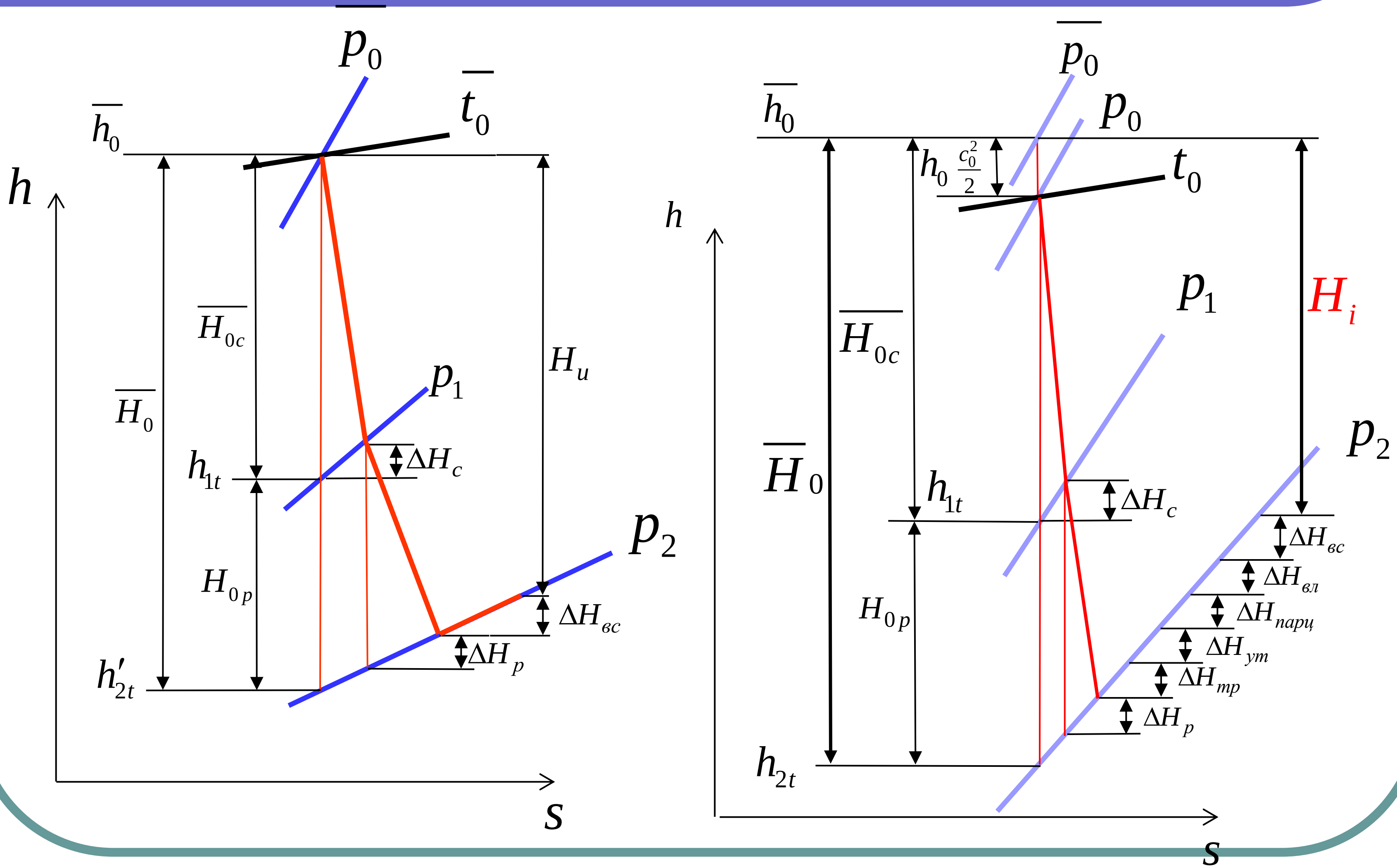
Steam expansion in the stage



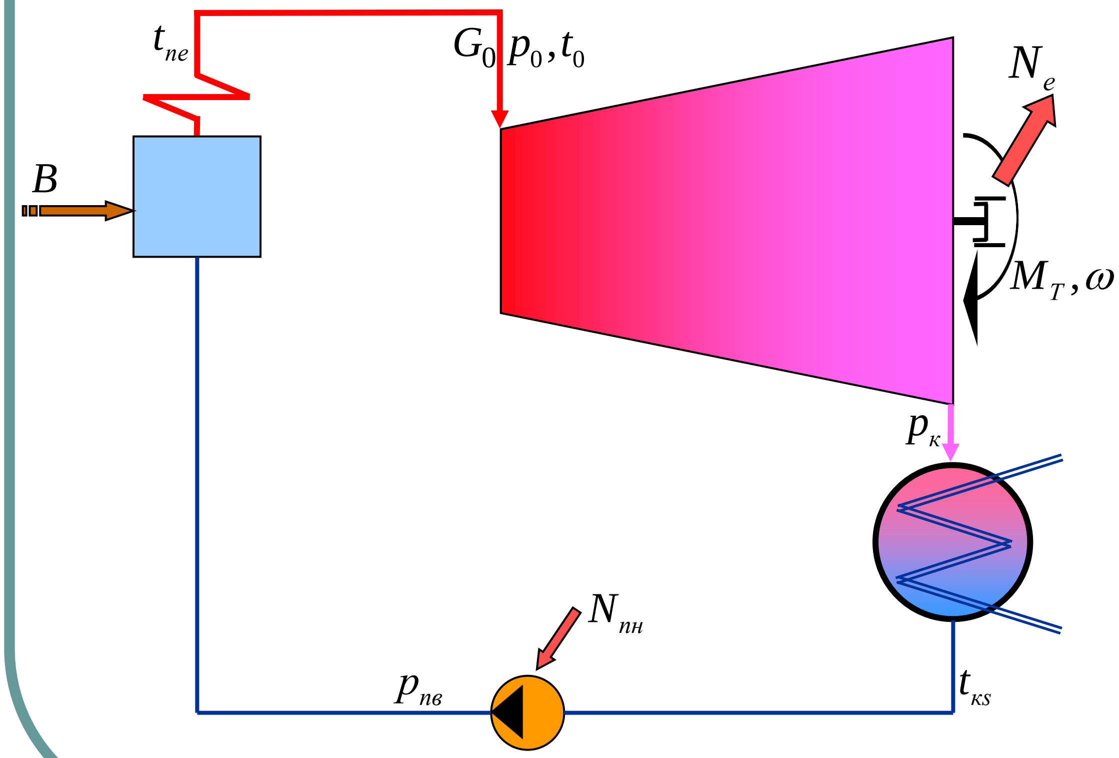
4. Multistage turbines

