TOMSK POLYTECHNIC UNIVERSITY

DEAERATION AT NPP

MAIN FEATURES

- Ways of non-condensing gases inlet
- Definition and purpose of deaeration
- Deaeration methods
- Basics of thermal deaeration
- Construction of deaerator
- Types of deaerators
- Control programs and schemes

TYPES AND WAYS OF NON-CONDENSING GASES INTRODUCTION

- The impurities of different types are present into feed water:

1. Gaseous.
2. Solid.
3. Natural chemical components.

- Non-condensing gases are introduced into feed water from:

1. **Air** sucking into condenser and low-pressure heaters;
2. Reactor and heat carrier (**radiolytic gases and radioactive noble gases**);
3. Chemical reactions into system (the most significant reaction of bicarbonate decomposition results into production of **carbon dioxide**).

The air (due to high oxygen content) and carbon dioxide are the most dangerous among them due to its high corrosion activity. The carbon dioxide is especially dangerous due to its high corrosion activity after carbonaseous acid formation.

The oxygen content into deaerated water is regulated to be less than 10 μg/kg for two-circuit NPP with tubes made from OC18N9T alloy.

CHARACTERISTIC CORROSION DAMAGES OF AUSTENITIC ALLOYS

Stress corrosion

DEFINITION AND PURPOSE OF DEAERATION UNIT

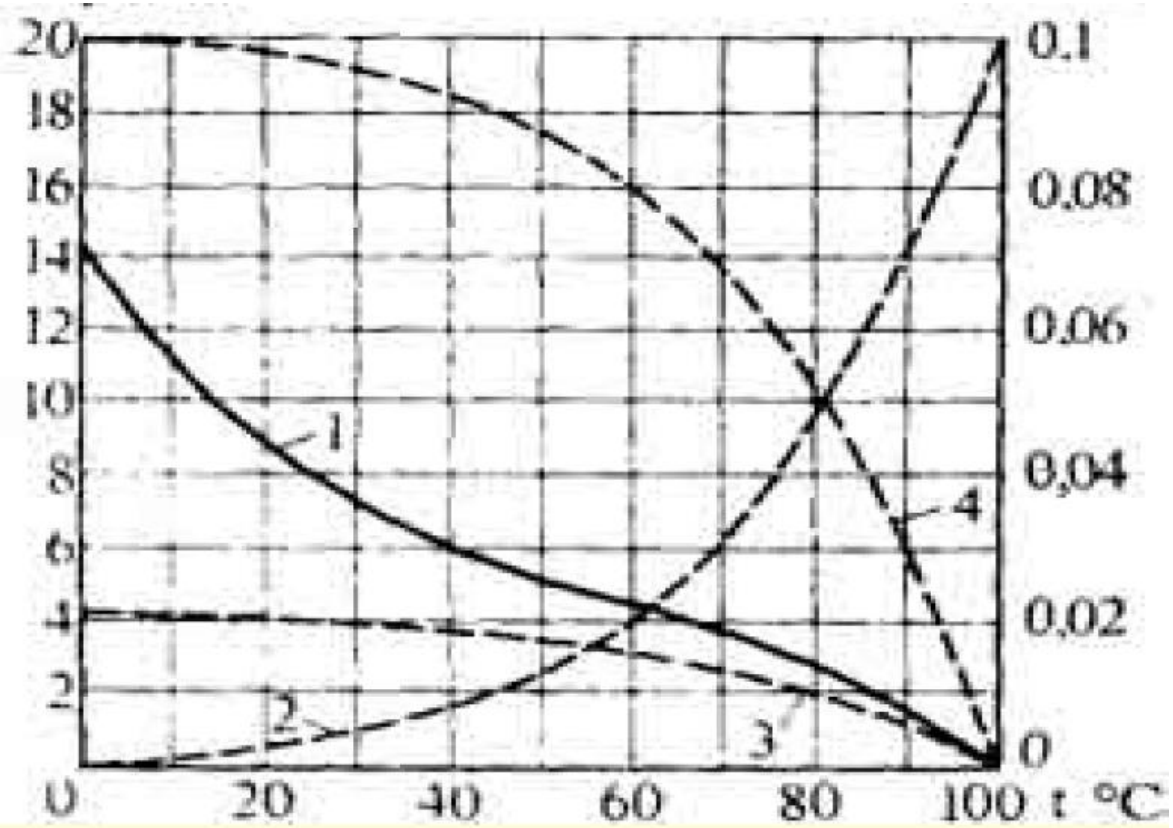
- **Deaeraor** – apparatus designed to extract and remove gases from feed water.
- Existing methods of deaeration:
  - Thermal method (applies effect of decreasing solubility of gases into water with increasing temperature);
  - Chemical methods (applies chemical reactions of nom-condensing gases with reactants, for example, hydrozin).
- Advantages of thermal deaeration:

1. Removal of all gases from water;
2. No additional components introduced into water.

THEORETICAL BASICS OF DEAERATION PROCESS

- Henry law: $G_{O2}=k_{O2} \cdot P_{O2}$
- Dalton law: $P=P_{H2O}+P_{O2}+\sum P_{ig}$

- Dependence of partial pressure of oxygen, carbon dioxide and other gases into water at atmospheric pressure.



