TOMSK POLYTECHNIC UNIVERSITY

SEPARATION AND INTERMEDIATE HEATER NPP

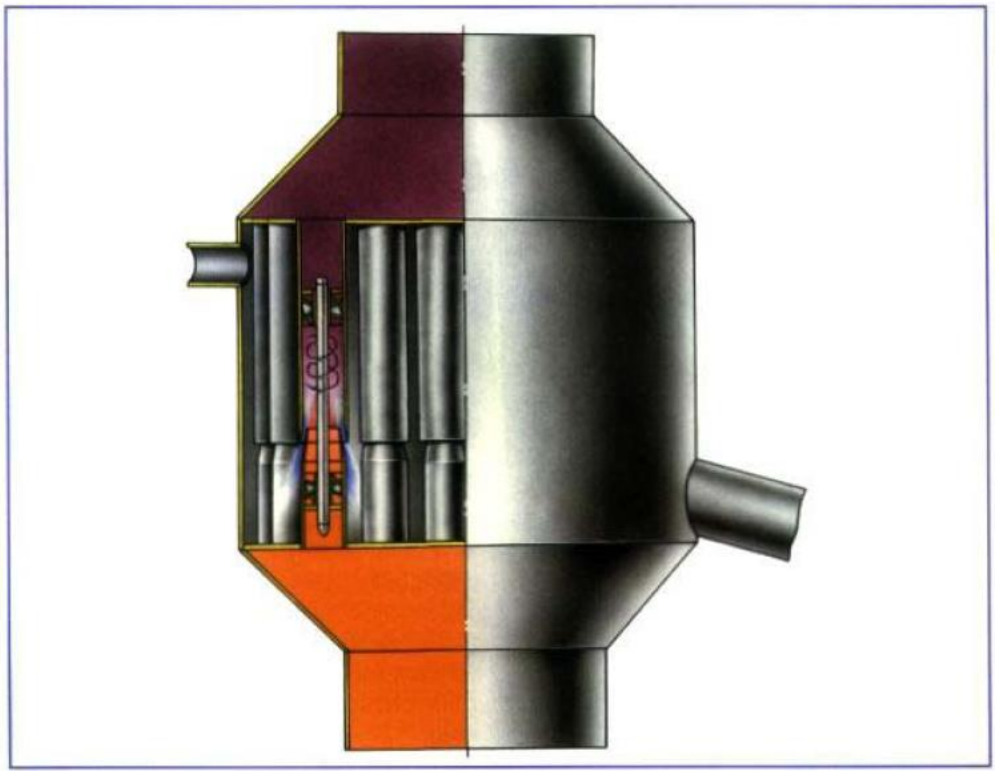
MAIN FEATURES

- Definition
- Intermediate separation of steam
  - Vortex (centrifugal) separator;
  - Wire mesh separator;
  - Chevron separator;
- Intermediate superheating of steam
  - By number: one- and two-stage;
  - By type: horizontal and vertical.

CENTRIFUGAL SEPARATOR

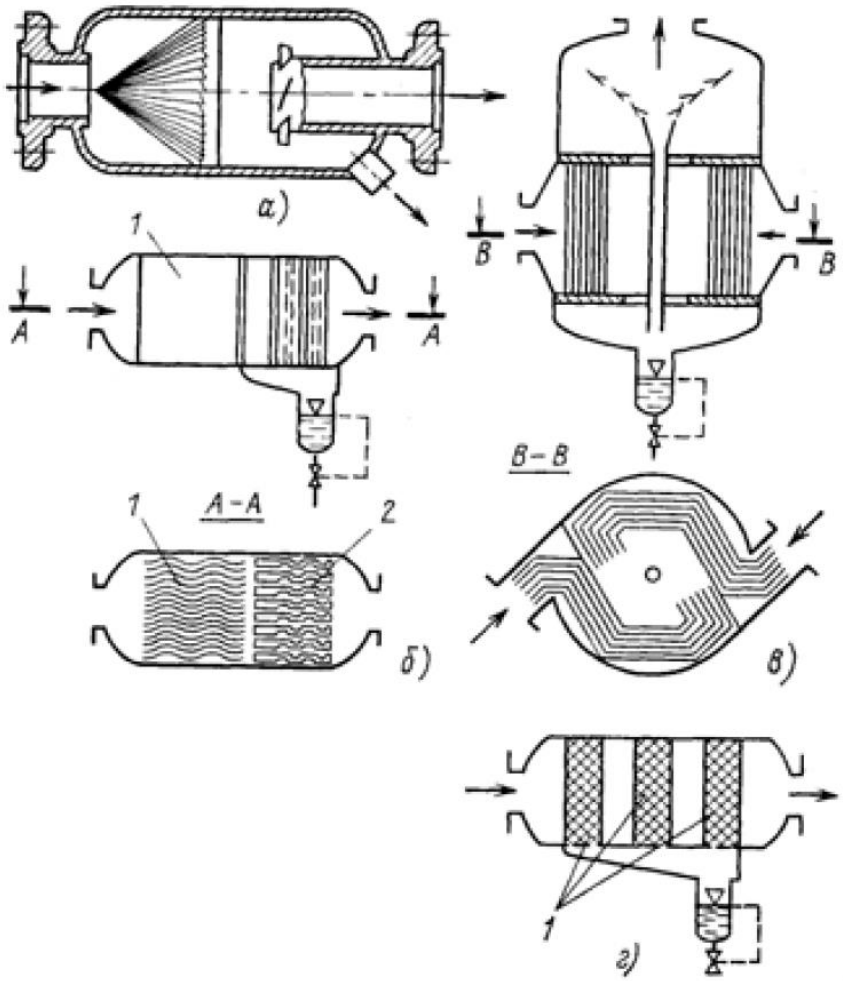
- Centrifugal separator – separator which applies the effect of higher inertia of water droplets during centrifugal movement of saturated steam.
- Construction: cylinder with nozzles or blades which supply centrifugal movement of steam.
- **Advantages:** low pressure drop and easiness of water removal.
- **Disadvantages:** large size and intermediate efficiency.