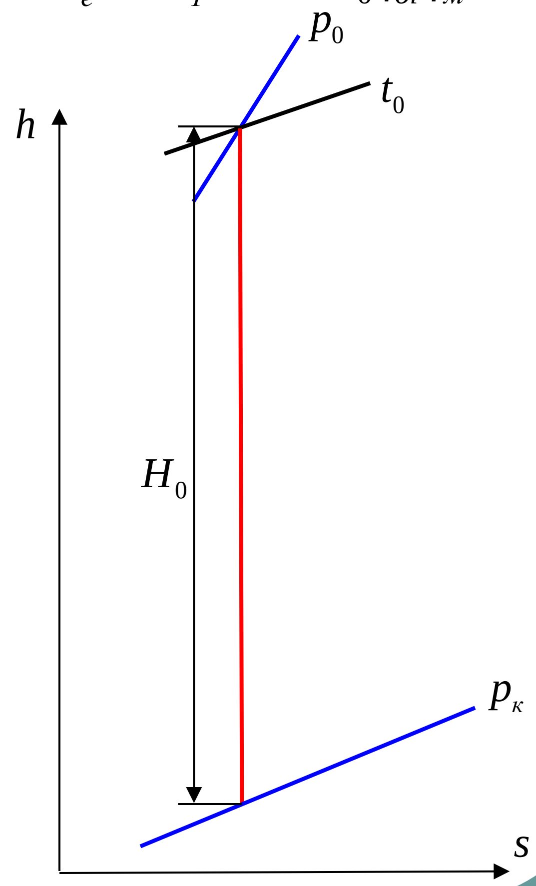
- Advantages of multistage turbines
- Reheat factor
- Axial thrust on the turbine rotor
- Gland seal in turbines

