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Nuclear power plants

Gas treatment systems

RELEASING OF RADIOACTIVE GASES AND AEROSOLS AT NPP

- The technological process at NPP involves formation of gas-aerosol radioactive wastes. It also involves the continuous removal of gases and aerosols that are formed and present, their purification and reduction of activity before releasing into the environment. The main active gases at NPPs are nuclides of xenon, krypton, argon (the so-called Inert Radioactive Gases - IRG), volatile iodine compounds, and tritium. Aerosol particles are represented mainly by isotopes ^{14}C, ^{89}Sr, ^{90}Sr, ^{134}Cs, ^{137}Cs.
- The most important task is to remove from air ^{129}I ($T_{1/2}=1,6\cdot10^{7}$ years), ^{131}I ($T_{1/2}=8,1$ days), ^{133}Xe ($T_{1/2}=5,3$ days) и ^{85}Kr ($T_{1/2}=10,8$ years).

CLASSIFICATION OF AEROSOLS AND GASEOUS CONTAMINANTS AT NPP

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- **Aerosol** – sustainable system, which consist of carrier-gas and dispersed solid particles or liquid droplets.
- **Gaseous contaminants** – contaminants presented by substances in gaseous phase, which wouldn't condense at ambient conditions.

Aerosols are classified by:

- Type of origin
  - Dispersed;
  - Condensed;
  - Dusts;
  - Smokes;
  - Mists.
- Size of particles/droplets:
  - Highly dispersed (<1 μm);
  - Intermediately dispersed (1-10 μm);
  - Roughly dispersed (>10 μm).

Gaseous contaminants (including IRG) are classified by activity:

- Low activity – less than 3,7 Bq/m^3 ($1 \cdot 10^{10}$ Ci/m^3);
- Average activity – from 3,7 Bq/m^3 ($1 \cdot 10^{10}$ Ci/m^3) to $3{,}7 \cdot 10^4$ Bq/m^3 ($1 \cdot 10^{10}$ Ci/m^3);
- High activity – more than $3{,}7 \cdot 10^4$ Bq/m^3 ($1 \cdot 10^{10}$ Ci/m^3).

APPROXIMATE AMOUNTS OF CONTAMINATED GASES FORMATION

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- The gases removed from the circuit and process equipment usually consist of N, H, contain water vapor impurities and gaseous fission and activation products, i.e. Kr, Xe and Ar radionuclides. At NPPs with VVER, the flow rate of these gases is relatively small and amounts to 4-70 m^3/hour, and at RBMK NPPs it is higher, 300-350 m^3/hour. At BN reactors, due to their greater tightness, the flow rate of the gases formed is much lower. The gas volume of this reactor is filled with a protective gas with a pressure higher than atmospheric, which can lead to its leakage together with the decay products. Since the protective gas is in the reactor for a long time, the concentration of most decay products in these gases is quite small.

AMOUNT OF GASES FORMED AT REACTOR AND OTHER EQUIPMENT

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- The volume of blowdowns from the refueling box for ^{133}Xe at the end of the refueling is 38.4 m^3 and 1370 MBq/l.
- The volume of blowdowns of the reactor gas space for ^{133}Xe at the stopped reactor is 88.2 m^3 and 596 MBq/l.
- The activity of the reactor gas space is determined mainly by leaks of gaseous decay products from the fuel through microcracks. If there are no defective fuel elements in the core, then the activity of the reactor gas cavity is determined by the surface contamination of the fuel elements with fuel and is determined by the radionuclide ^{41}Ar (16.1 MBq/l).

AMOUNT OF GASES FORMED AT REACTOR AND OTHER EQUIPMENT DURING REFUELING AND MAINTENANCE

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Source	Volume, m^3	Activity, Bq
Gas cavity	89,0	$6{,}1 \cdot 10^{14}$
Exposure receivers	89,0	$9{,}5 \cdot 10^{11}$
Drums of burnt fuel	21,6	$6{,}3 \cdot 10^{11}$
Drums of fresh fuel	650	$6{,}3 \cdot 10^{10}$
Refueling box	1500	$6{,}3 \cdot 10^{10}$
Washing box	1450	$6{,}3 \cdot 10^{10}$
Washing fuel assembly	80	$1{,}1 \cdot 10^{12}$
Fuel elevator	1700	$6{,}3 \cdot 10^{10}$
Water supply for washing	650	$1{,}2 \cdot 10^{10}$
Vacuuming equipment of circuit	500	$1{,}0 \cdot 10^{12}$
Sampling valve of 1^{st} circuit	1	$1{,}0 \cdot 10^{5}$
Lab access to 1^{st} circuit	40	$4{,}0 \cdot 10^{12}$