Centrifugal separators for turbine units of nuclear power plants



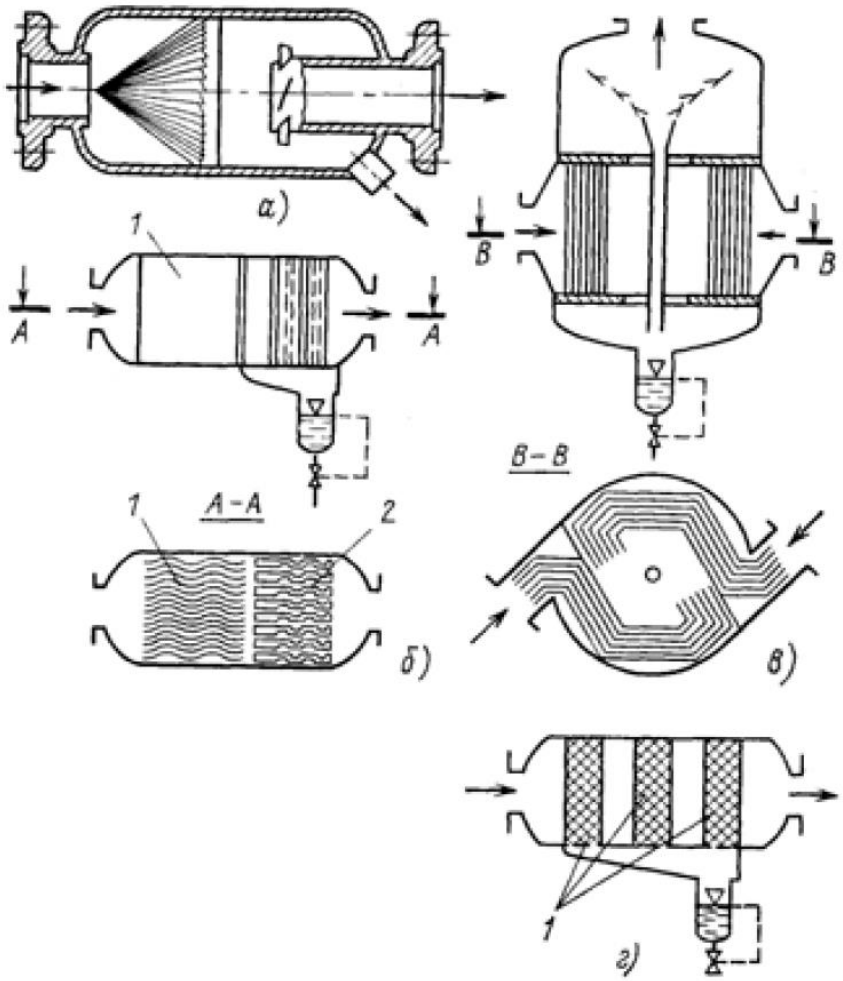
WIRE-MESH AND CHEVRON SEPARATOR

- Wire-mesh separator –applies the property of water droplets to adhere to solid surface.
- Chevron separator – applies inertia of water droplets into saturated steam during flow through curved surfaces.
- **Advantages:** small size and high efficiency.
- **Disadvantages:** complexity of water removal and high pressure drop.



WIRE-MESH AND CHEVRON SEPARATOR

- Wire-mesh separator –applies the property of water droplets to adhere to solid surface.
- Chevron separator – applies inertia of water droplets into saturated steam during flow through curved surfaces.
- **Advantages:** small size, simplicity of construction and high efficiency and reliability.
- **Disadvantages:** complexity of water removal and high pressure drop.



SEPARATION EFFICIENCY EVALUATION

- To evaluate efficiency of separation the separation coefficient is used:

$$\eta_{cen} = \frac{y_0 - y_1}{y_0(1 - y_1)}$$

y_0 and y_1 are steam humidity on the inlet and outlet of separator.

- Increasing of y by 1% results into:
  - Decreasing of NPP efficiency by 0,3-0,4 %;
  - Danger of destruction of blades and rotor;
  - Decreasing efficiency of steam superheater;
  - Decreasing of thermodynamic efficiency.
- The following parameters of separators are used on real NPP:

y_1=0,005-0,010; η_{sep}=0,91-0,99 (η_{sep}=0,98-0,99 at y_0=0,10-0,15 are used)

CONSTRUCTIONAL REQUIREMENTS TO SEPARATORS

Increasing of pressure losses in separator by 1 % ($\Delta p/p=0,01$) result into decreasing of thermal efficiency of NPP by 0,10-0,15 %.

Taking it into account the following requirements could be formulated:

- Moderate dimensions and mass;
- Even distribution of steam velocity field;
- High efficiency of separation;
- Low hydraulic resistance;
- Optimal configuration and size of chevron separator:
  - Smoothness of channel;
  - Large number of turns on 90°.