ESSENCE OF THERMAL DEAERATION

- Essence of deaeration process:
  - Heating water to boiling temperature;
  - Creation of maximal possible partial pressure of steam.

If $\mathbf{P=P_{H2O}}$ then $\mathbf{\sum P_g=0}$

- Factors affecting thermal deaeration efficiency:
  - Temperature (higher temperature – higher efficiency);
  - Ejecting effect of heating steam (higher pressure – higher ejecting properties).
  - Contact surface area of water and steam.

CONSTRUCTION OF DEAERATOR

- Deaerator elements:
  - Deaerator column (DC) – designed to increase contact surface area of steam and water and to remove gases from water;
  - Accumulating tank (AT) – needed to accumulate deaerated water and create emergency water reserve;
  - Vapor cooler (VC) – needed to increase thermal efficiency of deaerator.

DEARATOR CLASSIFICATION

1. By purpose:
    1. Deaeration of feedwater for:
        1. Steam generator and reactor;
        2. Evaporators;
        3. Steam converters;
    2. Deaeration for:
        1. Additional and blow-down water of the first contour;
        2. Additional water of thermal network.
2. By pressure:
    1. High pressure (0,6; 0,7 and 0,8 MPa);
    2. Medium pressure (0,12 MPa);
    3. Vacuum pressure (0,0075-0,05 MPa).

DEAERATOR CLASSIFICATION

3. By water dispersing method:
    1. Jet-typed;
    2. Bubble-type;
    3. Film-type;
    4. Nozzle-type;
    5. With directing nozzles.

The deaerators with excess pressure of bubble-type are usually applied on NPP.

DEAERATORS OF NPP

- Functions of deaerators on NPP:
  1. **Removal of non-condensing gases;**
  2. Heating of feed water;
  3. Creation of emergency reserve of feed water;
  4. Supplying steam for ejectors;
  5. Collecting high-potential drainage.

For deaeration of steam generators and reactors:

- Combined jet and bubble-type; pressure – 0,6: 0,7; 0,9 and 1,2 MPa.

For deaeration of evaporator feed water:

- Bubble-type; pressure – 0,12 MPa.

For deaeration of additional network water:

- Bubble-type; vaccum deaeration (at temperatures 60-70 °C).

CHOOSING OF PRESSURE PROGRAM INTO DEAERATOR

- Pressure control programs:
  1. Variable pressure;
  2. Constant pressure;

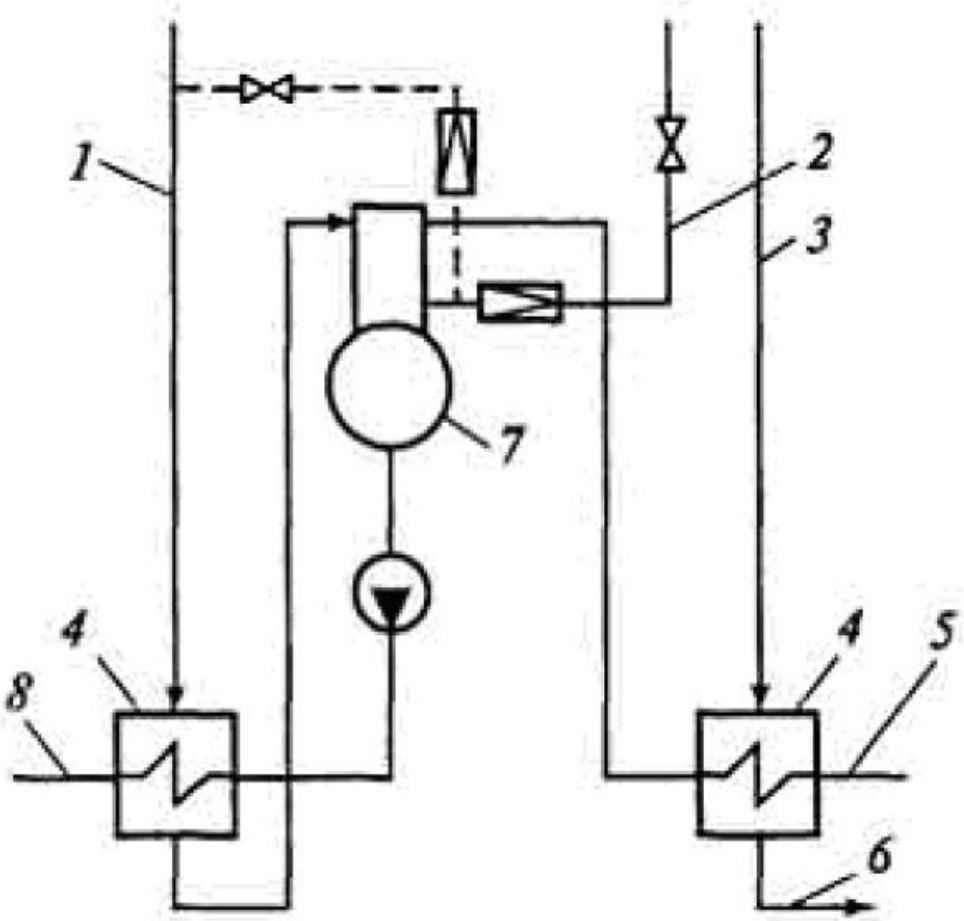
- Variable pressure:
  - **Advantages:** optimal heating of feed water;
  - **Disadvantages:** possible failures of feed water pump and injection of water droplets into deaeration column.