FEATURES OF AEROSOL CLEANSING

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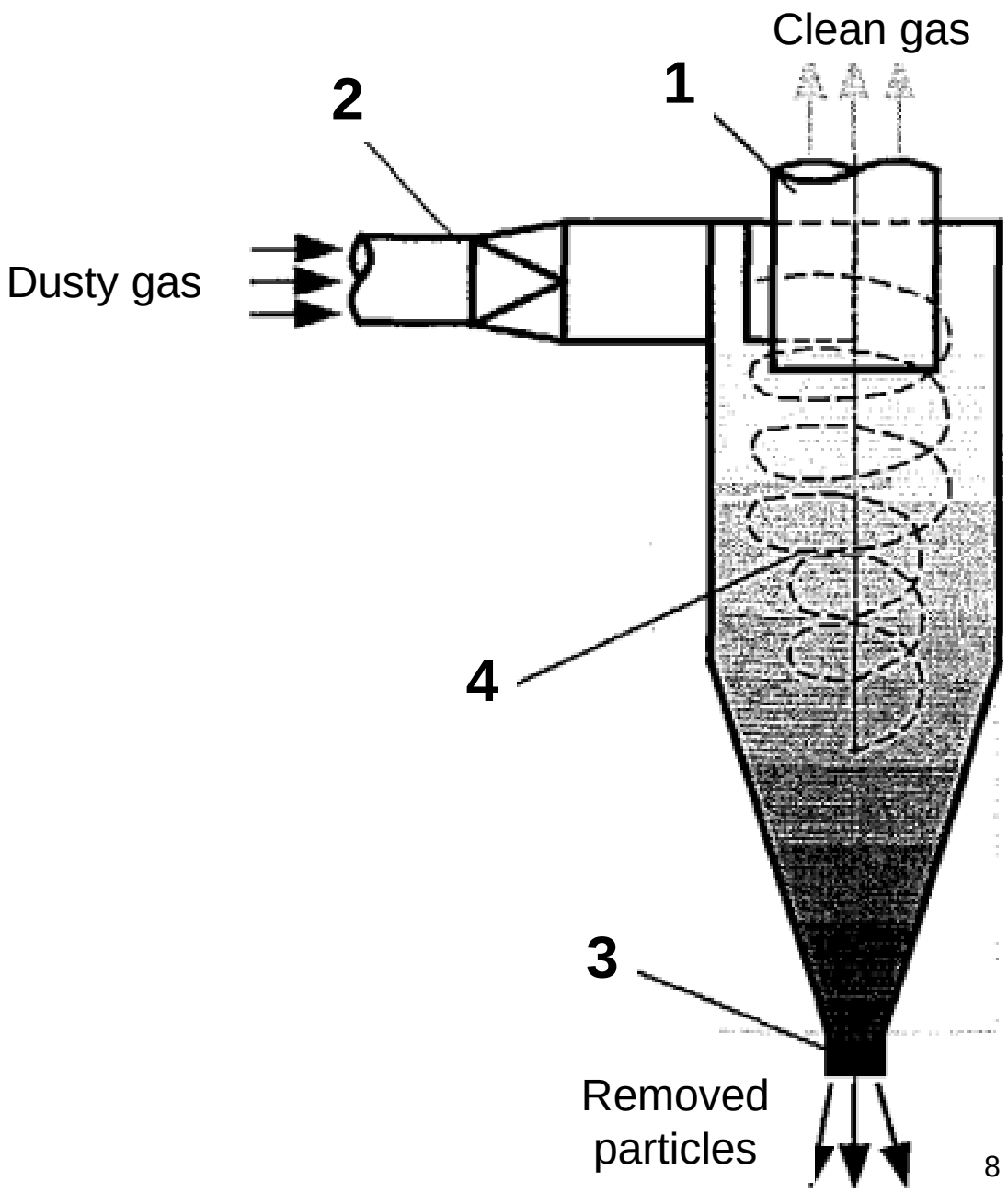
- The task of cleaning gas-aerosol emissions from NPP is to reduce the activity of aerosols, iodine radionuclides and IRGs entering the emission to acceptable values. All of these substances are formed in different phases, which determines different technologies for their removal.
  - Aerosols are particles and aerosol filters, which are also used in other industries, are suitable for their capture.
  - To capture radioactive iodine isotopes, the properties of some substances are used, such as activated carbon, to effectively absorb iodine or use the chemical activity of iodine and remove it from the gas flow through chemical reactions with substances firmly fixed in filters.
  - To remove IRGs, they must be kept in a sorption material or gas holder.

CYCLONE SEPARATOR

1. Air exhaust
2. Air inlet
3. Dust outlet
4. Housing



VENTURI SCRUBBER

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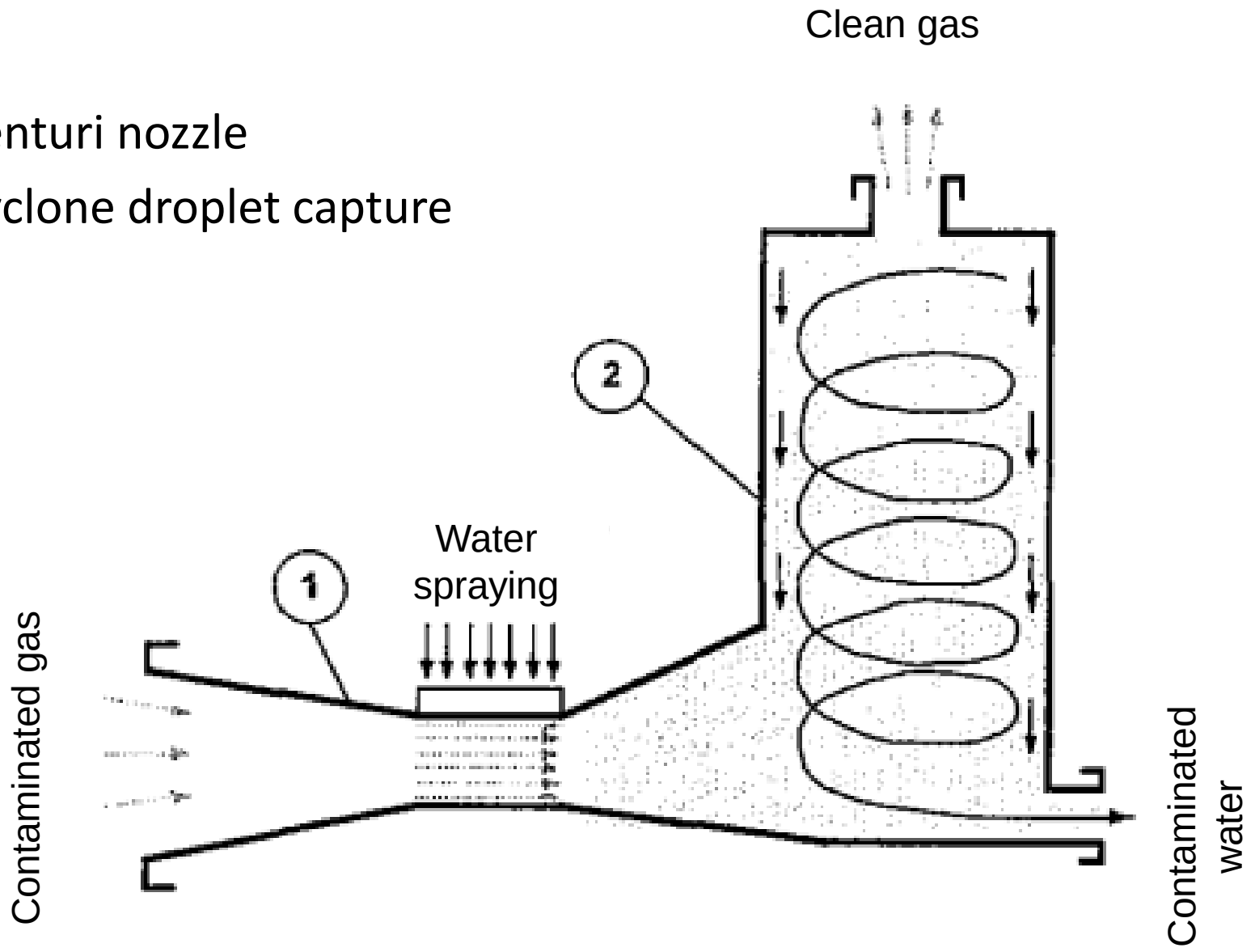
1. Venturi nozzle
2. Cyclone droplet capture