4.1. Advantages of multistage turbines

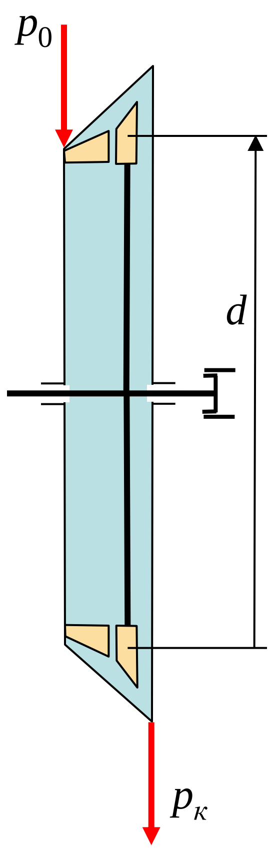
A. Statement of a question

$$N_e = M_T\omega = GH_0\eta_{oi}\eta_м$$





$$H_0 = (1100 \div 1700)\ [кДж/кг]$$



Single-stage turbine

$$\overline{H_0}^{opt} = \frac{2\pi^2 d^2 n^2 (1-\rho)}{\varphi^2 \cos^2 \alpha_1} \Longrightarrow \left(\overline{H_0}^{opt}\right)_{\rho=0} = 52,5d^2$$

$$H_0 \approx 1500 \Rightarrow d_{cp}^{opt} \approx 5,3м$$

1. $u = \pi d \omega \Longrightarrow u \approx 832 м/с$

Inadmissible centrifugal forces !!!

2. $\varepsilon_1 \ll \varepsilon_*$ $\Longrightarrow$ Supercritical flow through the stage rings

