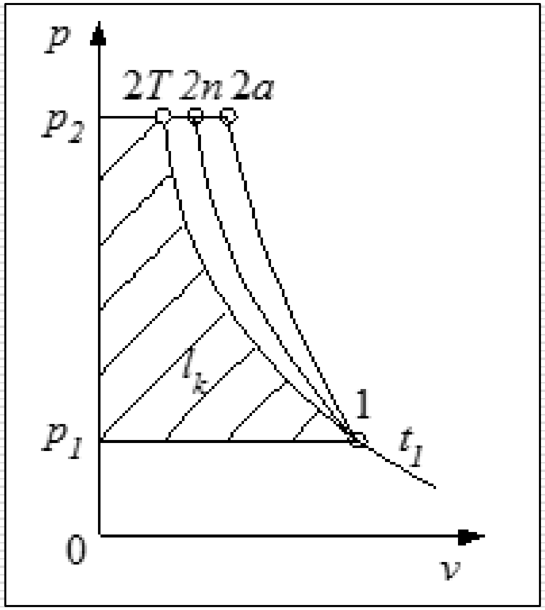
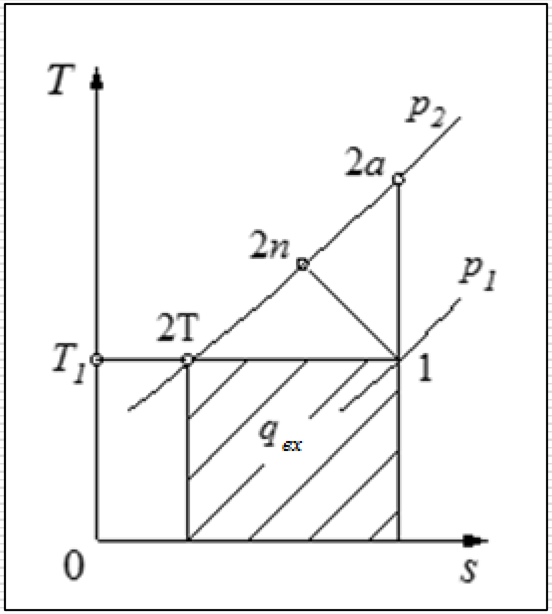
COMPRESSION IN COMPRESSORS

PROCESSES IN COMPRESSORS

The compressor is an energy machine or device to increase pressure (compression) and movement of gaseous substances



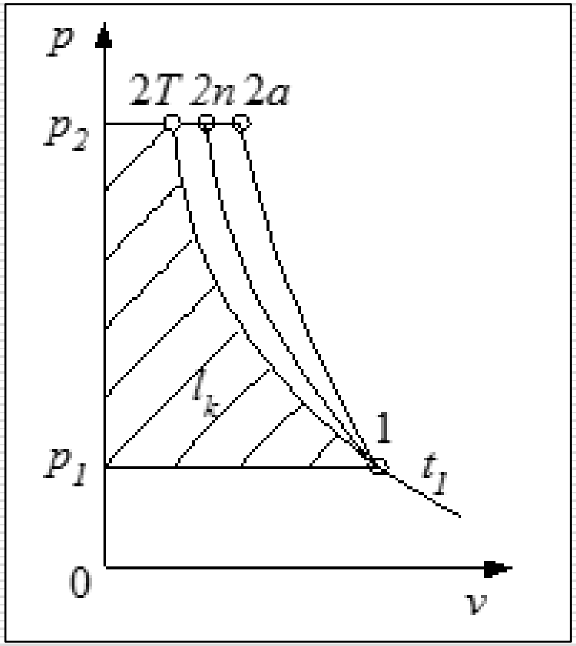


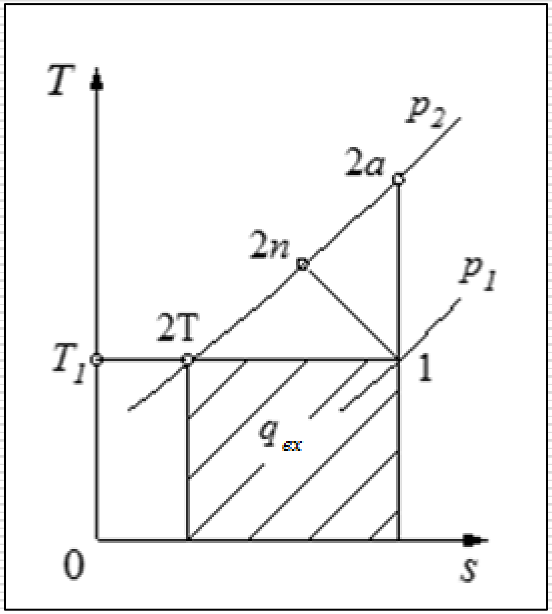
Isothermal, adiabatic and polytropic processes of gas compression in compressor in the pv– and Ts– diagrams

