OUTLET PARAMETERS OF STEAM ON NPP

NUCLEAR POWER PLANTS, TOMSK, 2018

MAIN FEATURES

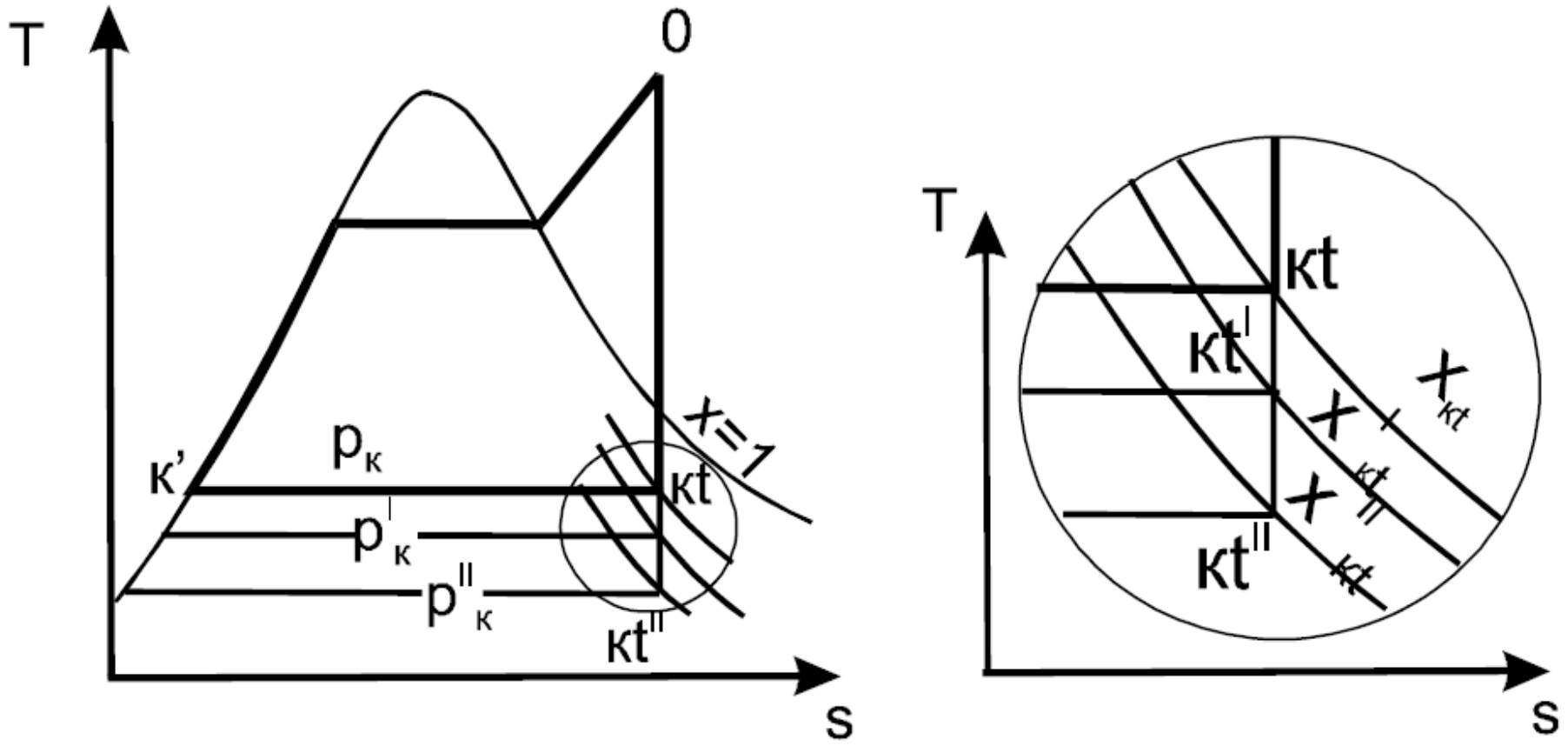
- **Effect of outlet steam parameters on thermal efficiency of NPP**
- **Optimal technic-economic values of p_k**

