TOMSK POLYTECHNIC UNIVERSITY

EQUIPMENT OF TWO-CIRCUIT NPP

MAIN FEATURES

- Definition and main properties of reactor
- Main schemes and equipment
- Construction of reactor part
- Subsystems of 2-circuit NPP

DEFINITION AND MAIN FEATURES

- Two-circuit NPP are the most widespread schemes of power stations in the world now. They represent the most developed, safe and effective technological solutions for energy production.
- The substance of the first circuit is called coolant. Usually its pressurized non-boiling water (in CANDU reactors the heavy water is used). The substance of the second circuit is called working medium or working fluid which applies saturated or slightly overheated steam.
- The description of such systems will be carried out on the example of NPP with WWER-1000 reactor system.

- The reactor part of WWER NPP could be divide into two parts:
  - Main systems of circulating contour.
  - Subsystems of reactor part.

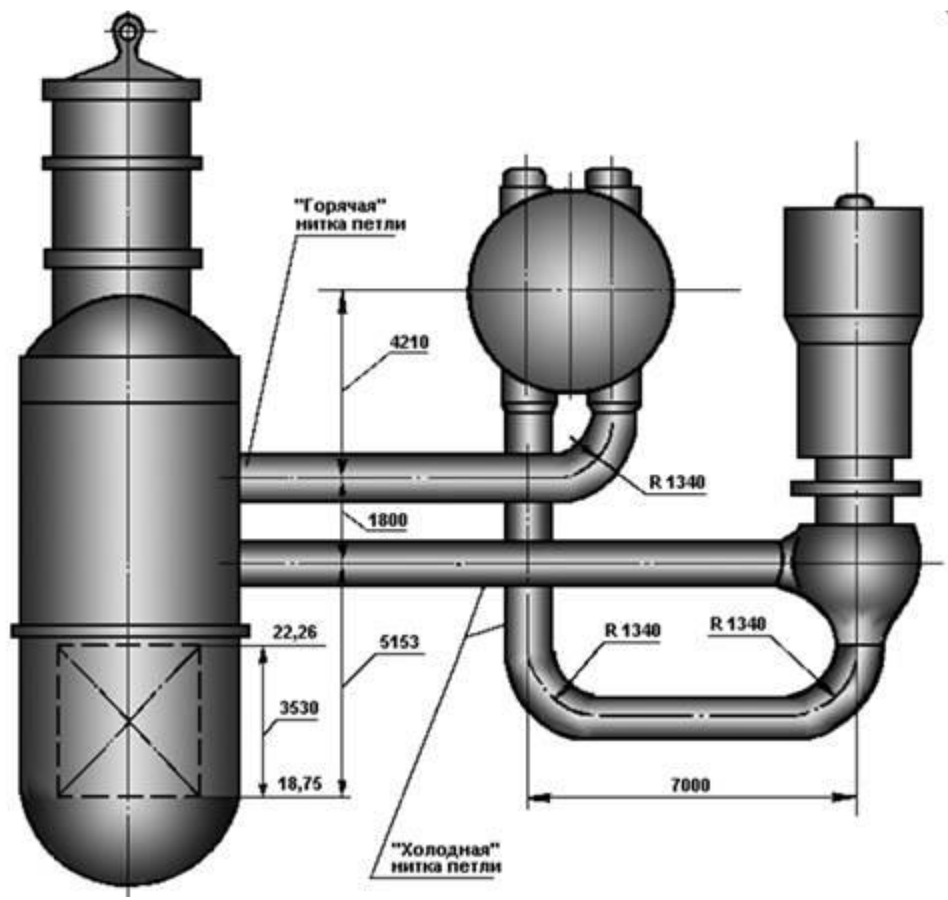
MAIN CIRCULATING CONTOUR (MCC)

- MCC is circuit which represent the way of coolant circulation through active zone. Main purpose – cooling of active zone and heat transfer to the working fluid.
- The first contour (MCC) includes:
  - Reactor;
  - Steam generator;
  - Main circulating pump;
  - Subsystems:
    - Pressure compensation system;
    - Additional water inlet and cleansing system;
    - System of emergency cooling of active zone;
    - System of gas vent;
    - Other lesser systems (organized leakage, water treatment drainage).

MAIN CIRCULATING CONTOUR (MCC)