Isothermal compression

The process (*1-2T*)

Consumed work of compression «l_k» and the heat «q_{ex}» exhausted during compression are shown in shaded areas in the diagrams





Temperature of the compressed gas $T_2=T_1$

$$l = q_{ex} = RT_1 \ln \frac{p_2}{p_1}$$

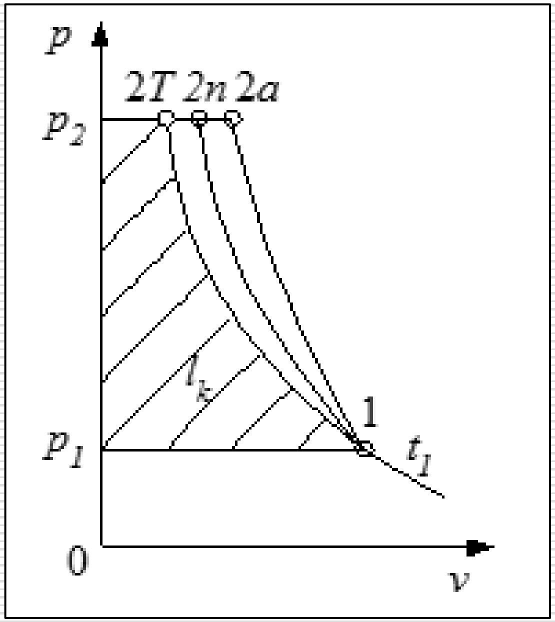
Isothermal compression

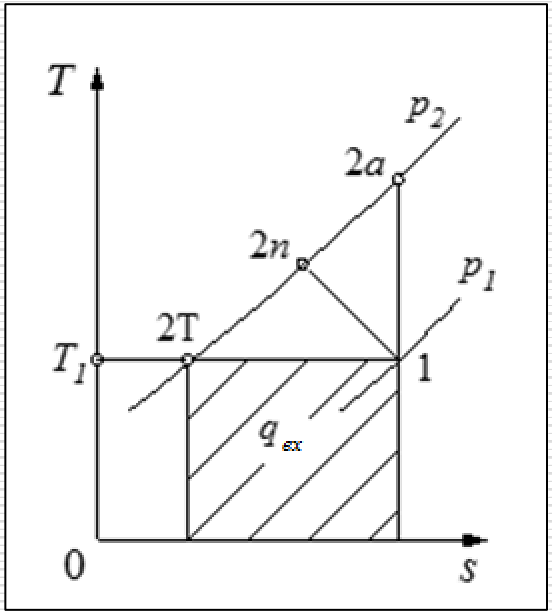
- Isothermal compression **of the cooled compressor** is not used, because it would require intensive cooling with infinitely large heat exchange surface, which is economically disadvantageous

Polytropic compression

The process (*1-2n*)

Polytropic compression with polytropic exponent is used in all cooling processes $1 < n < k$





$$l = \frac{n}{n-1} \cdot R \cdot (T_2 - T_1)$$

$$q_{ex} = c_v \cdot \frac{n-k}{n-1} \cdot (T_2 - T_1)$$

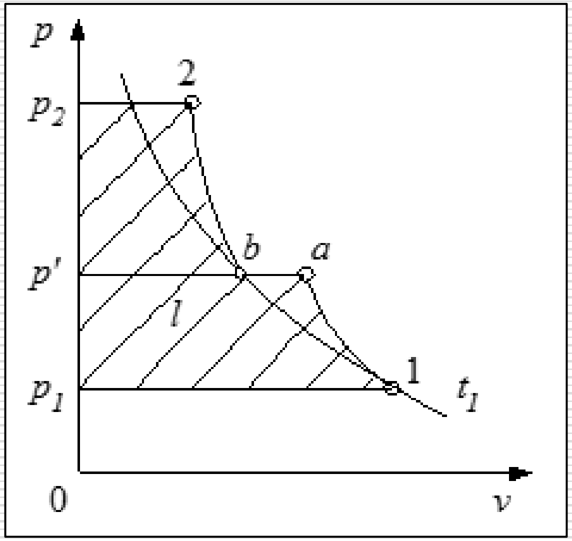
$$T_2 = T_1 \cdot \left(\frac{p_2}{p_1} \right)^{\frac{n-1}{n}}$$

