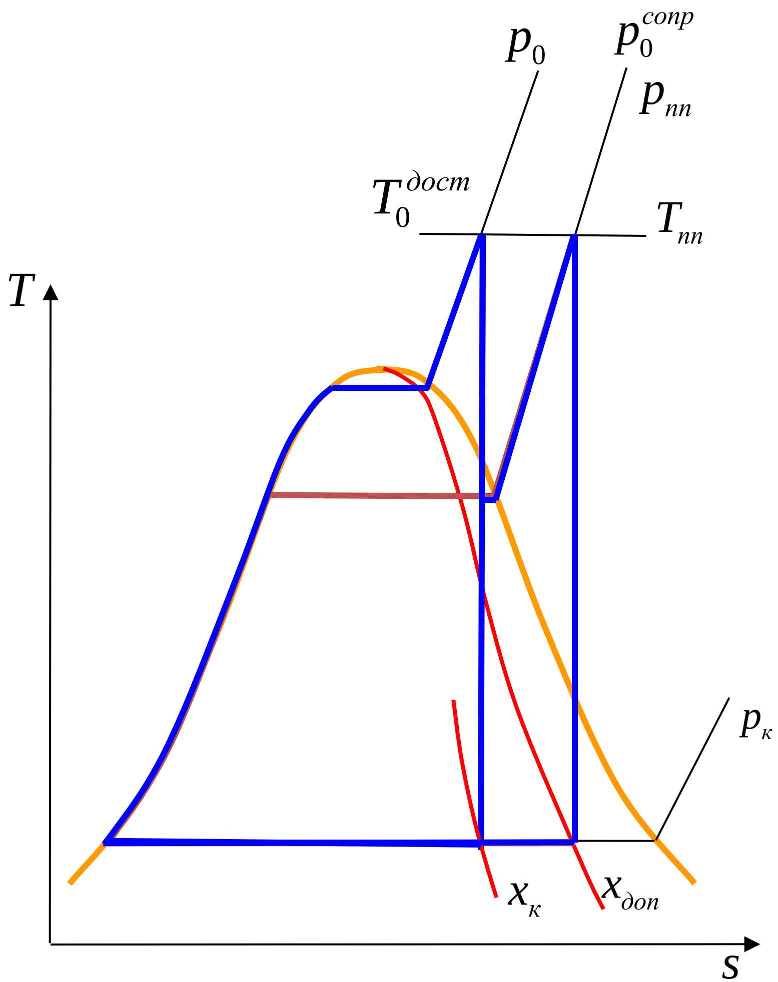
Considering the current state and techniques to compensate for the negative impact:

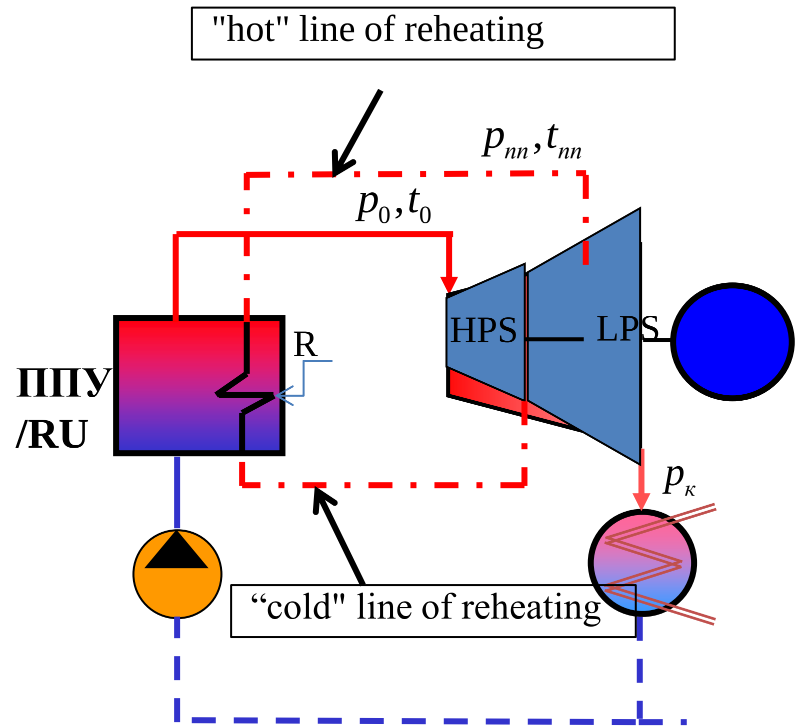
- at available initial temperatures, modern energy cannot provide the initial pressure to ensure maximum η_t
- negative effect caused by increase in the final moisture can be eliminated through **reheating stage**

Impact of steam reheating on EF of the steam turbine

Steam reheating in the steam turbine was originally used as a technique to control the exceeding level of final humidity.