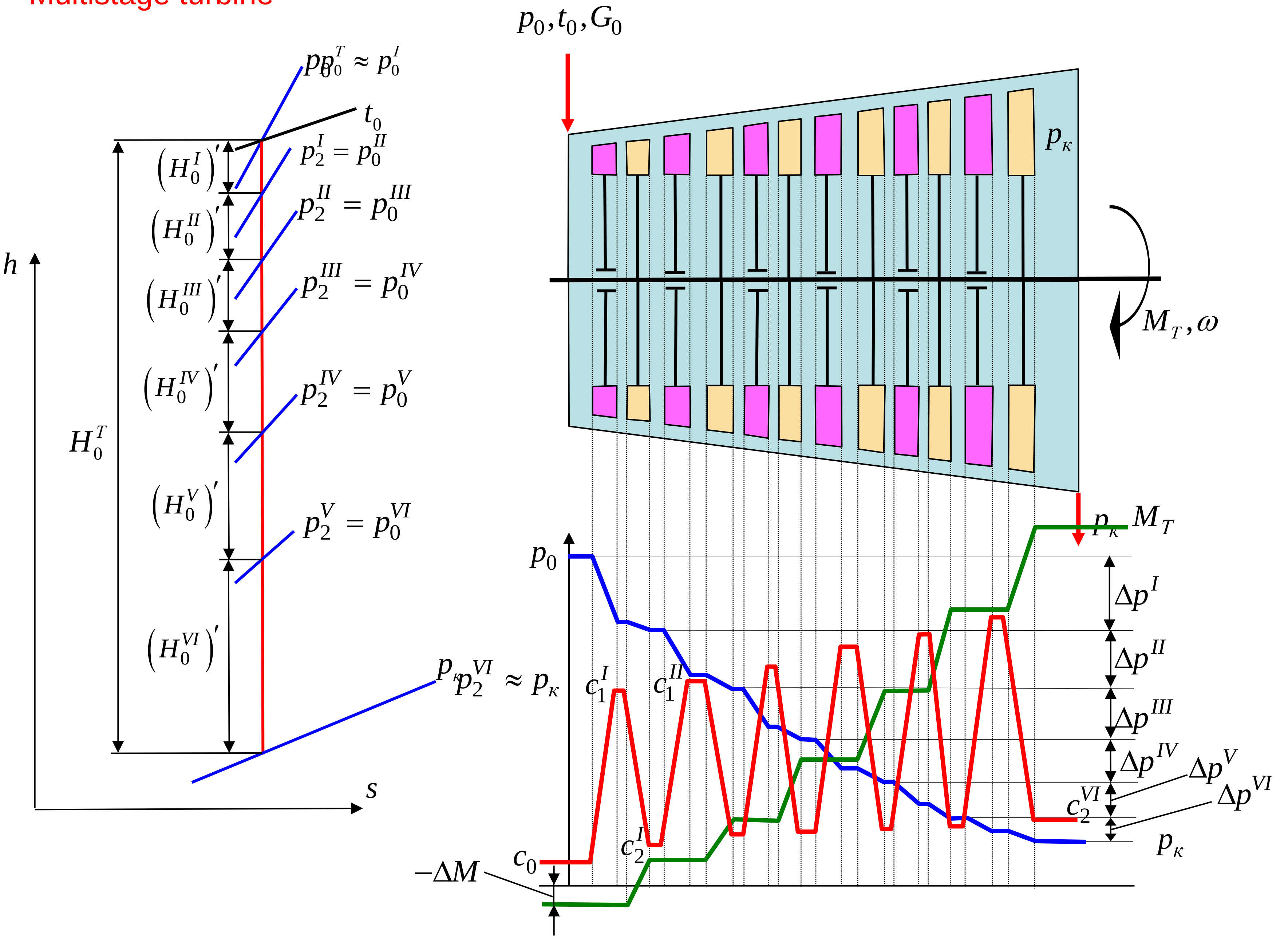
Large (extremely large) losses in the rings !!!

3. $l_1 = \dfrac{F_1}{\pi d_{cp} \sin\alpha_1} = \dfrac{G\upsilon_{1t}}{\pi d_{cp} c_{1t} \mu_c \sin\alpha_1}$; $\left(l_{1*} = \dfrac{F_{1*}}{\pi d_{cp} \sin\alpha_1} = \dfrac{G\upsilon_{1t*}}{\pi d_{cp} c_{1t*} \mu_c \sin\alpha_1} \right)$

$l_2 = \dfrac{F_2}{\pi d_{cp} \sin\beta_2} = \dfrac{G\upsilon_{2t}}{\pi d_{cp} w_{2t} \mu_p \sin\beta_2}$; $\left(l_{2*} = \dfrac{F_{2*}}{\pi d_{cp} \sin\beta_2} = \dfrac{G\upsilon_{2t*}}{\pi d_{cp} w_{2t*} \mu_p \sin\beta_2} \right)$

Conclusion: Single-stage turbine either cannot be designed to implement currently implemented heat drops (claim 1); or (in case of advanced materials) it is uneconomical and exigeant.