FILTERS OF SPECIAL GAS TREATMENT SYSTEM

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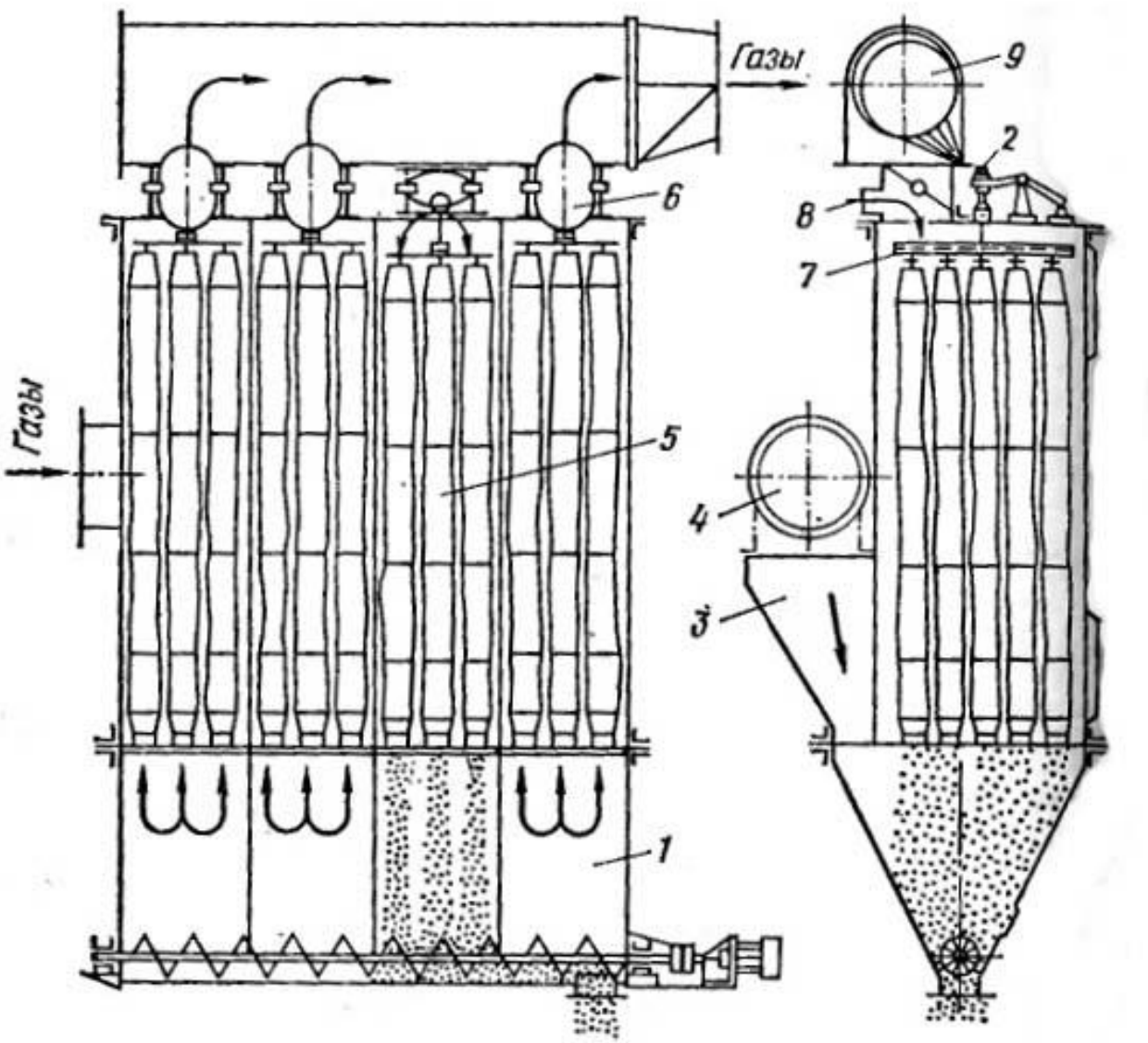
The following filters are most widely used:

- metal-fabric;
- metal-ceramic;
- packed;
- fabric;
- filters equipped with Petryanov fabric;
- electrostatic filters;
- nuclear filters.