1. Schematic diagram and cycle of the turbine with the reheating stage





R – reheater

HPS – high-pressure section

LPS – low-pressure section

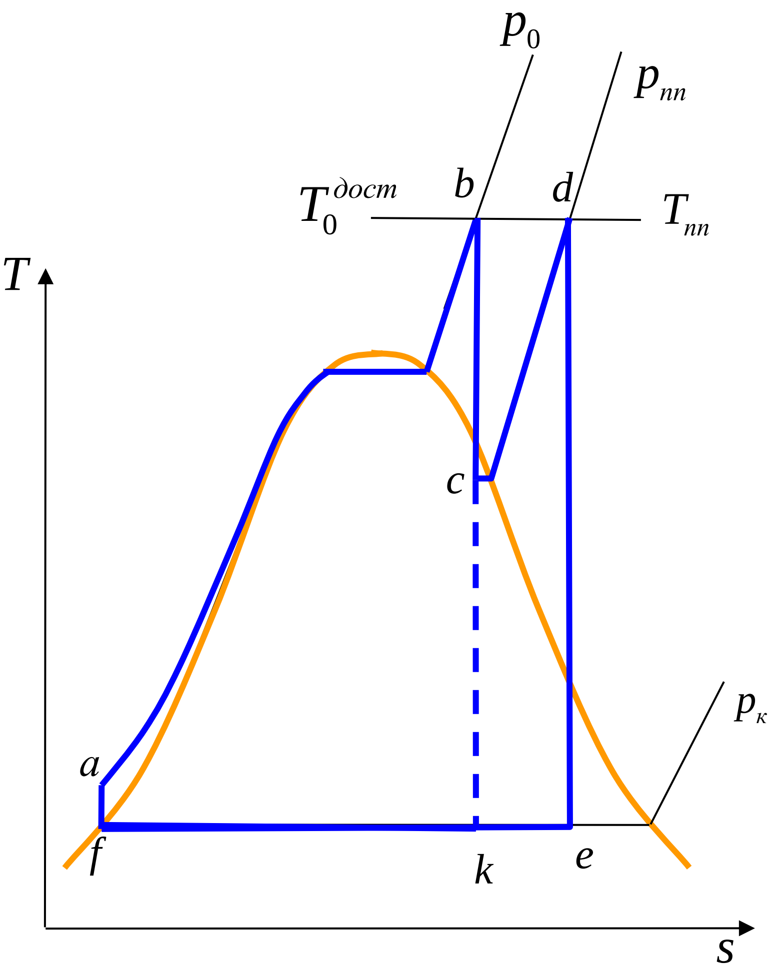
$$t_{пп}^{opt} \approx t_0$$

$$p_{пп}^{opt} = \left(0{,}15 \div 0{,}25\right) p_0$$

$$\delta\eta_t = \frac{\eta_t^{сПП} - \eta_t^{безПП}}{\eta_t^{безПП}} = 0{,}04 \div 0{,}06$$

The schematic diagram shows the so-called **fired** steam reheating

2. Impact of reheating on the cycle economy



Turbine cycle with reheating stage – *abcdefa*.

Divide this cycle into two parts:

- basic cycle *abkfa* – o
- additional cycle *cdekc* – Δ

The EF of the cycle with the reheating stage is:

$$\eta_t^{cПП} = \frac{l_ц}{q_{ТУ}}$$

$$l_ц = l_o + l_\Delta \qquad q_{ТУ} = q_o + q_\Delta$$

$l_ц$ – process *bc+de-af* q_{TE} – process *ab+cd*

l_o – process *bk-af* q_o – process *ab*

l_Δ – process *de-ck* q_Δ – process *cd*

$$\eta_t^{cПП} = \frac{l_o + l_\Delta}{q_o + q_\Delta} = \frac{l_o}{q_o}\frac{1+\dfrac{l_\Delta}{l_o}}{1+\dfrac{q_\Delta}{q_o}}$$

