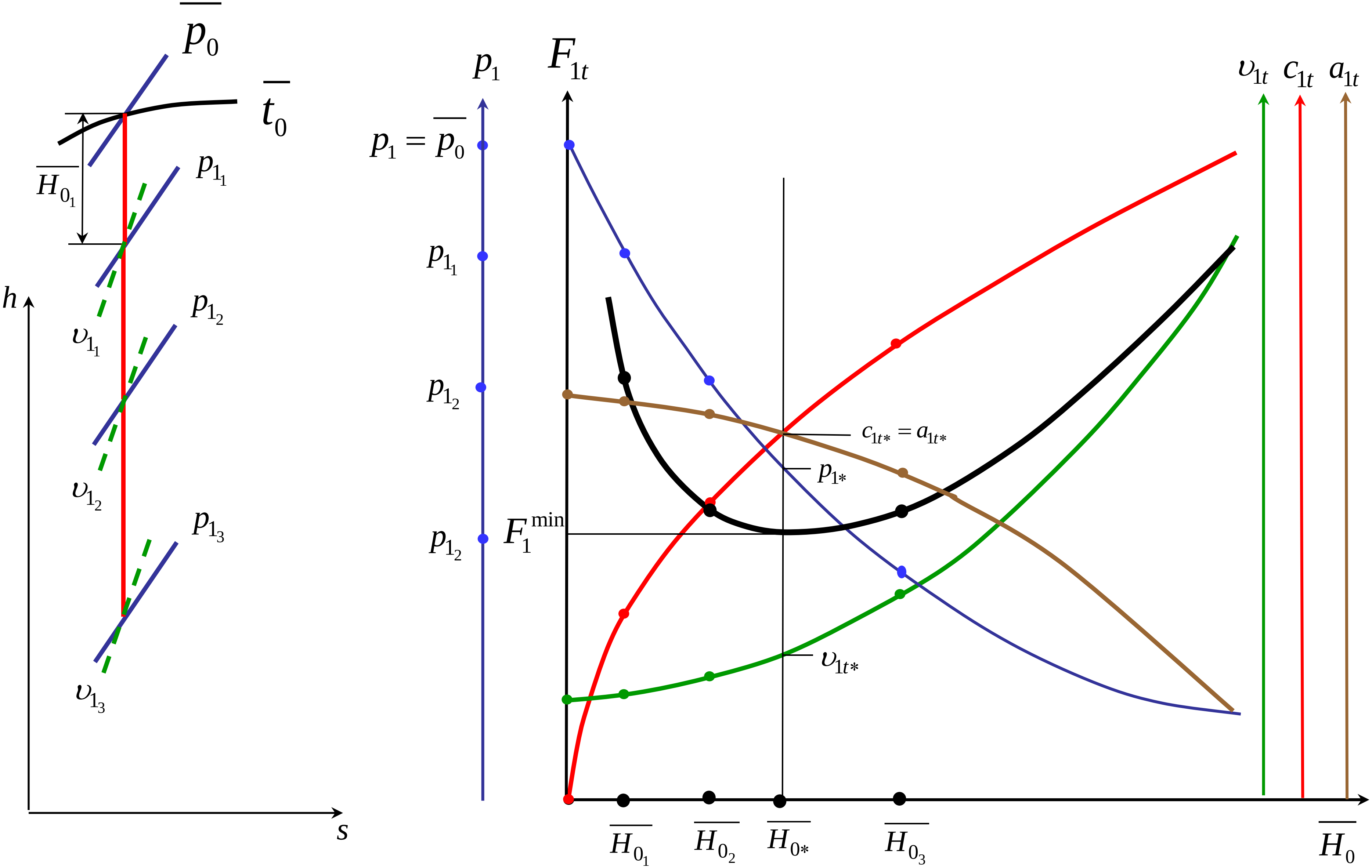
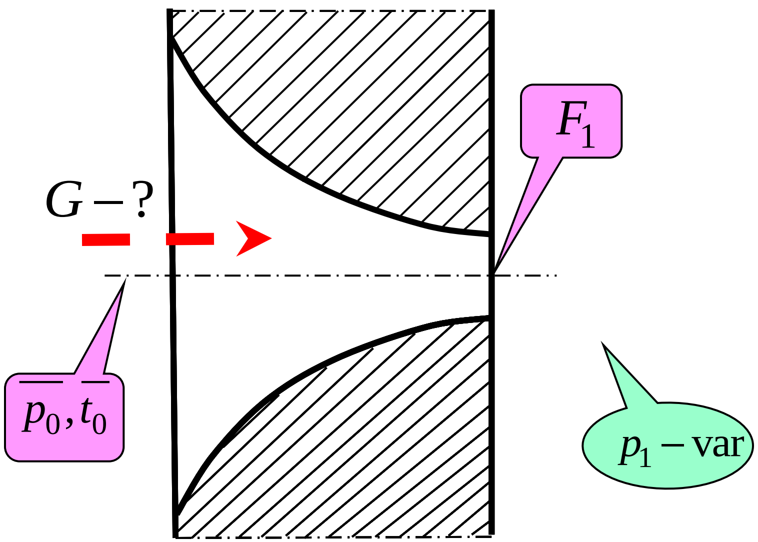