METAL-FABRIC FILTER



1 – hopper

2 - shaking mechanism

3 – collector

4 - dusty gas duct

5 - filter section during regeneration

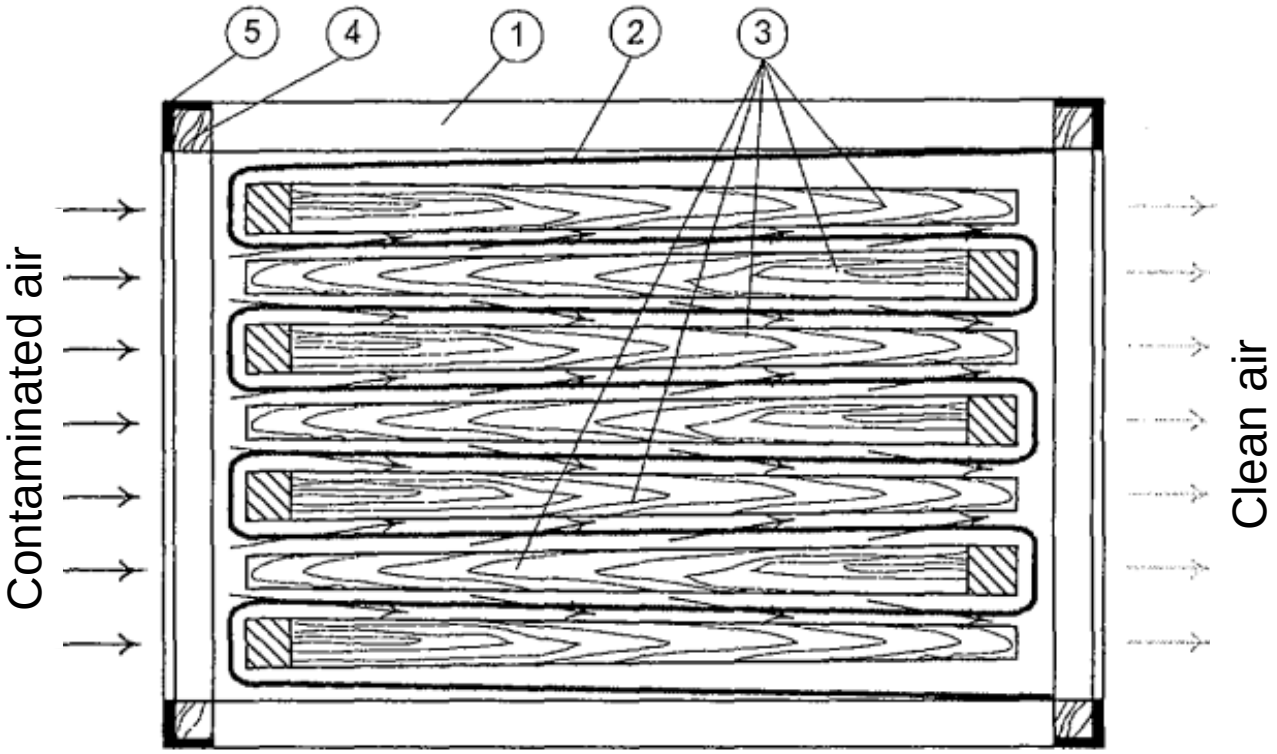
6 - gas valve

7 - sleeve suspension frame

8 - purge valve

9 - outlet collector

FABRIC FILTER



1 – housing

2 – filter material – Petryanov fabric

3 – separator frames

4 – connecting flange

5 – rubber gasket

FABRIC FILER COMPOUNDING

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1 – air ducts

2 – valves

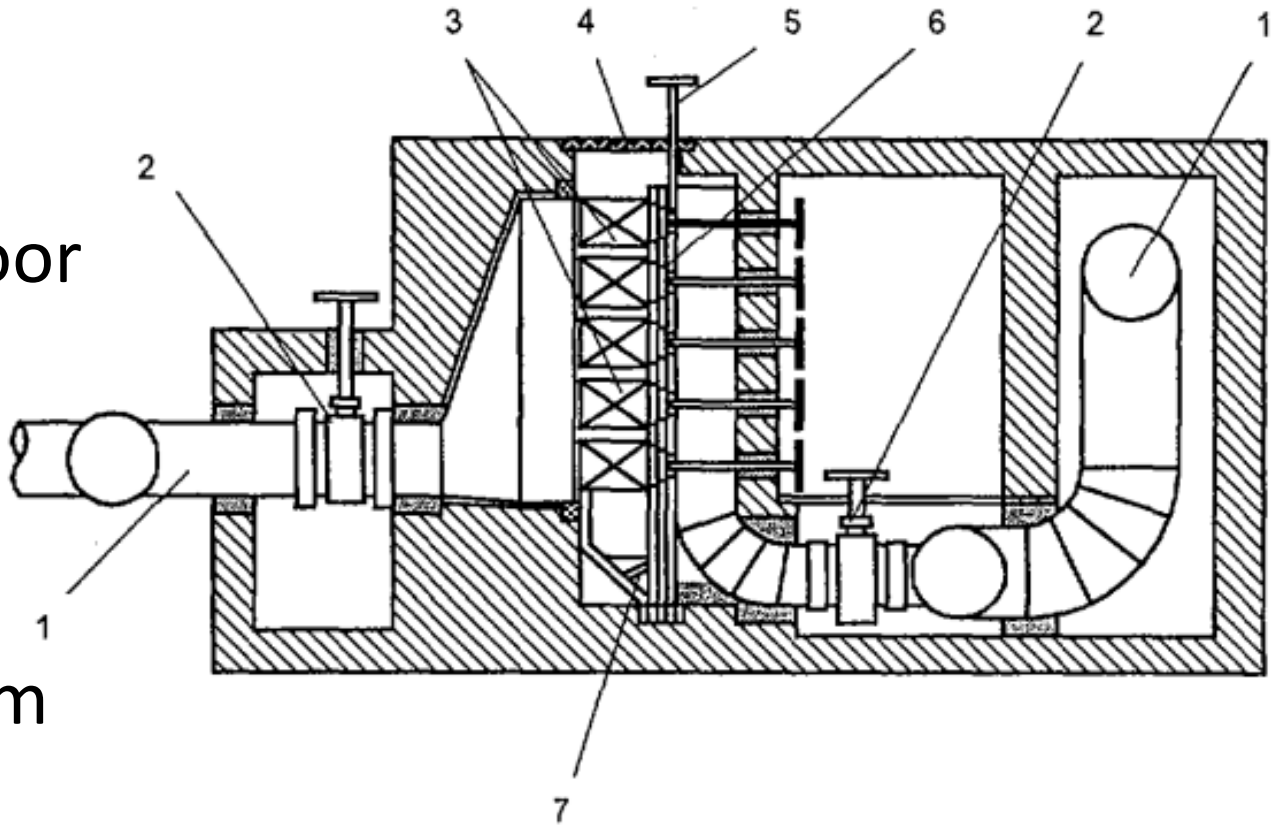
3 – filters

4 – removable floor

5 – filter moving drive

6 – fixing device

7 – lifting platform



