TOMSK POLYTECHNIC UNIVERSITY

CONDENSING UNITS OF NPP

MAIN FEATURES

- Definition

- Effect of non-condensing gases

- Contents and scheme of condensing unit

- Pressure into condenser

- Condensate overcooling

- Condenser construction

DEFINITION

Condenser – equipment for turning exhaust steam from turbine into liquid.

Purposes:

- Condensing of the steam;

- Obtaining pure condensate;

- Establishing and containing deep vacuum after last stage of turbine.

EFFECT OF FINAL PRESSURE ON EFFICIENCY OF TURBINE UNIT

Main features of condensation process is following:

- The lower cooling water temperature the lower temperature and pressure of condensing steam and higher thermal efficiency of NPP.

Increasing of final pressure by 1 kPa result into decreasing of NPP efficiency by 1,5-2 %.

Actual pressure into condenser:

- On large TPP and NPP – 3,5-5,5 kPa;

- For other TPP and HNPP – 6-10 kPa.

GASES INTO CONDENSER

- Due to low pressure into condenser (much lower than atmospheric pressure) the air and other non-condensing gases enter condenser through leakages and accumulated there.

- The main sources of air leakages into system are turbine, steam pipelines, leakages into coupling, seals, regenerative heaters etc. The other gases are carbon oxides and acids and ammonium.

- The amount of non-condensing gases leaked into condenser is strongly depend on load. The radioactive products of radiolysis exist into condensers of 1-circuit NPP.

| Load, %		30	50	80	100
Maximal air leakage value, kg/h	TPP	30	40	60	-
	NPP	-	60	-	120

NEGATIVE EFFECT OF NON-CONDENSING GASES

Non-condensing gases result into:

- Increased pressure into condenser:

  - Presence of gas into condenser results into proportional increasing of pressure.

- Corrosion of condensate pipeline;

- Decline of heat-transfer process:

  - Only 1 % of non-condensing gases results into decreasing heat-transfer coefficient by twice.

  - 2,5-3,0 % decrease it up to 4 times.

The elimination of such gases needs creation of even lower pressure into ejector. As long as amount of taken away gases strongly depends on pressure difference the energy spent on them could be significant.

CONDENSATION UNIT ELEMENTS

Steam from turbine

Working fluid inlet

Into regeneration system
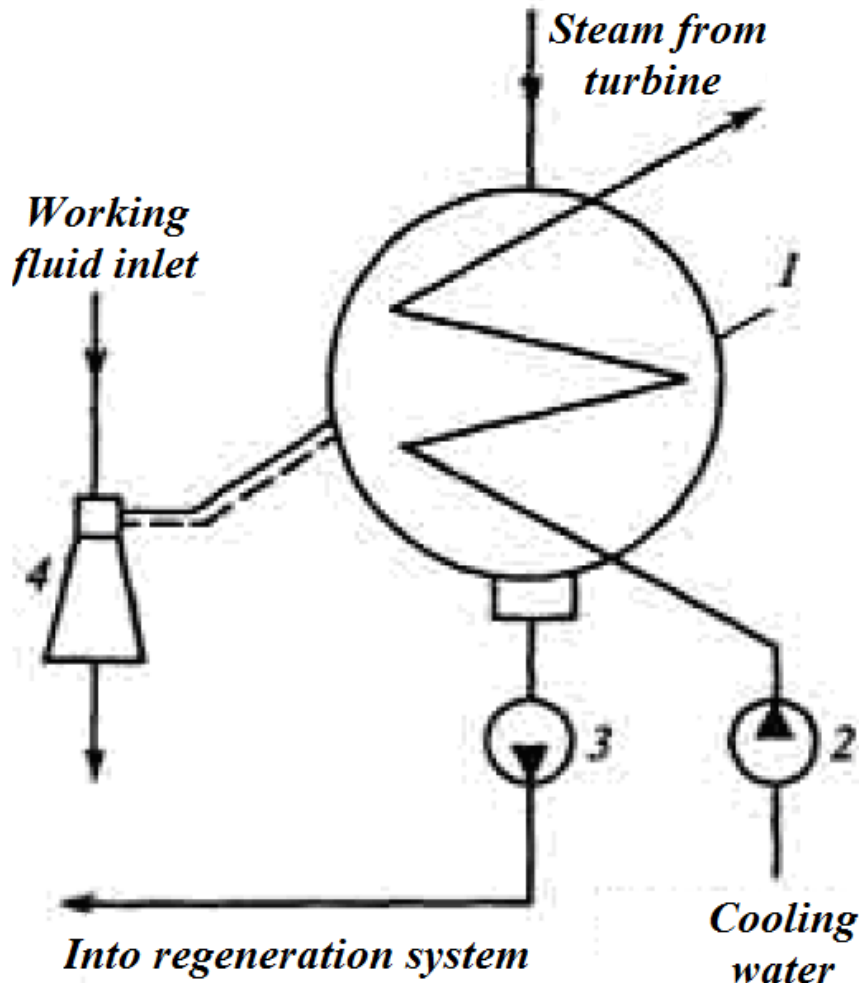
Cooling water

- Condenser
- Condensing pumps
- Pipelines
- Air-removing equipment
  - *Ejectors* – device for creating low pressure by using high velocities of steam (small amount of steam is removed as well).
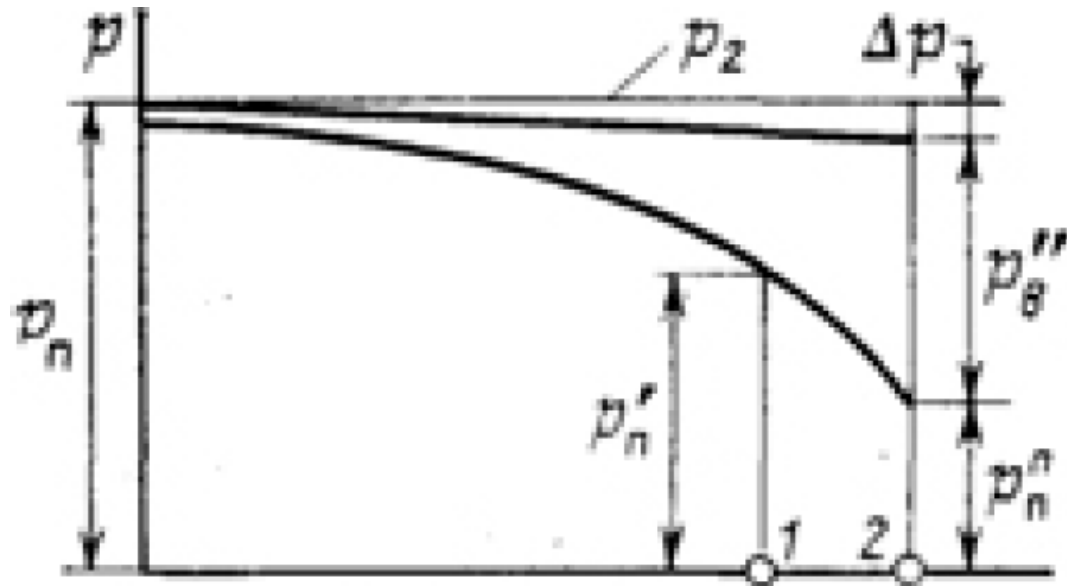
DEPENDENCE BETWEEN TEMPERATURE OF COOLING WATER AND PRESSURE

■ Condensate temperature is always higher than temperature of cooling water: $t_k > t_{w2}$.

■ Temperature head is equal to $\delta t = t_k - t_{w2} = 3\text{-}10\ °C$ ($t_{w2} > t_{w1}$, $\Delta t_w = t_{w2} - t_{w2}$).

■ In this case, condensate temperature is $t_k = t_{w1} + \Delta t_w + \delta t$.

■ Temperature of cooling water on the inlet to condenser t_{w1} which, in turn, depend on:

   ■ Source and type of cooling water;

   ■ Climate parameters;

   ■ Time of the year.

■ Actual t_{w1} temperatures are assumed to be in range:

   ■ 10-20 °C for NPP;

   ■ 20-30 °C for NPP with heat supply.

OPTIMAL POINT OF AIR REMOVAL

- Applying Dalton law to air and steam at the inlet of condenser the relation between gas constants for steam and air is equal to $R_{air}/R_s=0{,}622$. It defines thermodynamically optimal relation between steam and air in removed substance.

- On the inlet to condenser the relation between partial pressure of air and steam is low. With condensation process going on in reaches the thermodynamically optimal value.

CONDENSATE OVERCOOLING

- The difference between temperatures of steam t_k and condensate into condensate accumulator t_k': $\Delta t_k = t_k - t_k'$.

Condensate overcooling results into:

- Additional energy losses on keeping the vacuum.