Polytropic compression

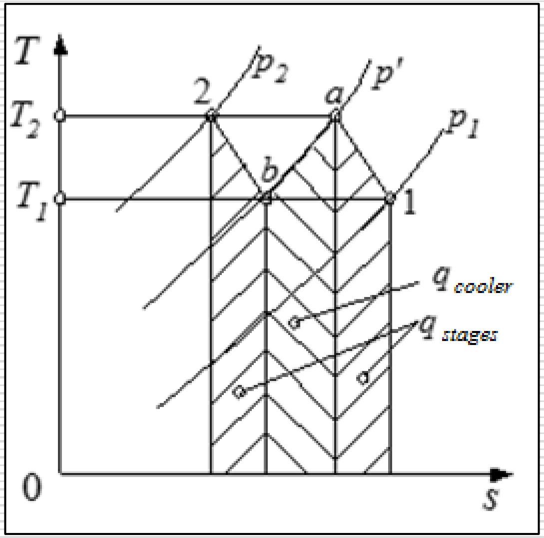
- The cost of work for polytropic compression is less than that for adiabatic compression , but bigger than that for isothermal compression
- The temperature of the compressed gas in polytropic process is less than that in adiabatic process, which increases the compressor reliability .

Multistage compression

When $\beta = \frac{p_2}{p_1} > 10$ multistage compression, gas cooling in intermediate coolers, is used in compressors.



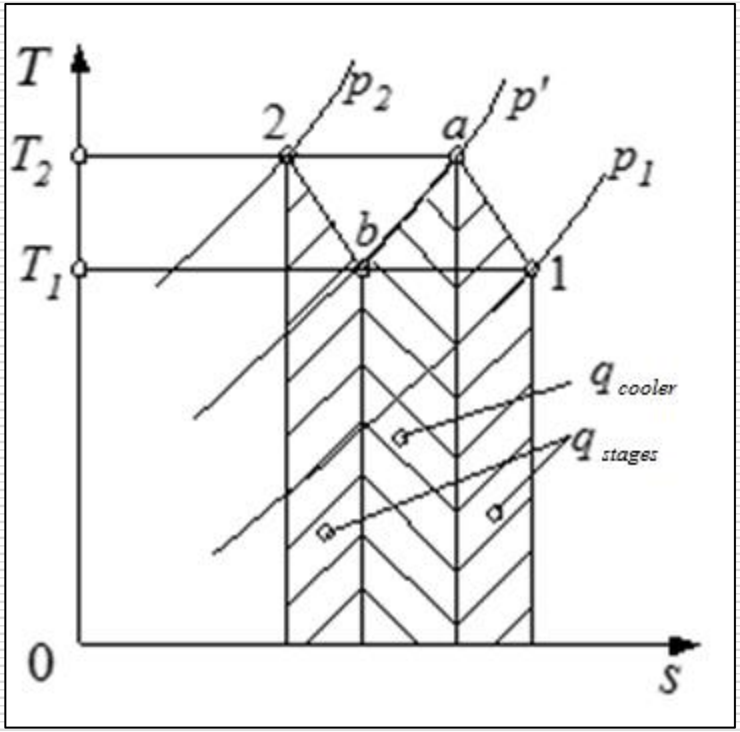
pv – diagram



Ts – diagram

The process of polytropic compression in a two-stage compressor

Multistage compression



$1 - a$, $b - 2$ are gas compression in the first and second stages of the compressor