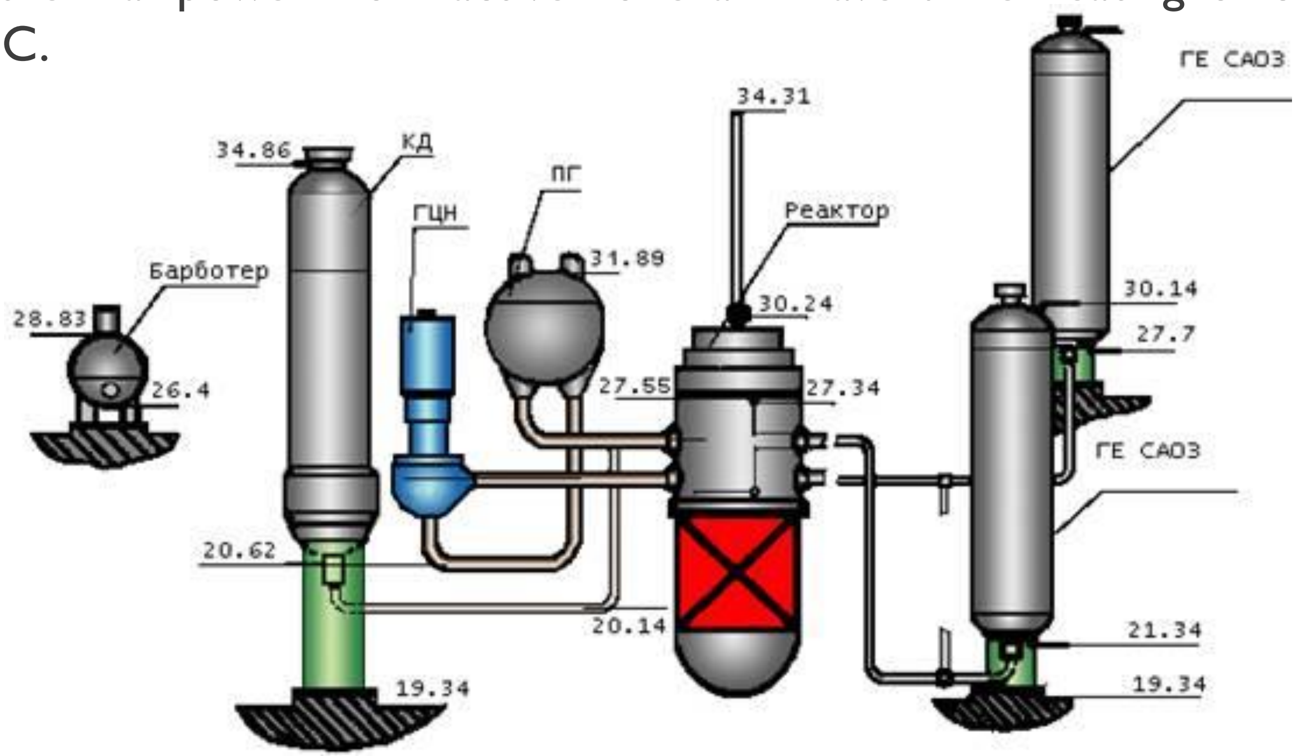
MCC exploited under high pressure to avoid boiling of coolant. Working pressure is equal to 16 MPa. Being closed it plays role of barrier which prevents leakage of fission products.

- Thermal power – 3000 MW,
- Outlet temperature – 322 °C
- Flow rate – 15800 kg/s



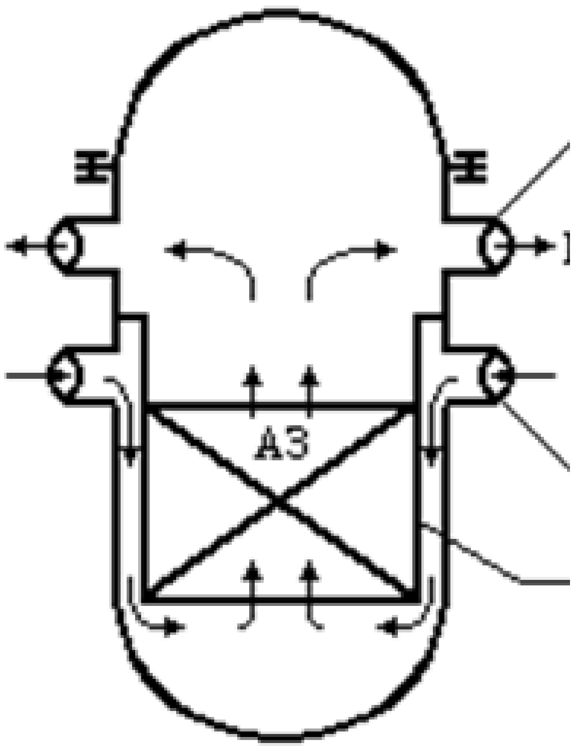
MAIN CIRCULATING CONTOUR (MCC)

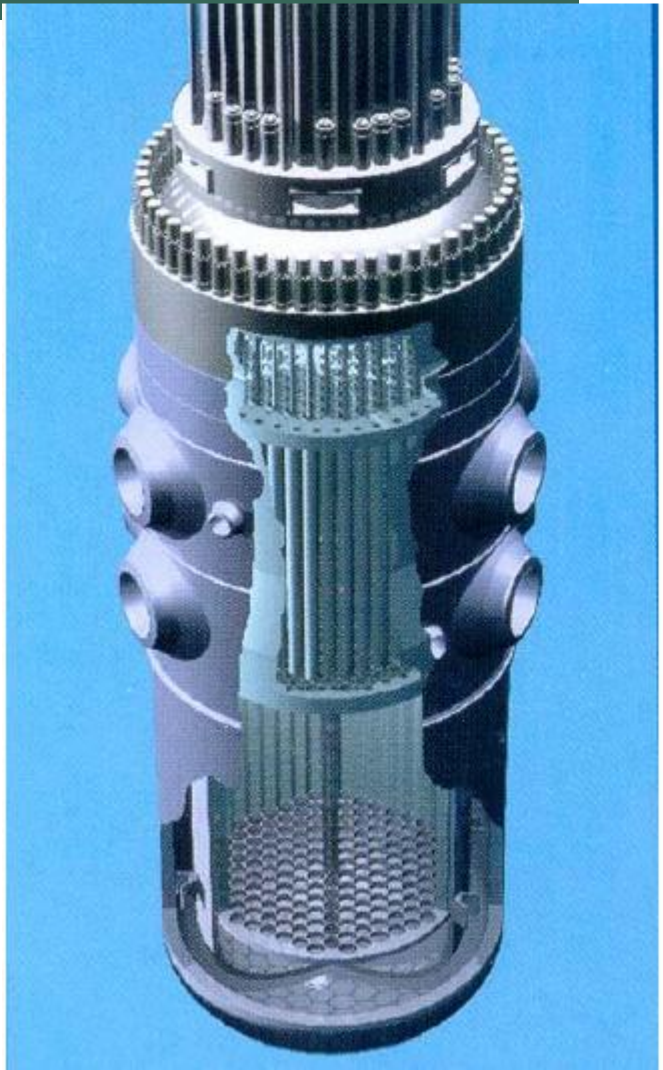
- Design of equipment allows the emergency cooling of reactor into system of natural circulation by situating equipment with large water storage higher in comparison with active zone. After shut-down the forced circulation is changed on natural circulation due to main circulation pump inertia. It will allow to take up to 10 % of nominal thermal power from active zone and have underheating of coolant more than 15 °C.



