7. AUXILIARY SYSTEMS

This Section describes the numerous cooling circuits of the plant. This includes circuits using purified and demineralized water employed for cooling safety related equipment around the core block, circuits for cooling pumps, diesel generators and the service water circuit which uses lake water. Gas mixtures are also employed for cooling purposes in special locations. This is described in the Subsection outlining the Reactor Gas Circuit.

7.1 RECOVERY AND PURIFICATION OF DEMINERALIZED WATER

The water from the MCC, which contains a small amount at radioactive materials is referred to as demineralized water. A system is provided for the collection and purification of this Demineralized Water (DW). The purpose of the system is to collect contaminated water, to purify it and to supply purified water where it is needed. During normal operation at any reactor power level and during planned preventive maintenance the DW collection and purification system performs the following functions:

- Collects and purifies DW from the following sources:

  - contaminated water from the tank of condensate of the turbine generators,
  - water from leaks and contaminated water from the fuel storage tanks and the control rod cooling circuit,
  - water from backflushing of ion exchange filters of the DW purification facilities,
  - contaminated water from the hot condensate chambers of the ACS,
  - water resulting from hydraulic testing (after repair and hydraulic testing of low pressure condensers) and water resulting from the flushing of turbine generator equipment,
  - excess water from the primary circuit during reactor heating up.

- The system supplies purified water to the following equipment:

  - low pressure turbine condensers and to the seals of the purification and cooling system pumps (during their operation),
  - refueling machine,
  -control rod cooling circuit during planned preventive maintenance,
  - fuel storage tanks and hot condensate chambers of the ACS,
  - water required for backflushing of ion exchange filters and for other needs of the DW purification facilities,
  - water required for up of equipment.

The system for recovery and purification of DW includes three subsystems (Fig. 7.1):

- pumping station of the contaminated DW,
- DW purification facility,
- pump station of purified DW.

7.1.1 Pumping Station of the Contaminated DW

The pumping station of contaminated DW consists of a receiving tank for contaminated DW (1- see Fig. 7.1), three pumps (2) for supplying water to the DW purification facility and two pumps (3) which periodically mix the water in the tank to prevent build-up of sediment. The tank has a volume of 1500 m^3 and is combined located at a 12 m distance from the building B1 (B2) (see Section 1). The tank is made of reinforced concrete and is clad inside with stainless steel sheets of thickness from 3 to 5 mm. Sensors are available for monitoring the temperature and liquid level in the tank. Design specifications for the tank are presented in Table 7.1.

The pumps (2, 3) are located in building B1 (B2). Design specifications for the pumps are provided in the Table 7.2. Process piping, connecting the tanks with the pumping stations, are designed as leak protected of "tube-in-tube" type, and they are placed in the shielded channels. The tank and the shielded channels are provided with a remote leak monitoring system.

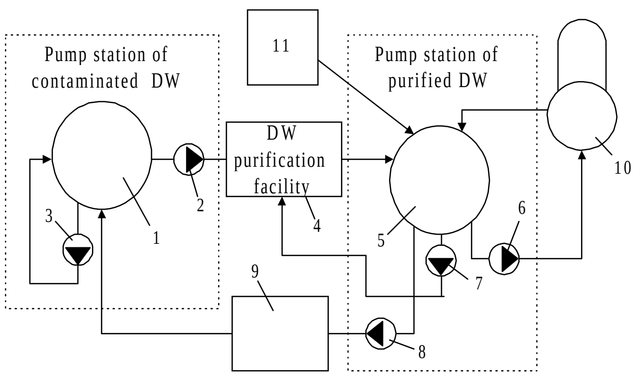

Fig. 7.1 Schematic representation of system for the recovery and purification of demineralized water
1 - receiving tank for the contaminated DW, 2 - pumps for supplying DW to the purification facility, 3 - mixing pumps, 4 - DW purification facility, 5 - tank to collect purified DW, 6 - auxiliary deaerator makeup pumps, 7 - pumps to supply water for internal needs of DW purification facility, 8 - feed-water pumps, 9 -

fuel storage pool, ACS, turbine generators and other systems, 10 - deaerators, 11 - tanks of primary grade water