GENERAL IMAGE OF FILTER UNIT

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1 – connection chamber

2 – connection pipe

3 – filter for capturing fog and droplets

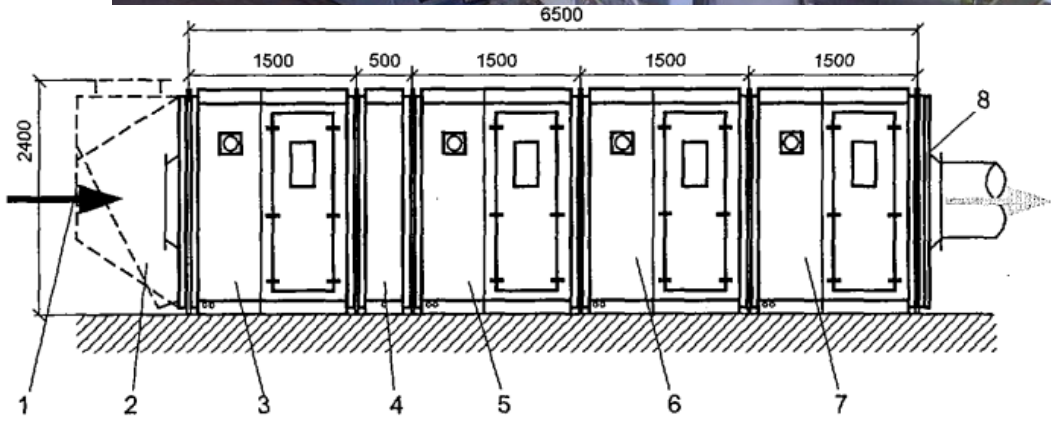
4 – electric air heater

5 – aerosol pre-filter

6 – high-efficiency aerosol filter

7 – iodine filter

8 – connection pipe



COMPLEX GAS CLEANSING

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1 - fuel cutting unit

2 - solvent apparatus

3 – condenser

4 - recombination column

5 - desorption column

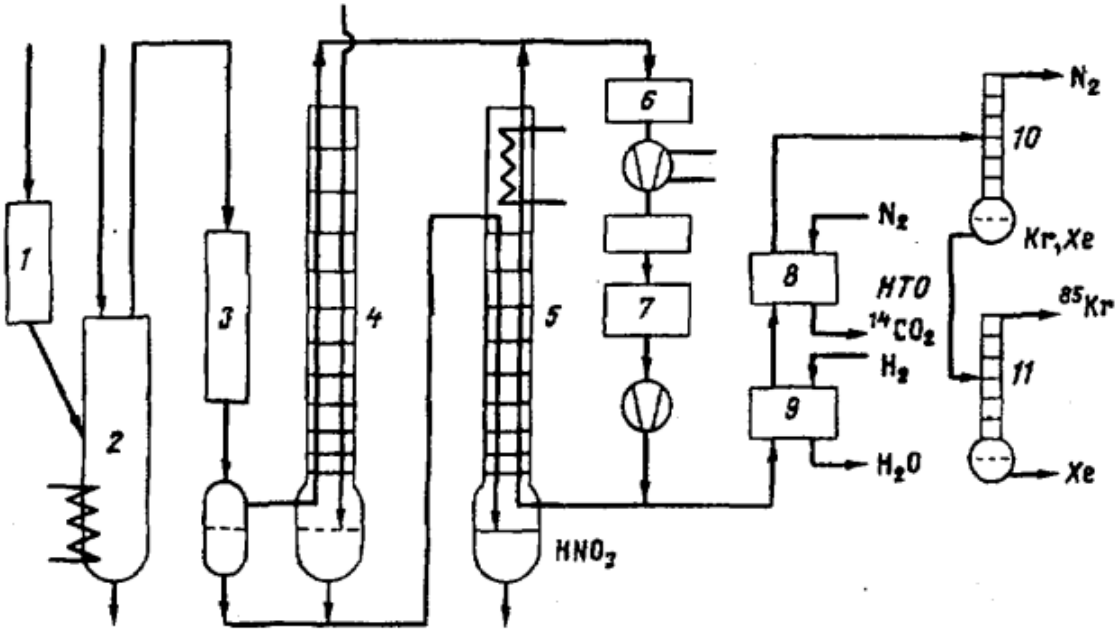
6 - system of filters for coarse, fine and absolute purification