- Higher pressure into condenser.

- Enrichment of water by oxygen.

To avoid condensate overcooling the air-coolers and condensers of regenerative type is applied.

SCHEME AND CONSTRUCTION OF CONDENSER UNIT
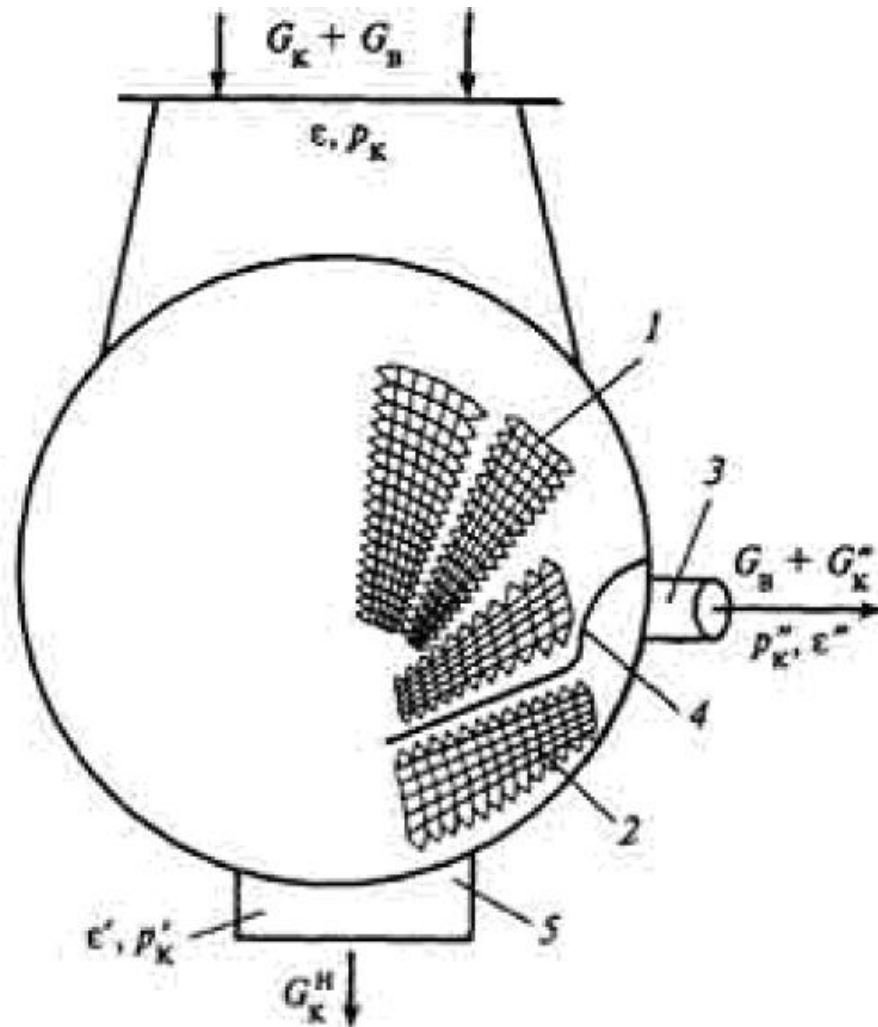
SCHEME AND CONSTRUCTION OF CONDENSER UNIT

- Heat of steam-air condensation is used into ejector cooler.
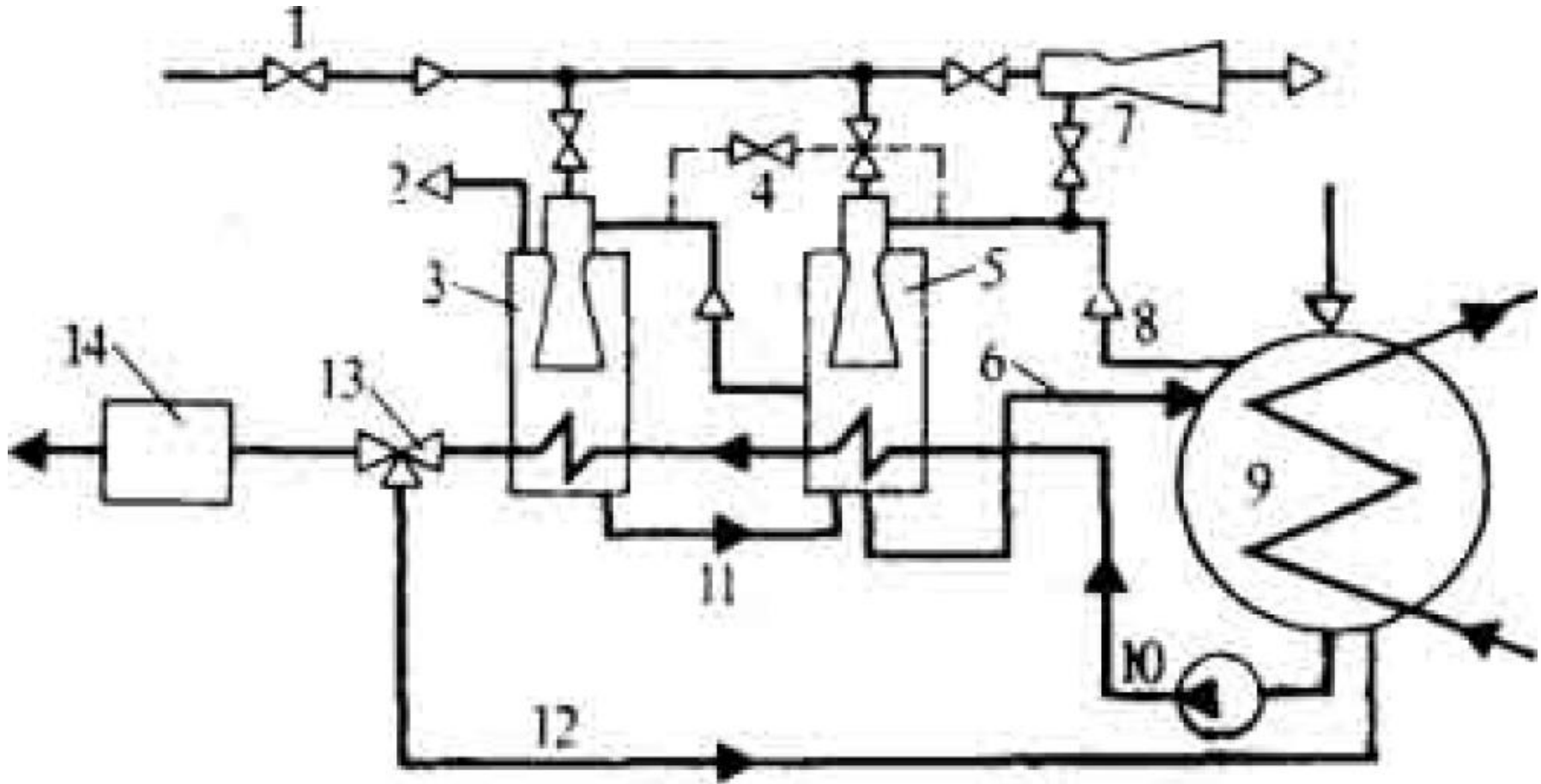
CONSTRUCTION OF CONDENSATE

■ The number of condensers is defined by number of low pressure cylinders.

■ Usually each cylinder has its own condenser.

■ Condensers usually made with one-through or two-through circulation by water.

