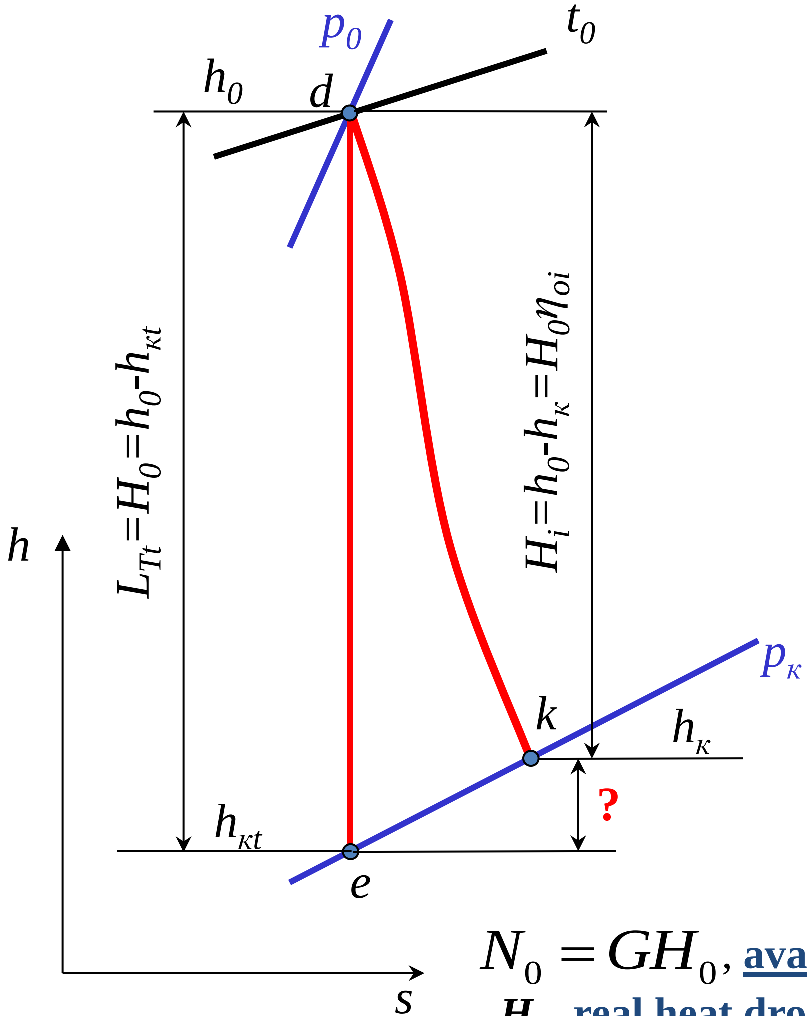
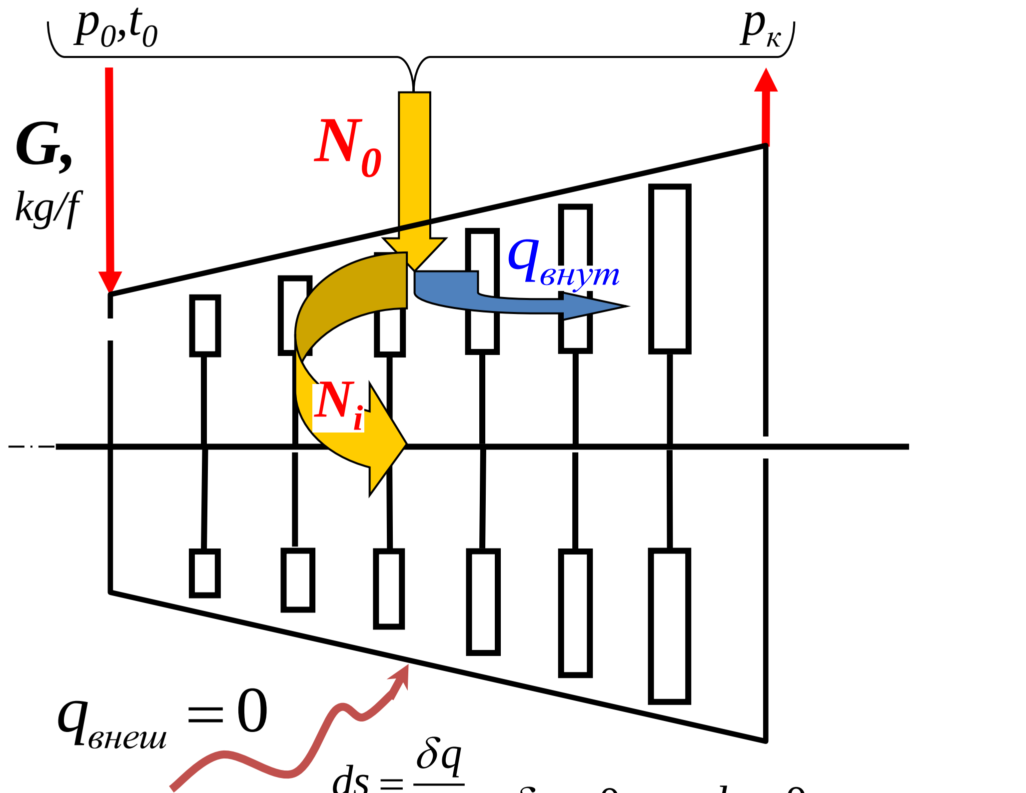
• *Power and relative EF of the turbine generator*