  Constant pressure:
  - **Advantages:** independence of deaeration parameters from other equipment;
  - **Disadvantages:** non-optimal heating of feed water.

SCHEMES OF DEAERATOR INTEGRATION INTO THERMAL SCHEME OF NPP

Two possible schemes exist:

- Fork-type connection (the heater with same pressure is situated after deaerator);
- Stand-alone stage of regenerative heating (operates on sliding pressure, bleed pressure is chosen to be higher by 30 %).

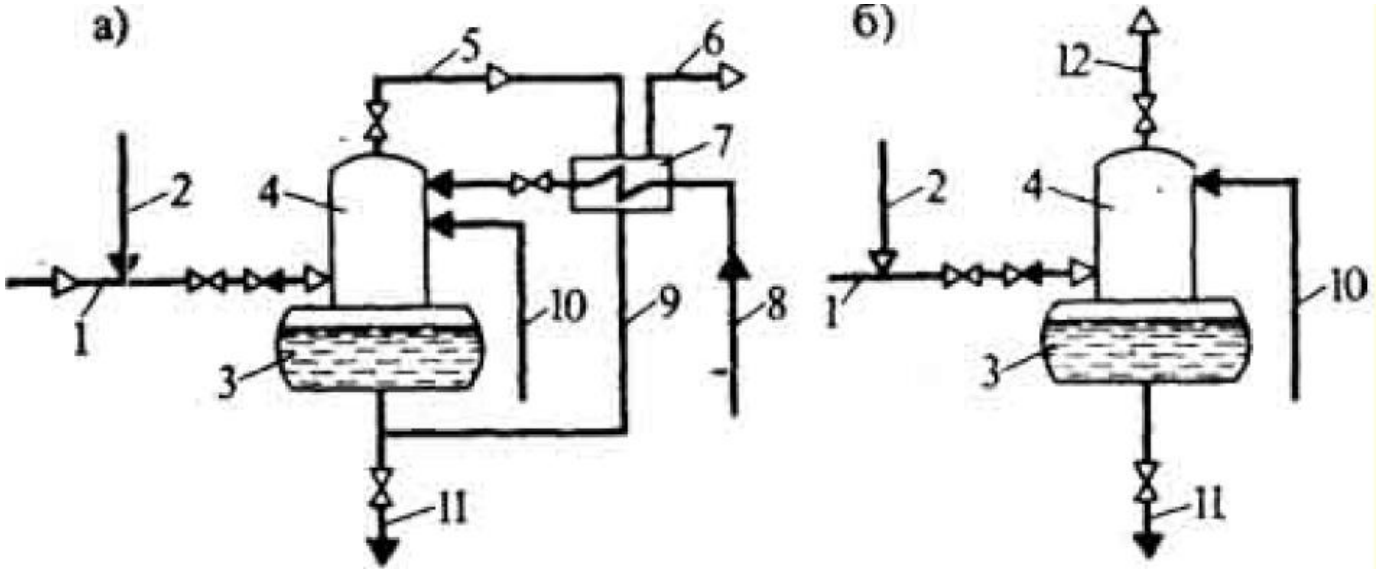


Stand-alone connection

TYPES OF DEAERATING COLUMNS

- Types of deaerating columns:
  - Jet-type;
  - Film-type;
  - Bubble-type.