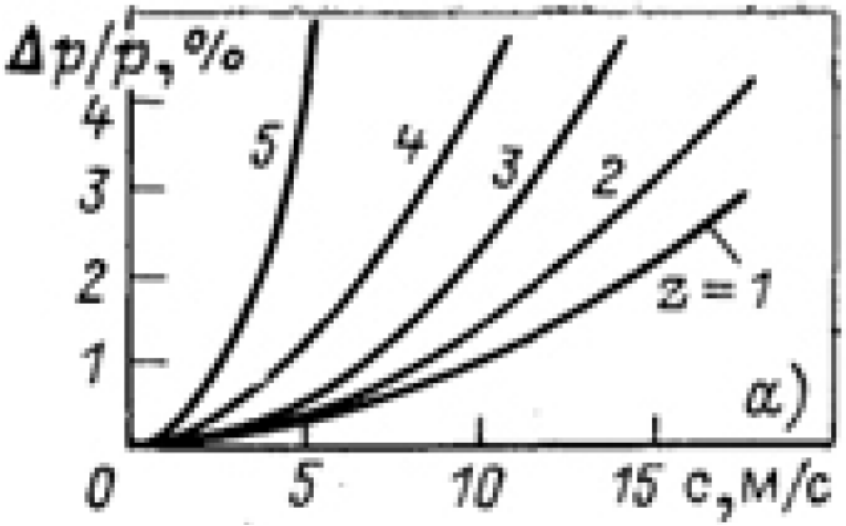
ROLE OF STEAM VELOCITY

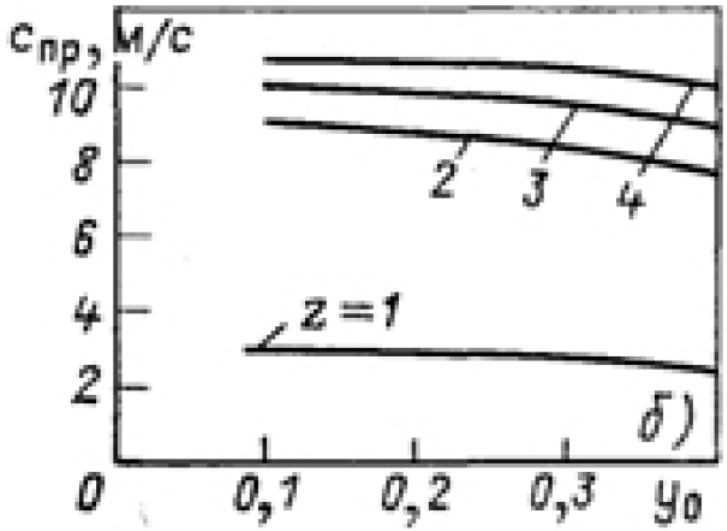
- Increasing steam velocity results into lower dimensions of separator.
- Reaching critical velocity of flow results into carrying away the water membrane and significant decreasing of separation efficiency.
- Increasing velocity below critical results into increased efficiency of deposition and lower humidity on the outlet.

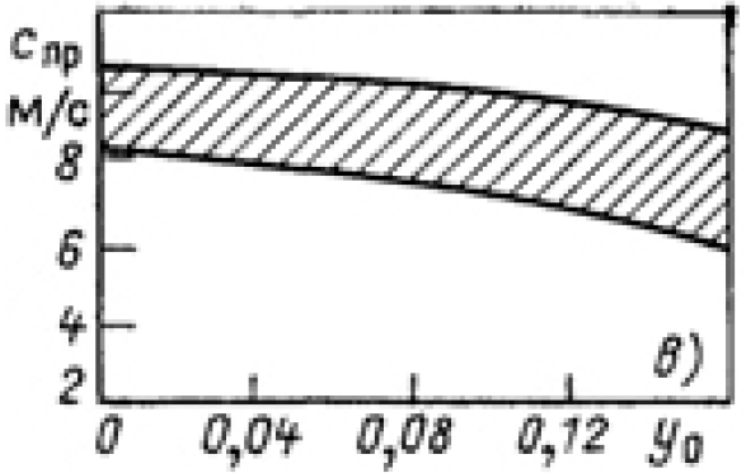
The velocity of saturated steam into separator should be close to critical but lower at all regimes.

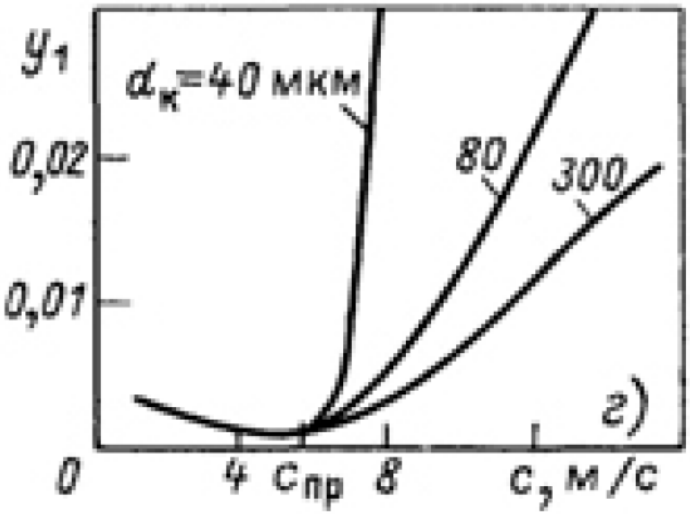
- While critical velocity c_{cr}=4-12 m/s the actual velocity is c=4-6 m/s.