7 - silver filter

8 - reactor for removing oxygen and residual nitrogen oxides

9 - filter filled with molecular sieve

10,11 - rectification columns for the extraction and separation of krypton and xenon



RESEARCH REACTOR SPACE CLASSIFICATION

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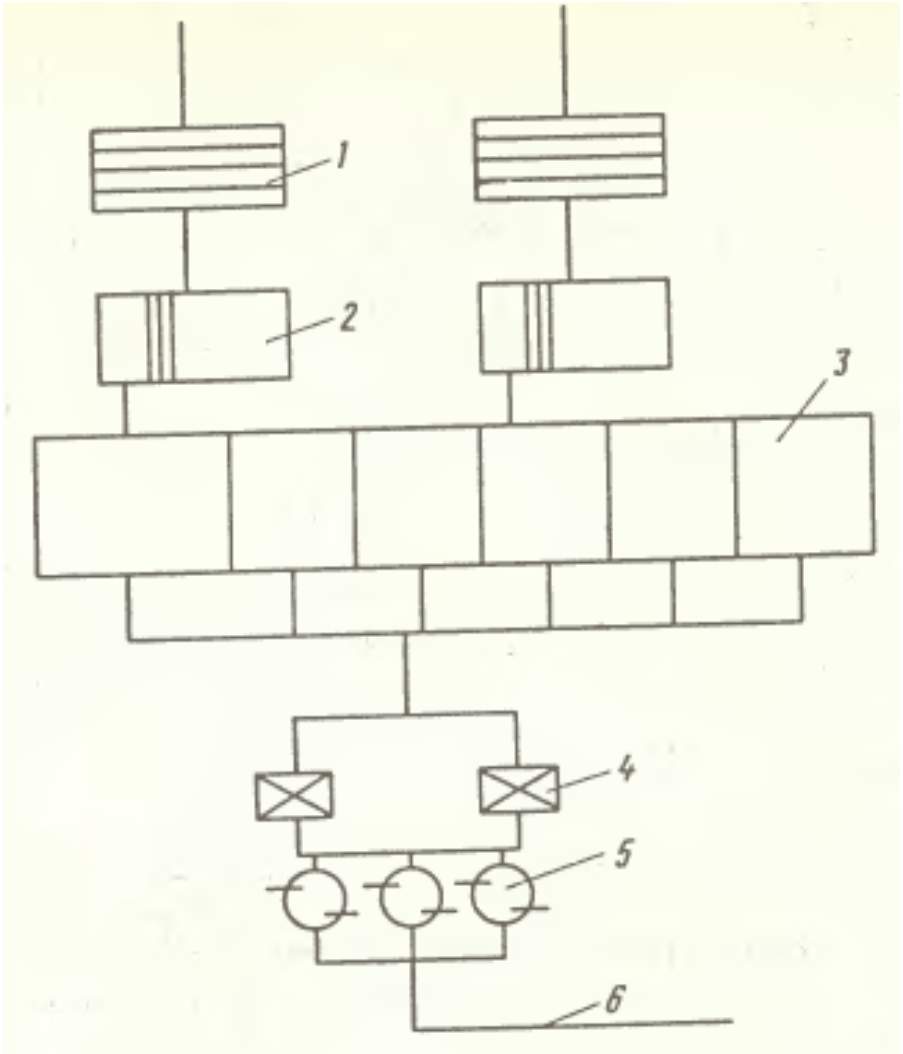
- The NPP rooms are divided into:
- Free regime zone;
- Strict regime zone (reactor island):
  - Serviced rooms (t=20-22 °C);
  - Semi-serviced rooms (t=40 °C);
  - Unserviced rooms (t=60 °C).
- Research reactor ventilation systems must ensure:
  - Creation of vacuum in the room;
  - Removal of excess heat and moisture;
  - Creation of conditions for equipment operation;
  - Creation of normal conditions for personnel;
  - Creation of conditions for equipment operation during repair and reloading operations during the reactor shutdown.



