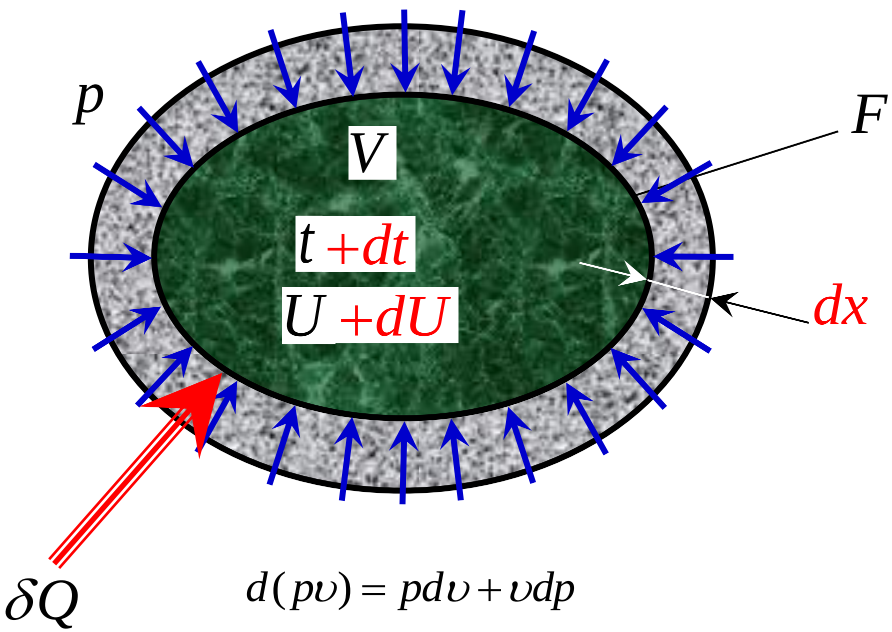
Change in the state of matter:

occurs as a result of the **thermodynamic process** under the impact of anything in the environment

since **thermodynamic properties** change

We consider thermal and mechanical interaction with the environment

The first law of thermodynamics (The Law of Conservation of Energy)



$pF = A$ force

$A \cdot dx = pFdx$ work (mechanical)

The Law of Conservation of Energy

$\delta Q = dU + pFdx$

$Fdx = dV$ change in the volume

$\delta Q = dU + pdV$ $| :G$ (we refer to a unit mass of the substance)

pdV expansion work

The supplied heat is spent on the change in the internal energy, and on the expansion work.

$d(p\upsilon) = pd\upsilon + \upsilon dp$

Physics:

$pd\upsilon$ expansion work

$d(p\upsilon)$ driving work

$pd\upsilon$ technical work (outward useful work

$$\delta q = du + pd\upsilon$$

$$\delta q = du + d(p\upsilon) - \upsilon dp$$

$$\delta q = d(u + p\upsilon) - \upsilon dp$$

$u + p\upsilon = h$ enthalpy

$$\delta q = dh - \upsilon dp$$

$$\delta q = dh - \upsilon dp$$

The supplied heat is spent on the **change in the enthalpy** and **mechanical work.**

Particular cases:

Isobaric process: $p = const$

$\delta q = dh;$ **the supplied heat** is spent only on the **change in the enthalpy**

The amount of the supplied heat is determined as:

$$q = \int_{нач}^{кон} dh; \qquad q_{p=const} = h_{кон} - h_{нач}$$

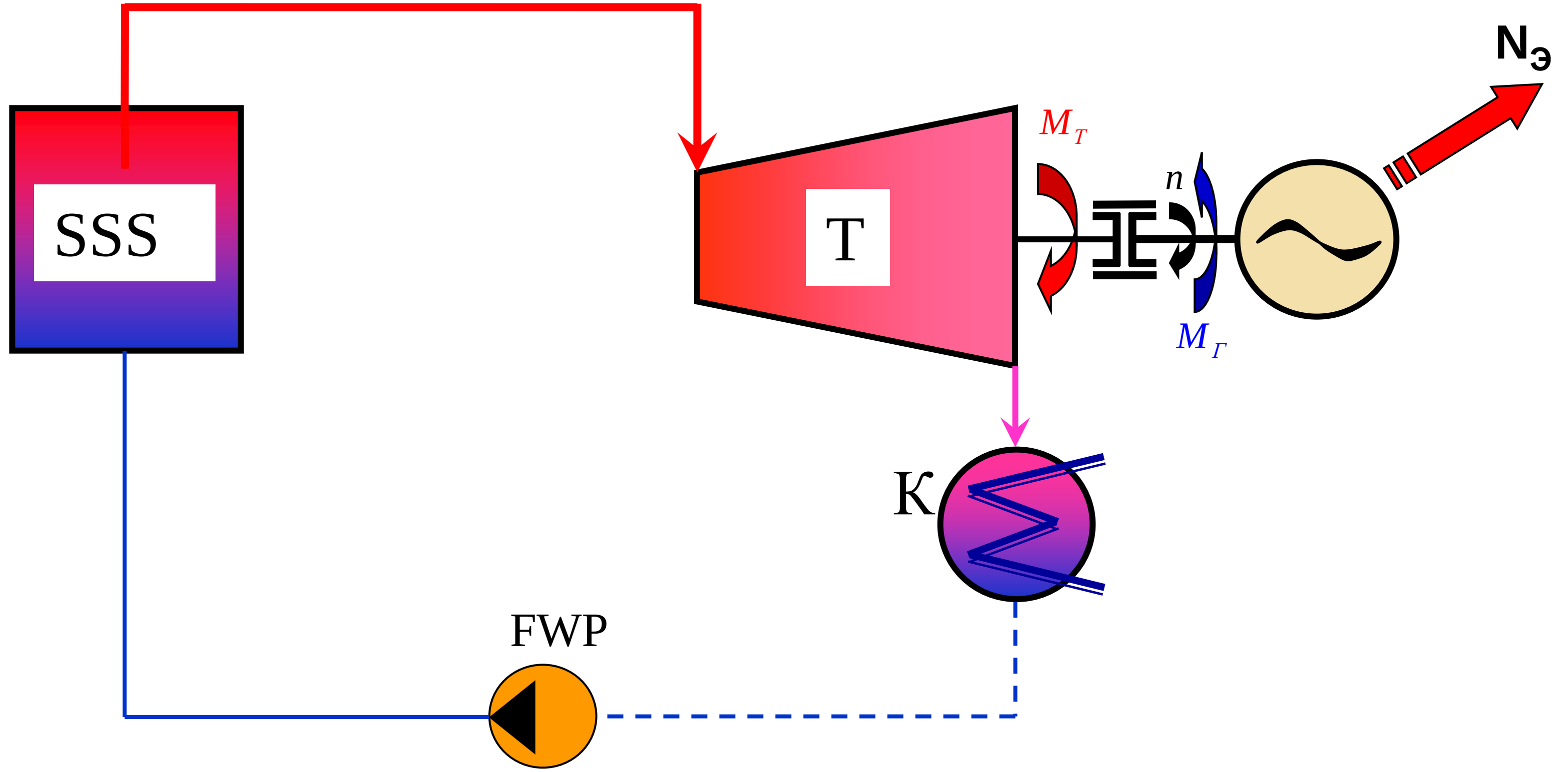
Adiabatic process: $\delta q = 0:$ *hence:* $ds = 0:$ т.е. s=*const*.