PROPERTIES OF SEPARATORS



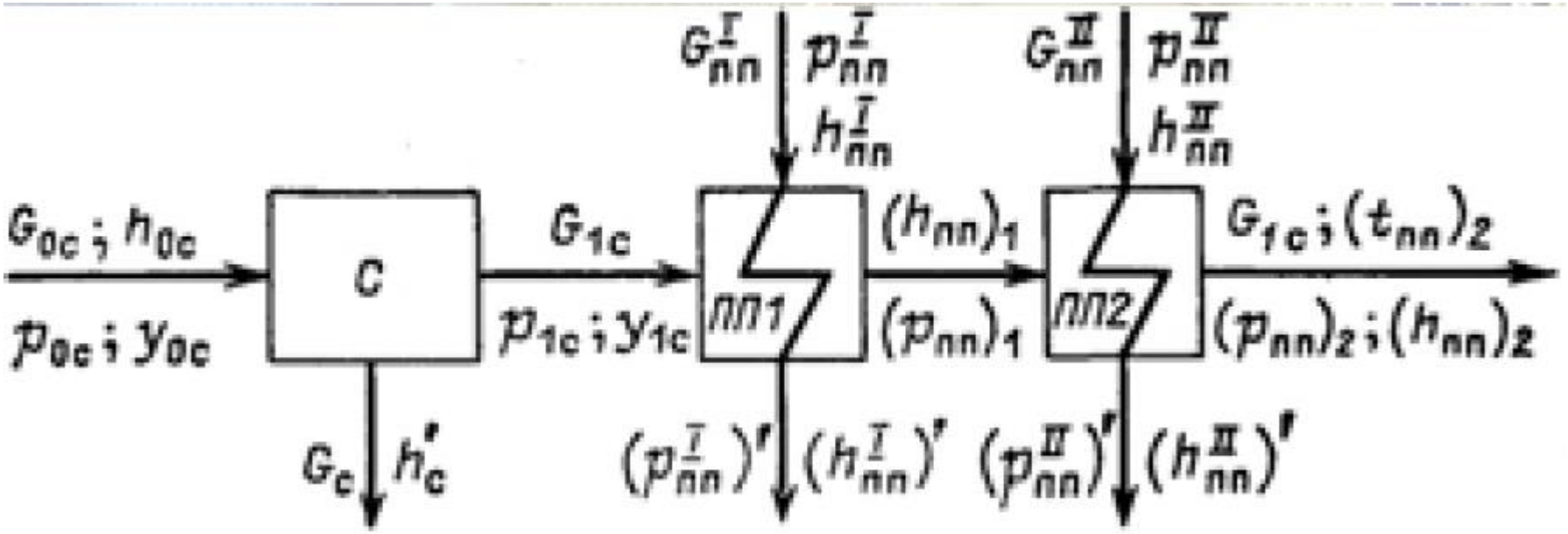






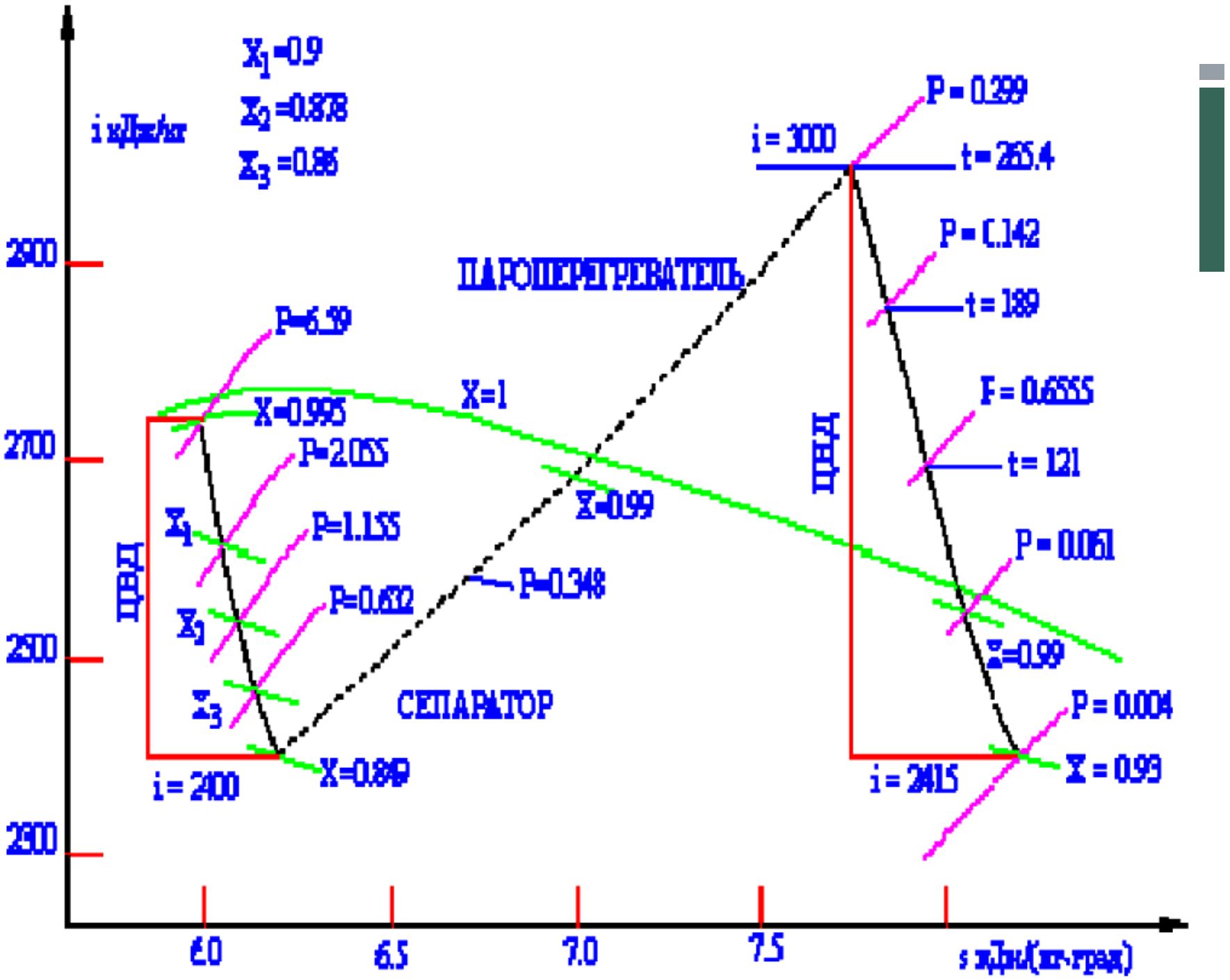
PROPERTIES AND CALCULATION OF SEPARATORS