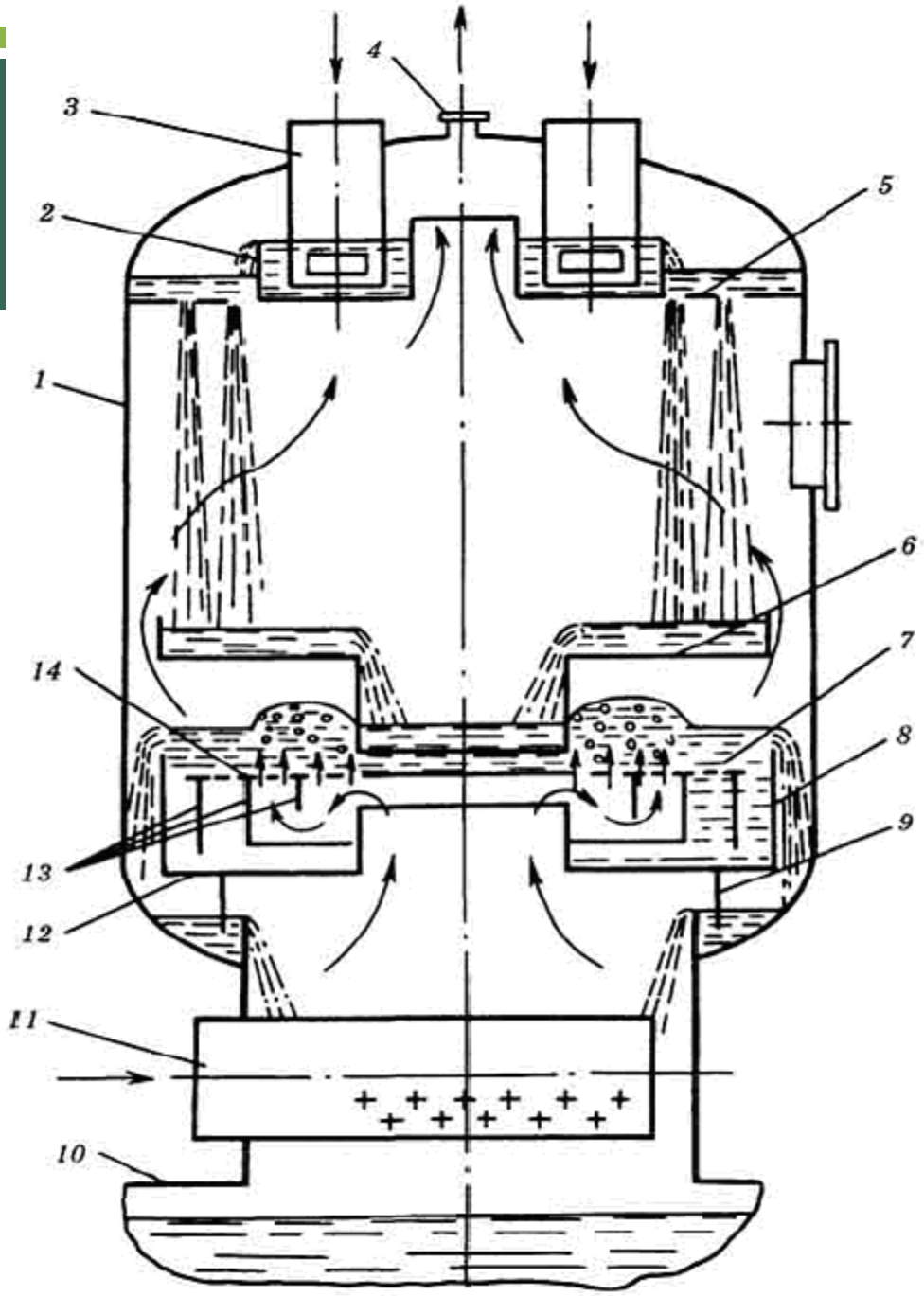
The columns of jet- and bubble-type are the most widespread.



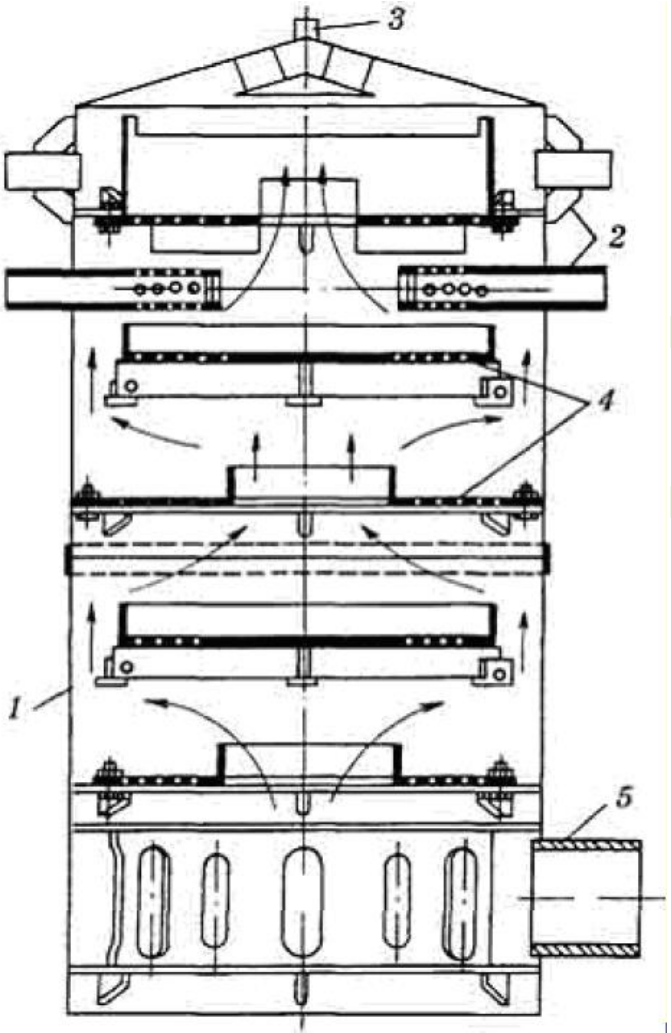
CONDITIONS OF EFFECTIVE DEAERATION

Needed conditions for effective deaeration:

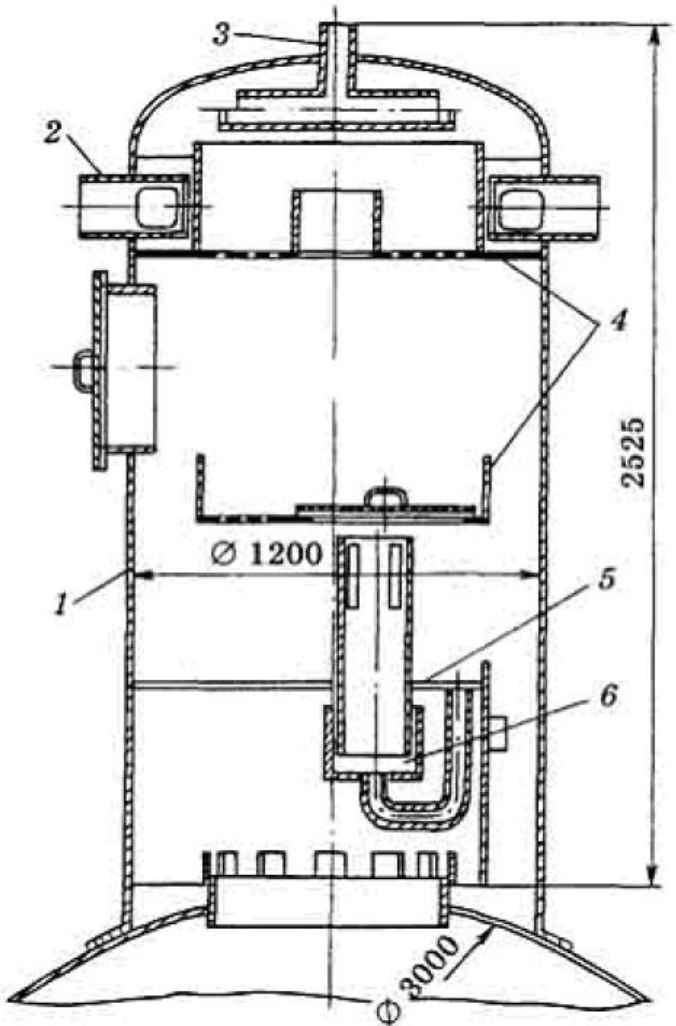
- Heating of feed water to saturation temperature at given bleed pressure;
- Ensuring needed deaeration duration;
- Supplying sufficient area of contact between steam and water;
- Removal of vapor.



CONSTRUCTION OF DEAERATION COLUMNS OF DIFFERENT TYPES



- Jet-type (left)
- Combined jet-bubble type (right)



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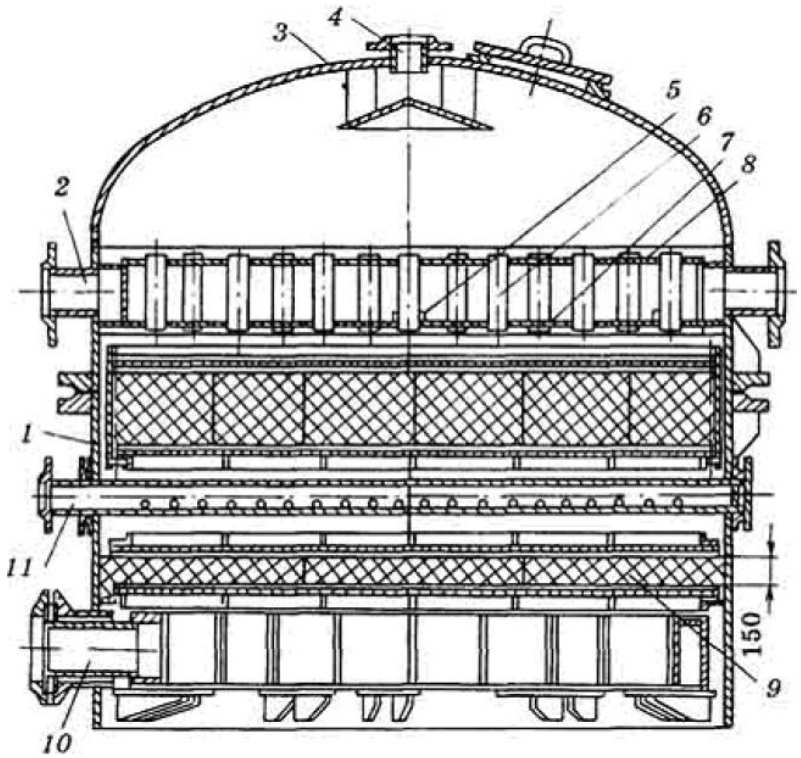
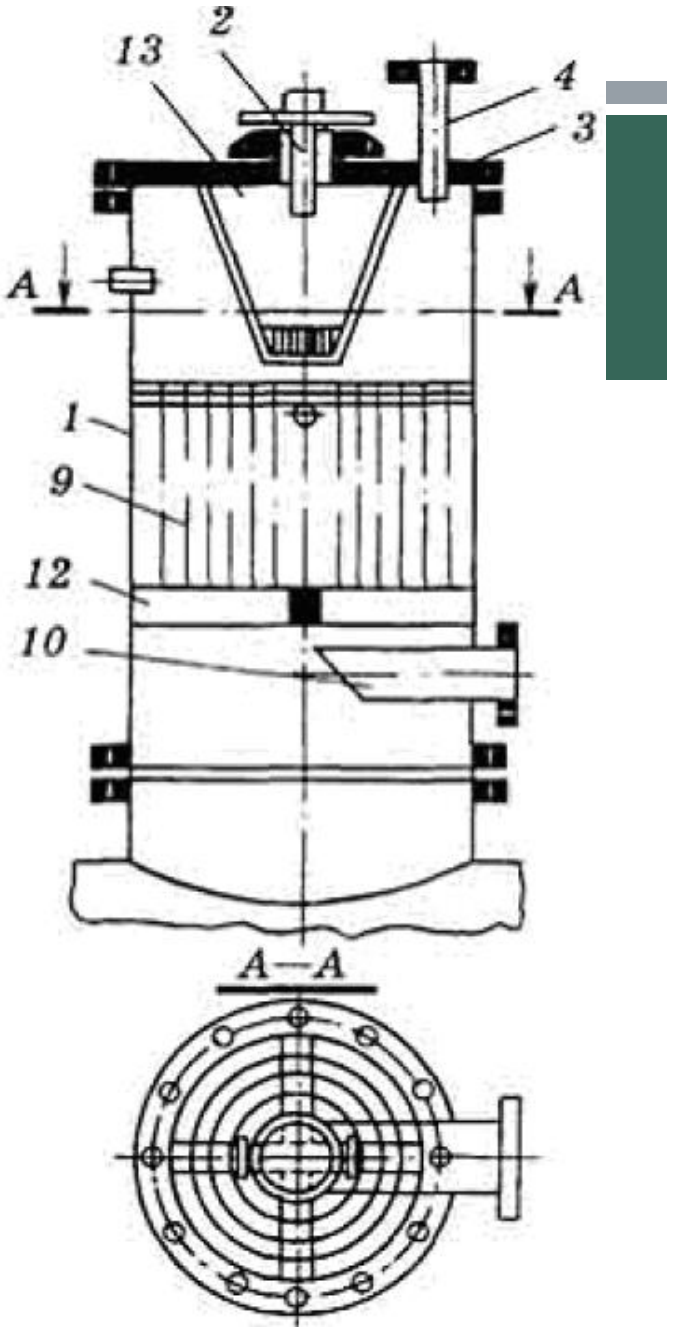