$$ds=\frac{\delta q}{T} \qquad \delta q=0 \;\Rightarrow ds=0 \;\Rightarrow s=const$$

H_0, **available heat drop** in the turbine , *kJ/kg.*

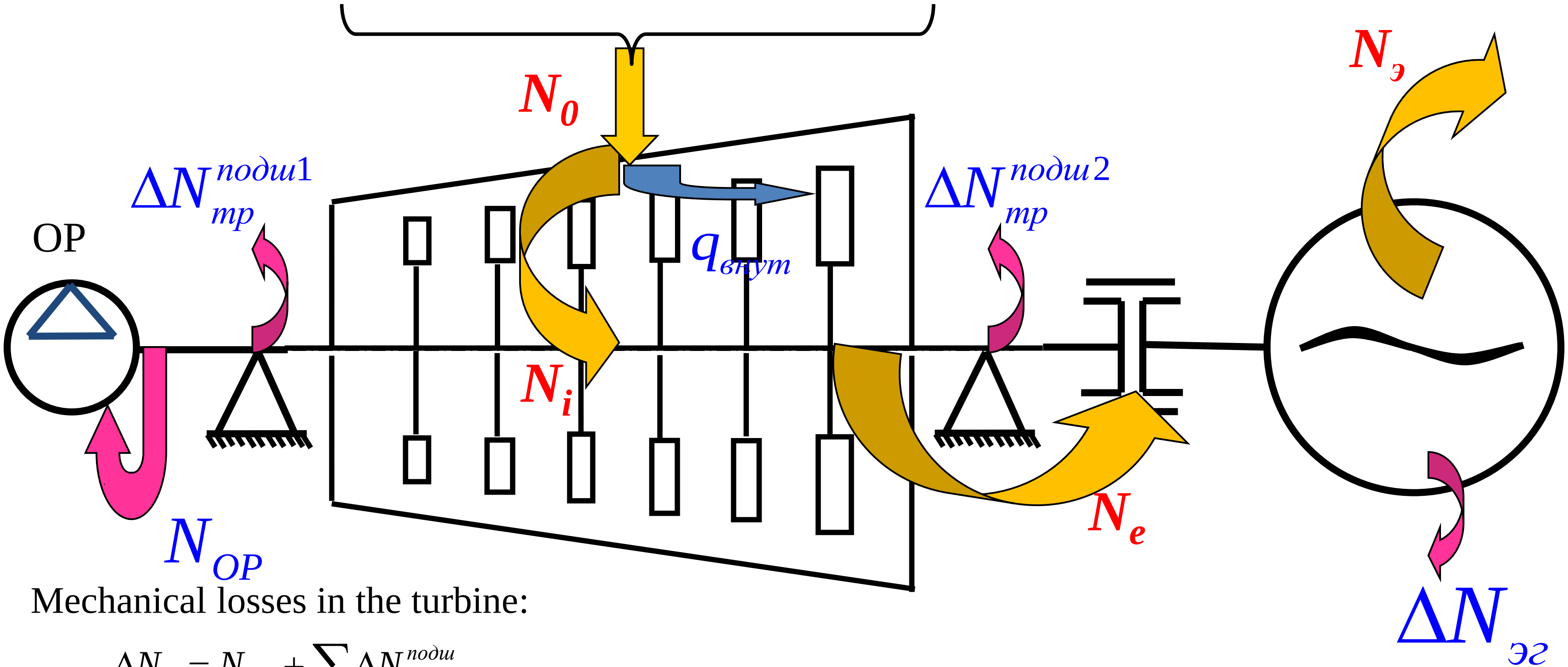
$N_0=GH_0$, **available** power (power of an **ideal turbine**), *kW.*

H_i, **real heat drop** in the turbine , *kJ/kg.*

$N_i=GH_i$, internal power, *kW.* The power transferred from the steam to the turbine shaft.