- Pressure losses of main flow in real equipment Δp=2,5-3 % of pressure before it.
- Pressure losses in CHP line before separator are Δp_{in}=0,5-0,7 %.
- The flow rate of steam after separator could be defined as follows:



INTERMEDIATE SUPERHEATER

- Steam superheating is realized into heat-exchangers of surface-type where steam flows either inside tubes or in space between tubes.
- Classification of superheating:
  - One-stage superheating (by either fresh steam or bleed steam);
  - Two-stage superheating (by both fresh and bleed steam);
  - Three-stage superheating (are very rare).
- Application of two-stage heating (in comparison with one-stage heating) results into:
  - Insignificant increasing of efficiency (by 0,3-0,5 %);
  - Significant increasing of system complexity.


i кДж/кг
X1=0.9
X2=0.878
X3=0.86
2900
2700
2500
2300
ПАРОПЕРЕГРЕВАТЕЛЬ
P=6.39
X=0.995
P=2.055
P=1.155
P=0.632
X1
X2
X3
ЦИЛИНД
i = 2400
X=0.849
X=1
X=0.99
P=0.348
СЕПАРАТОР
i = 3000
P = 0.299
t = 265.4
P = 0.142
t = 189
P = 0.6555
t = 121
P = 0.0061
X=0.99
P = 0.004
X = 0.93
i = 2415
6.0
6.5
7.0
7.5
s кДж/(кг·град)

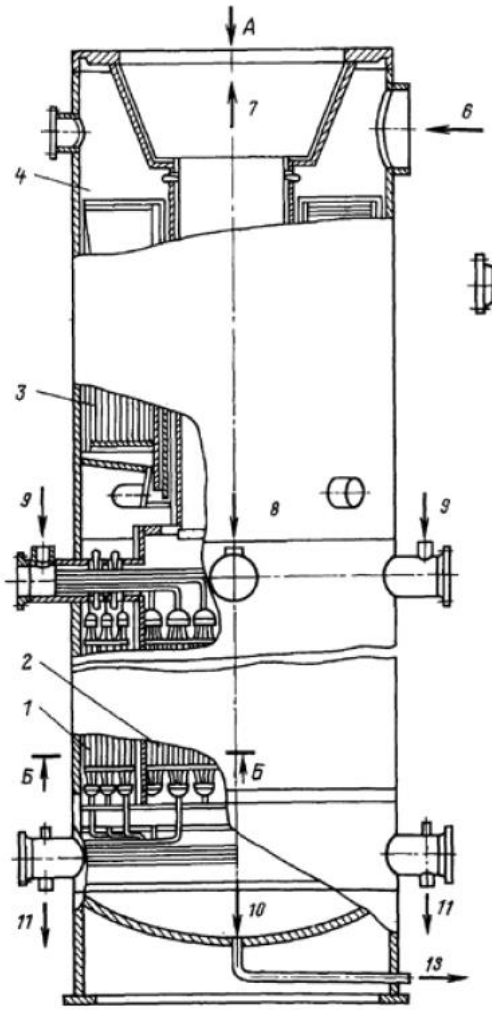
MATERIAL OF HEAT-TRANSFER SURFACE OF SUPERHEATER

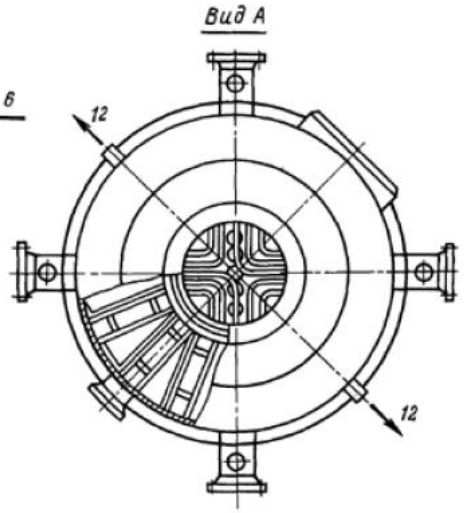
- The steel alloy **08Cr14MoV** is the most widespread.
- Advantages:
  - Is not liable to corrosion;
  - Cheaper than alloys with similar properties;
  - No nickel present.