AIR VENTILATION SYSTEM

1 - outdoor air purification filter

2 - ventilation unit with heating

3 - ventilated rooms

4 - aerosol filter

5 - iodine filter

6 - outlet to the vent pipe

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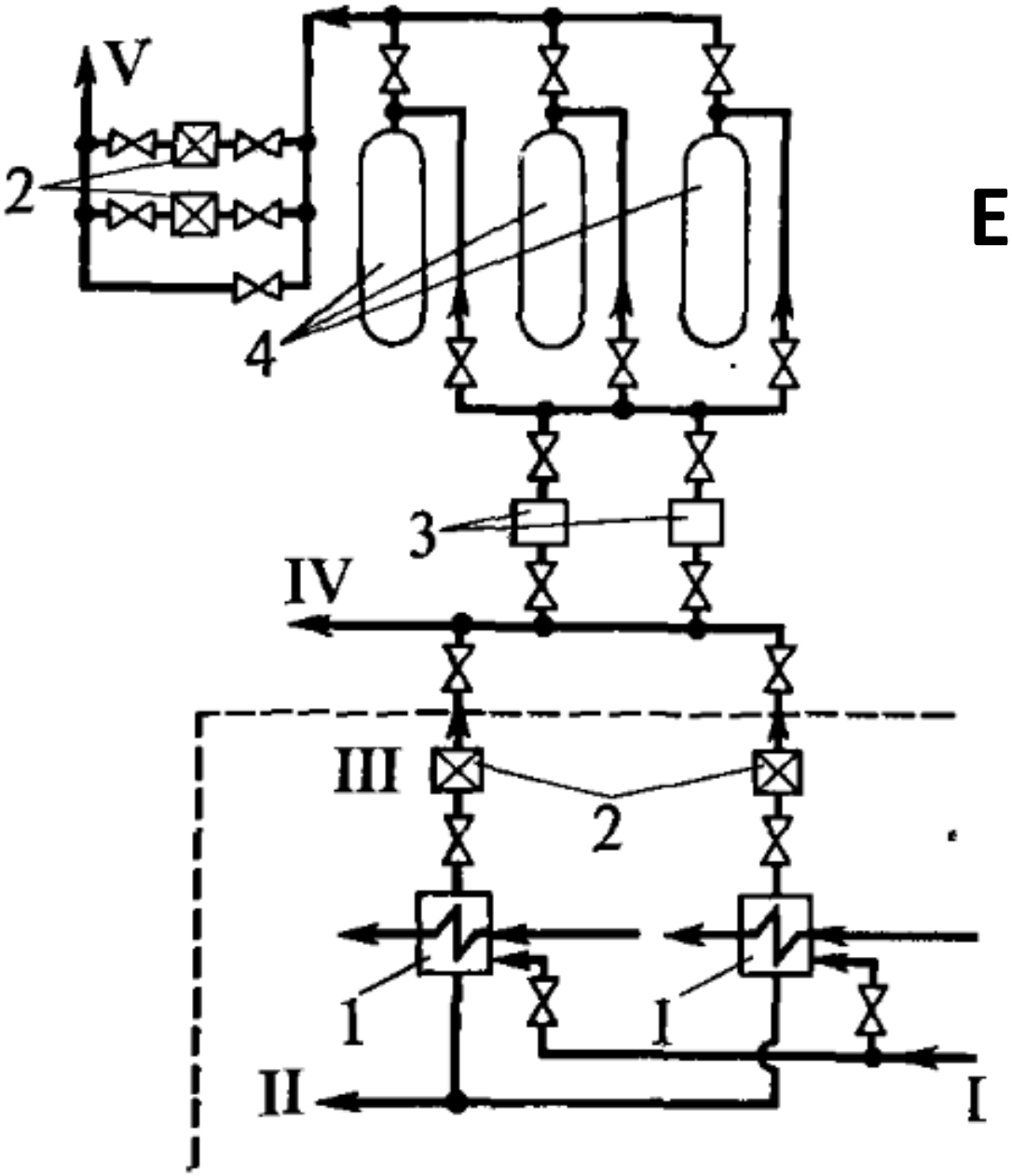
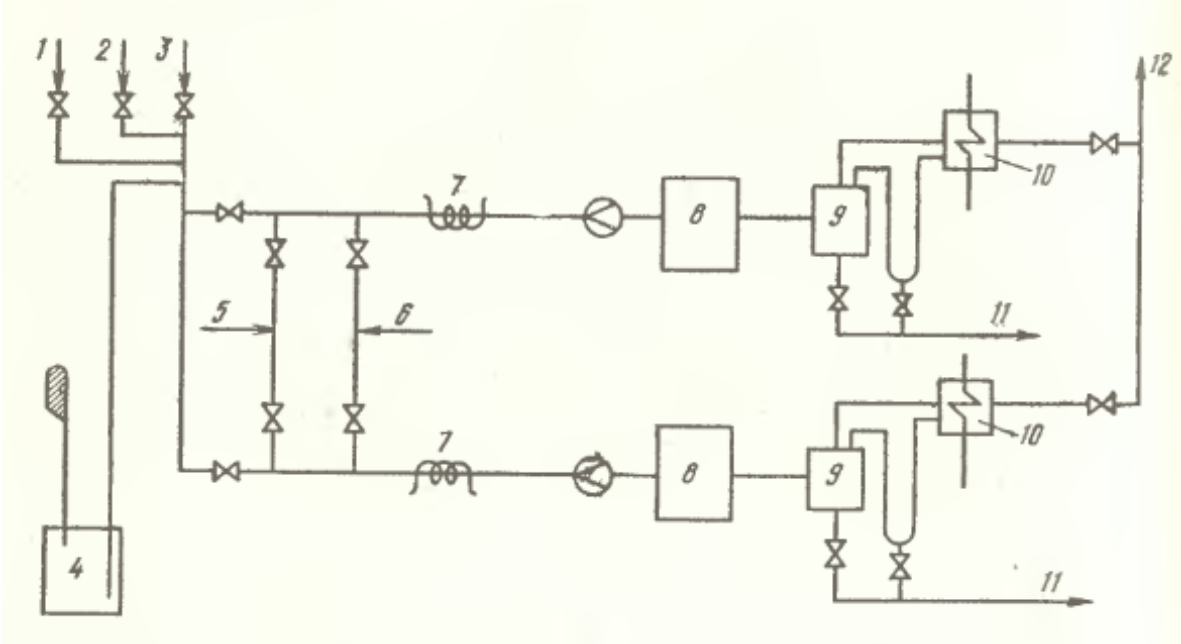
GASHOLDER EXPOSURE SYSTEM



1 – gas cooler
2 – aerosol filter
3 – compressor
4 – gas holder
5 – gas outlet to ventilation pipe

HYDROGEN COMBUSTION SYSTEM

1 – inlet from starting ejector
2 – inlet from process condenser
3 – ejector exhaust
4 – hydraulic seal
5 – air inlet
6 – steam inlet
7 – heater
8 – contact apparatus
9 – separator
10 – cooler
11 – condensate outlet
12 – outlet to exposure chambers



SPECIAL GAS TREATMENT SYSTEM

1 – first stage of the cooler (cooling with process water)

2 – second stage of the cooler (cooling with water from the refrigeration machine)