■ Water chambers are separated from steam by tube desk.
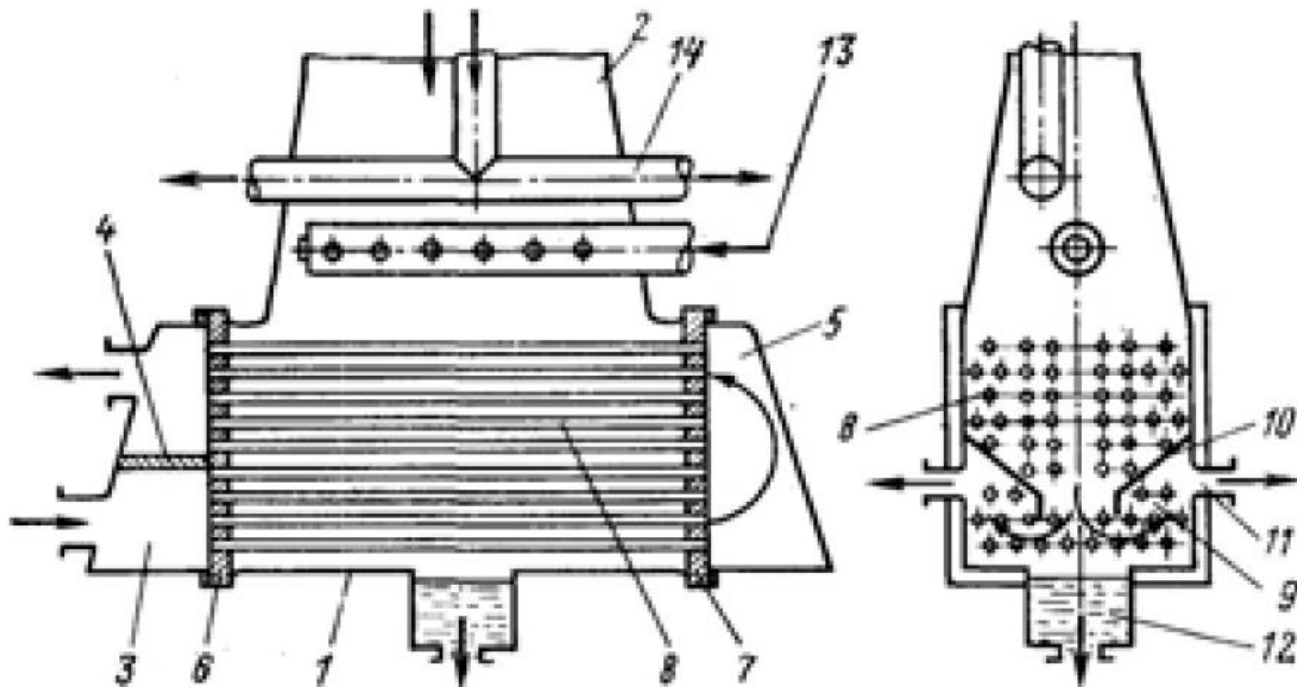
INSTALLATION OF CONDENSER
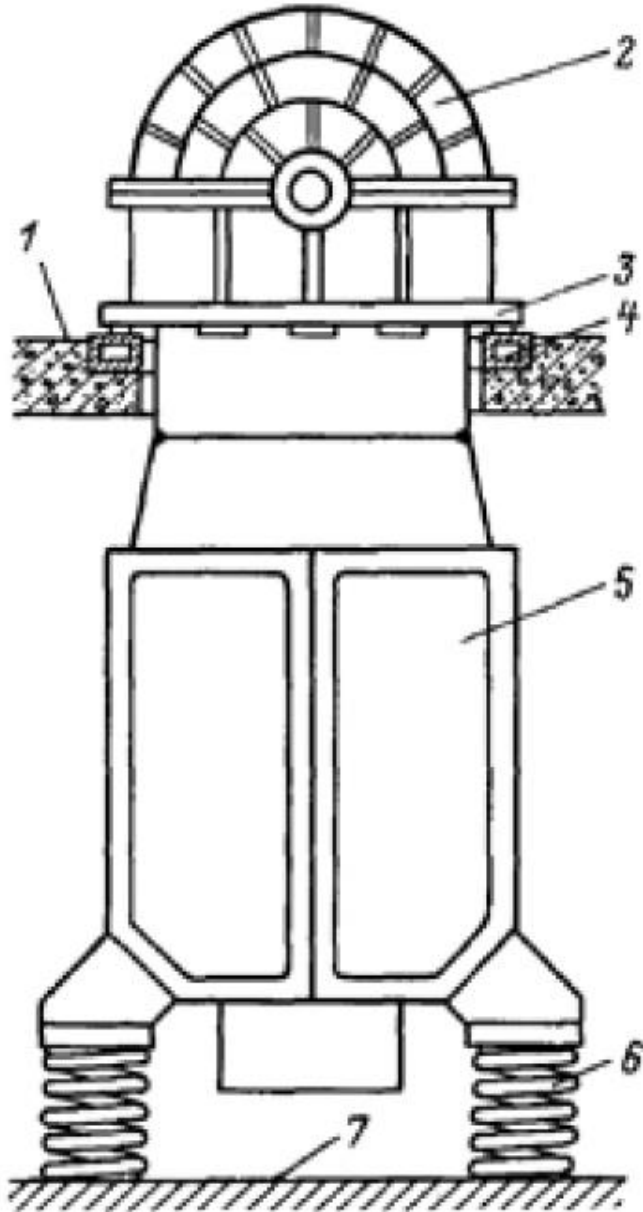
- The condenser is strictly connected to outlet pipe of turbine. That is why thermal expansion of turbine will result into displacement of turbine rotor.

- To avoid this the spring anchorage is applied.
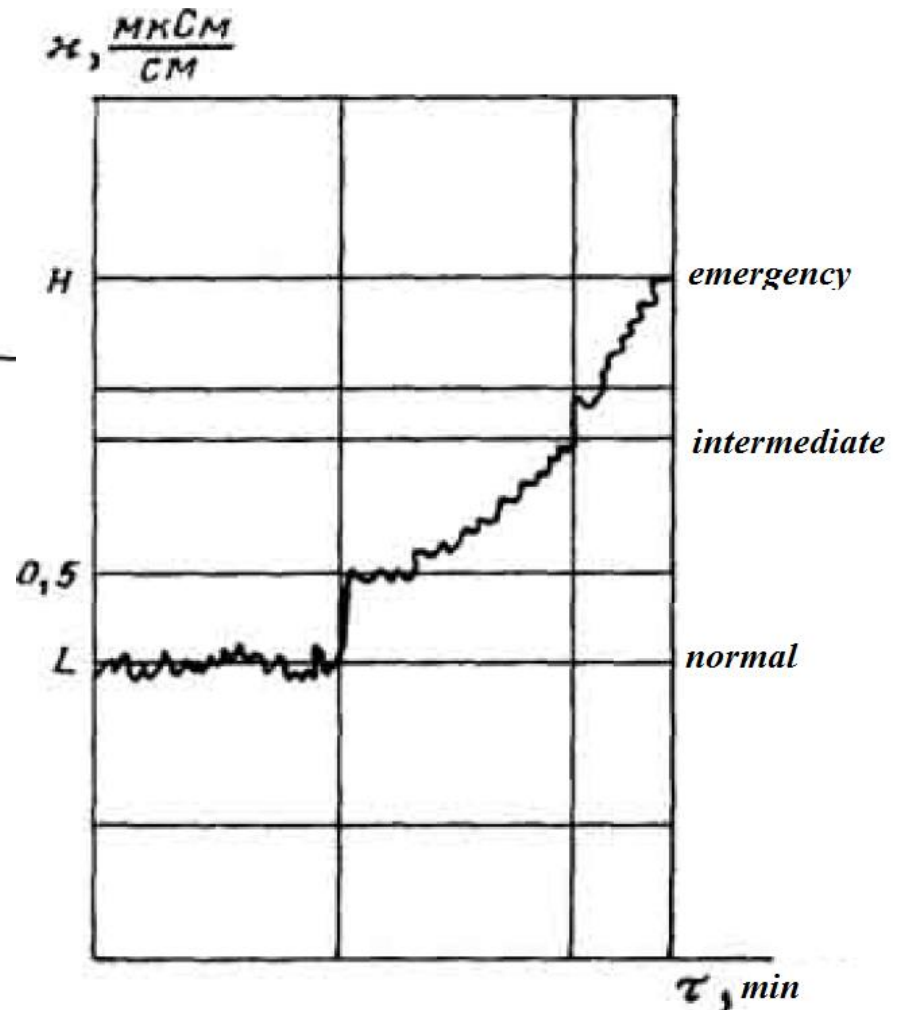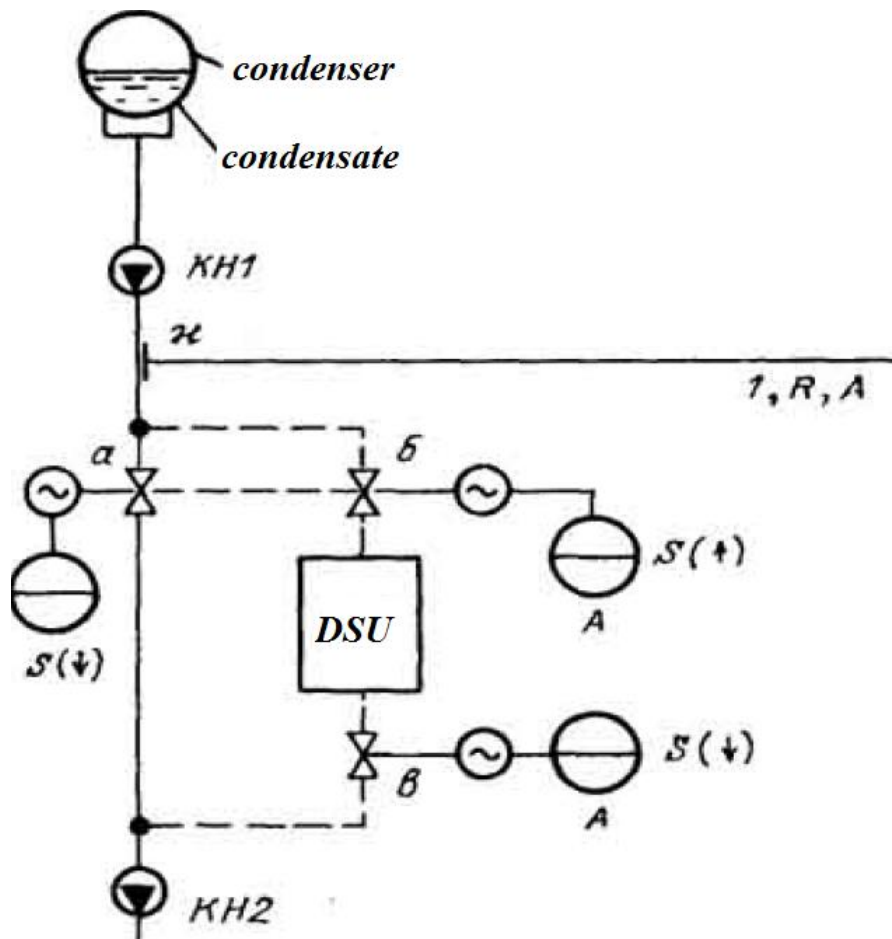
TUBE PACK