Relative internal EF of the turbine:

$$\eta_{oi}=\frac{N_i}{N_0}=\frac{H_i}{H_0}$$



Mechanical losses in the turbine:

$$\Delta N_м = N_{OP} + \sum \Delta N_{тр}^{подш}$$

Effective turbine power

$$N_e = N_i - \Delta N_м \qquad N_i \rightarrow N_e$$

Mechanical EF of the turbine

$$\eta_м = \frac{N_e}{N_i} = 1 - \frac{\Delta N_м}{N_i}$$

Note: if n = const, mechanical losses do not depend on the power of the turbine [$\Delta N \neq f(Ni)$] (it is determined by the weight of the rotor, bearings and lubricant system…). Therefore, $\eta_м = f(N_i)$

Power losses in the generator: $\Delta N_{эг}$

Electric power of the turbine generator

$$N_э = N_e - \Delta N_{эг} \qquad N_i \rightarrow N_e$$

Electric EF of the generator

$$\eta_{эг} = \frac{N_э}{N_e} = 1 - \frac{\Delta N_{эг}}{N_e}$$

Relative effective EF of the turbine

$$\eta_{oe} = \frac{N_e}{N_0} = \frac{N_i}{N_0}\frac{N_e}{N_i} = \eta_{oi}\eta_{м}$$

Relative electric EF of the turbine

$$\eta_{oэ} = \frac{N_э}{N_0} = \frac{N_i}{N_0}\frac{N_e}{N_i}\frac{N_э}{N_e} = \eta_{oi}\eta_{м}\eta_{эг}$$

- *Absolute EF of the turbine equipment*

Absolute EF of the turbine ***equipment***

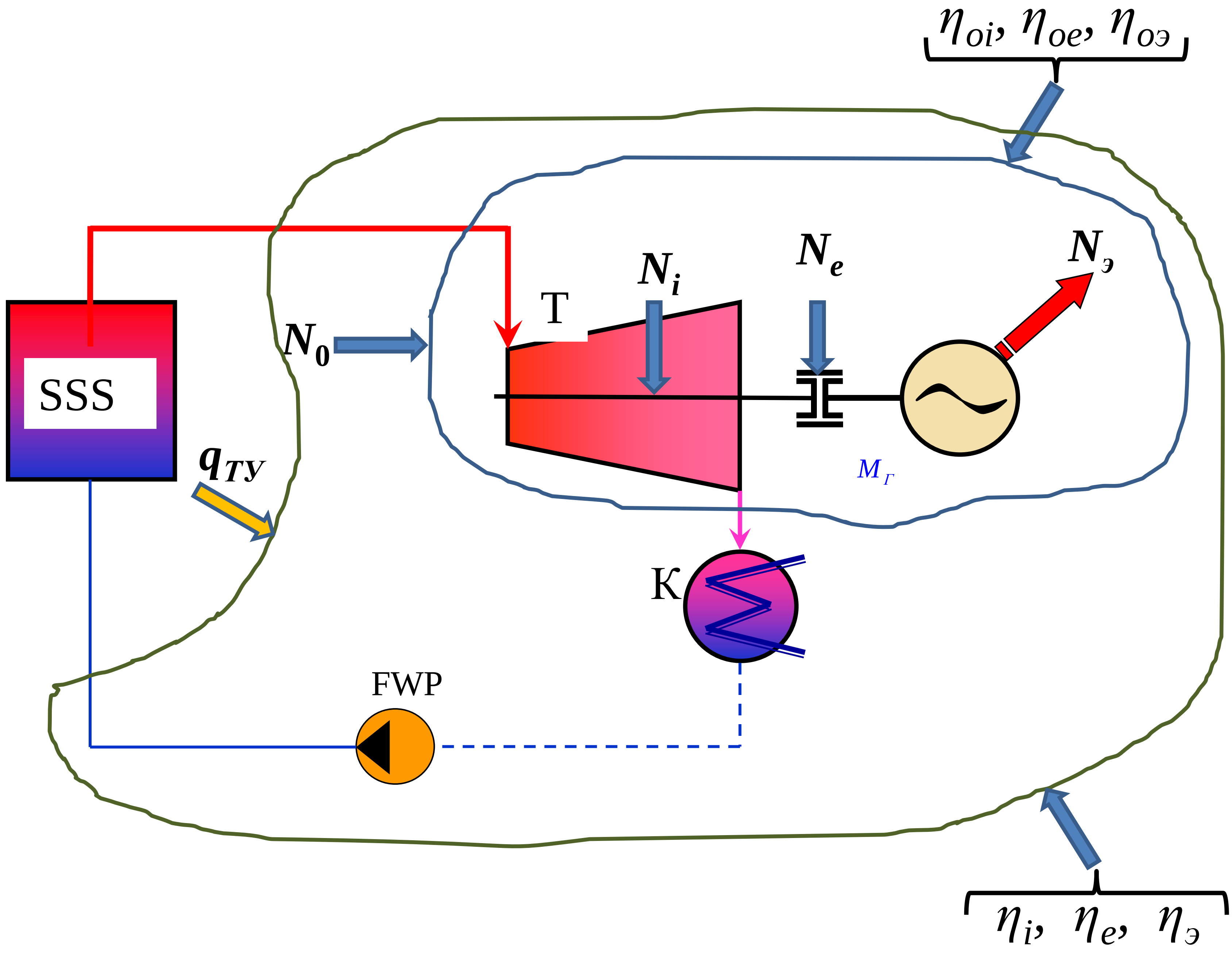
$$\eta_i = \frac{L_{Ti}}{q_{TУ}} = \frac{H_i}{h_0 - h'_к} = \frac{H_0 H_i}{\left(h_0 - h'_к\right) H_0} = \eta_t \eta_{oi}$$