Multistage turbine

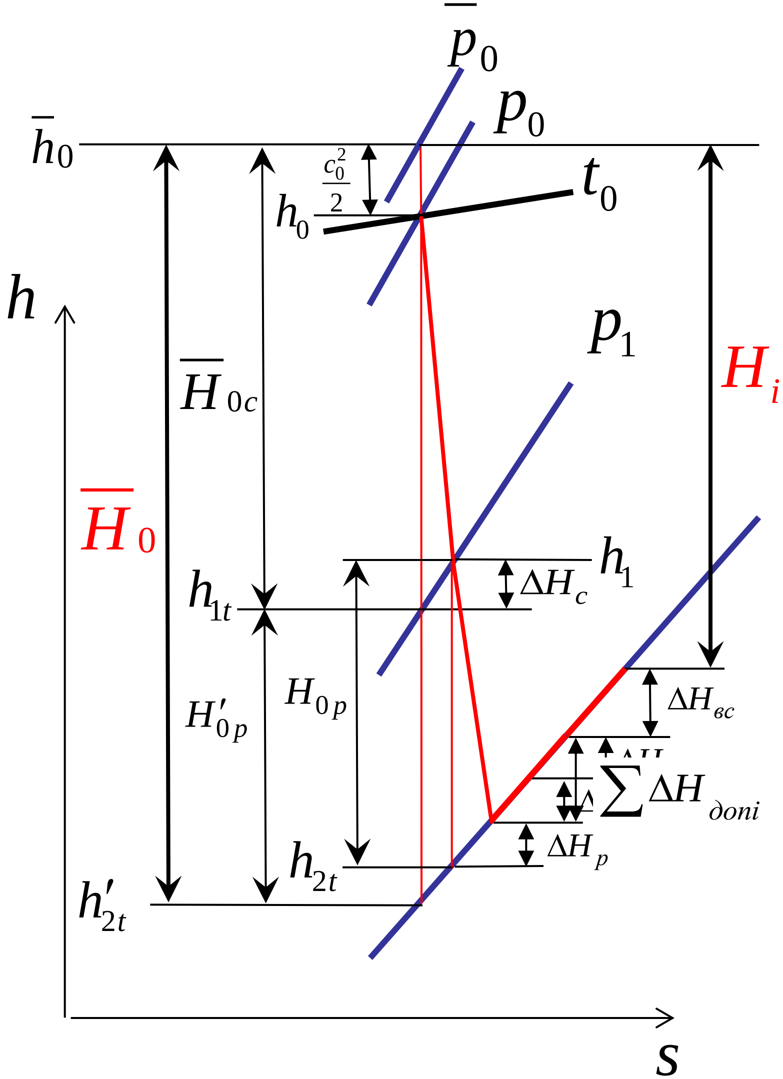


B. Advantages of multistage turbines

1. In a multi-stage turbine, the optimum velocity ratio and hence high efficiency can be easily obtained through reduced heat drop per one stage