$a - b$ is gas cooling

p_1, T_1 are the parameters of gas at the inlet

p_2, T_2 are the parameters of gas compression

p' is intermediate pressure

l is consumed work

q_{stages} is heat rejection to stages

q_{cooler} *is* heat rejection to cooler

Multistage compression of gas

- the degree of pressure increase of the stage are chosen equal
- the minimum work required for compression

$$\beta_1 = \beta_2 = \sqrt{\beta} = \sqrt{\frac{p_2}{p_1}}$$ for two-stage compression

$$\beta_1 = \beta_2 = \beta_3 = \sqrt[3]{\beta} = \sqrt[3]{\frac{p_2}{p_1}}$$ for three-stage compression

The equal pressure ratio in stages gives:

- equal temperature as the gas at the exit of each stage
- equal heat rejection in each cooler
- equal heat rejection in each stages

Multistage compression

For example, for *a two-stage* compressor :

$$l = 2 \cdot \frac{n}{n-1} \cdot R \cdot (T_2 - T_1)$$ → consumed work

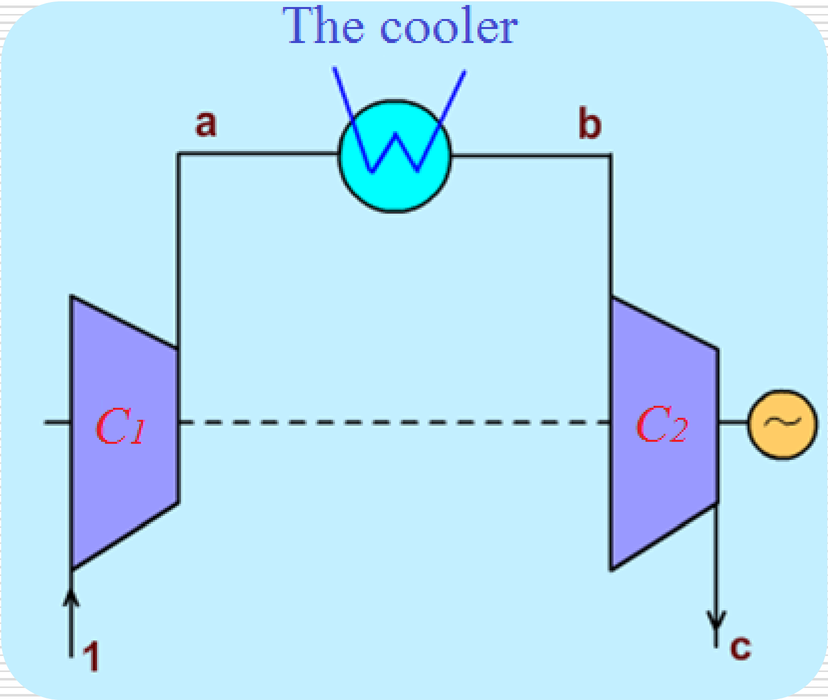
$$T_2 = T_1 \cdot \beta_1^{\frac{n-1}{n}}$$ → the outlet gas temperature of the first and second stages

$$q_{stages} = 2 \cdot c_v \cdot \frac{n-k}{n-1} \cdot (T_2 - T_1)$$ → the heat removal from the stages

$$q_{coller} = c_p \cdot (T_2 - T_1)$$ → the heat removal in the cooler

$$q_{ex} = q_{stages} + q_{cooler}$$ → The total heat removed from the compressor