- Tube pack for cooling water circulation is formed by number of condensate tubes.

- Outlet diameter of tubes is usually in range 25-28 mm with thickness 1 mm and length close to 9 m. Long tubes is supported by separating plate.

- The tube material:
  - Brass (high thermal conductivity);
  - Copper-nickel alloy (high thermal conductivity);
  - Rarely – titanium alloy.

- Cooling water velocity: 2-2,1 m/s for brass and 2,5-2,7 m/s for alloys.

- The tubes are fixed into tube desk by expander. To improve tightness the following materials are used:
  - Bitum or epoxide material;
  - Welding (in case of metal tubes);
  - Double tube desk.

DOUBLE TUBE DESK

- Double tube desks are used to decrease water leakages. The condensate with high pressure (higher than pressure of cooling water) is put into space between two tube desks.

- Main disadvantages: complexity of production and repair.
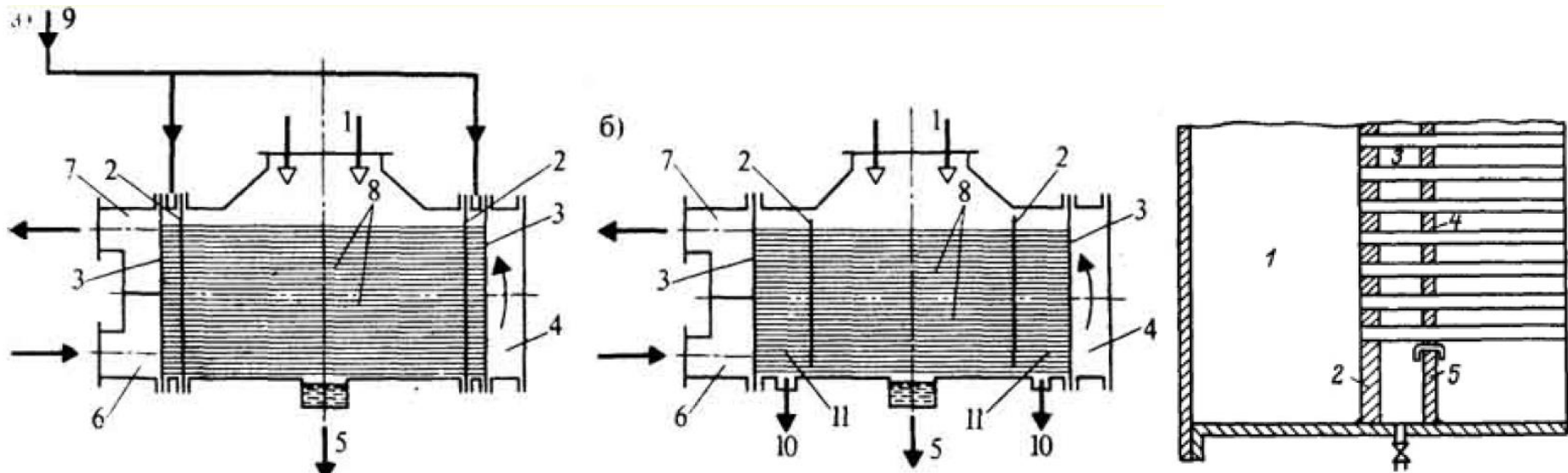
EMERGENCY SCHEME OF CONDENSER WITH DESALINATE UNIT

TUBE PACK RATIONAL COMPOUNDING

Aim:

- Decreasing of temperature head;

- Decreasing of steam resistance;

- Decrease amount of steam removed with gases.

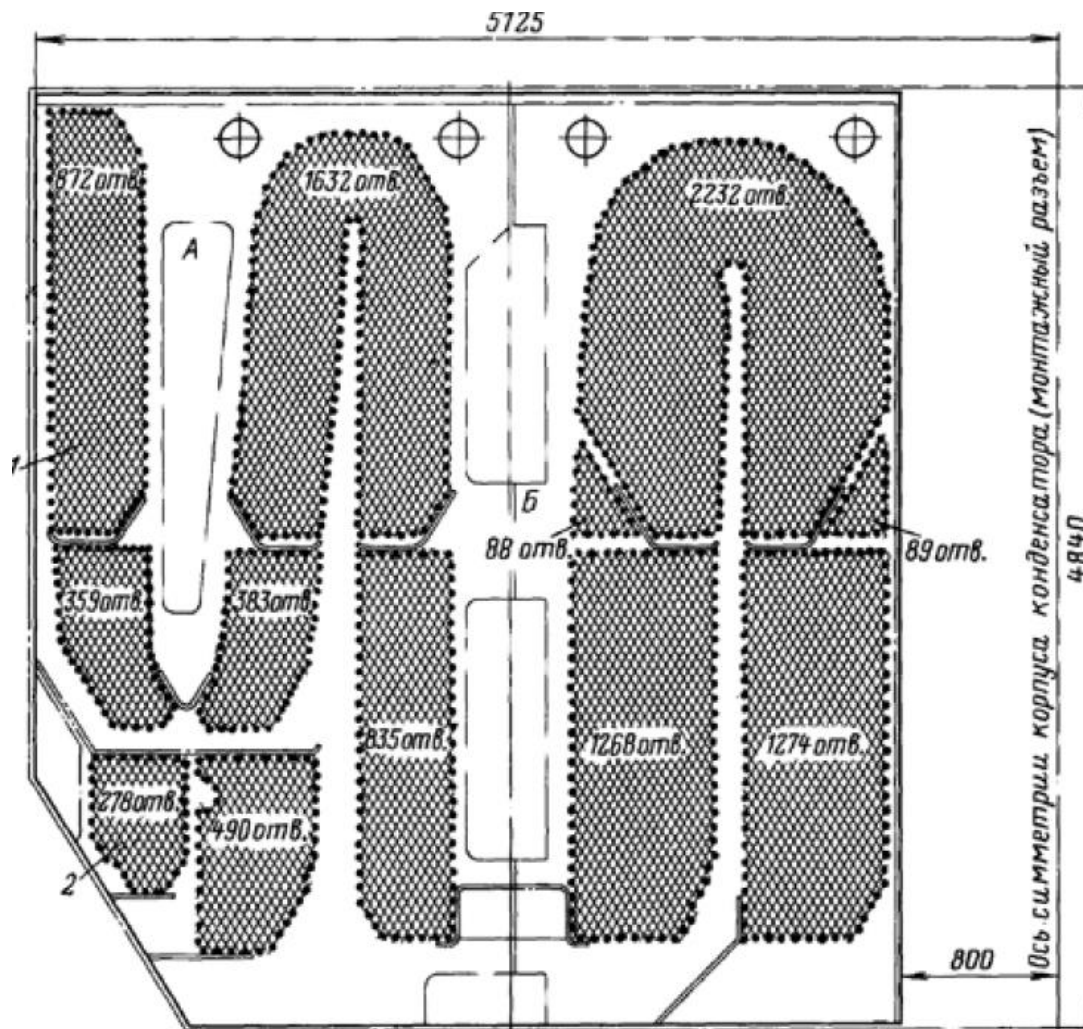The compounding of following types is used on NPP:

- Belt-type;

- Modular.

- Condenser feeding by cooling water is always applied by two flows. This results into increasing of pressure into condenser.

- It allows to avoid shutdowns:

  - To investigate and clean condenser;

  - Repair one part of tubes.