$dh = \upsilon dp$ **changed enthalpy** leads to **technical work**

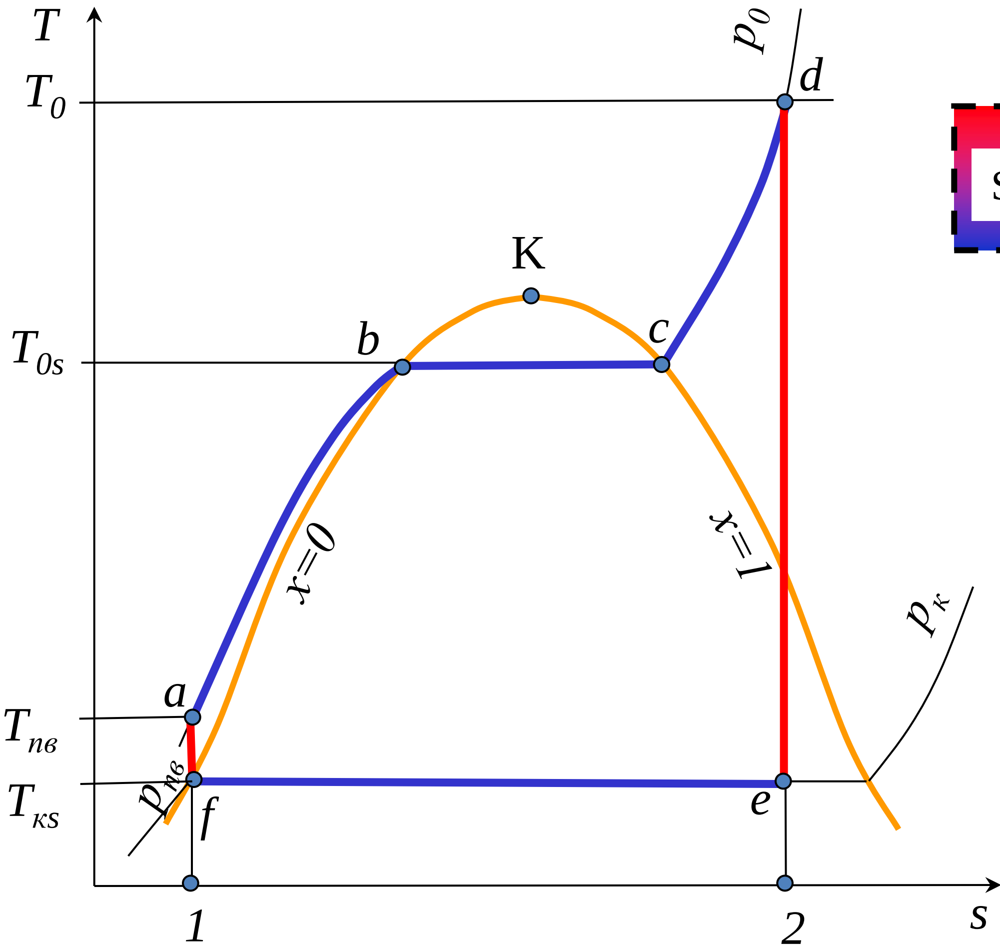
The amount of work obtained in the adiabatic process is determined as:

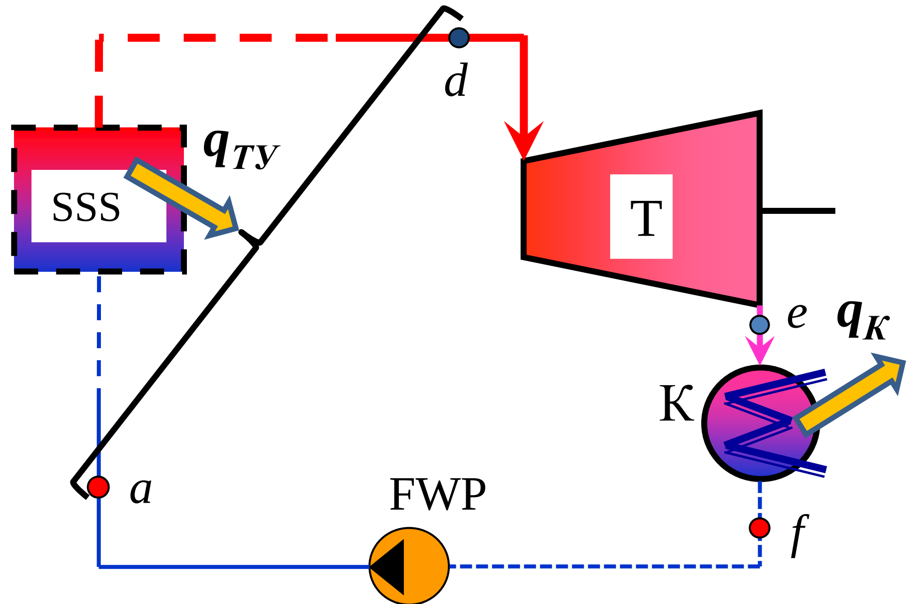
$$l_{mex} = \int_{нач}^{кон} \upsilon dp = \int_{нач}^{кон} dh = h_{кон} - h_{нач}$$