Thermal efficiency of NPP:

$$\eta_t = 1 - \frac{T_k}{T_0}$$

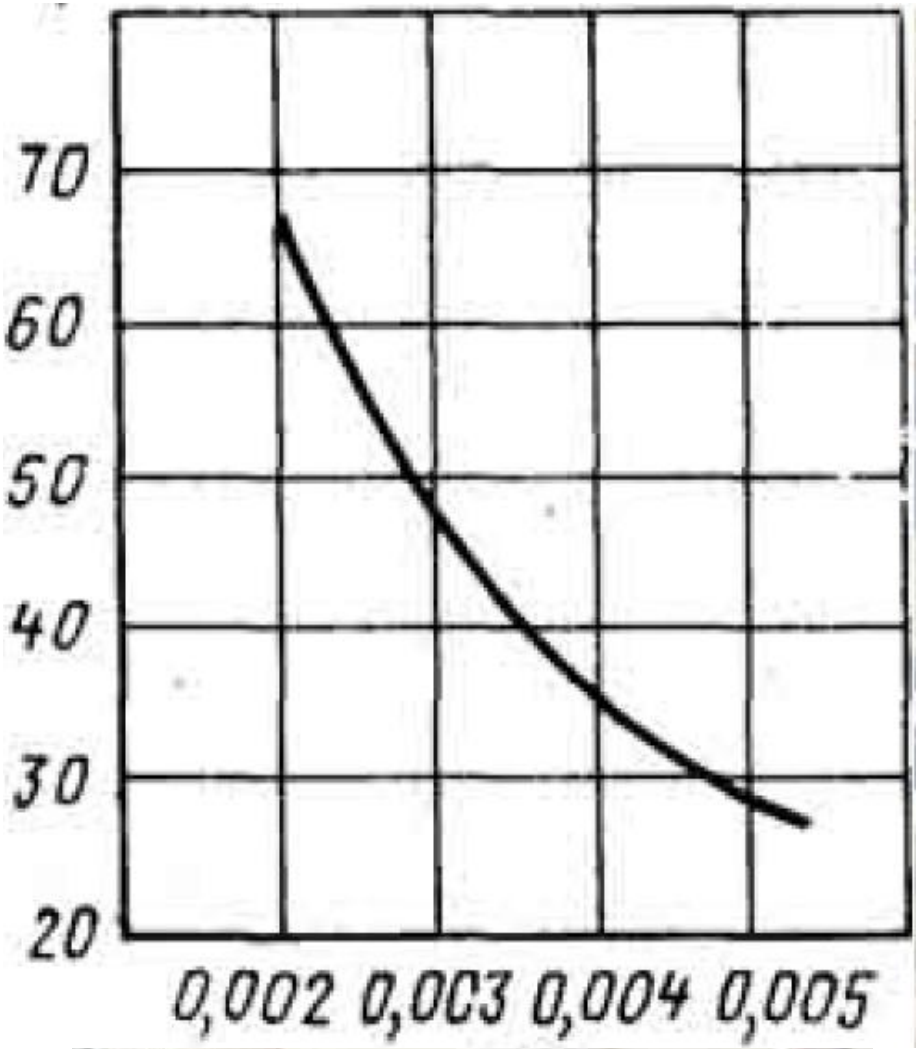
Even insignificant decreasing of Tk results into large increasing of thermal efficiency.