WWER REACTOR CONSTRUCTION

- Reactor is vertical, shell-type with water coolant.



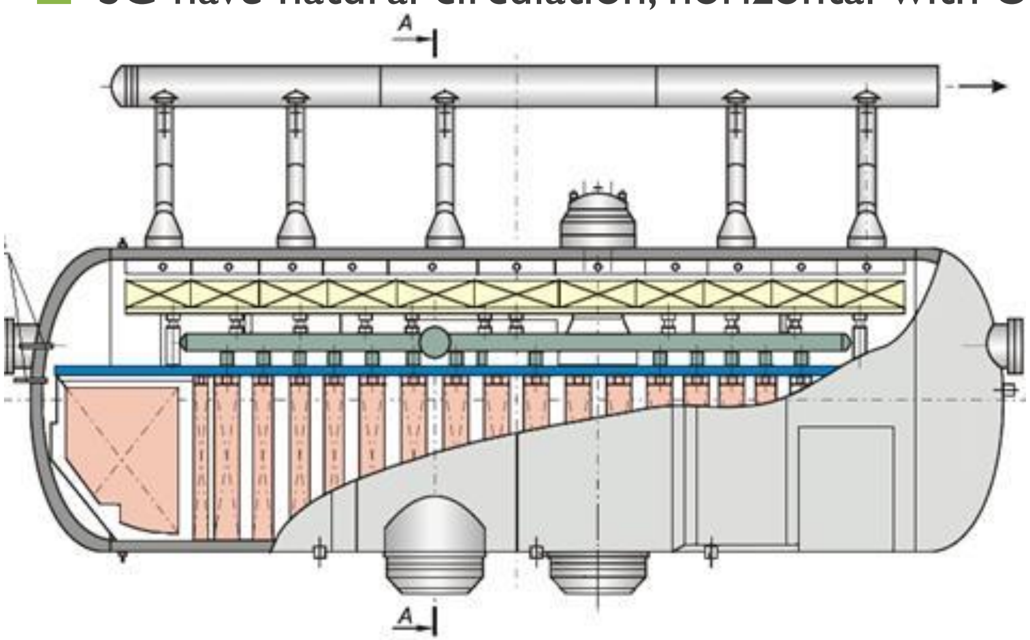


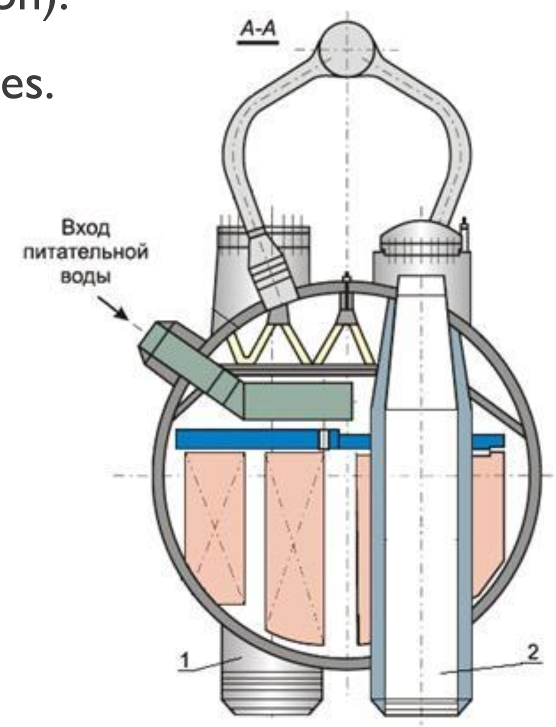
WWER STEAM GENERATOR SYSTEM

- Steam generating unit includes water treatment system for additional and blowdown water. It consists of deaerating tanks with deaerating columns, feedwater pumps with power-driven turbines and additional pumps.
- Two pumps with power-driven turbines feed water to steam generator from two deaerator through regeneration system and four collectors. Two pumps with electric drive is installed in parallel to ensure exploitation in launch and shut-down regimes.
- It allows to ensure load of steam generator in all regimes. In emergency cooling regime it supplies cooling of steam generator with 30 °C/h rate.
- The blowdown water system includes:
  - Blowdown expander;
  - Regenerative heater;
  - Blowdown and drainage coolers;
  - Pumps and tanks of steam generator drainage.