Absolute effective EF of the turbine ***equipment***

$$\eta_e = \frac{N_e}{Q_{TУ}} = \eta_i \eta_м = \eta_t \eta_{oi} = \eta_t \eta_{oi} \eta_м$$

Absolute electric EF of the turbine ***equipment***

$$\eta_э = \frac{N_э}{Q_{TУ}} = \eta_e \eta_{эг} = \eta_t \eta_{oэ} = \eta_t \eta_{oi} \eta_м \eta_{эг}$$



ηoi, ηoe, ηoэ
SSS
T
Ni
Ne
Nэ
N0
qТУ
MГ
K
FWP
ηi, ηe, ηэ

Power and EF of the turbine and turbine equipment

EF / Power	Relative EF	Absolute EF	Power
Ideal turbine	1	$\eta_t = \frac{H_0}{q_{ТУ}} = \frac{h_0 - h_{кt}}{h_0 - h_{пв}}$	$N_0 = GH_0$
Internal	$\eta_{oi} = \frac{N_i}{N_0} = \frac{H_i}{H_0}$	$\eta_i = \frac{N_i}{Q_{ТУ}} = \eta_t \eta_{oi}$	$N_i = GH_i = N_0 \eta_{oi}$
Effective	$\eta_{oe} = \frac{N_e}{N_0} = \eta_{oi} \eta_м$	$\eta_e = \frac{N_e}{Q_{ТУ}} = \eta_t \eta_{oe}$	$N_e = GH_i \eta_м = N_0 \eta_{oe}$
Electric	$\eta_{oэ} = \frac{N_э}{N_0} = \eta_{oi} \eta_м \eta_{эг}$	$\eta_э = \frac{N_э}{Q_{ТУ}} = \eta_t \eta_{oэ}$	$N_э = GH_0 \eta_{oi} \eta_м \eta_{эг} = N_0 \eta_{oэ}$

1.3. EF value

$$\eta_э = \eta_t \eta_{oi} \eta_м \eta_{эг}$$

А. EF is a **tool** to find technical ways to improve the energy conversion processes

Б. We should know EF to solve the problem of relating the electric power to the consumed heat power of the steam turbine (further on, to the heat power of the reactor)

$$\eta_э = \frac{N_Э}{Q_{ТУ}}$$

What amount of heat must be consumed by the turbine to produce the given power?

$$Q_{ТУ} = \frac{N_Э}{\eta_э}$$

What is the power level that can be obtained if we spend the given amount of heat?

$$N_Э = Q_{ТУ}\eta_э$$

B. Why EF is to be improved?

How much fuel should be burnt in TPP (NPP-?) to produce the given power?

$$Q_{ТУ} = \frac{N_Э}{\eta_э} \quad \Rightarrow Q_c = \frac{Q_{ТУ}}{\eta_{ППУ}} \quad \Rightarrow B = \frac{Q_c}{Q_H^P} \quad = \frac{N_Э}{\eta_э \eta_{ППУ} Q_H^P}$$

Q_H^P fuel heating power , *kJ/kg*.