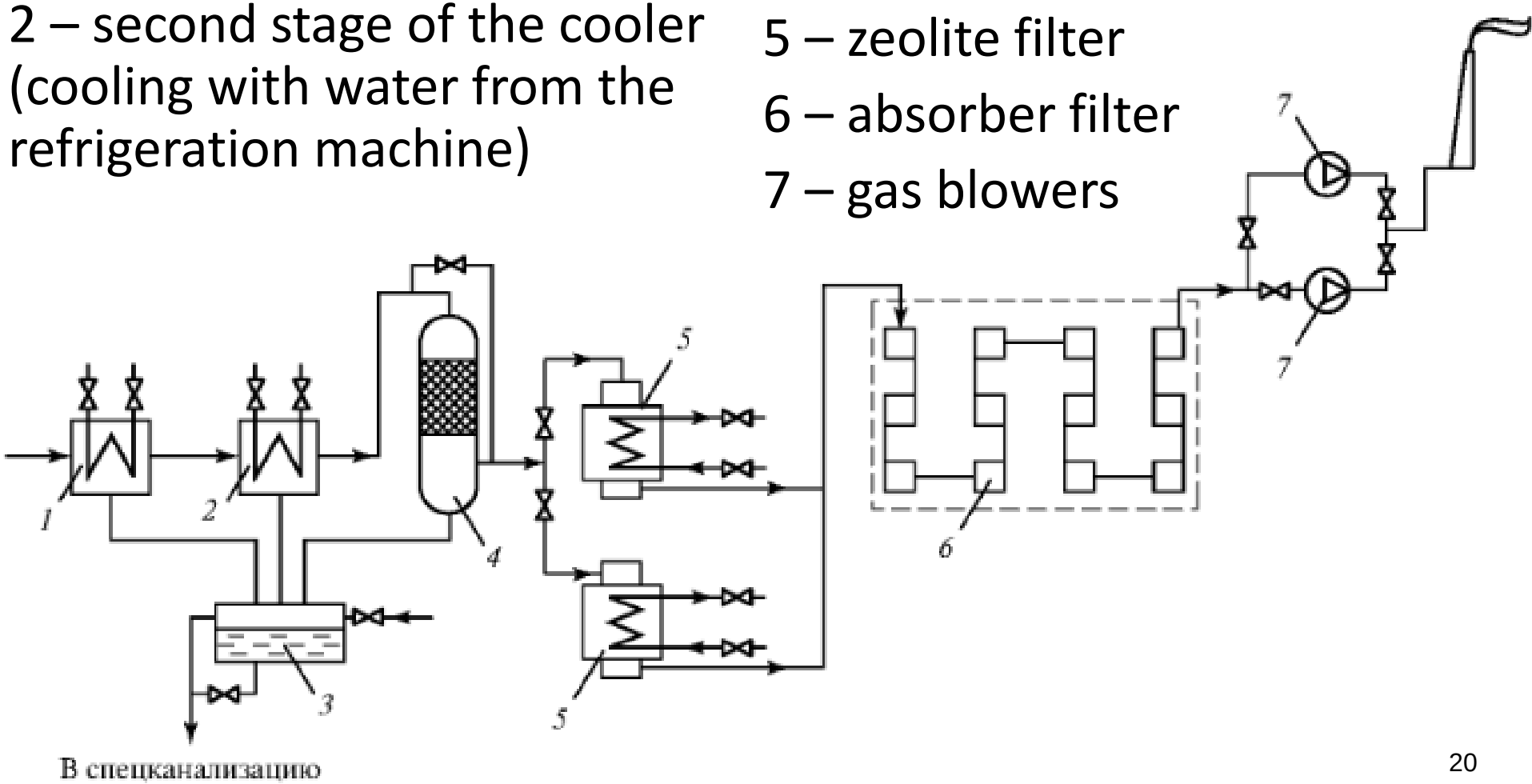
3 – water seal tank

4 – aerosol filter

5 – zeolite filter

6 – absorber filter

7 – gas blowers

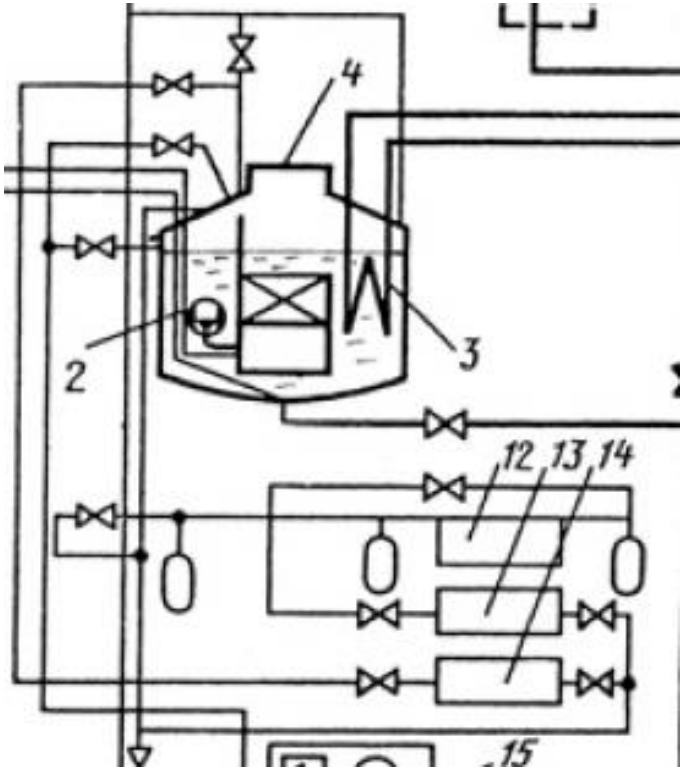


REACTOR GAS TREATMENT SYSTEM

12 – argon purification system

13 – active argon exposure system

14 – active argon purification system



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Thanks for attention!