WWER STEAM GENERATOR CONSTRUCTION

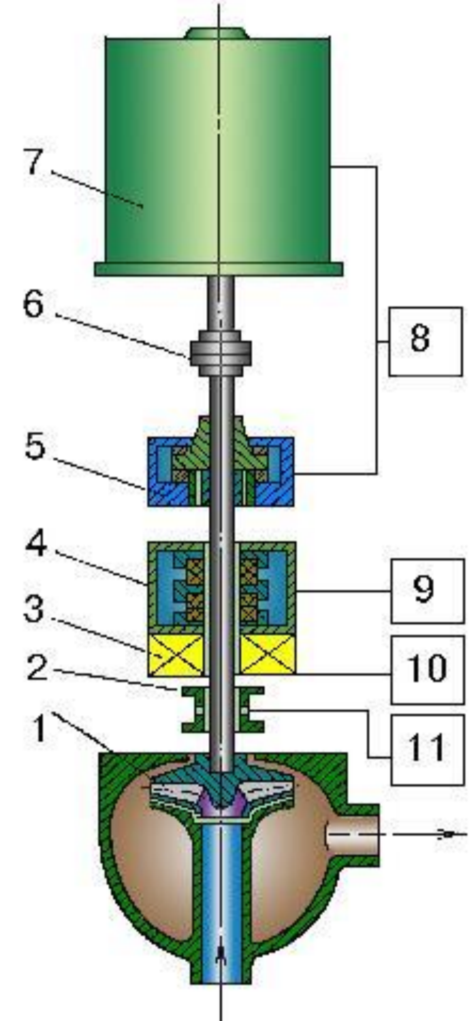
- Main functions of steam generator (SG) are:
  - Production of steam for turbine;
  - Keeping the regime of reactor cooling.
- That is why steam generator is equipped with emergency feed water supplying as well as system of passive cooling (due to natural circulation).
- SG have natural circulation, horizontal with U-shaped tubes.





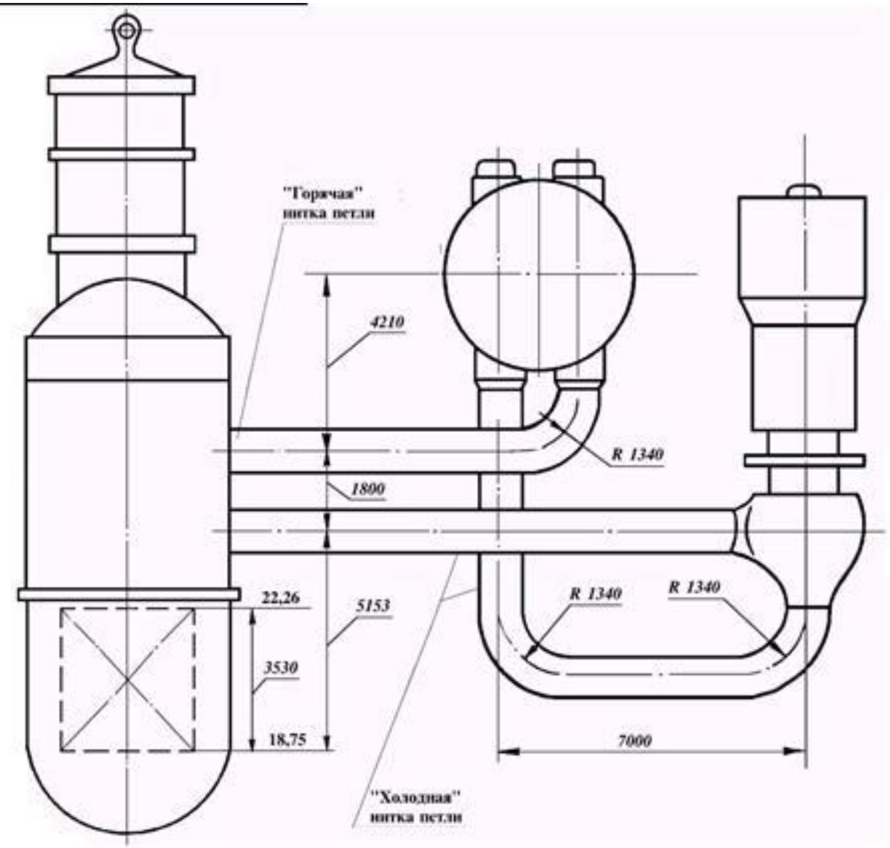
WWER MAIN CIRCULATING PUMP (MCP)

- Main function of MCP is to ensure circulation in MCC. MCP is designed to work at high pressure but could operate at lower pressures (from 2 MPa) during launch regime.
- The completely tight MCP have low efficiency and high cost. As the result the pumps with controlled leakages which later returned into circuit are used.
- The pump unit has auxiliary systems: an oil system for supplying oil to the lubrication of the upper bearing, consisting of oil pumps, oil coolers and filters; cooling system of elements of the pump unit and electric motor with intermediate circuit water; a make-up system designed to shut off the primary coolant in the sealing zone of the pump shaft by feeding cleaned and deaerated coolant into the sealing chamber with a pressure exceeding the pressure in the loop. In this case, part of the sealing water through the seal enters the circuit, preventing the release of radioactive water, and the remainder is discharged into the circuit feed deaerator.
- To prevent instant stopping of MCP the flywheel is additionally installed to ensure prolonged exploitation (up to 2 minutes) during energy shut-down.