$$\frac{dF}{F} = \frac{d\upsilon}{\upsilon} - \frac{dc}{c}$$

2.2.3. Steam (gas) flow rate through the convergent nozzle

Consider the problem.

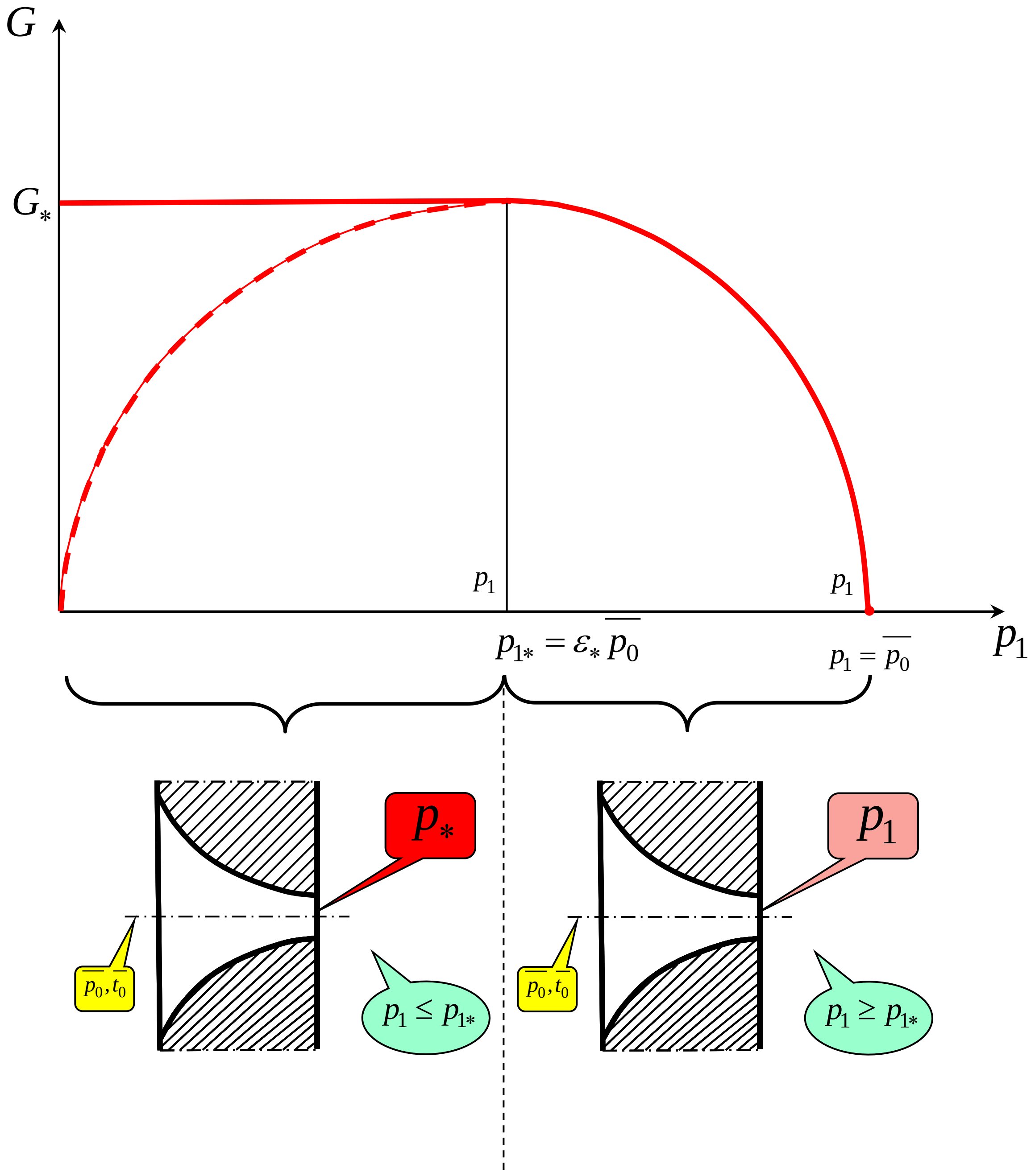
how will the flow rate G through the convergent nozzle of the area F_1, change at different parameters of deceleration at the inlet $\left(\bar{p}_0 = const, \bar{t}_0 = const\right)$ and alternating pressure after the nozzle p_1 ?