Table 7.1 Specification of reception tank for contaminated DW

Number per reactor	1
Diameter, m	18.5
Height, m	7
Capacity, m^3	1500

Table 7.2 Specification of pumps

Pump of DW supply to the purification	
Number per reactor	3
Pump head, MPa (kgf/cm^2)	0.83 (8.5)
Capacity, kg/s (m^3/h)	25 (90)
Drive power, kW	55
Pump of DW mixing	
Number per reactor	2
Pump head, MPa (kgf/cm^2)	1.37 (14)
Capacity, kg/s (m^3/h)	25 (90)
Drive power, kW	100

Table 7.3 Design specifications of the DW purification facility

Perlite filters	
Number per reactor	3
Working pressure, MPa (kgf/cm^2)	up to 0.98 (10)
Capacity, kg/s (m^3 /h)	8.3-27.8 (30-100)
Diameter, mm	1200
Height, mm	3540
Filtering surface, m^2	13.5
Ion exchange filter	
Number per reactor	2
Operating pressure, MPa (kgf/cm^2)	up to 0.98 (10)
Capacity, kg/s (m^3 /h)	up to 33.3 (120)
Diameter, mm	2000
Height, mm	4320
Volume of filtering media, m^3	6
Ionic trap filter	
Number per reactor	1
Operating pressure, MPa (kgf/cm^2)	up to 0.98 (10)
Capacity, kg/s (m^3 /h)	up to 33.3 (120)
Diameter, mm	600
Height, mm	3000
Filtering surface, m^2	4.6

Table 7.4 Specifications of tank of purified DW

Number per reactor	1
Diameter, m	18.5
Height, m	7
Working volume, m^3	1500

The pumps are provided with two independent power sources and switchover between them is provided automatically.

7.1.2 The DW Purification Facility

The DW purification facility (4) consists of three perlite filters to eliminate insoluble substances and petro-chemicals from the water, two ion exchanging filters to extract soluble salts and a trap filter to protect the tank of purified water from possible ingress of ion exchange resins. Equipment of the DW purification facility is located in building B1 (B2). Design specifications are presented in the Table 7.3.

7.1.3 The Pumping Station of Purified DW

The pumping station of purified DW consists of a tank to collect purified DW (5), auxiliary deaerator makeup pumps (6), feed-water pumps (8) and pumps (7) to supply water for internal needs of DW purification facility. The feed-water pumps (8) are intended to supply water to fuel storage pool, ACS, turbine generators and other systems. The tank (5) is located near to the tank (1) to receive contaminated DW. The purpose of tank (5) is to collect purified DW, emergency water overflow from deaerators and primary grade water if the deaerator auxiliary makeup system is in operation. The design specifications of the tank are presented in the Table 7.4.

No less than 1000 m^3 of purified DW would be maintained in the tank of during reactor operation at any power level should. Pumps (6, 7, 8) are located in building B1 (B2) at an elevation -7.20 m. Pumps for the auxiliary deaerator makeup (6) are placed 1.2 m above the floor of the room to prevent flooding. There is a concrete ceiling above the pumps. The power supply to the auxiliary deaerator makeup pumps (6) and feed-water pumps (8) is provided through individual cables from the safety bus. In case of loss of offside power, the power supply is automatically switched over to the diesel generators. Pumps (7) are provided with two independent power sources, and switchover between them is provided automatically. Cables are covered with fire proof compounds. The design specifications of the pumps are presented in the Table 7.5.

Table 7.5 Specification of pumps

Feed-water pumps	
Number per reactor	3
Pump head, MPa (kgf/cm^2)	0.83 (8.5)

Capacity, kg/s (m^3/h)	25 (90)
Drive power, kW	55
Pumps to supply water for internal needs of the DW purification facilities	
Number per reactor	2
Pump head, MPa (kgf/cm^2)	0.83 (8.5)
Capacity, kg/s (m^3/h)	25 (90)
Drive power, kW	55

7.1.4 System Operation

Contaminated DW is delivered through the piping into the receiving tank (1). From the tank contaminated DW is supplied by pumps (2) at a flow rate of 8.3-22.2 kg/s (30-80 m^3/h) to the purification devices (4). The required water quality before and after purification is presented in the Table 7.6.

During filtering the pressure drop on perlite filters is increasing. When the pressure drop reaches 0.39 MPa (4 kgf/cm^2) the operator puts an auxiliary filter in operation and takes the exhausted filter out of operation to remove contaminated filtering perlite and to produce a new filtering layer. Also, perlite filters are taken out of operation if the concentration of petro-chemicals in the filtered water increases above 100 μg/dm^3. After the perlite filters, water is conveyed subsequently through two ion exchanging filters, which are loaded with strong acidic cationite and strong alkaline anionite to purify water from dissolved salts. Periodically the DW purification facility is in outage for chemical regeneration according to the degree of exhaustion of ion exchanging material. After the ion exchanging purification, water is conveyed via trap filter and comes into the tank of purified DW (5).