EFFECT OF OUTLET PRESSURE



$$p_к^{II} < p_к^{I} < p_к \qquad x_{кt}^{II} < x_{кt}^{I} < x_{кt}$$

DEPENDENCE OF EFFICIENCY ON OUTLET PRESSURE

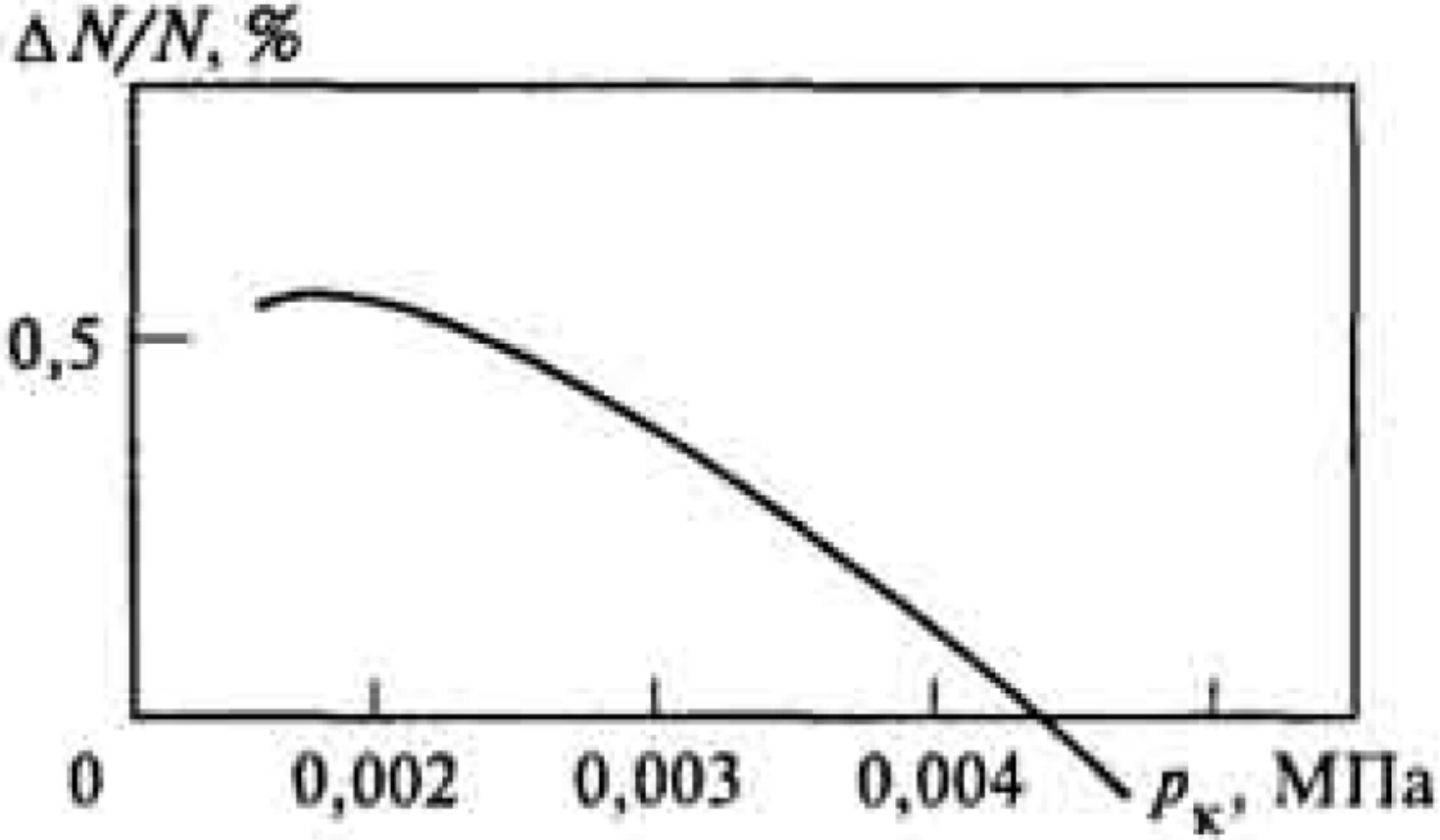


Decreasing p_k results in:

- **Increasing humidity and velocity of outlet steam;**
- **Increasing losses in turbine;**
- **Decreasing internal relative efficiency of turbine;**
- **Increasing of volumetric steam flowrate into condenser.**

Decreasing pressure from 4,5 kPa to 3,5 kPa results into increasing of efficiency by 1,5 % and increasing outlet steam specific volume from 31,7 to 40,2 m^3/kg.

DEPENDENCE OF TURBINE POWER ON OUTLET PRESSURE



The optimal outlet pressure exists. It connected to fact that at some value of outlet pressure the cross-section becomes critical. When ability to increase steam velocity of tempered nozzle is completed. In this case real heat flow doesn't change and steam expands after the turbine stage.

OPTIMAL TECHNIC-ECONOMIC ANALYSIS

Technic-economic analysis results into higher values of optimal outlet steam pressure (condenser pressure) in comparison with theoretically optimal.

One of reasons is connection between condenser pressure and temperature of cooling water:

$$t_n = t_{w1} + \frac{h'' - h'}{c_p \cdot m} + \delta t = t_{w2} + \delta t$$

t_{w1} – temperature of cooling water; t_{w2} – temperature of cooling water after condenser; m – cooling ratio; δt – temperature difference between cooling water and condensing steam.