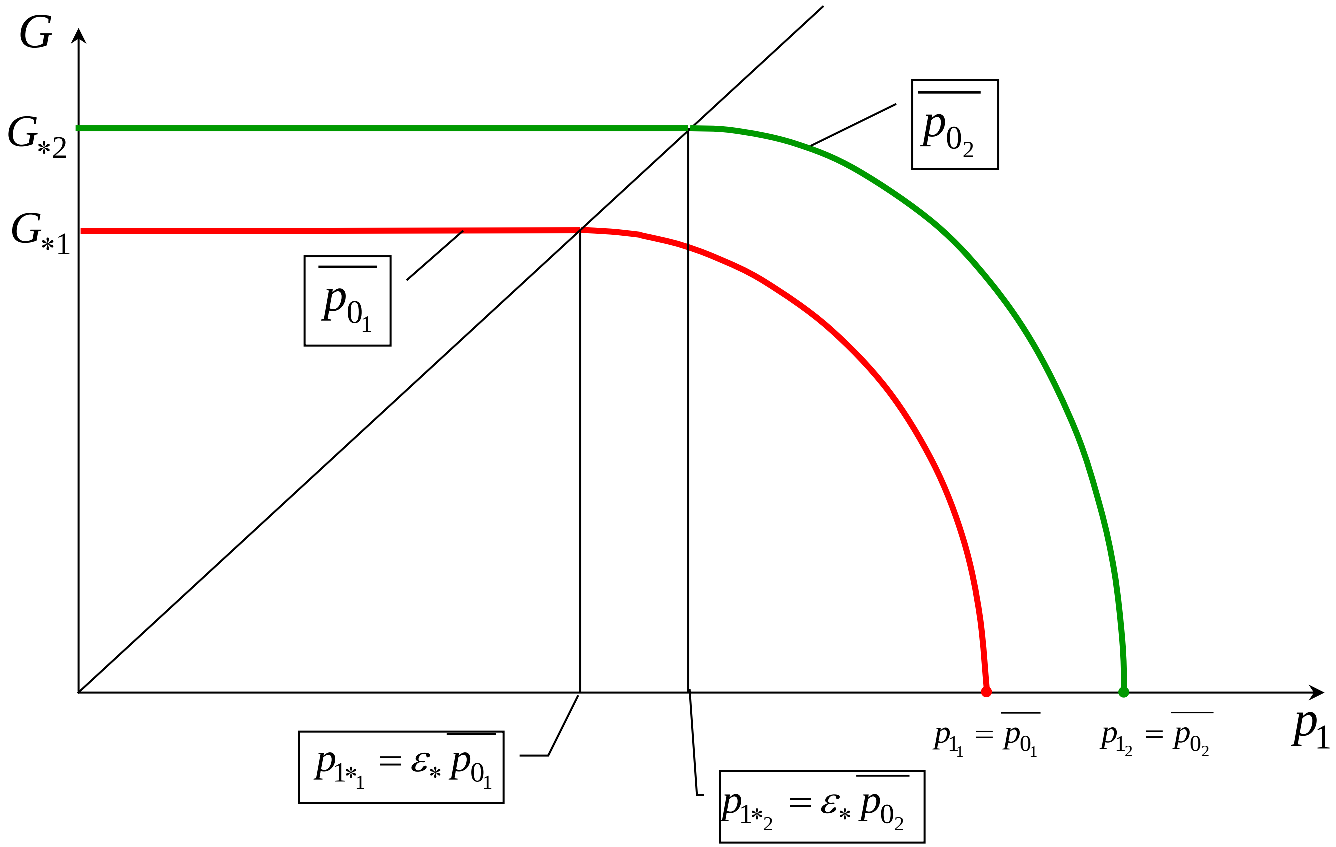
$$G = F_{1t}\frac{c_{1t}}{\upsilon_{1t}}$$