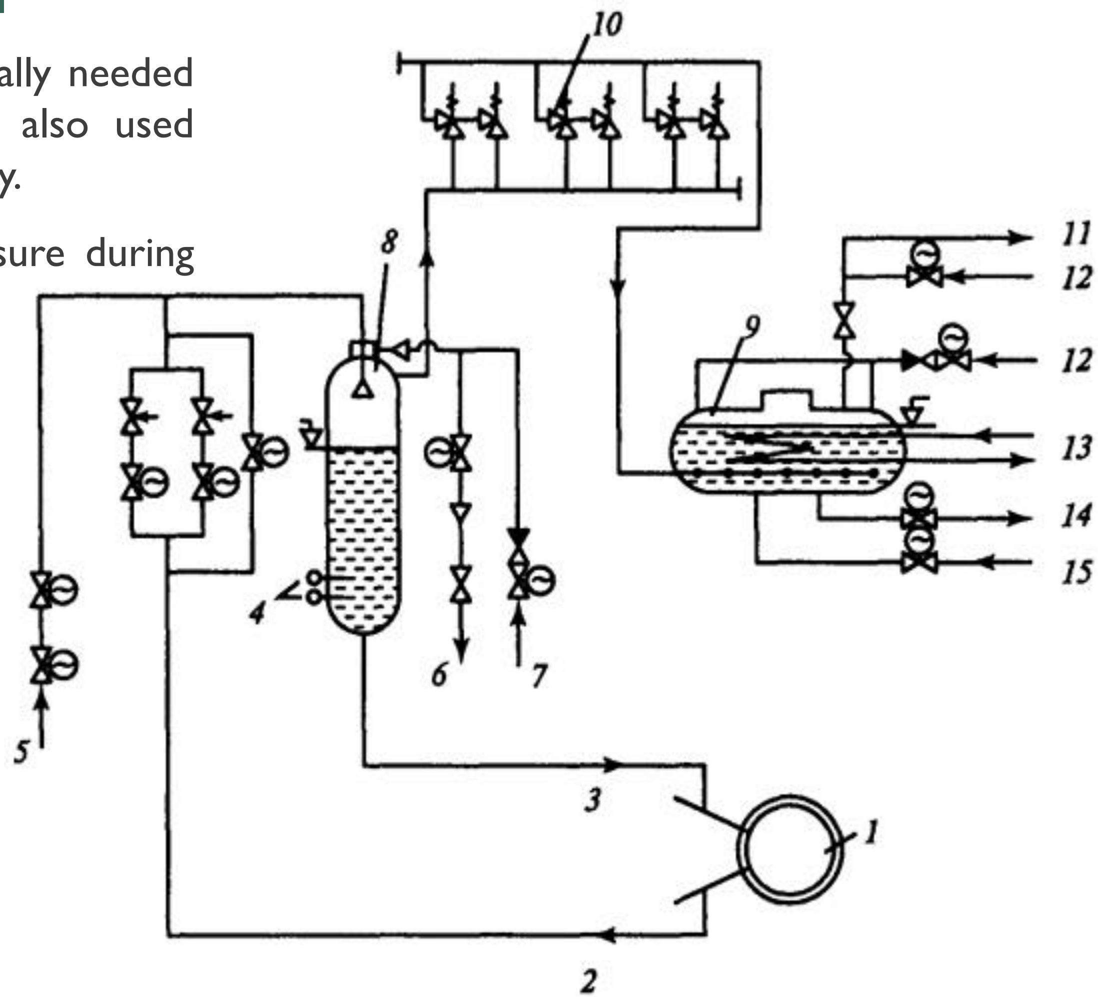
WWER MAIN CIRCULATING PIPELINES (MCPL)

- MCPL includes following parts:
  - Circulation pipes;
  - Bering elements;
  - Thermal insulation (to decrease thermal losses);
  - Subsystem fittings;
  - 182 thermal sensors with compensating devices.
- Thermal insulation consist of basalt plates with silica casing and thickness 60 mm. Usually two plates are used which are tightened up to 100 mm.
- While the system is in a hot state, even if there is a design thermal insulation on the equipment surfaces, there will be significant heat losses ~ 3 MW into the volume of the containment. Moreover, the heat losses of the loops (including steam generators) make up approximately 84% of the total heat losses.



WWER PRESSURE COMPENSATION CIRCUIT (PCC)

- Pressure compensation system is especially needed for reactors with water coolant. It is also used during launch, exploitation and emergency.
- PCC is passive and ensures same pressure during exploitation. It includes:
  - Steam pressure compensator;
  - Bubbler;
  - Impulse safety devices;
  - Pipelines and fittings.