Multistage compression

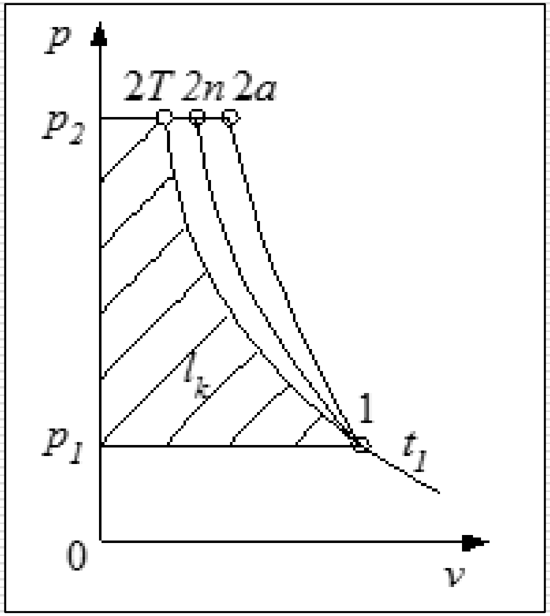


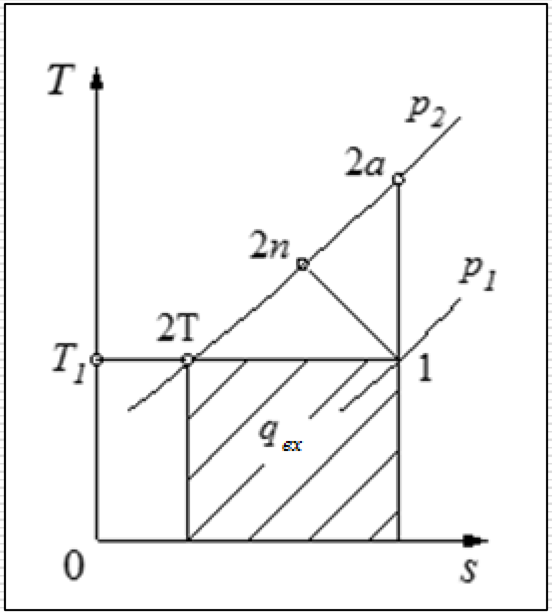
The scheme of two-stage compressor with intermediate Isobaric cooling air

Adiabatic compression

The process (*1-2a*)

Adiabatic compression is used in **uncooled compressors**





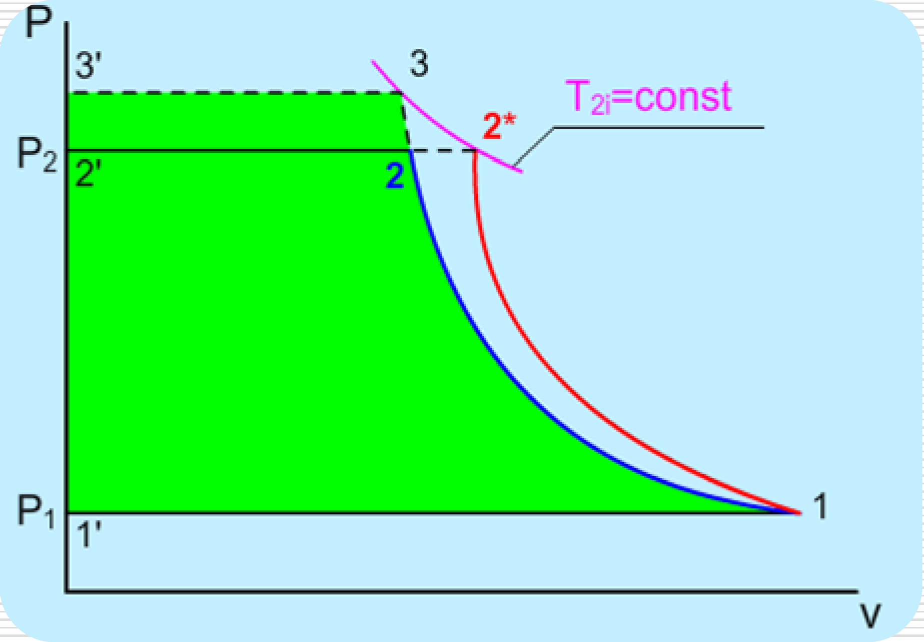
$$l = \frac{k}{k-1} \cdot R \cdot (T_2 - T_1)$$