Nominal capacity of the DW purification facility is 22.2 kg/s (80 m^3/h) with maximum capacity 27.8 kg/s (100 m^3/h). In emergency conditions the capacity of the facility can be increased up to 55.6 kg/s (200 m^3/h). In this case the water purification is provided only with the perlite filters.

Water is supplied to the plant unit systems from tank (5) by pumps (8):

- during power operation water is supplied into low pressure turbine condensers at flow rate 11.1-33.3 kg/s (40-120 m^3/h),
- periodically water is supplied into the fuel storage tank and the ACS for exchange purpose to maintain water quality in the systems within the operational limits,
- during refueling purified DW is supplied into the refueling machine,
- water supply to other systems is performed periodically and is controlled by the operator according to requirements.

To provide water supply for the systems listed above one of the pumps should be in operation and the second should be in standby mode (the third can be under maintenance).

7.2 AUXILIARY DEAERATOR MAKEUP SYSTEM

The Auxiliary Deaerator Makeup System (ADMS) is intended to supply water to the deaerators during reactor start-up and cooling down. Under accidental conditions it supplies water to deaerators and to the hot condensate chamber of the ACS.

Table 7.6 Required water quality

Parameter	**Requirements to the chemical composition of contaminated DW**	**Quality of water after purification**
pH	6,0-8,5	6,5-8,0
Electric conductivity, μSm/cm	no more than 20	1,0
Concentration of chloride ions, μg/dm^3	no more than 100	10
Concentration of petro-chemicals, μg/dm^3	no more than 500	100
Hardness, μg-eq/dm^3	-	no more than 3
Corrosion products recalculated into Fe, μg/dm^3	-	no more than 20

During normal operation at any power level and during planned preventive maintenance the equipment and piping of the system perform the following functions:

- maintenance of water reserve above 6000 m^3,
- storage of condensate (which is produced after utilization of plant drainage water), primary grade water and water from demineralized water purification facilities (see Subsection 7.1.2),
- supplies water for the following:
  - continuos makeup of turbine condensers,
  - filling of equipment,
  - internal plant needs of water purification facilities,
- water supply into control rod cooling circuit,
- water supply for sealing of Purification and Cooling System (PCS) pumps,
- water supply for sealing of Main Feed Water Pumps (MFWP) and Auxiliary Feed Water Pumps (AFWP) when the main condensate system is not in operation.

During reactor start-up and cool down the ADMS supplies water to deaerators in order to ensure proper operation of the AFWPs.

For accident conditions the ADMS provides water to ensure long-term cooling of the reactor. It is designed to:

- supply water from water reserves (up to 6000 m^3) to deaerators to ensure the proper operation of AFWPs,
- supply water to ACS hot condensate chambers in order to ensure the proper operation of ECCS pumps.

7.2.1 General Description

A schematic of the auxiliary deaerator makeup system is presented in Fig. 7.2. A tank (1) with a capacity of 5000 m^3 provides a reserve of condensate (which is produced after utilization of the plant drainage water).

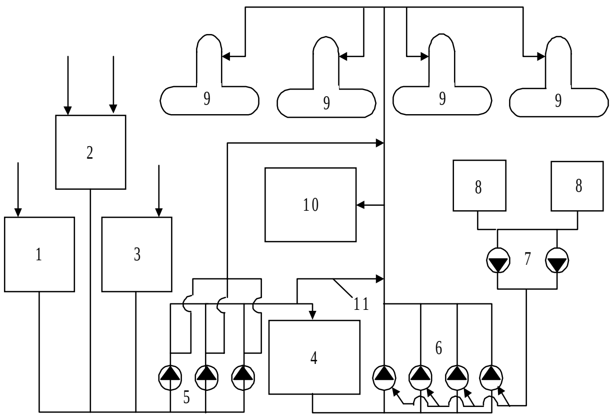

Fig. 7.2 Process scheme of auxiliary deaerator makeup system
1 - condensate tank, 2 - tank for receiving of condensate or primary grade water, 3 - primary grade water tank, 4 - tank of purified DW, 5 - pumps to supply water into tank of purified DW, 6 - auxiliary deaerator makeup system pumps, 7 - pumps to supply sealing and cooling water for ADMS pumps, 8 - tanks of water reserve for sealing and cooling of ADMS pumps, 9 - deaerators, 10 - hot condensate chambers of ACS towers, 11 - auxiliary pipeline