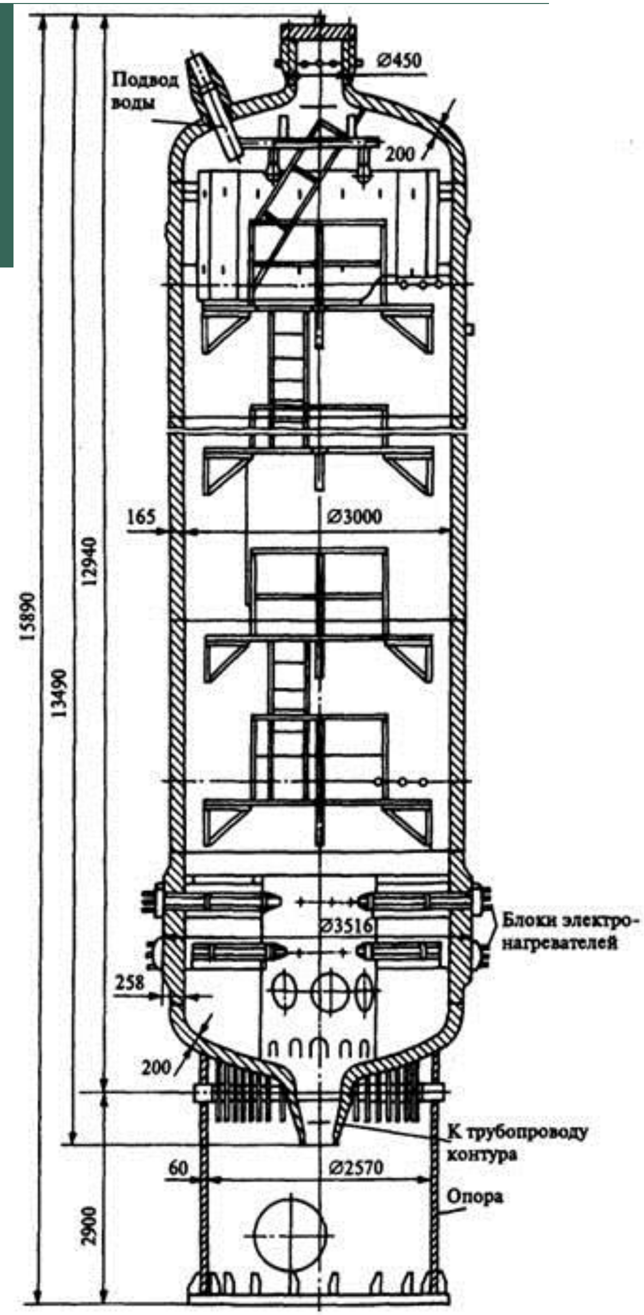


1 - reactor; 2 - water supply for injection; 3 - water drainage; 4 - electric heaters; 5 - emergency cooling; 6 - removal of gases; 7 - nitrogen supply; 8 - volume compensator; 9 - bubbler; 10 - safety valves; 11 - removal of gases; 12 - nitrogen supply; 13 - supply of technical water; 14, 15 - level maintenance

WWER PRESSURE COMPENSATOR PRINCIPAL OF WORK AND CONSTRUCTION

In the pressure compensation system, several technical solutions have been implemented, which, having consistently entered into operation, make it possible to solve the problem of maintaining coolant pressure in the reactor circuit within the design limits:

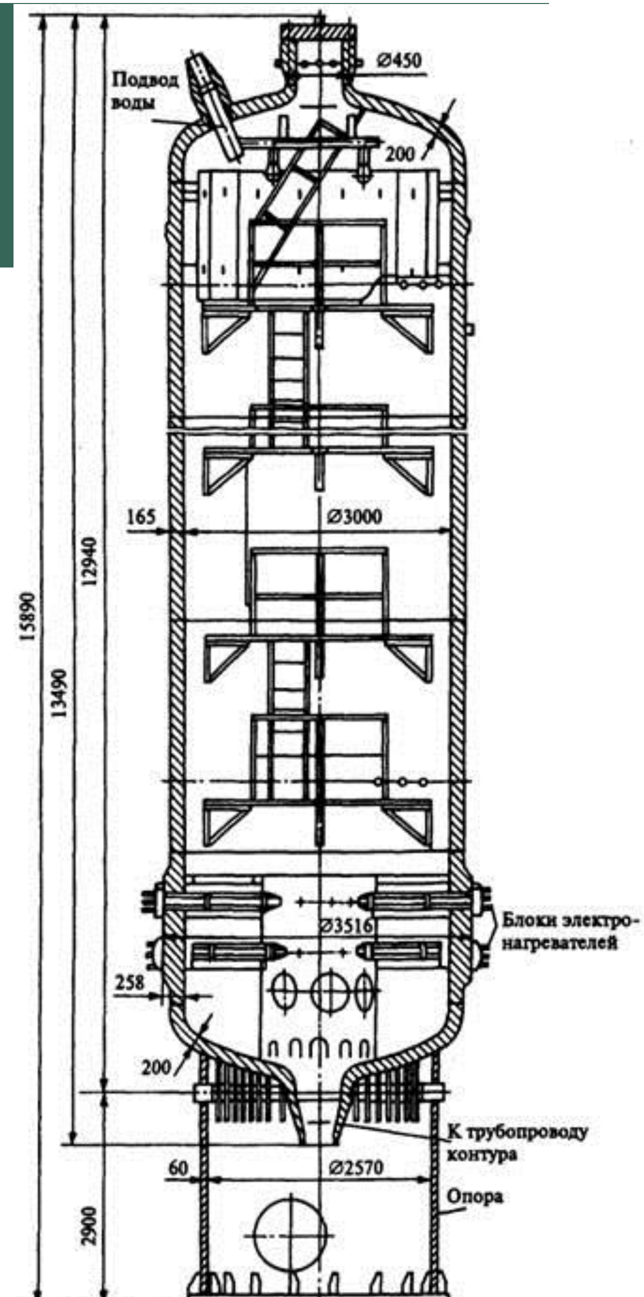
- The change in the volume of the vapor portion of the pressure compensator during phase transitions (a decrease in volume with an increase in pressure in the reactor loop and an increase in it with a decrease in this pressure);
- Switching on electric heaters with pressure reduction in the reactor circuit uncompensated due to the phase transition;
- Switching on the injection of water into the pressure compensator from the “cold” pipeline of the reactor circuit with an uncompensated increase in pressure in it;
- Discharge through safety valves (three pressure levels) of the vapor phase from the pressure compensator to the bubbler, where the steam condenses when the volume of the bubbler is cooled by intermediate circuit water and the pressure in the bubbler tank decreases;
- With an excessive increase in pressure in the bubbler tank, bursting membranes on the tank body open, due to which the pressure is reduced.