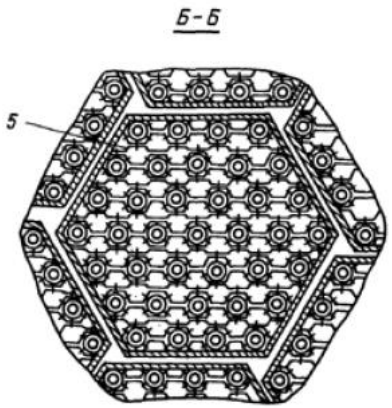
Alloy 08Cr14MoV is successfully applied into superheater on Kursk NPP.

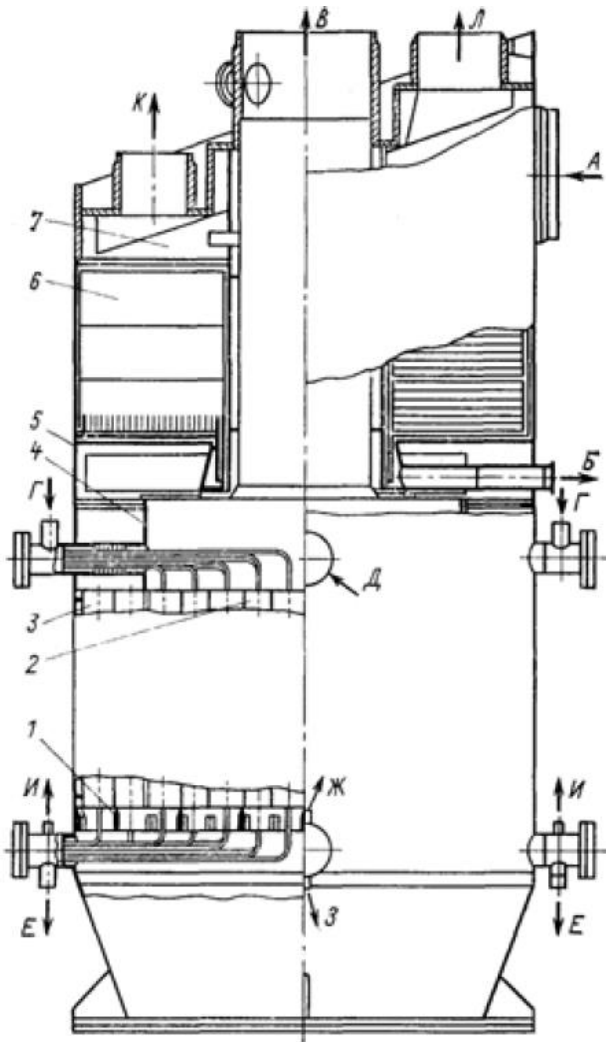
- There is 1, 2 or 4 separators-superheaters is used on NPP. Because 1 SSH could feed either one or two cylinders of turbine their number is usually even.
- Advantages:
  - Simplification of turbine unit.
  - Decreasing of dimensions, metal consumption and pressure losses.