$$\frac{l_o}{q_o} = \eta_o$$ – EF of the basic cycle

$$\frac{l_\Delta}{l_o} = A_Э$$ – energy efficiency of the additional cycle

$$\eta_t^{cПП} = \eta_o \frac{1 + A_Э}{1 + A_Э \dfrac{\eta_o}{\eta_\Delta}}$$

$$\frac{q_\Delta}{q_o} = \frac{q_\Delta l_o l_\Delta}{q_o l_o l_\Delta} = A_Э \frac{\eta_o}{\eta_\Delta}; \qquad \frac{l_\Delta}{q_\Delta} = \eta_\Delta$$ – EF of the additional cycle

$$\eta_t^{сПП} = \eta_o \frac{1 + A_Э}{1 + A_Э \dfrac{\eta_o}{\eta_\Delta}}$$

$$\delta\eta = \frac{\eta_t^{сПП} - \eta_t^{безПП}}{\eta_t^{безПП}} = \frac{\eta_t^{сПП} - \eta_o}{\eta_o} = \frac{1 + A_Э}{1 + A_Э \dfrac{\eta_o}{\eta_\Delta}} - 1 = \frac{A_Э - A_Э \dfrac{\eta_o}{\eta_\Delta}}{1 + A_Э \dfrac{\eta_o}{\eta_\Delta}}$$

$$\delta\eta = \frac{1 - \dfrac{\eta_o}{\eta_\Delta}}{\dfrac{1}{A_Э} + \dfrac{\eta_o}{\eta_\Delta}}$$

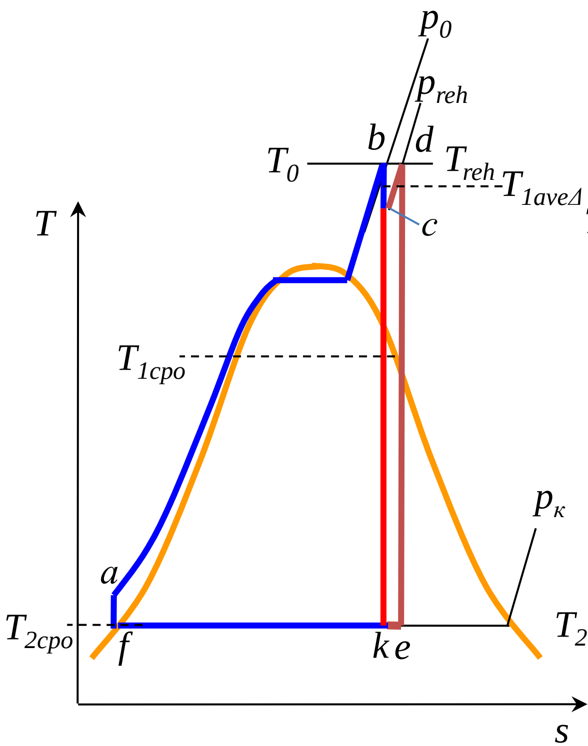
The numerator determines the sign of the $\delta\eta$ value.

if:

A. $\eta_\Delta > \eta_o$ ($\dfrac{\eta_o}{\eta_\Delta} < 1$, positive numerator) $\delta\eta > 0$

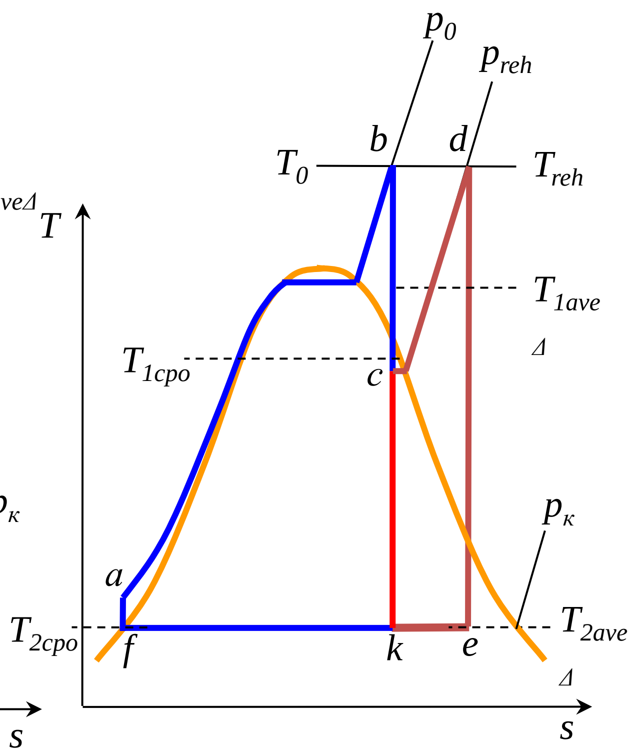
B. $\eta_\Delta < \eta_o$ ($\dfrac{\eta_o}{\eta_\Delta} > 1$, negative numerator) $\delta\eta < 0$