BELT-TYPE COMPOUNDING
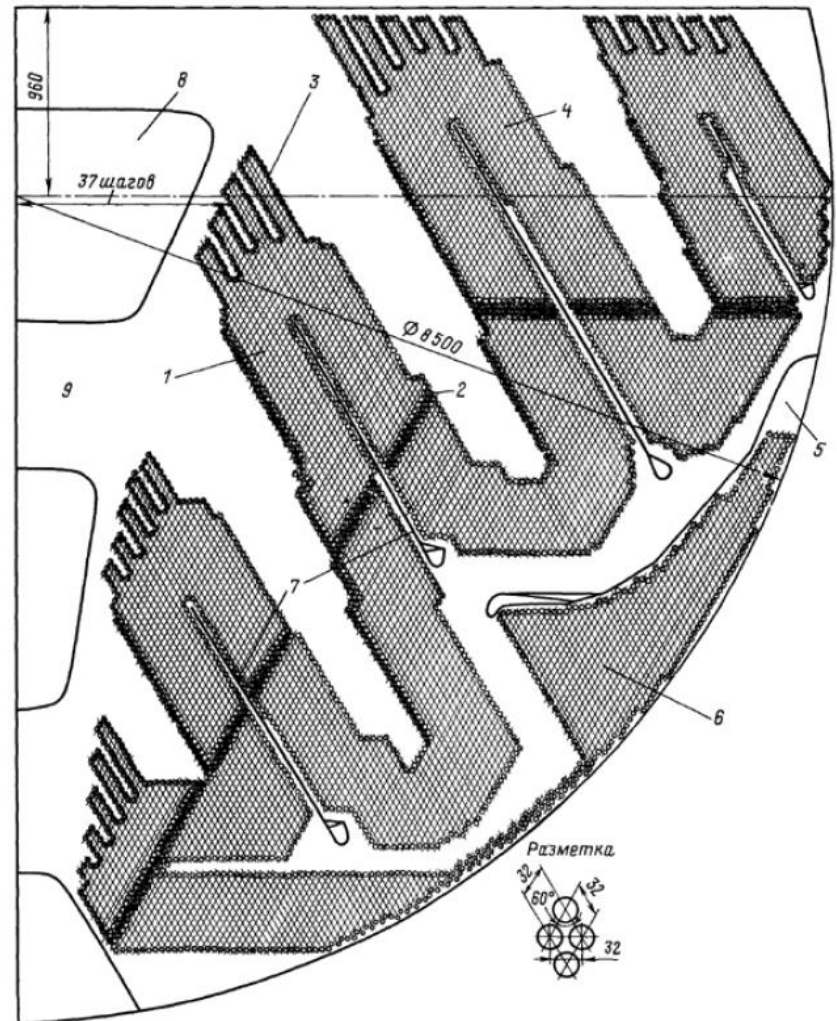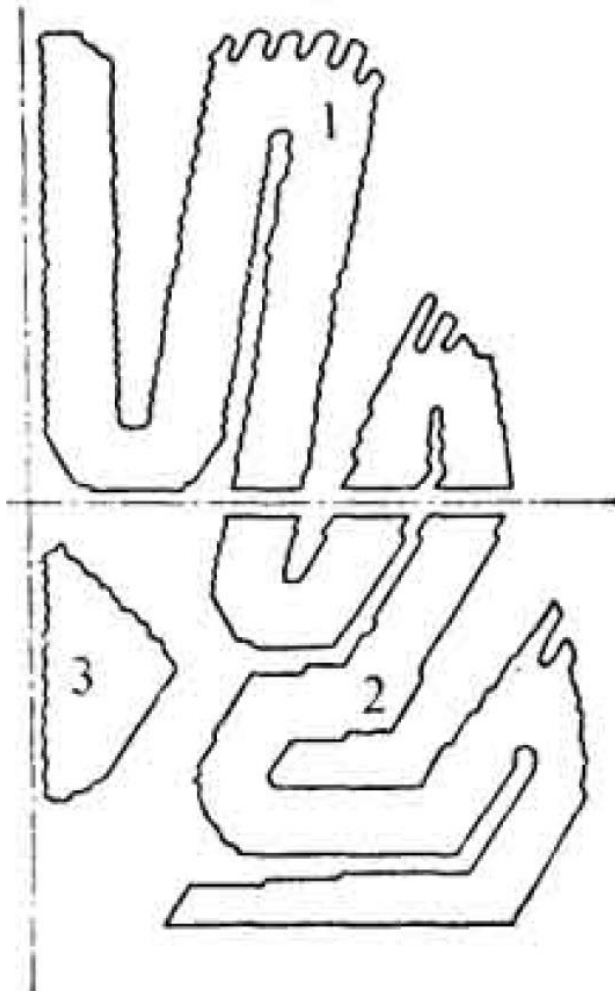
MODULAR COMPOUNDING

DEAERATION INTO CONDENSER

■ Deaeration into condenser is achieved by:

    ■ Constant removal of air by ejector;

    ■ Heating of condensate into condenser tank.

■ It allows to:

    ■ Decrease corrosion of condenser pipelines;

    ■ Decrease amount of reaction products into reactor (for 1-curcuit NPP);

    ■ Remove radiolitic oxygen (for 1-curcuit NPP).

THERMAL CALCULATION OF CONDENSER

Main purpose:

■ Define heat transfer surface area of condenser.

Main equations:

■ Heat transfer equation: $Q_k=F \cdot k \cdot \Delta t_{av}$ *(the logarithm-averaged Δt_{av} should be used)*

■ Thermal balance equation: $Q_k=D_k \cdot (h_{k-}h_k')=W_{cw} \cdot c_w \cdot (t_{w2}-t_{w1})$

Ratio of cooling water flow rate to condensing steam flow rate is called cooling ratio:

$$m=W_{cw}/D_k$$

For NPP real cooling ratio values are situated in range: m=50-100.

Increasing cooling ration results into:

■ Decreasing pressure into condenser;

■ Increasing flow rate of cooling water (and energy consumed on pumping);

■ Increased capital cost on condenser unit.
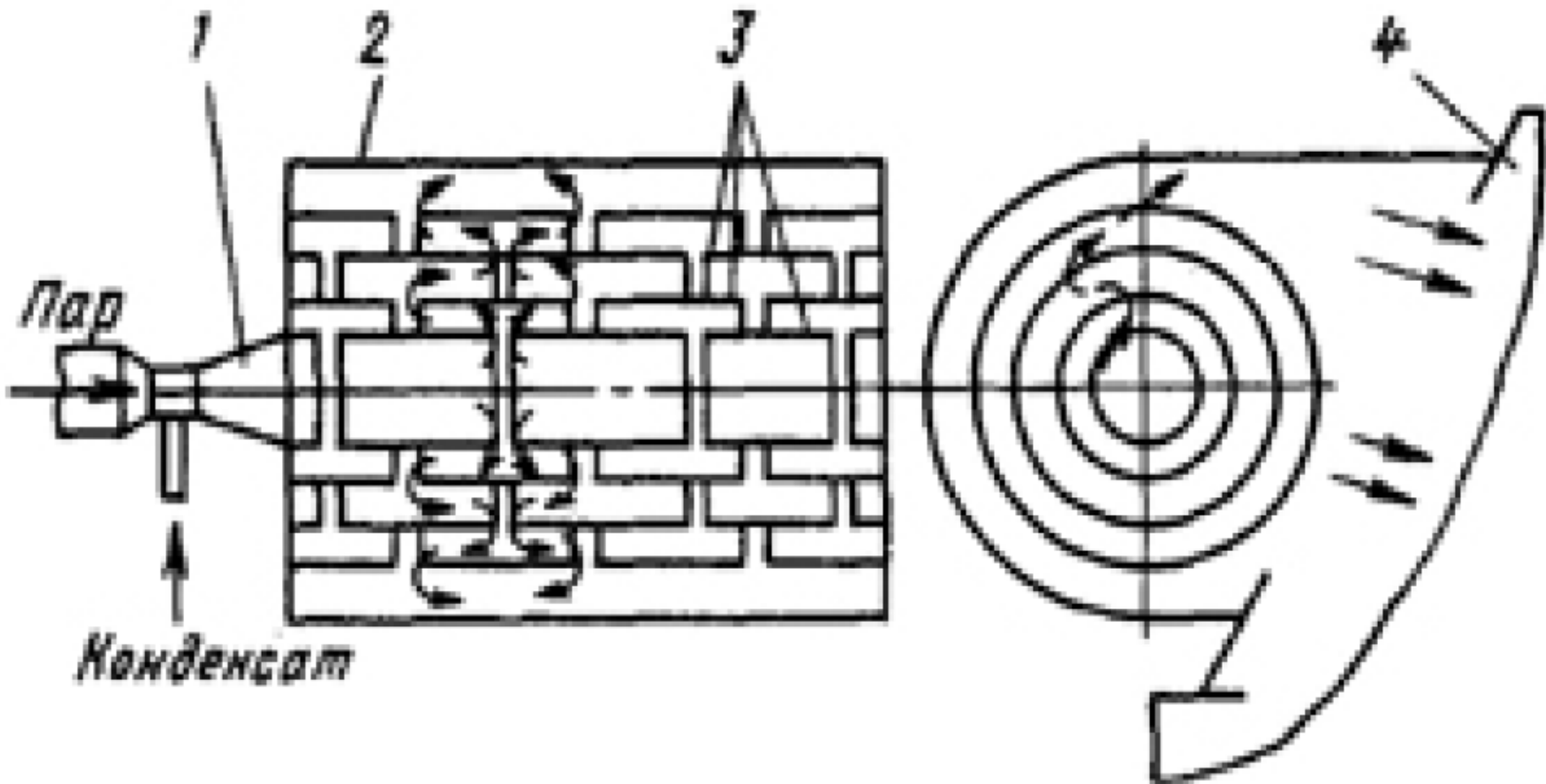
SPECIAL ELEMENTS AND FUNCTIONS OF CONDENSER UNIT