- Column of film-type with unordered cap



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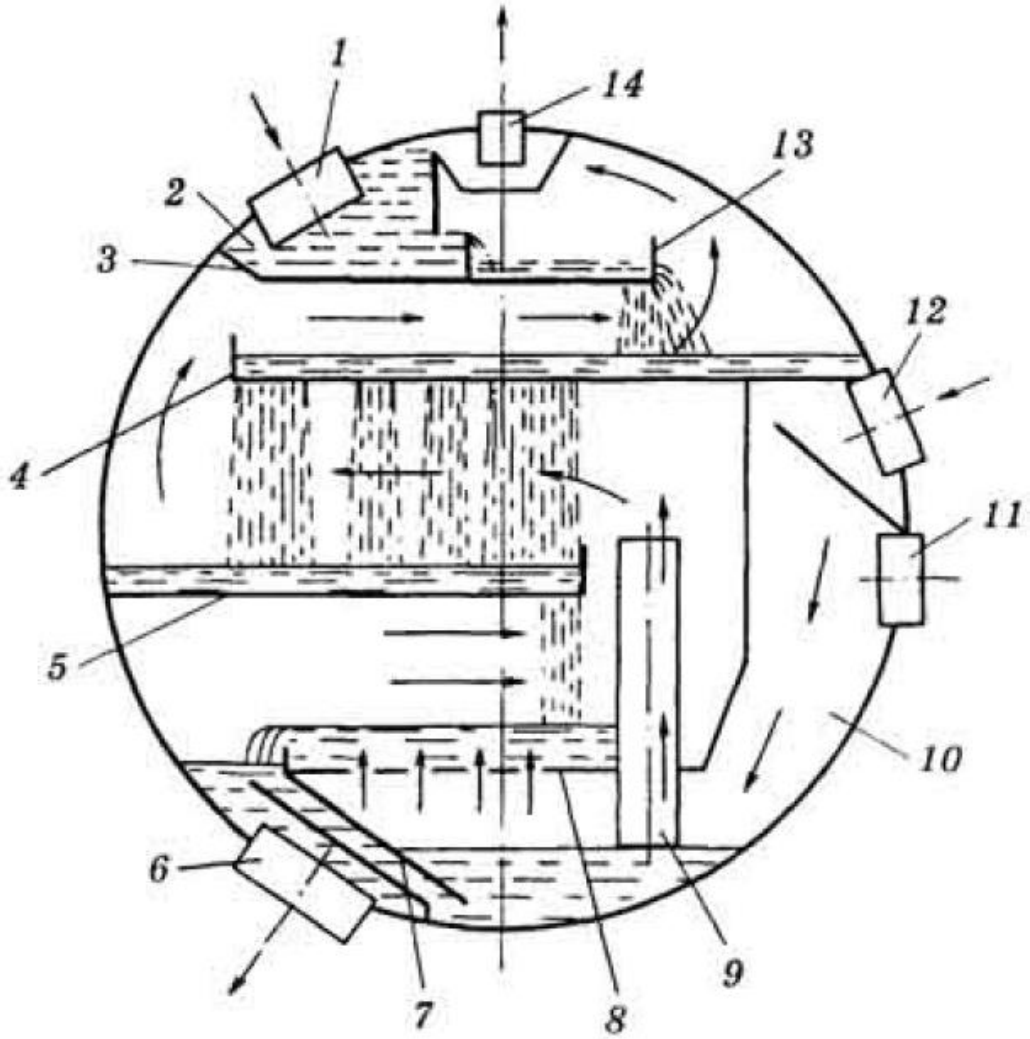
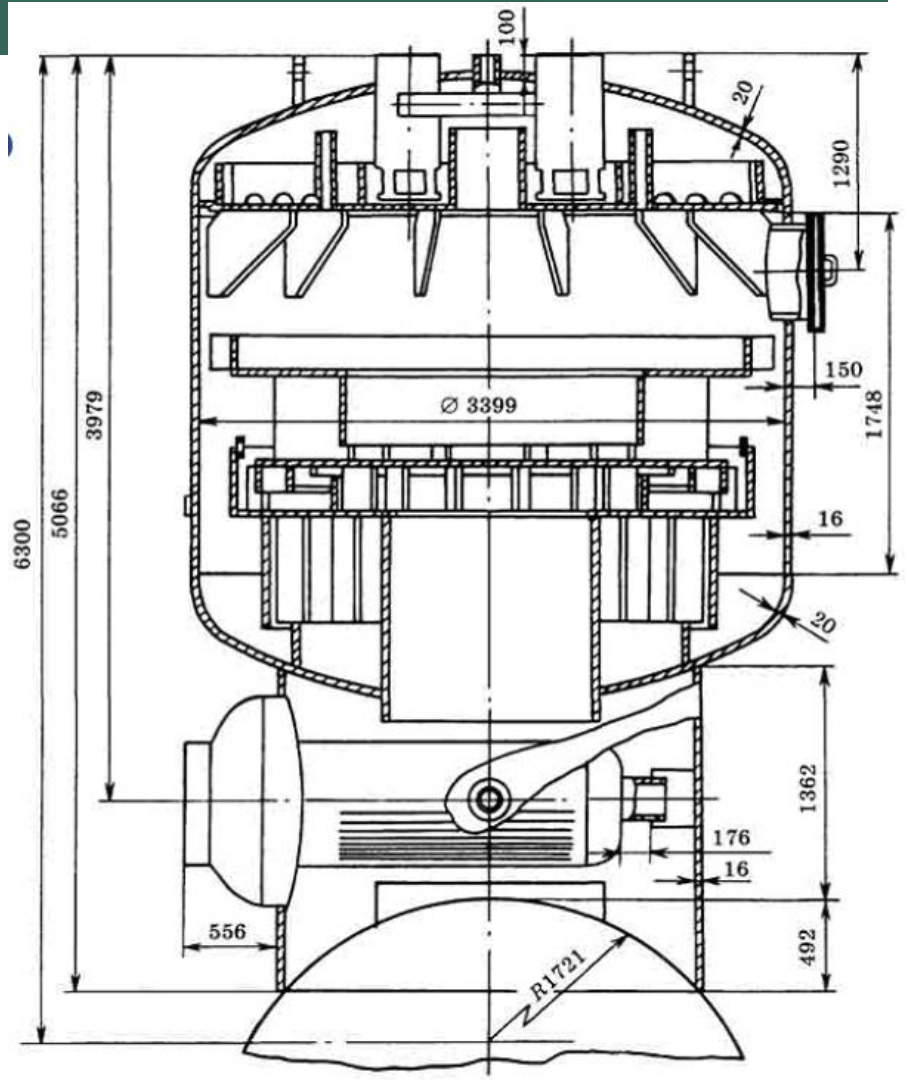


MAIN PARAMETERS OF DSP DEAERATORS FOR NPP WITH RBMK REACTOR

Characteristic	Unit	Type of deaerator			
		DP-1000	DP-1600-2	DP-2000	DP-2600
Flow rate	t/h	1000	1600	2000	2600
Pressure	MPa	0,7	0,7	0,7	0,7
Inner diameter	m	2,4	2,4	3,4	3,4
Total height	m	4,6	7,5	5,07	7,54
Geometric volume of accumulation tank	m^3	100; 120	185	150; 185	120
Type of power unit		K-500-65	K-500-60	K-500-60	K-750-65

MAIN PARAMETERS OF DSP DEAERATOR FOR NPP WITH RBMK REACTOR

Characteristic	Unit	Value
Flow rate	t/h	1000
Pressure	ksf/cm^2	
Design pressure	ksf/cm^2	
Design temperature	°C	
Inner diameter	mm	2408
Total height	mm	4661
Geometric volume	m^3	17
Mass (with water)	kg	23440