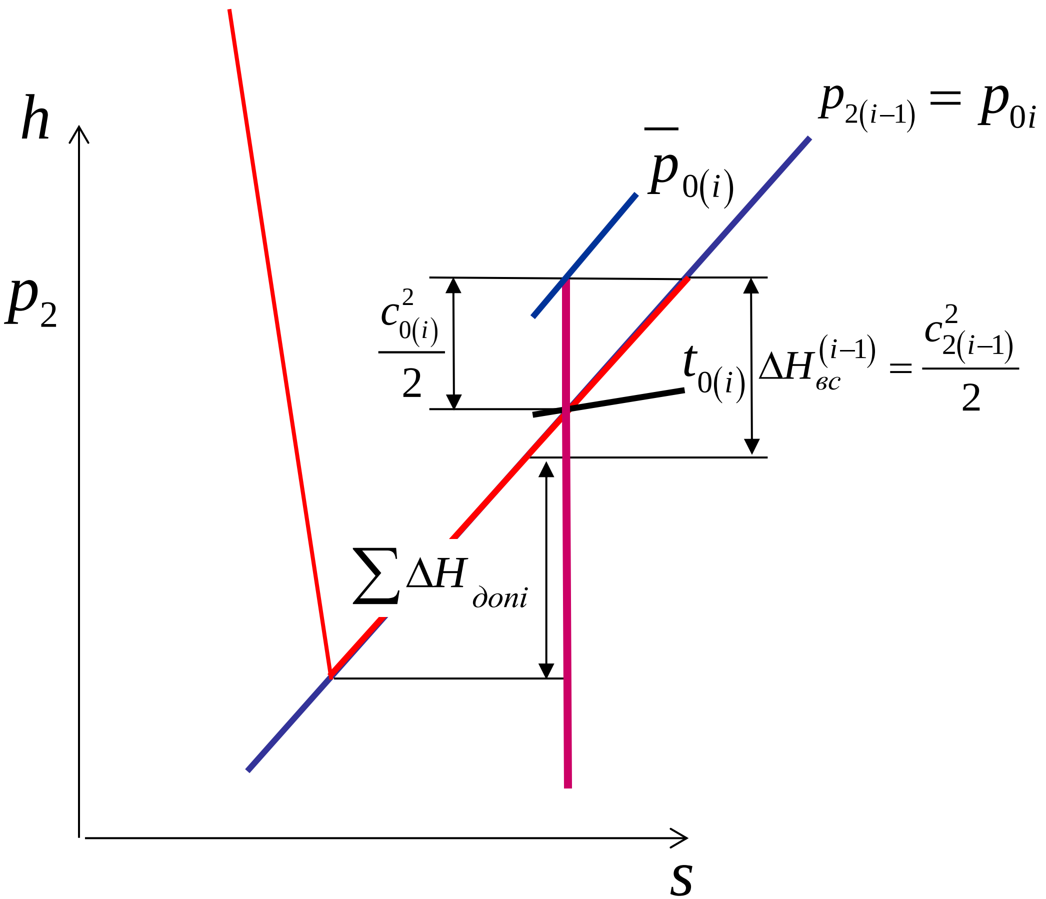
2. If the number of stages increases, the height of nozzle and rotor blades grows in all the stages

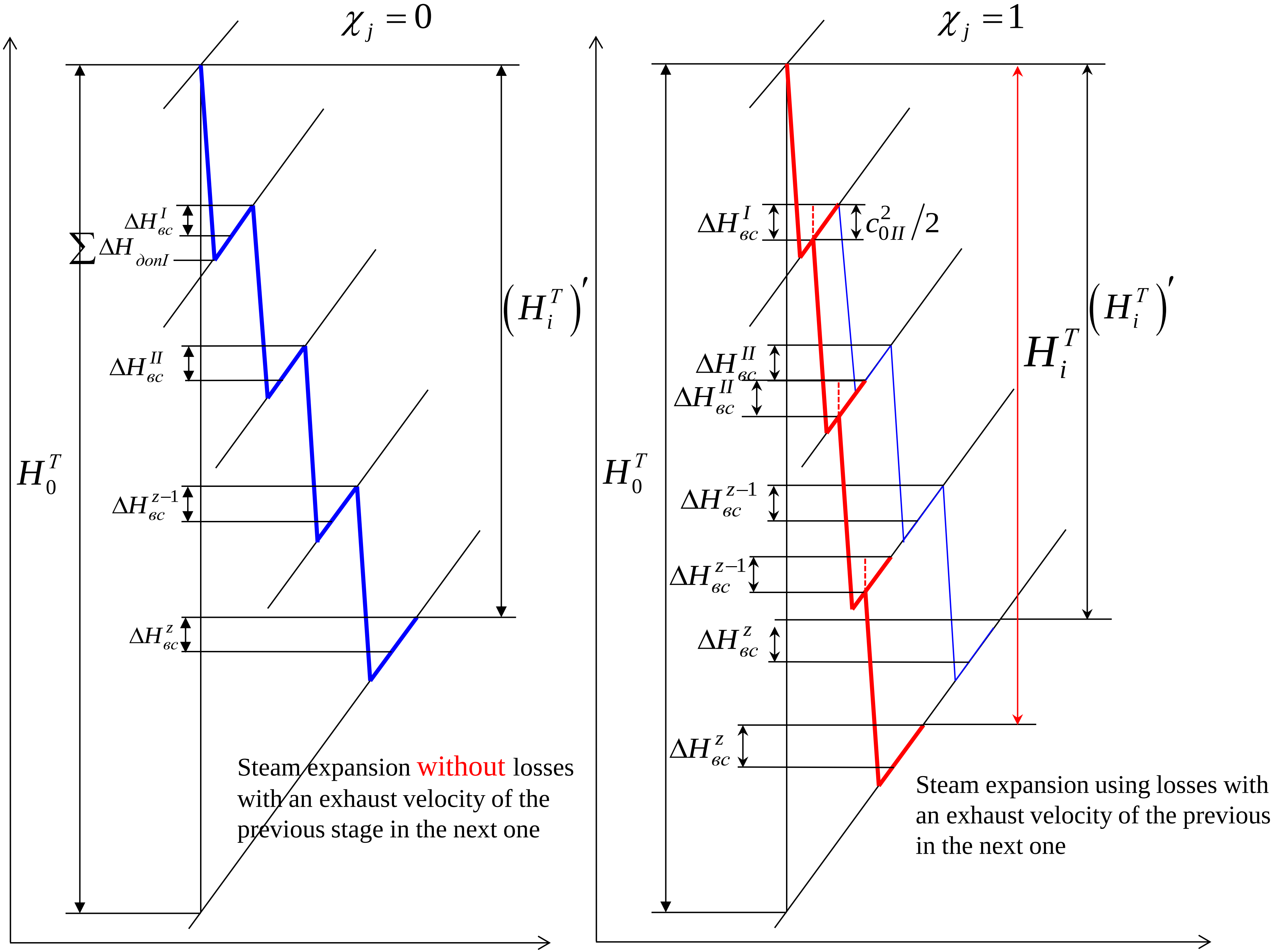
3. In multistage turbines, the energy of the exhaust velocity of the previous stage is used in nozzle blades of the next stage