Special elements:

- Receiving-discharging device;

- Integrated cogenerating packs;

- Ball cleaner of condenser;

Special functions:

- Sectioning of condenser;

- Deaeration in condenser tank;

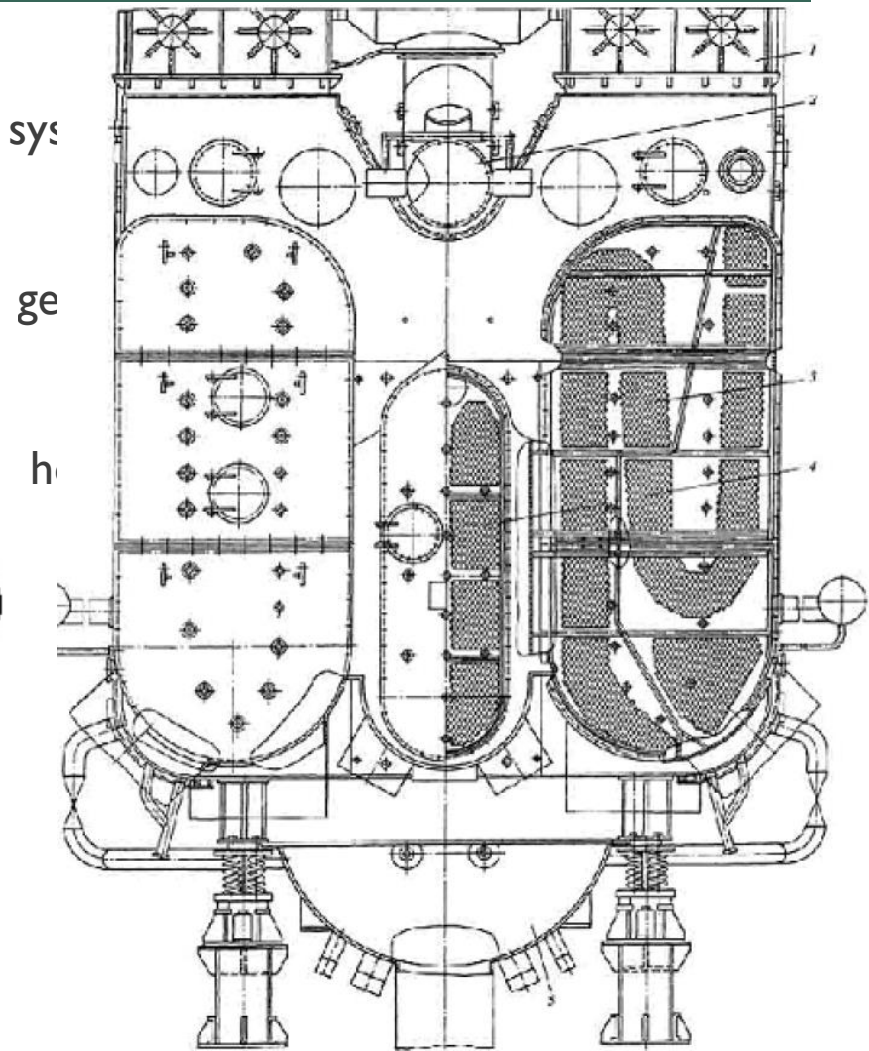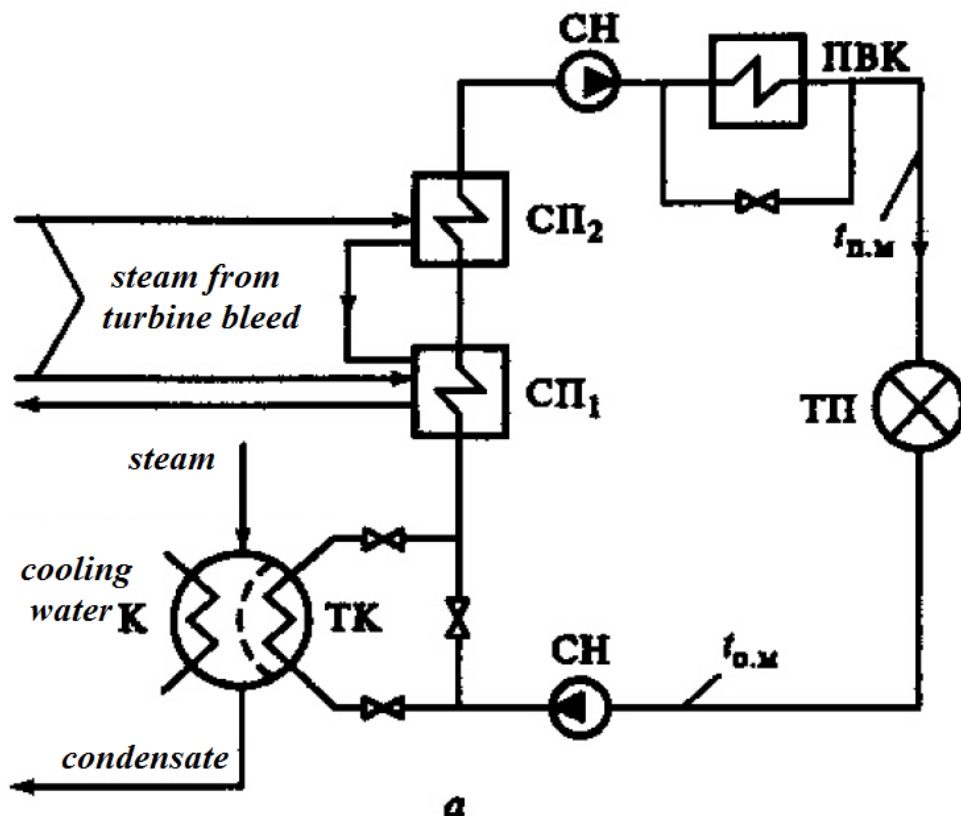- Hydrogen afterburning.

- Ejection.

RECEIVING-DISCHARGING DEVICE

INTEGRATED COGENERATION PACK

Purpose:

- Heating of return water from heat supply sys

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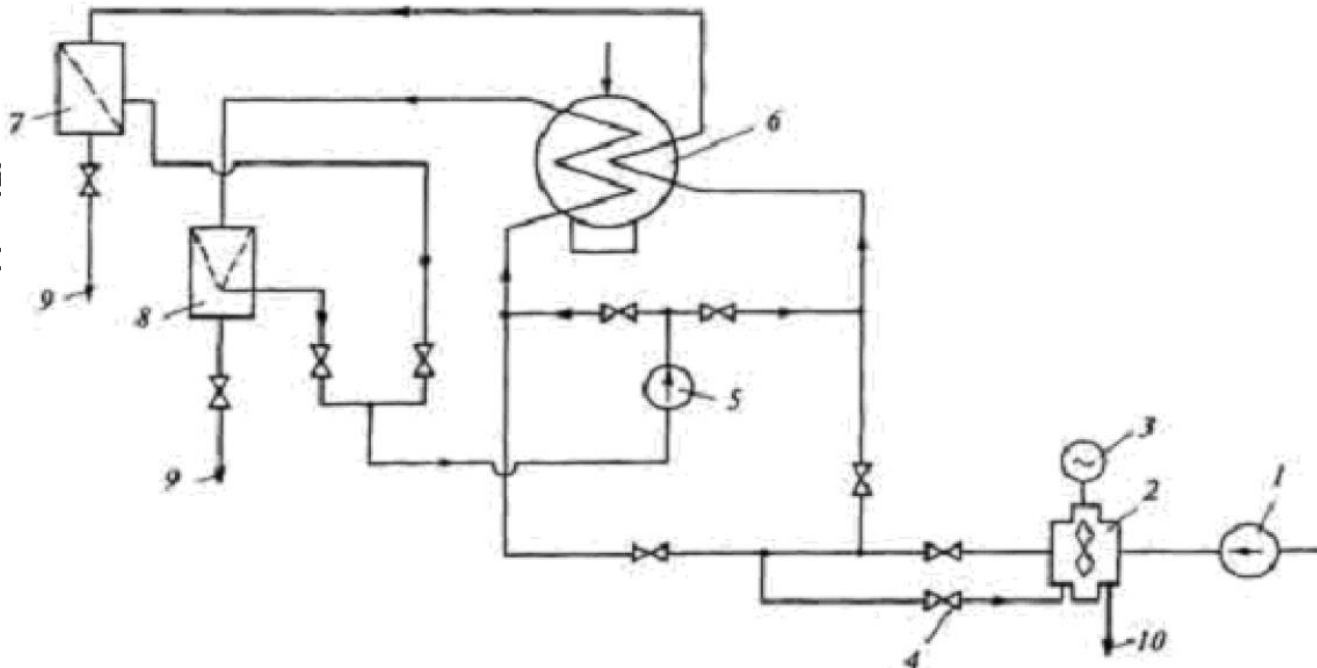# CLEANING OF CONDENSER TUBES

Purpose:

■ Cleaning tubes from deposition to improve heat transfer.

Construction:

■ Using ball cleaner of condenser needed to pump rubber balls through tubes. Balls should be larger
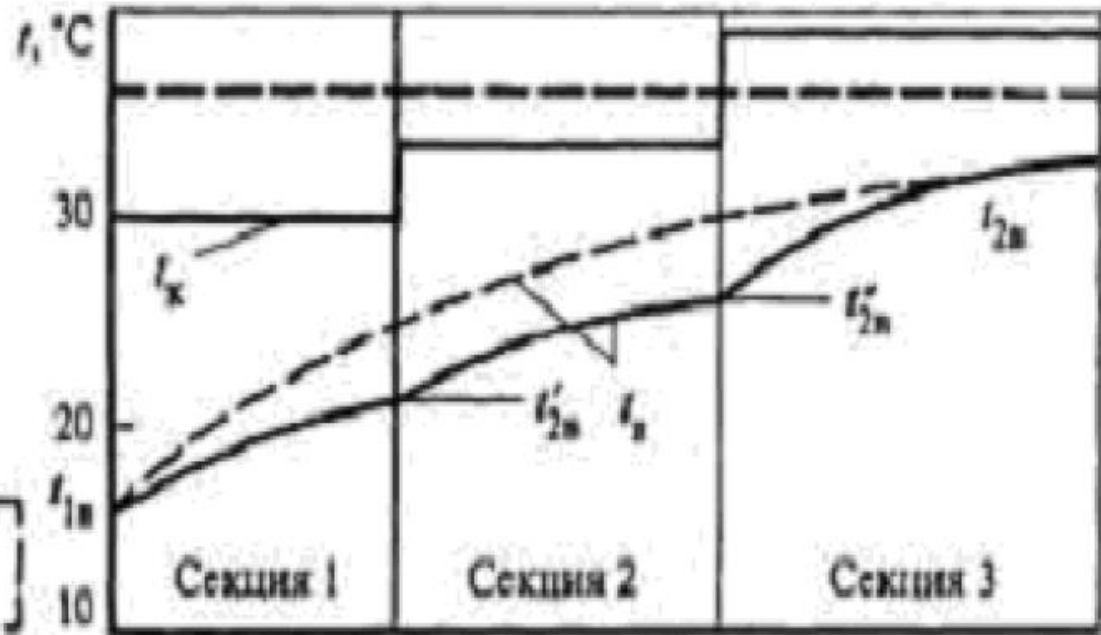
Result:
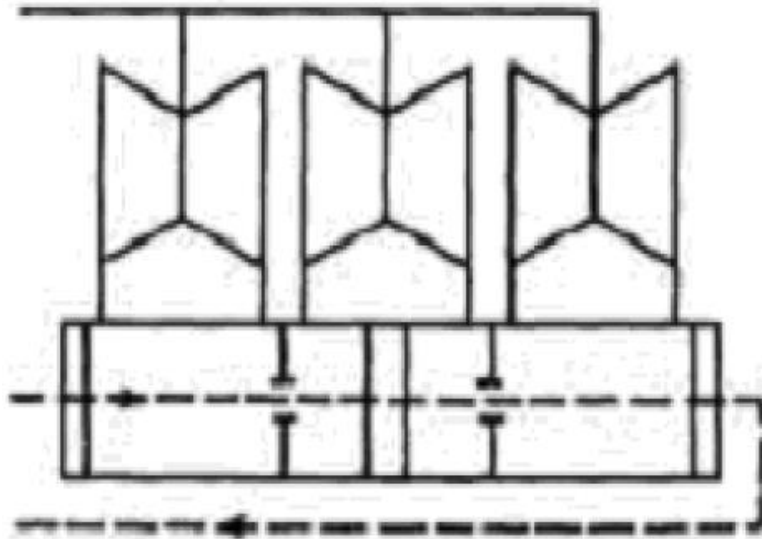
■ Increasing

■ Allows to

CONDENSER SECTIONING

Purpose

- The improved heat transfer properties of condenser.

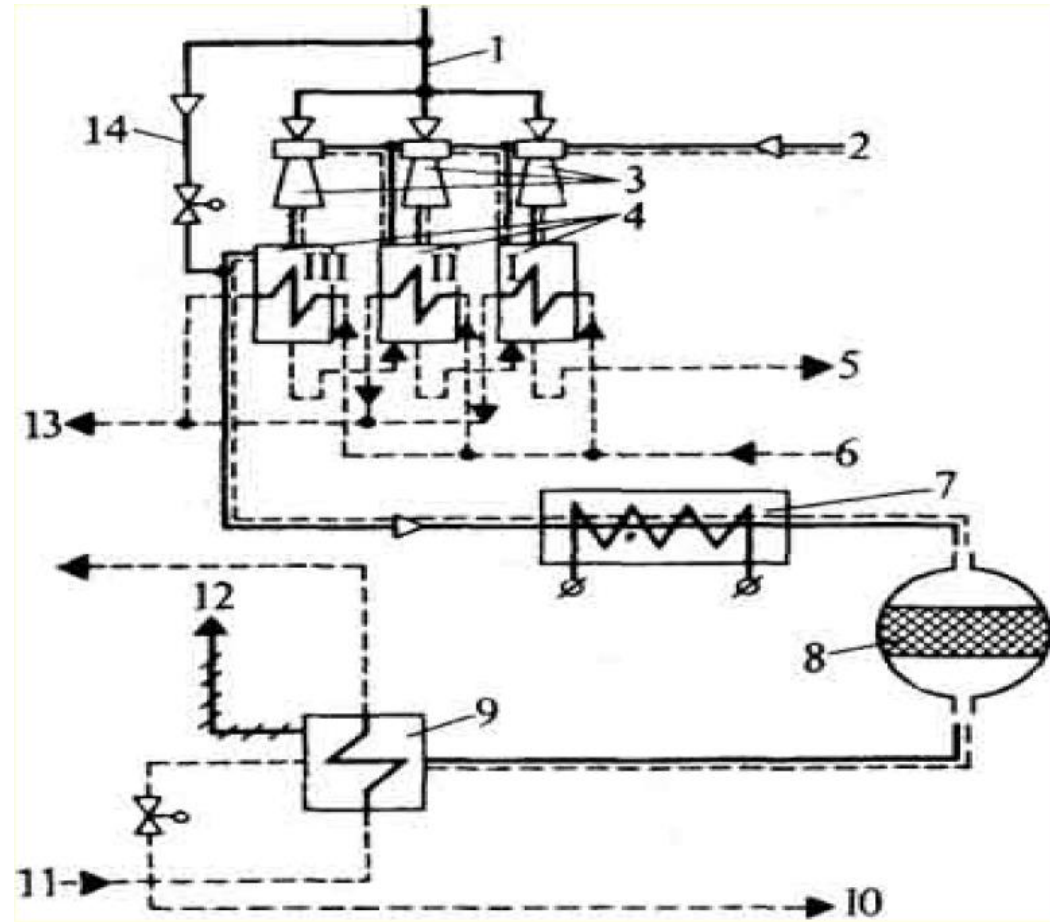- Third section results into decreasing heat transfer coefficient.