$$c_{1t} = \sqrt{\frac{2k}{k-1}\bar{p}_0\bar{\upsilon}_0\left(1-\varepsilon^{\frac{k-1}{k}}\right)}$$

$$p_1 \downarrow \Rightarrow c_{1t} \uparrow \Rightarrow \upsilon_{1t} \uparrow$$



G
G_*
p_1
p_1
$p_{1*} = \varepsilon_* \overline{p_0}$
$p_1 = \overline{p_0}$
p_1
p_*
p_1
$\overline{p_0}, t_0$
$p_1 \leq p_{1*}$
$\overline{p_0}, t_0$
$p_1 \geq p_{1*}$



G
G_{*2}
G_{*1}
$\overline{p_{0_2}}$
$\overline{p_{0_1}}$
$p_{1*_1} = \varepsilon_* \overline{p_{0_1}}$
$p_{1*_2} = \varepsilon_* \overline{p_{0_2}}$
$p_{1_1} = \overline{p_{0_1}}$
$p_{1_2} = \overline{p_{0_2}}$
p_1

* Practical implementation ε_*

Set: $\overline{p}_0, p_1,$ т.е. $\varepsilon = \frac{p_1}{\overline{\overline{p}}_0}$.

A. Choice of the nozzle type:

- if $\varepsilon < \varepsilon_*,$ the nozzle is to be divergent
- if $\varepsilon > \varepsilon_*,$ the nozzle is to be convergent

B. Operating mode of the convergent nozzle

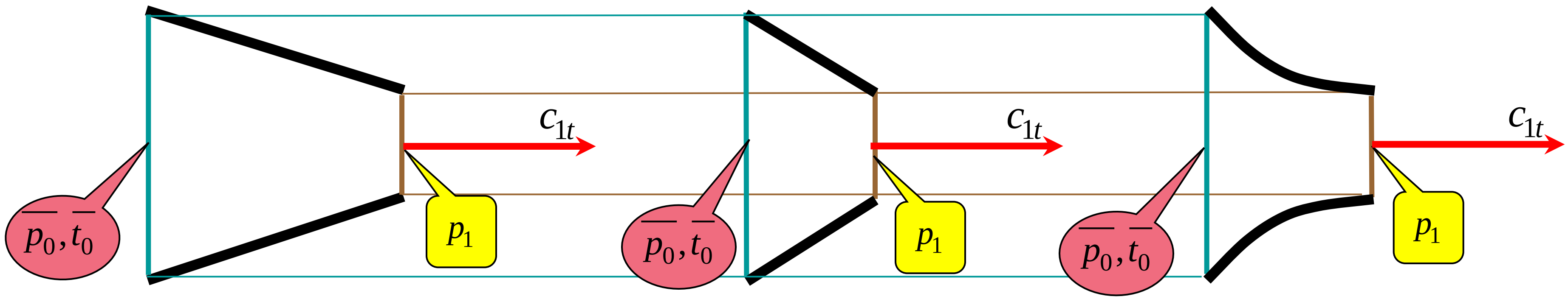
- if $\varepsilon > \varepsilon_*,$ the nozzle operates in the subcritical mode, and in the nozzle outlet section, the pressure is equal to the pressure after the nozzle (p_1)
- if $\varepsilon < \varepsilon_*,$ the nozzle operates in critical mode, and in the nozzle outlet section, the pressure is