χ the exhaust velocity utilization factor of the previous stage in the next one

$$\frac{c_{0(i)}^2}{2} = \chi_i \frac{c_{2(i-1)}^2}{2} \qquad 0 \le \chi \le 1$$





$\chi_j = 0$
$\Delta H_{вс}^{I}$
$\sum \Delta H_{допI}$
$\Delta H_{вс}^{II}$
$\Delta H_{вс}^{z-1}$
$\Delta H_{вс}^{z}$
H_0^T
$\left(H_i^T\right)'$
Steam expansion without losses with an exhaust velocity of the previous stage in the next one
$\chi_j = 1$
$\Delta H_{вс}^{I}$
$c_{0II}^2/2$
$\Delta H_{вс}^{II}$
$\Delta H_{вс}^{II}$
$\Delta H_{вс}^{z-1}$
$\Delta H_{вс}^{z-1}$
$\Delta H_{вс}^{z}$
$\Delta H_{вс}^{z}$
H_0^T
H_i^T
$\left(H_i^T\right)'$
Steam expansion using losses with an exhaust velocity of the previous in the next one

4.

The multi-stage turbines, thermal energy losses of previous stages is partially used to generate useful energy in subsequent stages through the phenomenon of returned heat in the multistage turbine

5.

Only in multistage turbine the design allows steam extraction for regenerative feed-water heating

and

steam extraction from /return in\ the turbine for intermediate heating

that essentially increases the absolute efficiency of the unit

Design solution:

- mounting diaphragms in beckets
- arrangement of stages in individual cylinders

C. Disadvantages of multistage turbines

1. As the stages grow in number, the complexity of the design and the manufacturing cost of the turbine increase. Capital costs grow

However,
turbine efficiency and thus efficiency of the steam turbine plant increase
Reduced operational costs

For power turbines reduced operational costs compensates for grown capital costs

2. Increased steam leakage losses in both the front end and in the diaphragm seals

Complicated gland seal system

3. Great axial forces emerge