$$q_{ex} = 0$$

$$T_2 = T_1 \cdot \left(\frac{p_2}{p_1} \right)^{\frac{k-1}{k}}$$

Irreversible compression

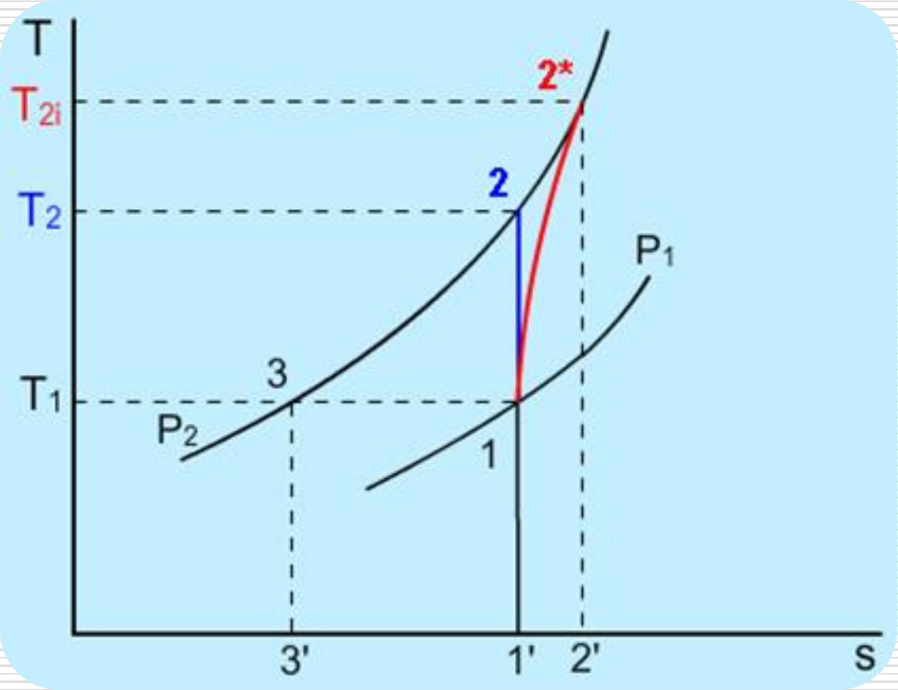
adiabatic processes of compression are considered to be most interesting



For ideal gas

- *1-2** is **irreversible** adiabatic compression of ideal gas
- the work of friction is defined as the square under the reversible adiabatic *2-3*
- the work for pressure changes in the flow during compression for an irreversible process *12** corresponds to square *133'1'1*
- *1-2* is **reversible** adiabatic compression of ideal gas

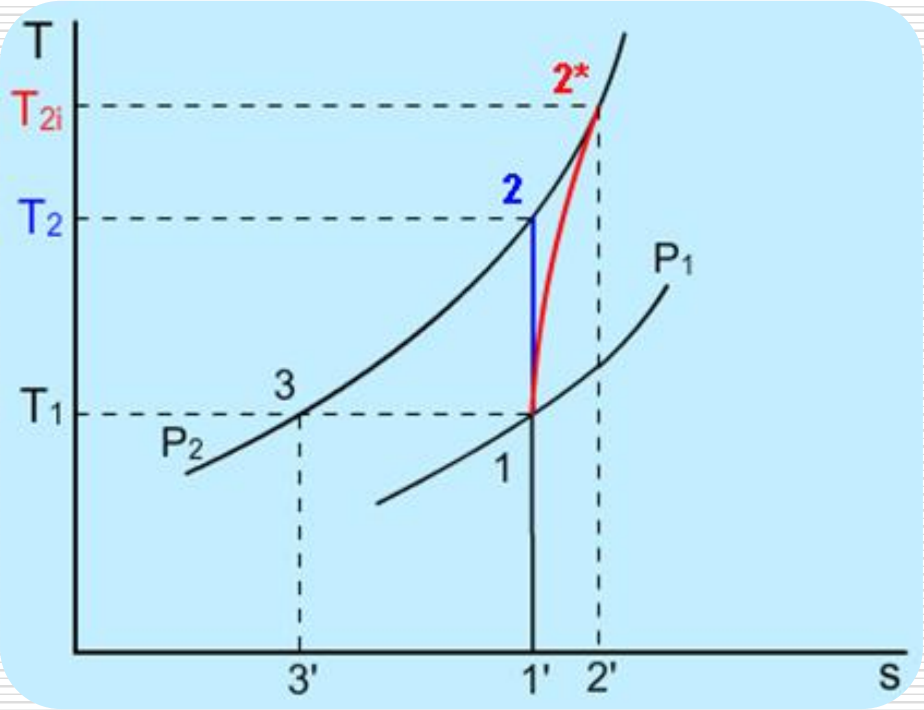
Irreversible compression



In the *Ts*–diagram, the work for pressure change in the adiabatic compression of an ideal gas

- for reversible process *12* is determined by square *21'3'32*
- for an irreversible process *12** s determined by square *2*2'1'2*

Relative internal efficiency of the compressor



Relative internal efficiency of the compressor

$$\eta_a = \frac{h_2 - h_1}{h_2^* - h_1}$$