$$p_{1*} = \varepsilon_* \overline{p}_0$$

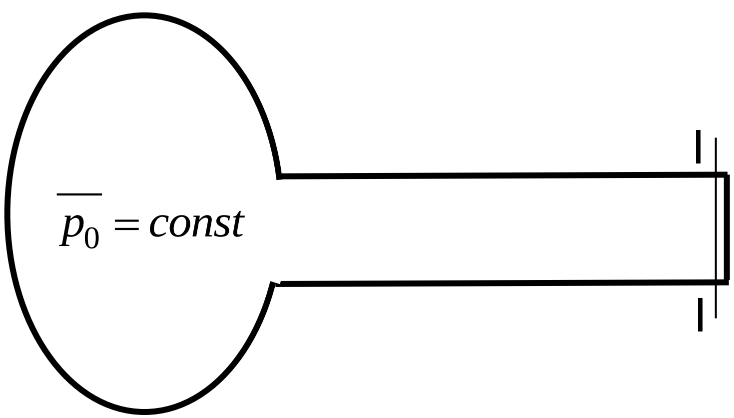
Questions which **must** occur when studying this unit:

I. No equations that allow us to determine the length of the nozzle.

$$G - \text{одинаковый} \quad \textit{equal}$$



II. The obtained result contradicts practical observations



$p = \text{атмос-}$ atmos

ферному pheric

а) $p_1 = \overline{p_0}$ $\quad c_{1t} = 0$

б) if $\dfrac{p}{\overline{p_0}} \geq \varepsilon_*$

$p_1 = p \quad c_{1t} = [\text{значение}]$ value

if $\dfrac{p}{\overline{p_0}} \leq \varepsilon_*$

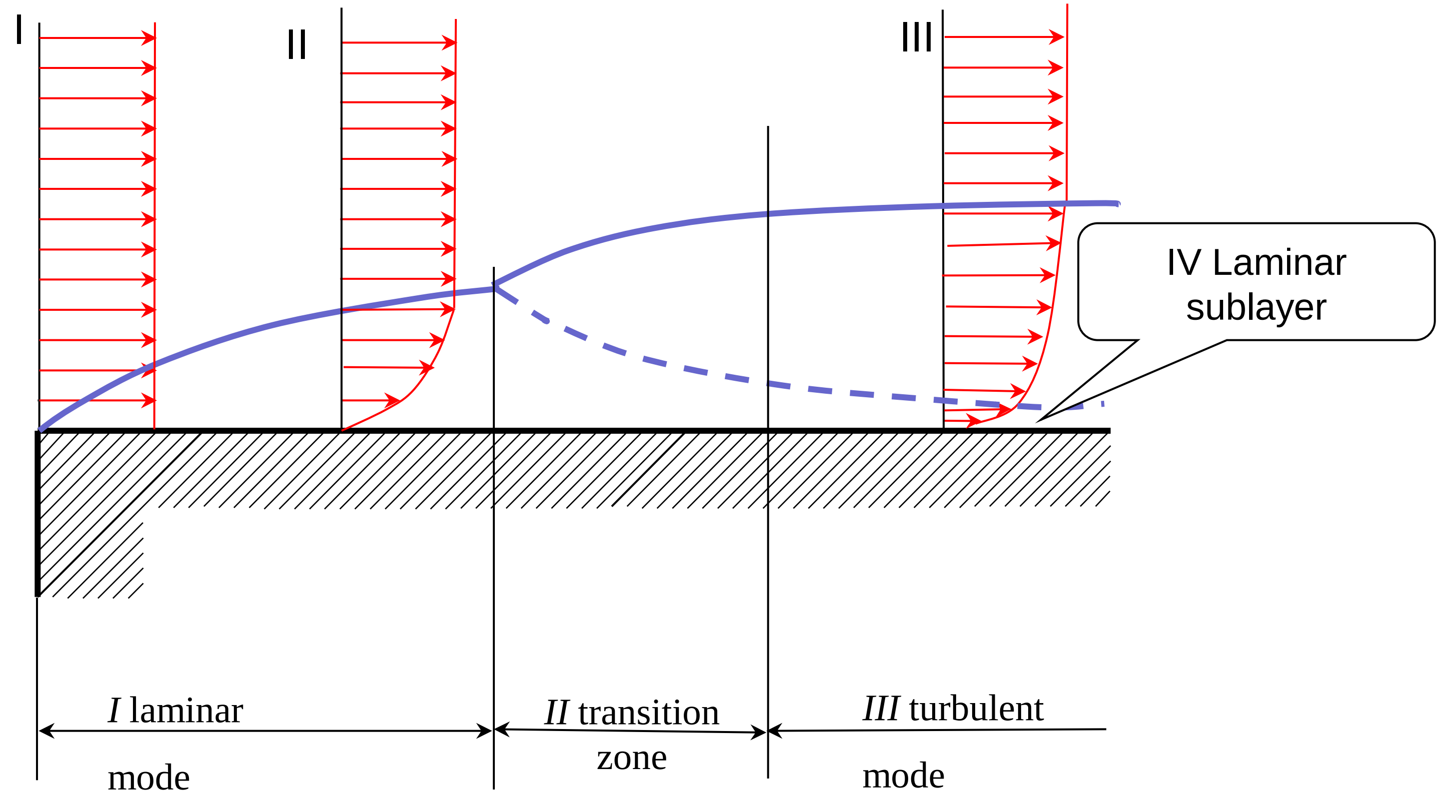
$p_1 = \varepsilon * \overline{p_0} \quad c_{1t} = c_*$