C. $\eta_\Delta = \eta_o$ ($\dfrac{\eta_o}{\eta_\Delta} = 1$, numerator equals zero) $\delta\eta = 0$



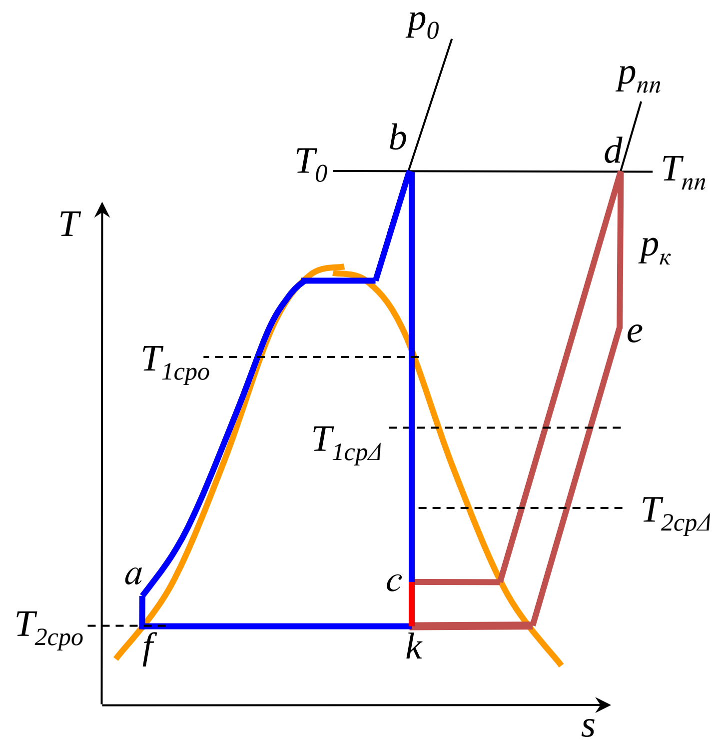
$\eta_\Delta > \eta_o$, as far as $T_{1ave\Delta} > T_{1cpo}$

$\delta\eta > 0$



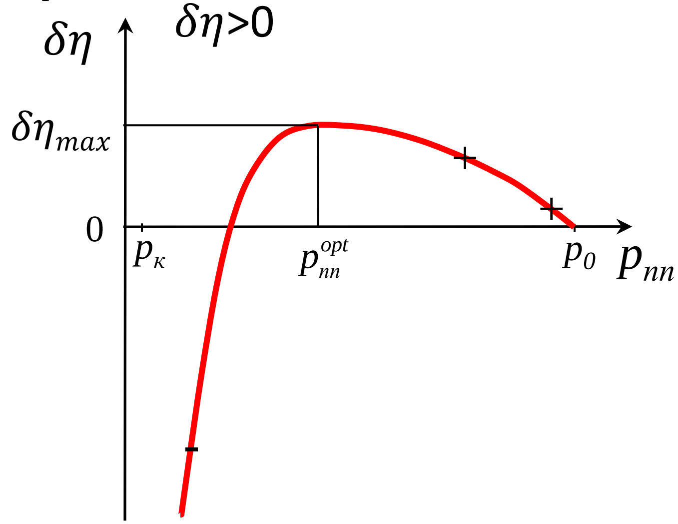
$\eta_\Delta > \eta_o$, as far as T_{1ave}