CONDITIONS OF OPTIMAL TECHNIC-ECONOMIC ANALYSIS

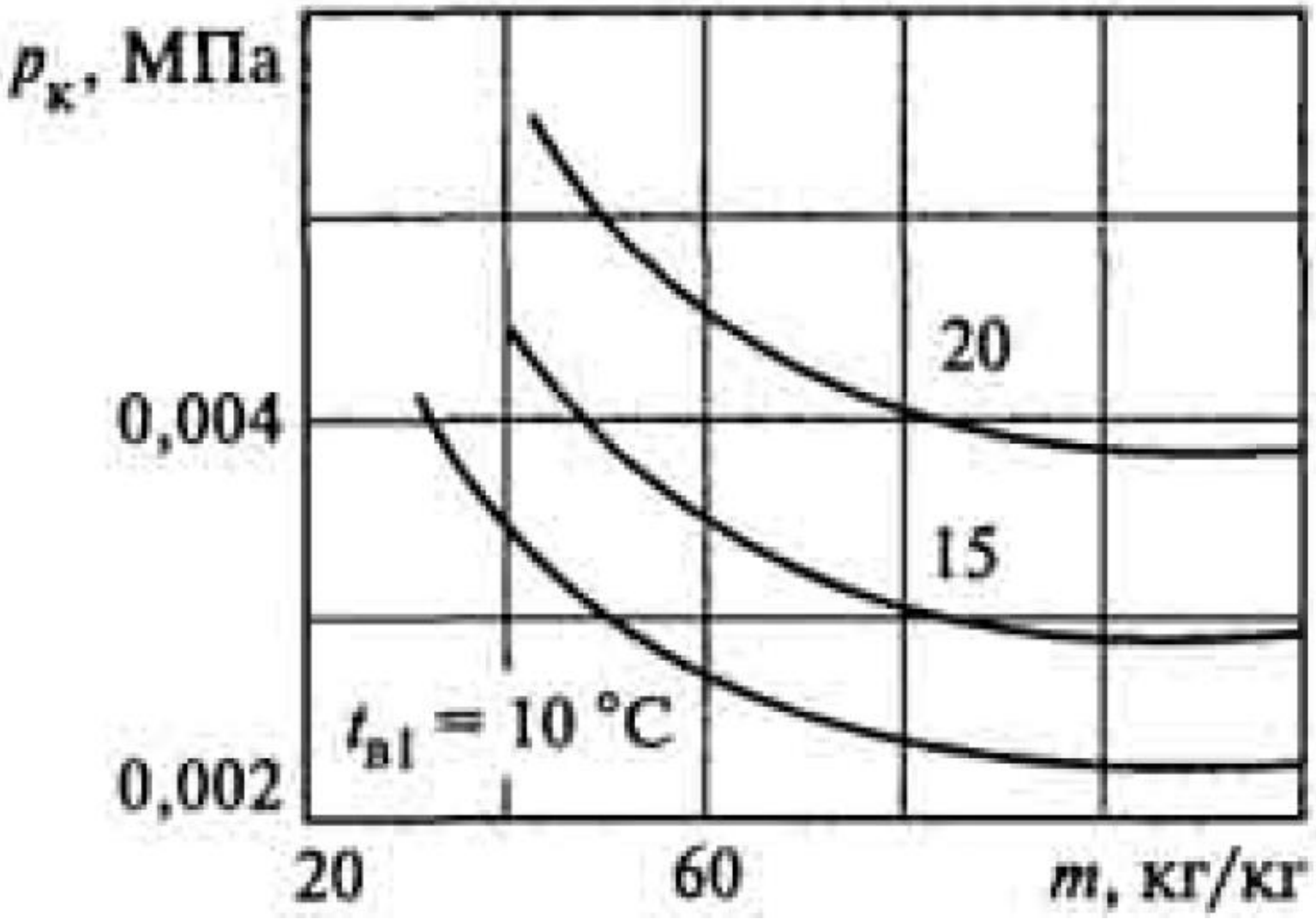
The values of pressure in condenser close to theoretically optimal is reached at following conditions:

- **Low values of cooling water temperature t_{w1};**
- **High cooling ratios m;**
- **Low values of temperature difference between cooling water and condensing steam δt.**

Fulfilling these conditions results into high cooling water flowrate and corresponding electrical power spend on pumping as well as high capital costs.

If additional power of turbine is less then additional spending the optimal pressure values becomes higher.

RANGE OF OPTIMAL PARAMETERS



EFFECT OF OTHER PARAMETERS

The lower temperatures of cooling water results into:

- **Lower capital costs of cooling system;**
- **Lower exploitation costs;**
- **Lower optimal condenser pressure values.**

Optimal pressure depend on fuel price: lower price - higher pressure.

The same refers to power and exploitation costs of station: higher power and costs result into lower optimal pressure.

The last parameter is rotation rate: for plants with high frequency the flow velocity is higher and outlet pressure is higher.

OPTIMAL OUTLET PRESSURE

For power plants on organic fuel optimal values are situated in range 3,0 ÷ 4,5 kPa.

NPP are considered to use cheap fuel and have relatively high power in comparison with other power plants.

NPP in Russia and abroad are situated in areas with relatively high temperature of outside air. For 1 and 2-circuit NPP the steam flowrates are high in comparison with power plants on superheated steam. To reach matching pressures the higher costs should be taken.

Taking into account presented factors the optimal outlet pressure in found to be in range 4,5 ÷ 5,5 kPa. For NPP with water cooling the condenser pressure is chosen to be higher than 4,0 kPa (even for 3-circuit plants).