TYPES OF SEPARATOR-SUPERHEATER



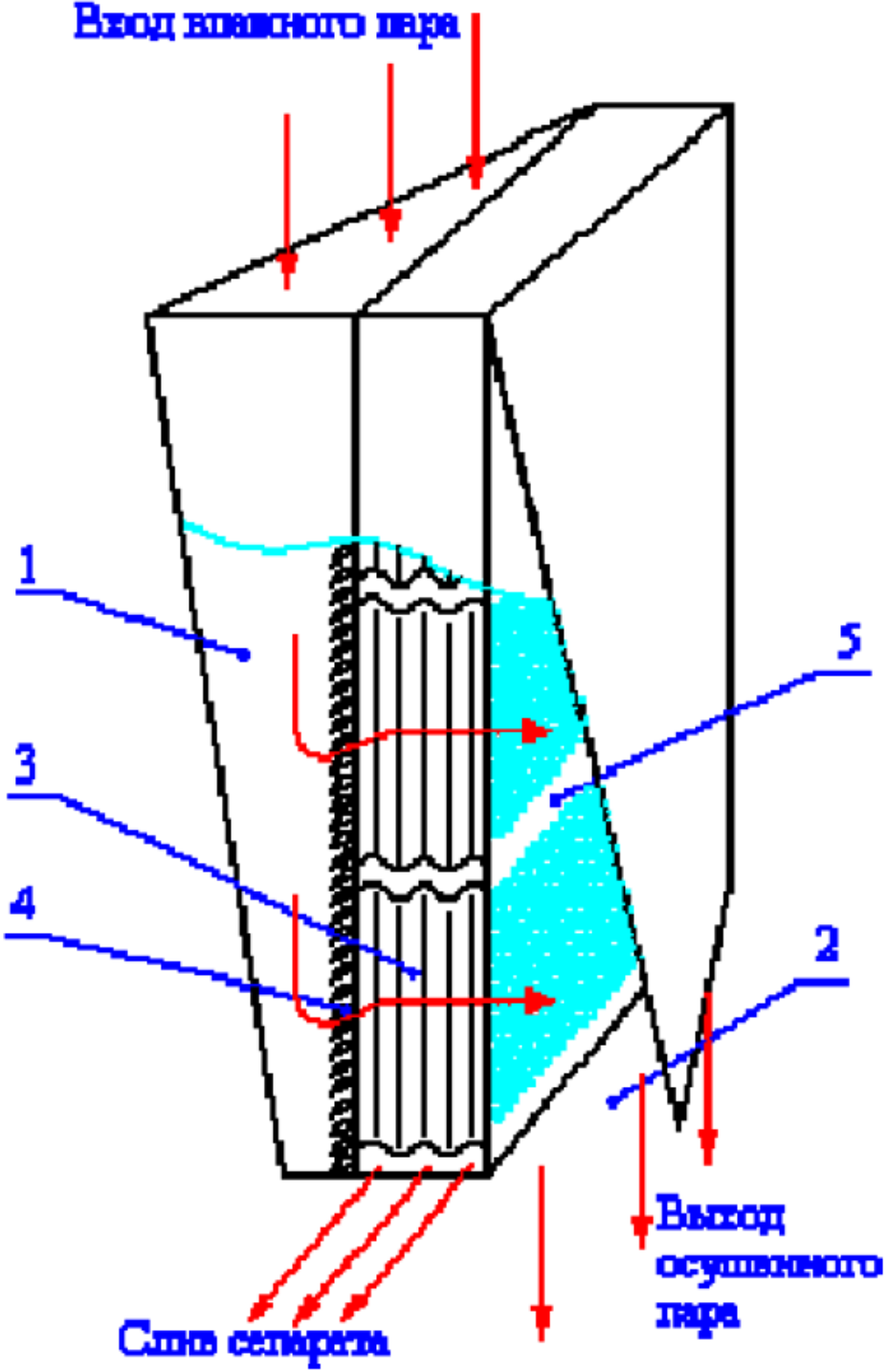






SCHEME OF SEPARATION BLOCK

- 1 – inlet channel
- 2 – outlet channel
- 3 – chevron plates
- 4 – guiding blades
- 5 – perforated list



COMPOSITION AND DESIGN OF SEPARATOR-SUPERHEATER

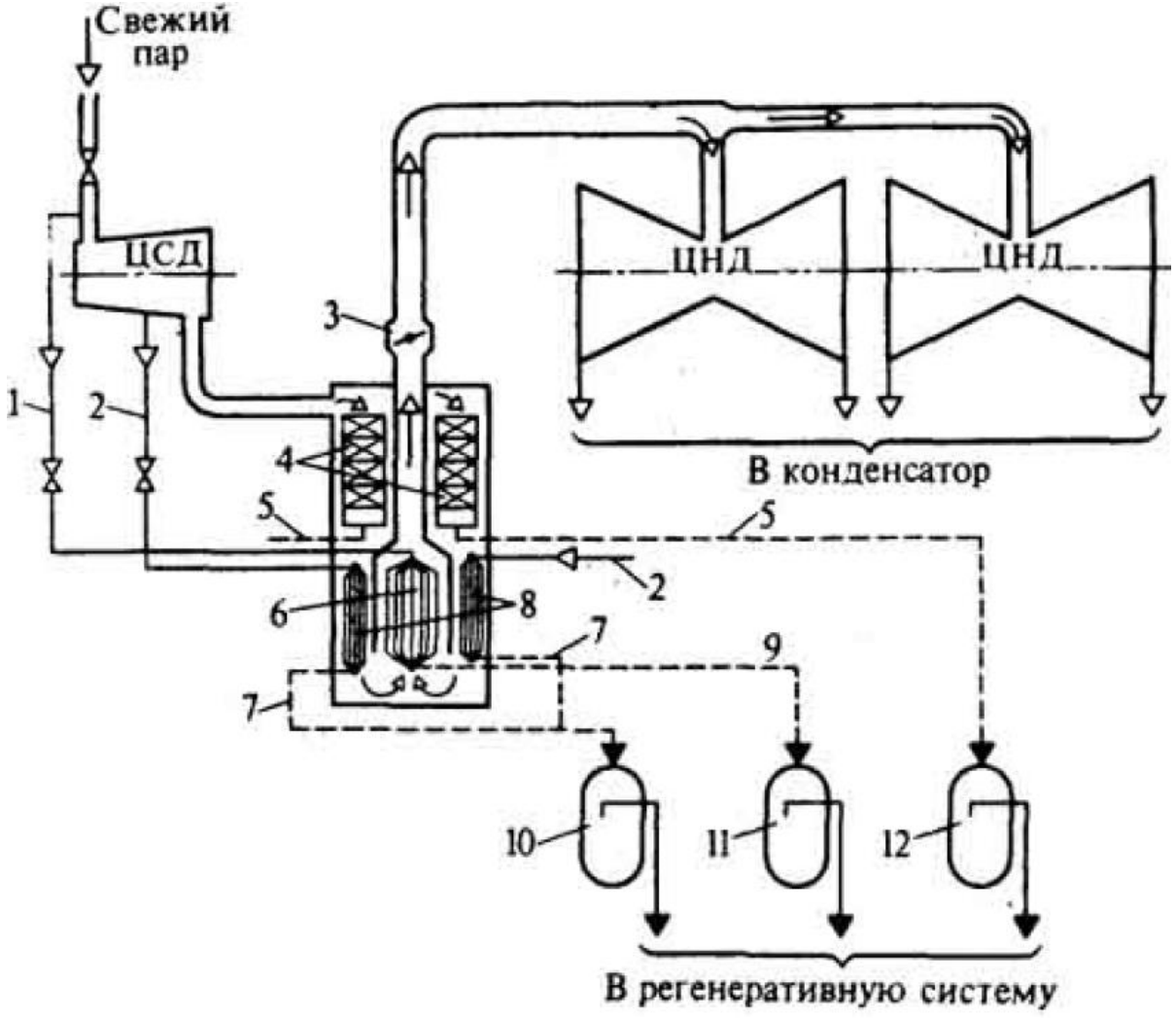
- Design of separator-superheater:
  - 1st stage – on the circumference of the SSH
  - 2nd stage – in the middle part of the SSH
  - Heating steam flows between tubes;
  - Heated steam flows inside tubes;
  - Removal of condensate is realized in the lower part of SSH.
  - SSH consist of modules:
    - 1st stage – 60 modules;
    - 2nd stage – 70 modules;
  - Modules are installed on the fixing mesh;
  - Tubes installed into tube plate and flared.