$\delta\eta > 0$

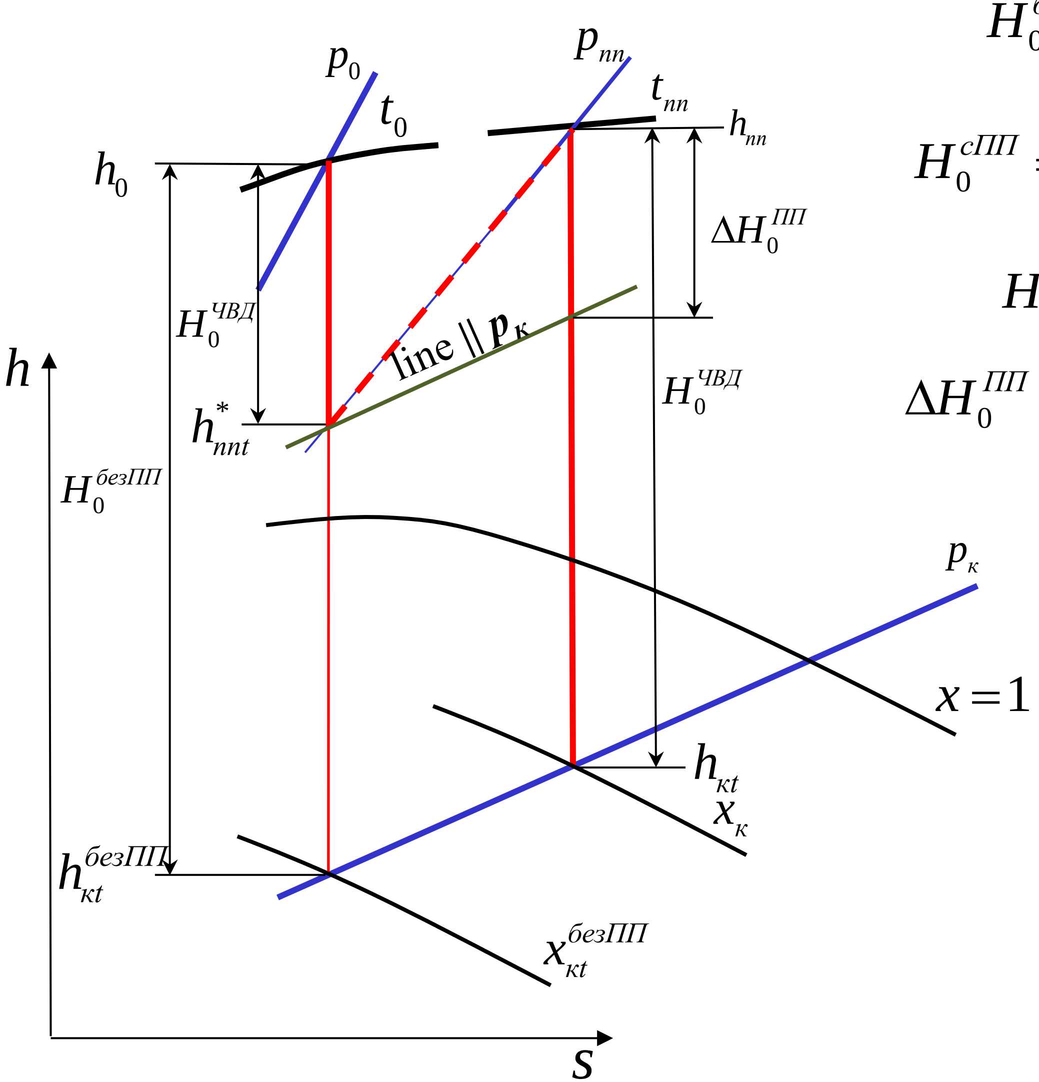


$\eta_\Delta < \eta_o$, s as far as $T_{1ave\Delta} < T_{1cpo}$ and $T_{2ave\Delta} > T_{2cpo}$

$\delta\eta < 0$



3. Available heat drop and the final dryness factor in the steam turbine with the reheating stage



$$H_0^{безПП} = h_0 - h_{кt}^{безПП}$$

$$H_0^{сПП} = H_0^{ЧВД} + H_0^{ЧНД} = h_0 - h_{пnt}^* + h_{пп} - h_{кt}$$

$$H_0^{сПП} == (h_0 - h_{кt}) + (h_{пп} - h_{пnt}^*)$$

$\Delta H_0^{ПП}$ - Increase in the available heat drop of the turbine with the reheating stage versus that of the turbine without the reheating stage, the initial parameters and final pressure being equal