WWER PRESSURE COMPENSATOR PRINCIPAL OF WORK AND CONSTRUCTION

The principle of operation of the steam pressure compensator is following. With constant operation under normal conditions, all valves, except shut-off valves, are closed. When the temperature changes, for example, when the water temperature in the circuit increases, some additional amount of water from the hot pipeline enters the casing, compressing the steam, whose pressure increases. As a result, the control valve on the injection line is triggered. By heating this water, some of the steam in the steam volume of the casing condenses, the pressure decreases to normal, at which the control valve automatically closes, stopping the flow of water to the injection. Connecting the injection to the "cold" pressure side of the main circulation loop allows the use of the MCP differential to overcome the resistance of the water injection system and reduces its consumption.

With minor temperature changes, the pressure is maintained without the injection of cold water. So, with a slight increase in temperature and vapor pressure, partial condensation of steam occurs, and with a decrease in temperature and pressure - partial evaporation of water in the water volume of the housing due to the operation of electric heaters. In this regard, the steam volume compensator maintains a constant pressure in the circuit with very high accuracy. The rate of heating of the volume compensator is limited (40 ° C / h) to prevent significant thermal stresses in the metal. The initial pressure in the volume compensator is created by nitrogen, which by the end of the warm-up period is completely removed by the resulting vapor.



WWER ADDITIONAL AND BLOWDOWN WATER SYSTEM

- Additional water supplying system ensures flow of additional water into system to keep needed level into pressure compensation. It has following functions:
  - Cleansing of additional water and its returning into system;
  - Filling of the first circuit;
  - Keeping pressure into the first circuit;
  - Cleansing of leakages;
  - Refilling of water losses;
  - Boron regulation.
- To increase boron concentration the part of coolant is directed through deaerators and special filters into boron enriched water tanks. To increase concentration of boron coolant from tanks is supplied into MCC.

WWER SAFETY SYSTEMS

The four groups of systems are distinguished:

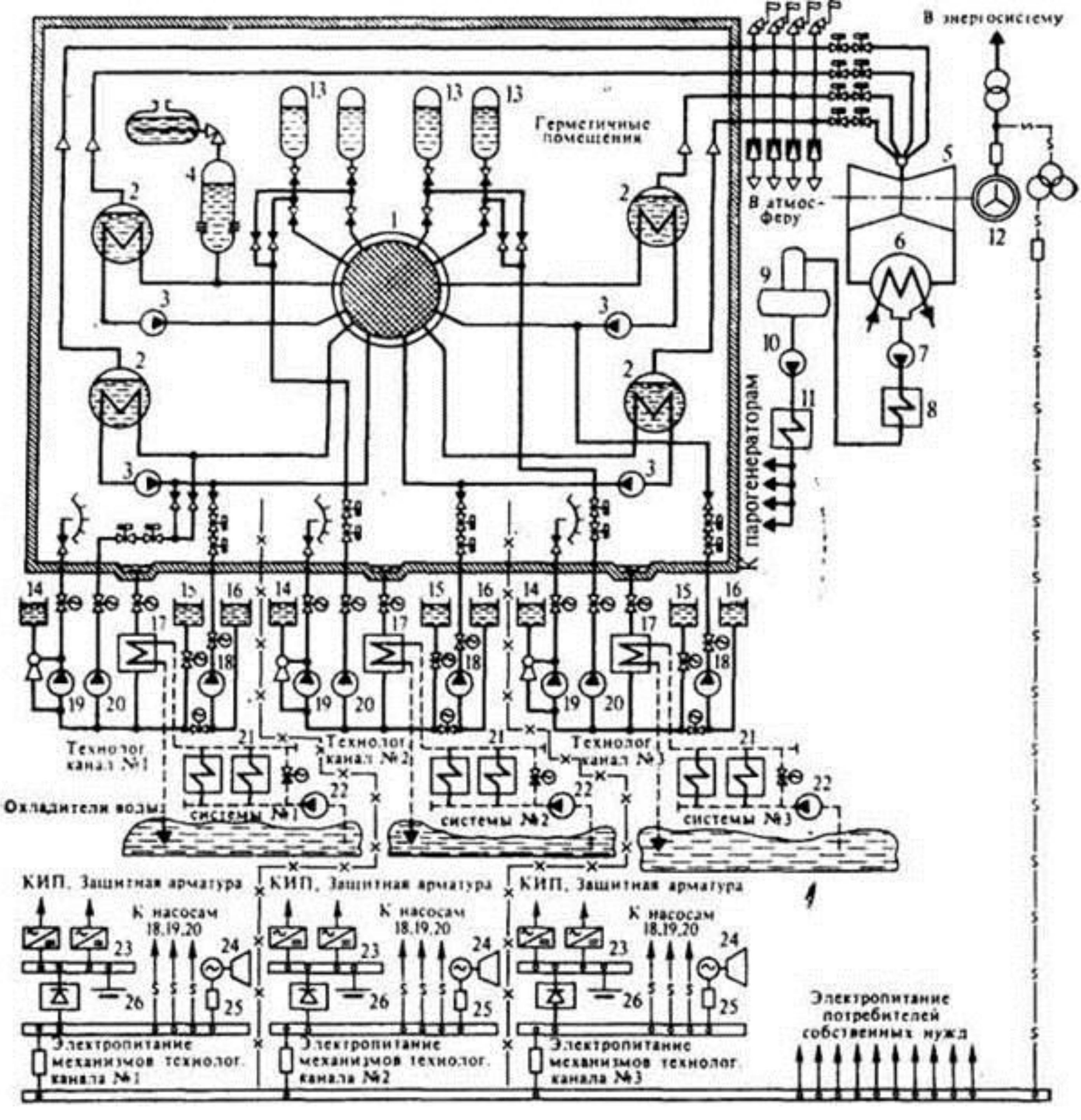
- **The first group:** the shut-down even for part of second is unacceptable. It is control and safety valves, automatics, emergency light.
- **The second group:** the shut-down for few seconds is allowed but the power is needed for exploitation of emergency systems. It is all mechanisms of reactor emergency cooling.
- **The third group:** allows shut-down while reserve systems in operation, does not needed during emergency.
- **The fourth group:** all other consumers.