CONDITIONS OF RELIABLE EXPLOITATION OF SSH

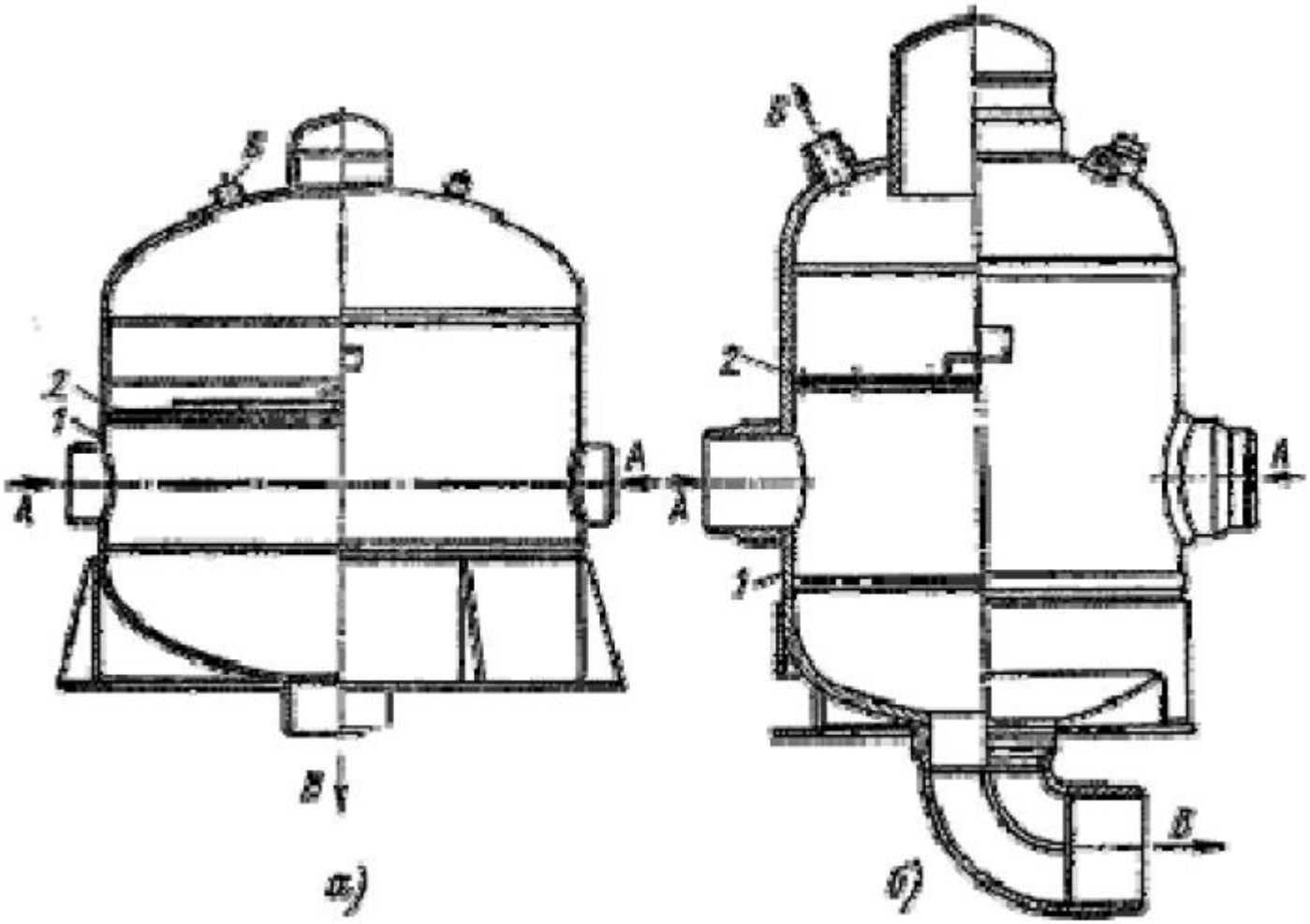
- Removal of separated water into intermediate tanks;
- Containing stable level of condensate into intermediate tanks;
- Removal of non-condensing gases from SSH;
- Protection from increasing pressure over nominal value.

- Dimensions of SSH are very significant:
  - For turbine unit with 1000 MW there is 4 SSH with 4 m diameter and 8 m height;
  - The shut-off valves are installed before SSH.

SCHEME OF NPP CYCLE



SCHEME OF SHH AND CONDENSATE TANKS



THANK YOU FOR YOUR ATTENTION