



TOMSK POLYTECHNIC UNIVERSITY

COGENERATION IN NPP SCHEMES

MAIN FEATURES

- Advantages of cogeneration cycle
- Backpressure scheme of turbine
- Steam turbine with controlled steam bleed
- Comparison of different cycles
- Special features and specific requirements of NPP with district heating (cogeneration)

INTRODUCTION

- More than half of heat supplied to cycle into steam generator is discharged into condenser. Because temperature of discharged heat is close to temperature of outside air it's nearly impossible to use it.
- Heated circulation water from condenser has temperature 10÷30 °C and has no energetic value. To use it for district heating this temperature should be increased to 80÷180 °C. To achieve them the pressure in the steam bleed should be equal to 0,077-0,100 MPa.

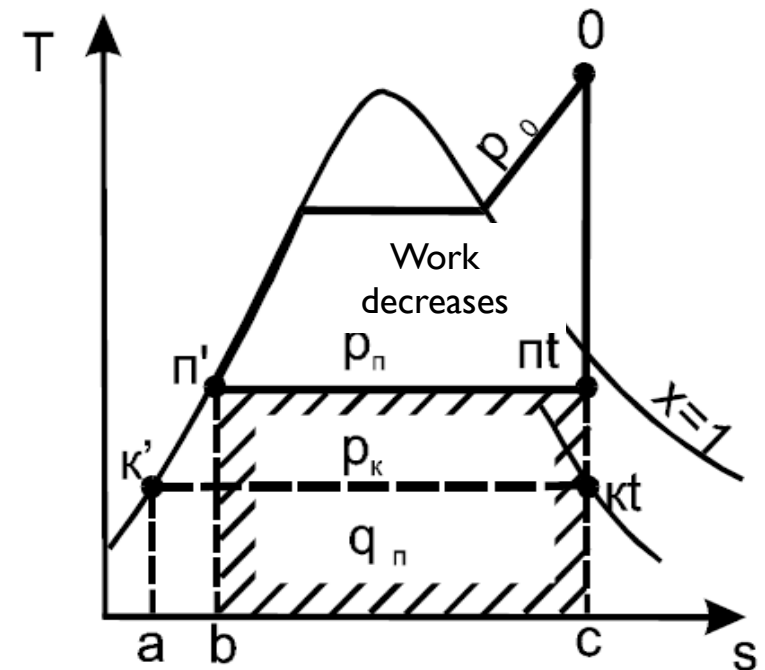
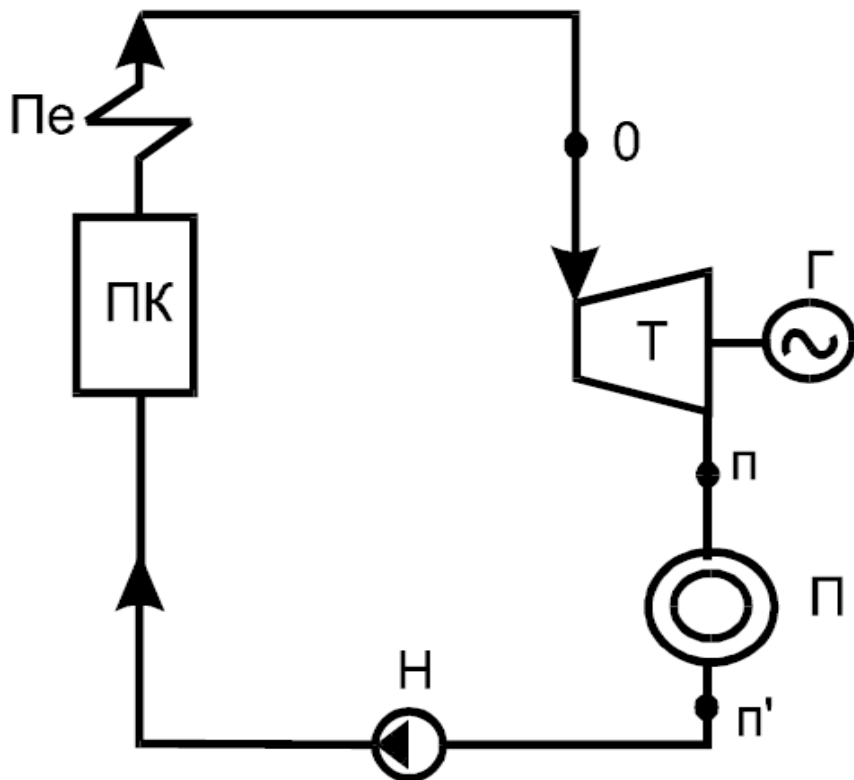
COGENERATION