1. Steam Supply System and its EF



1.1. Cycle of a simple steam turbine





$$ds = \frac{\delta q}{T} \qquad q = \int_{н}^{к} T ds$$

The amount of the heat supplied to the turbine:

$$q_{ТУ} = пл.1abcd21 = h_0 - h_{пв}$$

The amount of heat extracted from the turbine:

$$q_К = пл.1fe21 = h_{кt} - h'_к$$

$$\mathbf{q_T > q_K} \quad \mathbf{?}$$

$h_a \rightarrow h_{пв}$ enthalpy of the feedwater [$=f(p_{fw}, t_{fw})$];

$h_d \rightarrow h_0$ enthalpy of the main steam [$=f(p_0, t_0)$];

$h_e \rightarrow h_{кt}$ enthalpy of the steam at the end of the theoretical expansion process in the turbine [$=f(s_0, p_к)$];

$h_f \rightarrow h'_к$ enthalpy of the saturated water at the condenser outlet [$=f(p_к, x=1)$];

The change in the parameters is due to the external effect on the working medium, in particular:

the initial parameters are set by: p_0, the feedwater pump due to work input in compression;
$t_{0,}$ the steam supply system due to heat supply;

final pressure: p_c, the condenser due to heat removal.

- Work that can be produced within a cycle per 1 kg of steam:

$$L = q_{TY} - q_K = \left(h_0 - h_{пв}\right) - \left(h_{кt} - h'_к\right)$$

$$L = \left(h_0 - h_{кt}\right) - \left(h_{пв} - h'_к\right) = L_{Tt} - L_H$$

where

$$L_{Tt} = \left(h_0 - h_{кt}\right)$$

p. d p. e

work made by 1 kg of steam in an ideal turbine called **available** work

$$L_H = \left(h_{пв} - h'_к\right)$$

p. a p. f

work in the pump

1.2. Absolute and relative efficiency factor (EF)

The **effectiveness** of energy conversion in technical devices is estimated through the **efficiency factor** (**EF**)

- *EF of an ideal cycle*

$$\eta_t = \frac{L}{q_{TY}} = \frac{q_{TY} - q_K}{q_{TY}} = \frac{(h_0 - h_{\kappa t}) - (h_{n\epsilon} - h'_\kappa)}{h_0 - h_{n\epsilon} \quad + h'_\kappa - h'_\kappa}$$

$$\eta_t = \frac{L}{q_{TY}} = \frac{(h_0 - h_{\kappa t}) - (h_{n\epsilon} - h'_\kappa)}{(h_0 - h'_\kappa) - (h_{n\epsilon} - h'_\kappa)}$$

$$\eta_t \approx \frac{L}{q_{TY}} \approx \frac{h_0 - h_{\kappa t}}{h_0 - h'_\kappa}$$

η_t ***absolute,*** or **thermal**, EF of an ideal cycle.

$$\eta_t = \frac{q_{TY} - q_K}{q_{TY}} = 1 - \frac{q_K}{q_{TY}}$$

Test 1

Set: p_0 = **(var)** *MPa*; $x_0 = 1$; $p_к = 4$ *kPa*

Find: 1. η_t with no account of the expansion work in FWP;

2. η_t considering the expansion work in FWP;

3. $x_к$ – *the final degree of dryness*.

p_0 **, МПа**	
3,0	- Самех
5,0	- Джошуа
7,0	- Лиджу
9,0	- Принсвилл
13,0	- Ашок
17,0	- Стэлла
22,0	- Гордон

Work in the pump:

$$l_{FWP} = \int_f^a \upsilon dp = \int_f^a dh = h_{пв} - h'_к = \upsilon_{cp}\left(p_0 - p_к\right)$$

$$\upsilon_{cp} \approx 0,00101$$

Test 2

Set: p_0 = **(var)** MPa; $t_0 = (t_s + 50)$ **C**; $p_к = 4\ kPa$

Find: 1. η_t with no account of the expansion work in FWP;

2. η_t considering the expansion work in FWP;

3. $x_к$ – *the final degree of dryness*.

p_0, МПа	
3,0	- Самех
5,0	- Джошуа
7,0	- Лиджу
9,0	- Принсвилл
13,0	- Ашок
17,0	- Стэлла
22,0	- Гордон

Work in the pump:

$$l_{FWP} = \int_f^a \upsilon dp = \int_f^a dh = h_{пв} - h'_к = \boxed{\upsilon_{cp}\left(p_0 - p_к\right)}$$

$$\upsilon_{cp} \approx 0{,}00101$$