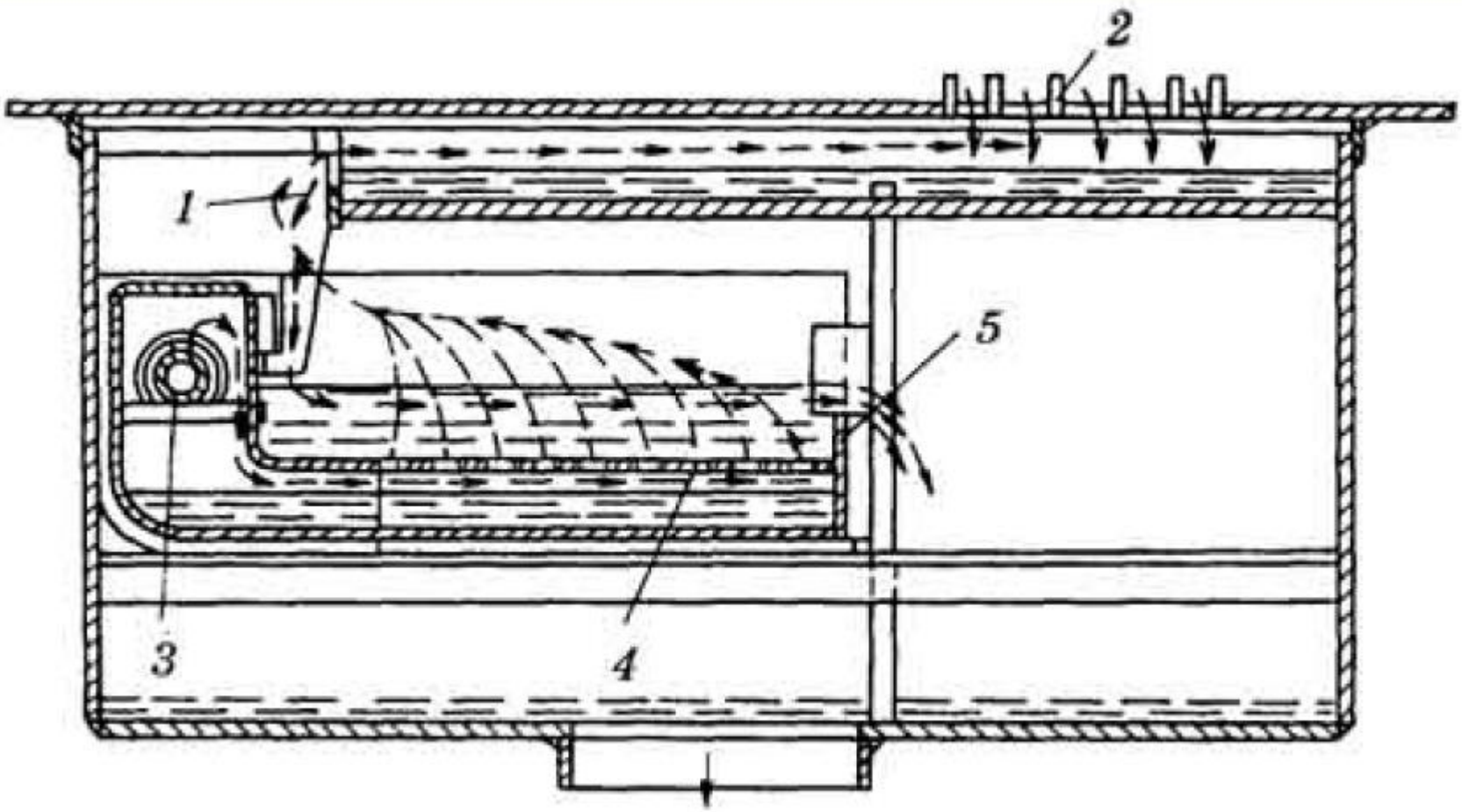


CALCULATION OF DEAERATOR

$$\left(D_{\text{п}}h_{\text{п}} + D_{\text{у}}h_{\text{у}} + \sum_{1}^{n} D_{j\text{в}}h_{j\text{в}} + D_{\text{о.к}}h_{\text{о.к}}\right)\eta_{\text{д}} = D_{\text{п.в}}h_{\text{п.в}} + \sum_{1}^{k} D_{j\text{п}}h_{j\text{п}}$$

$$\left(\alpha_{\text{п}}h_{\text{п}} + \alpha_{\text{у}}h_{\text{у}} + \sum_{1}^{n} \alpha_{j\text{в}}h_{j\text{в}} + \alpha_{\text{о.к}}h_{\text{о.к}}\right)\eta_{\text{д}} = \alpha_{\text{п.в}}h_{\text{п.в}} + \sum_{1}^{k} \alpha_{j\text{п}}h_{j\text{п}}$$

CONSTRUCTION OF BUBBLING DEVICE INTO CONDENSATE TANK



CHEMICAL DEAERATION

- To eliminate remaining oxygen the hydrazine solution is introduced into feed water.

THANK YOU FOR YOUR ATTENTION