- The high pressures at the outlet of turbine are reached by using so-called backpressure turbines.
- Theoretically, it would allow to utilize all heat of steam condensation. In this case, all steam would be used to produce positive work and, at the same time, obtain useful thermal energy.
- Such process of simultaneous production of electrical energy and useful heat for district heating purposes is called **cogeneration**.

Application of cogeneration results into massive increasing of NPP efficiency.

NPP WITH COGENERATION

- Power plant which produces both thermal and electrical energy is called CHP (combined heating and power).



ADVANTAGES AND DISADVANTAGES OF BACKPRESSURE TURBINE UNITS

Advantages:

- Thermal potential of steam at the outlet of turbine increases;
- Heat supplied to cold source increases insignificantly;
 - Such heat could be used for purposes of heating, industry etc.

Disadvantages:

- Internal electrical power of power unit decreases as well as thermal power:

$$N_i = G_{\Pi} \cdot (h_0 - h_{\Pi t}) \cdot \eta_{oi}$$

$$Q_{\Pi} = G_{\Pi} \cdot (h_{\Pi t} - h'_{\Pi})$$

- Load graphs of electricity and heat consumption are different;
- Electrical and thermal powers are strictly connected.

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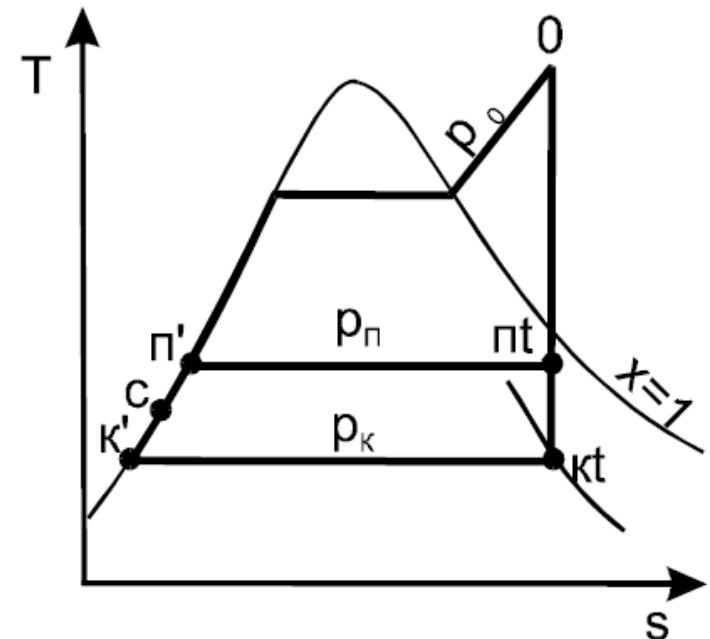
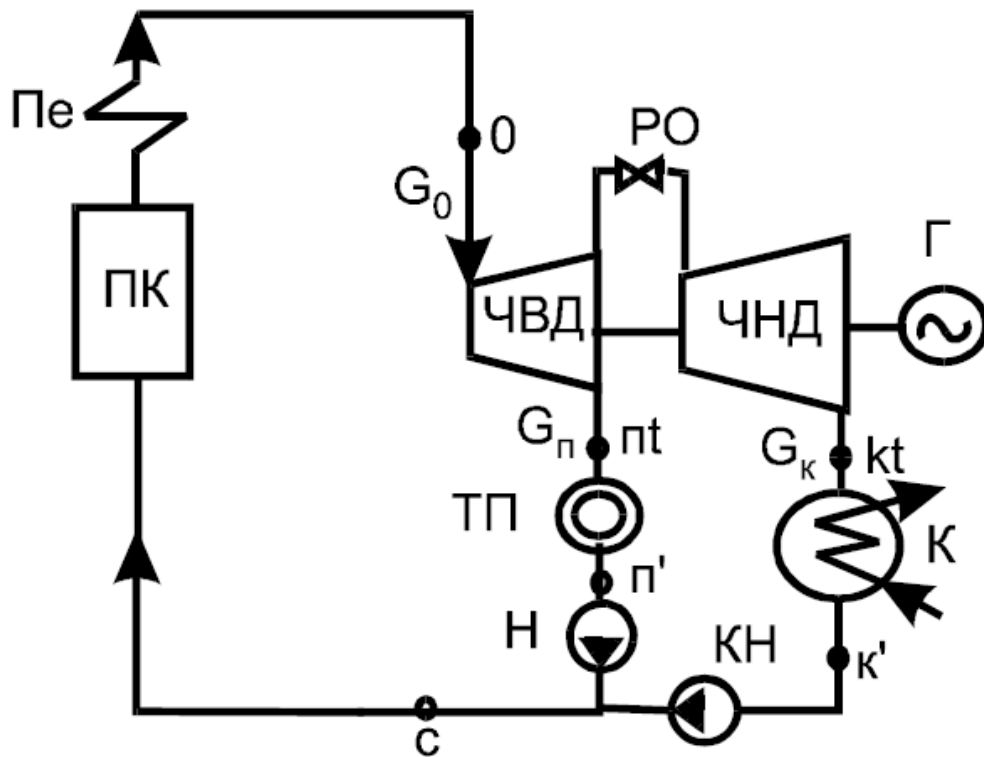
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BACKPRESSURE TURBINE WITH CONTROLLED STEAM BLEED