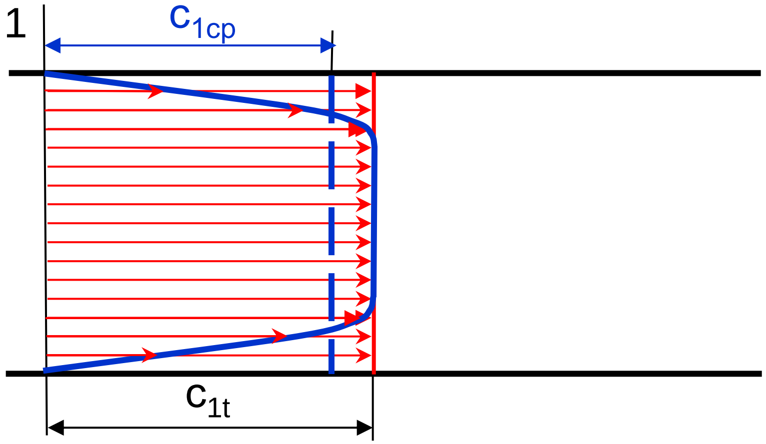
Thus, $c_{1t} \uparrow$, a $F_1 = const.$

Nonsense the continuity equation is not fulfilled.

2.3. Loss of available energy in the real gas flow in the channel

2.3.1 Physical nature of the available energy losses




1
c1cp
c1t

2.3.2. Characteristics of the real flow in nozzles

A) ***Energy characteristics***

Energy conservation equation:

- for real flow $$\frac{c_1^2}{2} = \overline{h_0} - h_1$$

- for isentropic process $$\frac{c_{1t}^2}{2} = \overline{h_0} - h_{1t}$$

Difference between the kinetic energies of the theoretical and real flows:

$$\Delta H_c = \frac{c_{1t}^2}{2} - \frac{c_1^2}{2} = h_1 - h_{1t}$$

The loss of available energy

Relative magnitude of the loss is referred to as a **loss coefficient**

$$\zeta_c = \frac{\Delta H_c}{\overline{\overline{H_0}}}$$

$$\zeta_c = \frac{\Delta H_c}{\overline{H_0}} = \frac{\frac{c_{1t}^2}{2} - \frac{c_1^2}{2}}{\frac{c_{1t}^2}{2}} = 1 - \left(\frac{c_1}{c_{1t}}\right)^2$$