How much fuel is to be burned in TPP to generate units of power?

$$\frac{B}{N_Э} = \frac{1}{\eta_Э \eta_{ППУ} Q_H^P}$$

How much fuel is to be burnt in TPP (NPP-?) to generate a unit of power per hour?

$$b = \frac{B}{Э} = \frac{3600}{\eta_Э \eta_{ПК} Q_H^P}$$

$\left(Q_H^P\right)_{УТ}$ calorific value of the **equivalent fuel**, =29300 *kJ/kg*.

$$b_{УТ}^Э = \frac{0{,}123}{\eta_Э \eta_{ПК}}$$

specific consumption of the equivalent fuel for electricity generation, *kg.e.f/kWh*

Fuel consumption is translated into an economic category – **money.**

Г. Solution of the technical and economic problem

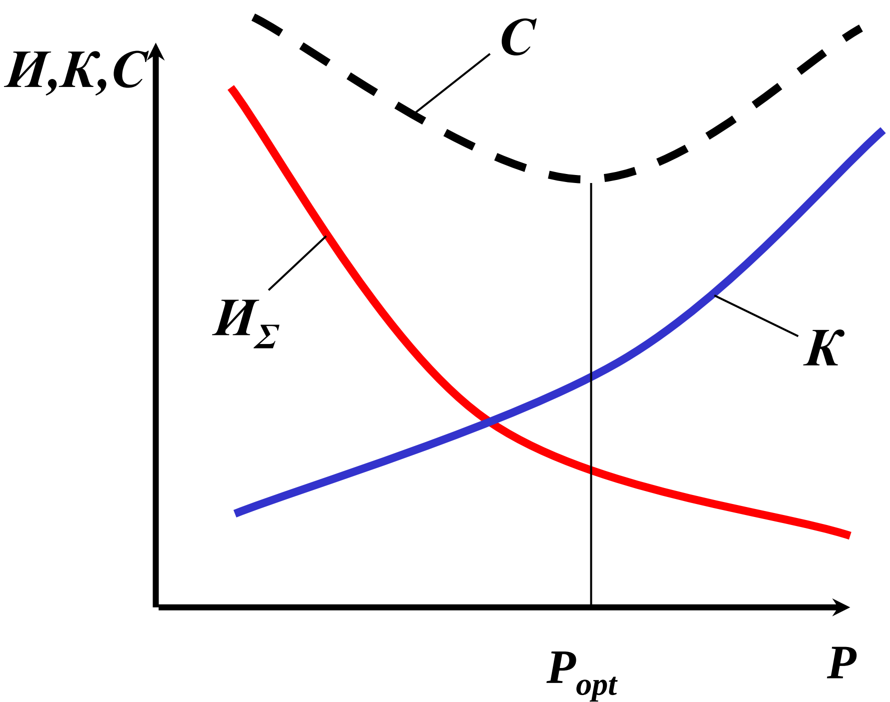
Technical and economic challenge implies the choice of the most advantageous (optimal) value of any parameter within the generalized criterion

- Capital inputs: $К_{\Sigma}=\Sigma К_j$ (inputs made prior to the start of operation)
- operating costs: (production costs are the inputs made during operation)

$$И_{\Sigma}=И_{ЗП}+И_{T}+И_{рем}+\ldots$$

$$И_{\Sigma} \approx И_{T} = ц_{T} B = f\left(\frac{1}{\eta}\right)$$

- Working cost : $C=И_T+ \Sigma a_j К_j$ (reduction of multi-term costs to one term)



Assume, there is a parameter P, and increase in this parameter leads to EF growth.

$$\eta_Э \uparrow = f\left(\boldsymbol{P}\uparrow\right)$$

Then $B\downarrow \Rightarrow И_T \downarrow \Rightarrow И_{\Sigma}\downarrow$

Typically, the EF growth is achieved through increase in capital inputs.

2. Methods to improve the thermal efficiency of steam turbines

$$\eta_э = \eta_t \eta_{oi} \eta_м \eta_{эг}$$

A. Thermodynamic methods

aimed to increase η_t . However, they affect η_{oi} .

- Increasing the initial parameters
- Reduction of the final pressure
- Resuperheating and moisture separation
- Regenerative feed-water heating

Combined production of electricity and heat

Thermodynamic cycles of NPP

Б. Constructional methods

Aimed to increase η_{oi}, $\eta_м$, $\eta_{эг}$.

of the Turbomachine in TPP