The first group is connected to source of direct current. The first and second groups are additionally supplied by reliable source of alternate current. It is batteries, current converters, diesel-generators with quick automatics.

Four groups of safety systems are used: *normal exploitation systems, protective systems, localizing systems, emergency cooling system (ECS)*. The two last systems are made for maximal design emergency. Purpose – prevent melting of active zone.

WWER SAFETY SYSTEM

1 - reactor; 2 - steam generator; 3 - MCP; 4 - volume compensator; 5 - turbine; 6 - capacitor; 7 - condensate pump; 8 - HPH group; 9 - deaerator; 10 - feed pump; 11 - LPH group; 12 - generator; 13 - pumping tank; 14 - stock tank of hydrazine hydrate; 15 - emergency reserve tank of boron solution; 16 - tank stock boric concentrate; 17 - ECS heat exchanger; 18 - high pressure pump for emergency supply of boron solution; 19 - sprinkler pump; 20 - low pressure emergency cooling pump; 21 - heat exchangers of the intermediate circuit of industrial water; 22 - industrial water supply pump; 23 - power tires of the first category; 24 - diesel generator; 25 - power supply tires of the second category; 26 - rechargeable battery



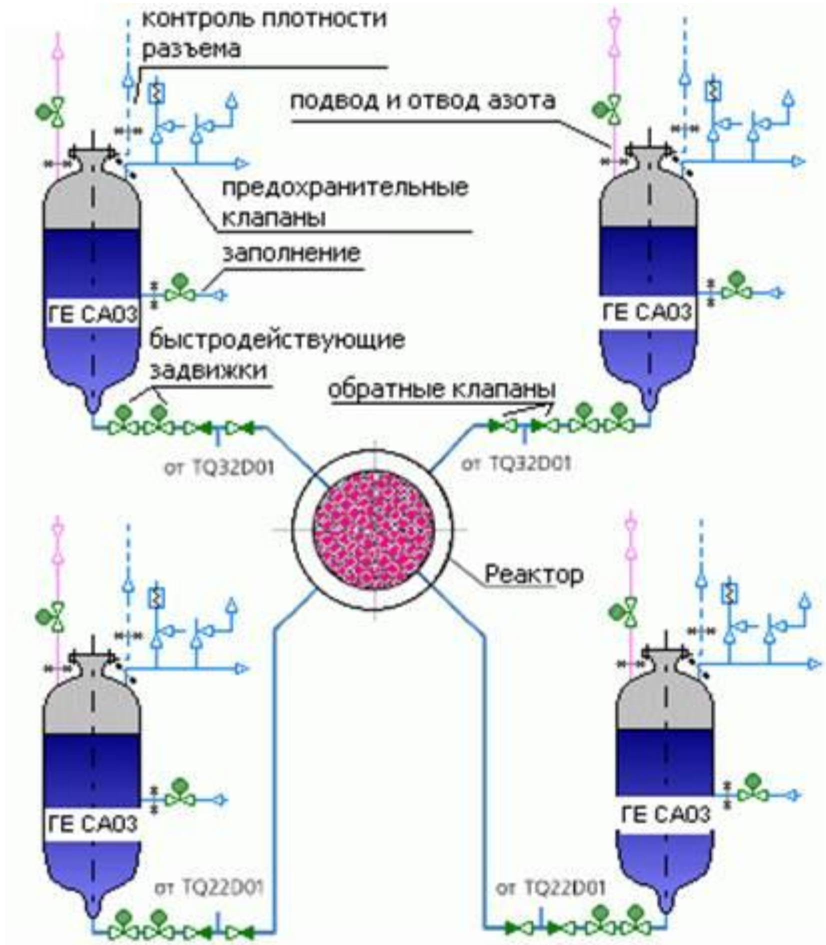
WWER EMERGENCY COOLING **SYSTEM**

Three groups of emergency cooling introduced:

- High pressure ECS to supply boron into active zone;
- Low pressure ECS to fill active zone after coolant leakages;
- Passive ECS.

Active systems include emergency pumps and tanks filled with boron enriched water.

Passive ECS includes hydraulic tanks, fittings and pipelines. They separated into two independent channels. Each have water with boron under pressure of nitrogen volume to ensure its supplying into active zone. Fittings include reverse valves and control valves. The complete emptying of tanks is avoided to prevent water leakages and air suction



THANK YOU FOR YOUR ATTENTION