Type of	Conden	Surface	Steam	Number	Cooling	Vaccum

HYDROGEN AFTERBURNING

Purpose:

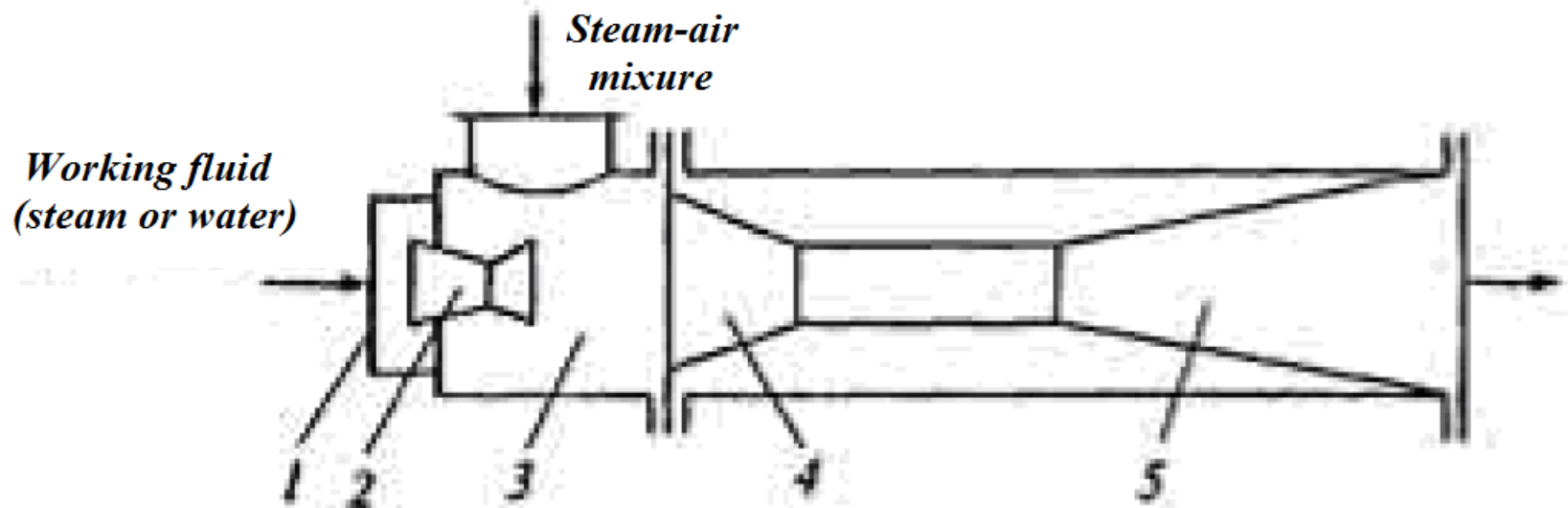- Utilization of hydrogen formed during radiolysis (1-curcuit NPP).
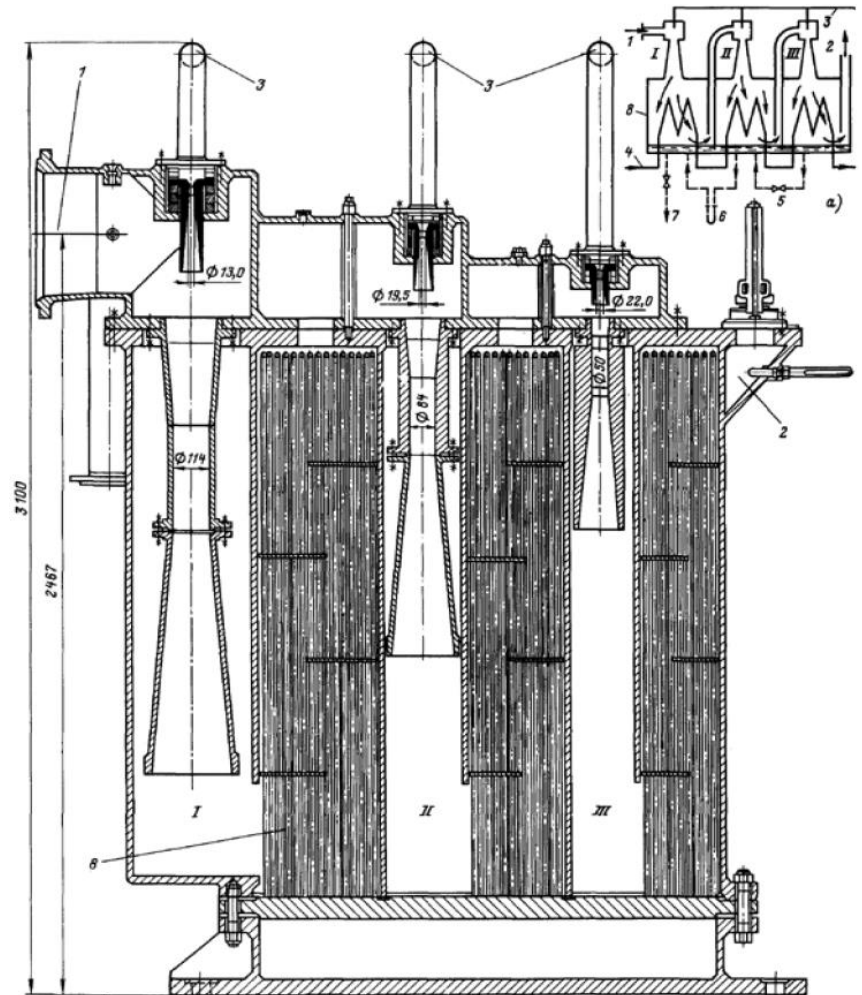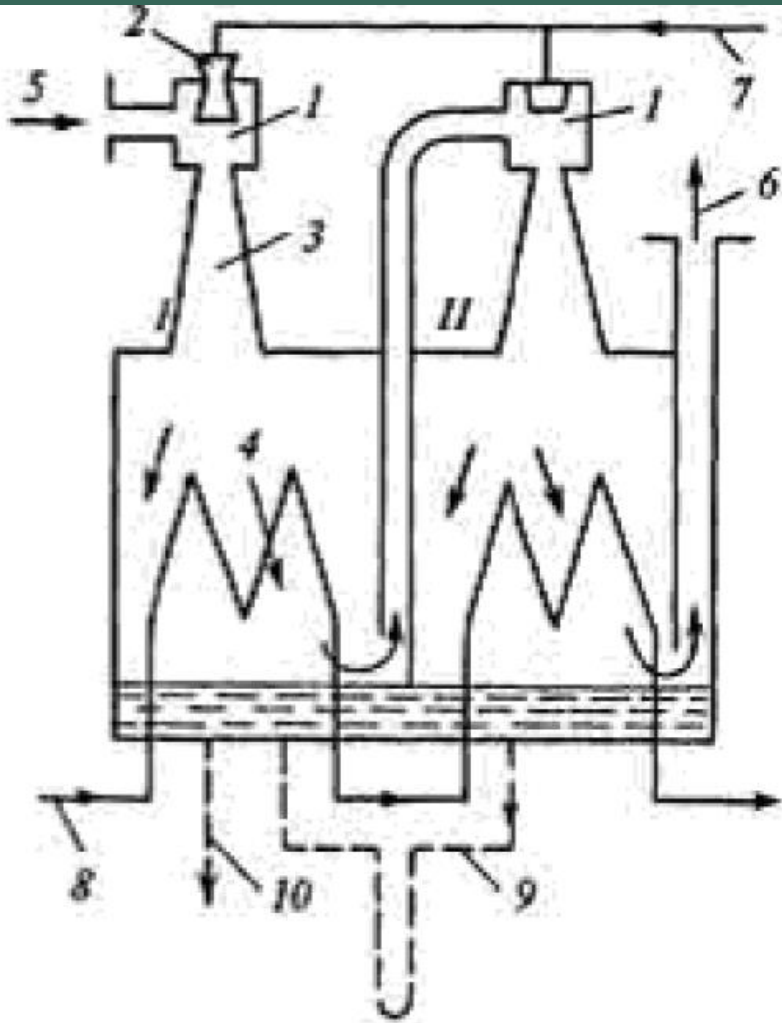
EJECTION

Purpose:

■ Ejection is needed to remove non-condensing gases from condenser.

Construction:

■ Nozzle with diffuser with pipe at point with the highest velocity and lowest pressure.

Steam-air mixure

Working fluid
(steam or water)

1 2   3   4   5

TWO- AND THREE-STAGED STEAM EJECTORS

WATER-STREAM EJECTOR

- Water-stream ejector uses high pressure water.

Advantages:

- Deeper vacuum.

Disadvantages:

- Heat of removed steam

THANK YOU FOR YOUR ATTENTION