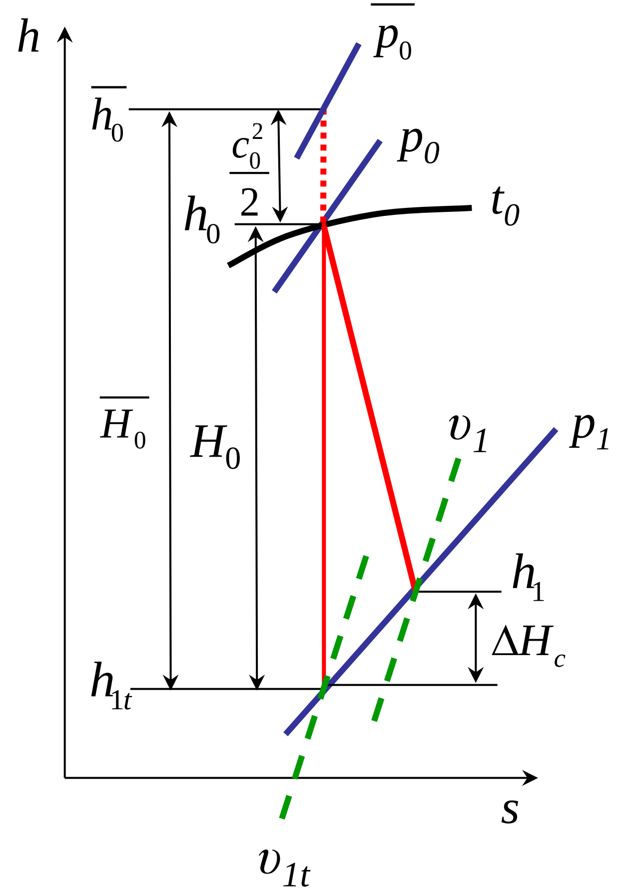
$$\overline{H_0} = \frac{c_{1t}^2}{2} \qquad \Delta H_c = \frac{c_{1t}^2}{2} - \frac{c_1^2}{2}$$

$$\varphi = \frac{c_1}{c_{1t}}$$

is nozzle velocity coefficient

$$\zeta_c = 1 - \varphi^2$$

$$\varphi = \sqrt{1 - \zeta_c}$$



ζ_c or φ is known (why)?

$$\Delta H_c = \zeta_c \overline{H_0}$$

$$h_1 = h_{1t} + \Delta H_c$$

Б) *Flow characteristics*

Known:

- the area of the nozzle outlet section (F_1);
- the initial parameters (p_0, t_0,c_0);
- final pressure (p_1).

Gas flow through the nozzle:

- for theoretical expansion

$$G_t = \frac{F_1 c_{1t}}{\upsilon_{1t}}$$

- For real expansion

$$G = \frac{F_1 c_1}{\upsilon_1}$$

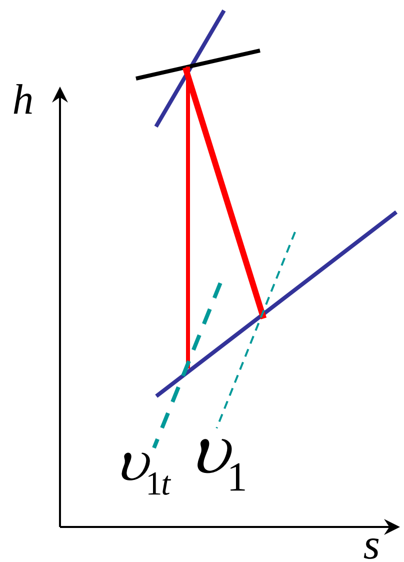
$$\mu = \frac{G}{G_t}$$

is nozzle flow coefficient

$$\mu = \frac{F_1 c_1}{\upsilon_1}\frac{\upsilon_{1t}}{F_1 c_{1t}} = \varphi\frac{\upsilon_{1t}}{\upsilon_1}$$

$$\upsilon_1 > \upsilon_{1t} \Rightarrow \mu < \varphi$$

It is true for a single-phase medium only!!!



Application of the notion

We know the theoretical expansion

What is the actual flow through the nozzle with a specified outlet area?

$$G = \frac{F_1 c_{1t}\mu}{\upsilon_{1t}}$$

Rarely occurring problem

What outlet area of the nozzle should be to allow the specified flow?

$$F_1 = \frac{G\upsilon_{1t}}{c_{1t}\mu}$$

The basis of the technique for turbine stage calculation