- To soften the connection between thermal and electrical power the controlled steam bleed is used.



ADVANTAGES AND DISADVANTAGES TURBINE WITH CONTROLLED BLEED

Advantages:

- Simplicity and smoothness of load regulation;
- Decreasing of connection between electrical and thermal loads.

Disadvantages:

- Complexity of NPP construction.

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HEAT APPLICATION COEFFICIENT

- Efficiency of CHP NPP is evaluated using heat application coefficient value by following equation:

$$\eta_{\text{H}} = \frac{l_{\text{H}} + q_{\text{H}}}{q_1}$$

- Theoretical value of η_{H} could reach 1. On practice its values varies in range 0,7÷0,8 due to:

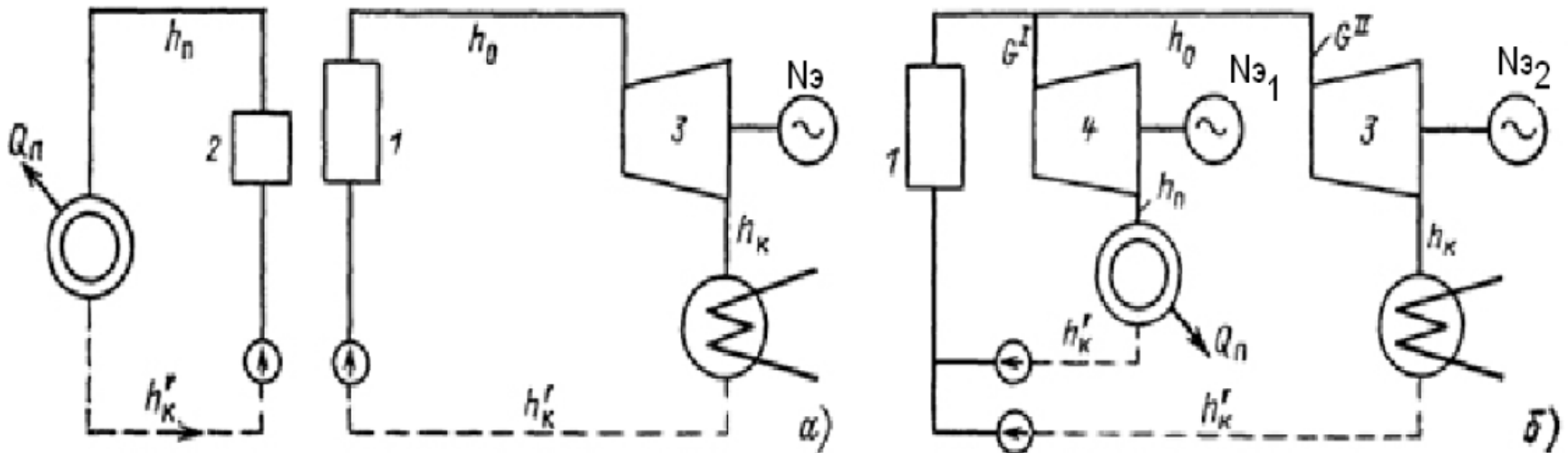
- Losses into:
 - Steam generator;
 - Mechanical devices;
 - Electrical generator;
- Energy spent on auxiliary needs of NPP.

COMPARISON OF NPP CYCLES WITH CO- AND SEPARATE GENERATION

- Specific production of electrical energy with thermal energy production – the most relevant factor of cogeneration efficiency.

$$\varepsilon = \frac{l_{\Pi}}{q_{\Pi}}$$

- Increasing of initial parameters results into increasing ε .



HEAT FLOW COMPARISON

- Heat flow at separate generation:

$$\begin{aligned} Q^{PA3D} &= G^{PA3D} \cdot (h_0 - h'_K) + Q_{II} = \\ &= \frac{N_i}{H_i^{II}} \cdot (h_0 - h'_K) + Q_{II} = \frac{N_i}{\eta_i} + Q_{II} \end{aligned}$$

- The flow rate at turbines with backpressure and condenser GI and GII.
- The power and steam flow rate through condense turbine will be:

$$N_i = N_i^I + N_i^{II} = G^I \cdot H_i^I + G^{II} \cdot H_i^{II}$$

$$G^{II} = \frac{N_i}{H_i^{II}} - G^I \cdot \frac{H_i^I}{H_i^{II}}$$

HEAT FLOW COMPARISON

- Heat flow at cogeneration:

$$\begin{aligned} Q^{KOMB} &= (G^I + G^{II}) \cdot (h_0 - h'_K) = \\ &= \left[\frac{N_i}{H_i^{II}} + G^I \cdot \left(1 - \frac{H_i^I}{H_i^{II}} \right) \right] \cdot (h_0 - h'_K) \end{aligned}$$

- The power and steam flow rate through condense turbine will be:

$$G^I = \frac{Q_{II}}{h_{II} - h'_K}$$

$$Q^{KOMB} = \frac{N_i}{\eta_i} + Q_{II} \cdot \frac{h_0 - h'_K}{h_{II} - h'_K} \cdot \left(1 - \frac{H_i^I}{H_i^{II}} \right)$$

ECONOMY OF COGENERATION

- Economy of thermal energy:

$$\Delta Q = Q^{\text{разд}} - Q^{\text{комб}} = Q_n \frac{H_i^1}{h_{\text{II}} - h_{\text{K}'}} \left(\frac{1}{\eta_{\text{II}}} - 1 \right)$$

- Cogeneration **always** results into increasing of NPP efficiency.

Features of NPP with district heating:

- Steam and water should have no radioactive contaminants.
- The distance between NPP and consumer should satisfy all requirements.
- The termination of heating during fuel reloading is unacceptable.

NPP is economically and technically justified at heat consumption rate

5000-7000 GJ/h.

FEATURES OF COGENERATING NPP

Special regime of turbine operation is applied:

- The steam flow rate is maximal and as constant as possible.
- The electrical power produced is changed according to thermal load.
- Reactors of any type could be used for district heating.
- For 1-circuit NPP the additional network water contour is introduced.
- For 2- and 3-circuit NPP additional contour is not needed but preferable due high cost of water preparation.
- For gas-cooled reactor even water of 2nd circuit could be used.

FEATURES OF COGENERATING NPP

To decrease costs of NPP with district heating:

- The diameter of network water pipes could be reduced:
 - By reducing water flow rate;
 - By increasing water temperature;
 - By increasing bleed steam pressure;
- The uncontrolled bleeds for heat consumer;
- The load could be controlled by steps using uncontrolled bleeds.



THANK YOU FOR YOUR ATTENTION