The second tank (2) is intended to provide a reserve of either condensate or primary grade water (which is obtained through purification of artesian water). The third tank (3) supplies a reserve of primary grade water. These tanks are located in the building with the facilities for recovery of liquid radioactive waste (see Section 1). The fourth tank of purified DW (4) (capacity 1500 m^3) is intended to provide a reserve of water from the diaonized water purification facility. The tank (4) is located at a 12 m distance from the building B1 (see Section 7.1). All tanks are made of reinforced concrete, the inner surface of which is clad with stainless steel of thickness from 3 to 5 mm. They are installed on special foundations and are provided with remote monitoring, for the detection of leaks. During operation at any power level at least 5000 m^3 of water is maintained in the first three tanks (1, 2, 3), total volume of water can be up to 15000 m^3. The tank of purified DW (4) - maintais a volume above 1000 m^3. Pumps (5) are used to supply water from the first three tanks into the tank of purified DW. Pumps (capacity - 500 m^3/h) are located in the building of waste-water tanks (see Section 1). Pumps of the auxiliary deaerator makeup system (6) are used to supply water into deaerators (9) or into the hot condensate chambers (10) of the ACS towers. Pumps designated as item (7) are used to supply sealing and cooling water to pumps (6). The smaller tanks (8) (capacity of 50 m^3 each) are intended to provide a reserve of sealing and cooling water for the ADMS. The technical specifications of the ADMS pumps are presented in the Table 7.7. Pumps (7) and tanks (8) are located in building B1 (B2). All equipment and piping of the sealing and

Table 7.7 Technical specification of the auxiliary deaerator makeup system pump (type - KsVA500-220, manufacturer - NPO named after Frunze, Sumi, Ukraine)

Number per reactor	4
Flow capacity, m^3/h	500
Pump head, m	220
Required cavitation margin, m	2.5
Temperature of feed water at the pump inlet, °C	no more than 125
Pressure at the pump inlet, MPa	no more than 0.98
Pump power, kWt	375
Rotation speed, rpm	1480

Table 7.8 Required water quality in the ADMS tanks

pH	5.5 - 7.2
Electric conductivity, µSm/cm	no more than 1.5
Concentration of chloride Cl ions, µg/dm^3	no more than 10
Concentration of petro-chemicals, µg/dm^3	no more than 100
Hardness, µg-eq/dm^3	no more than 3
Corrosion products recalculated into Fe, µg/dm^3	no more than 20

cooling water supply to the ADMS pumps have 100% redundancy. All pipelines of the system are placed in special conduits. They provide a water supply at a flowrate ~20% higher than is required according to safety conditions.

Water quality in any tank should comply with the requirements (Table 7.8).

7.2.2 Operation Procedures of the Auxiliary Deaerator Makeup System

To ensure reliable operation of the AFWS pumps for a range of accidental conditions, the water level in the deaerators is maintained by water supplied by the ADMS pumps (6) which takes water from the tank of purified DW (4). When the level in the deaerators (9) decreases down to 430 mm the standby mode ADMS pump is started automatically. After a time delay of 10 seconds the special regulating valve maintains both the pressure at the discharge section of the ADMS pump at 1.96 MPa (20 kgf/cm^2) and the level in deaerators at H=1500mm. If the discharge valve of the pump is not open in 2 minutes, this ADMS pump is switched off, and a stand-by pump is started to provide water supply into the deaerators (9) with a flowrate of 500 m^3/h. If this flowrate is not sufficient and the level in the deaerators continues to decrease and reaches 230 mm, the second ADM pump, which is in standby mode, is started. Two operating pumps can provide water flowrate of at least 1000 m^3/h. In parallel with the water supply into the deaerators (9) water is also supplied to cool the suction side of the AFWS pumps. If the water level in the deaerators increases up to H=2150 mm and all AFWS pumps are switched off, the signal for switching off the ADMS pumps is generated.

If the water volume in the tank of purified DW (4) decreases, the operator manually starts one of the pumps (5) to compensate the losses at a flow rate of at least 500 m^3/h from tanks (1, 2, 3). This action allows the system to operate during long term periods.

If necessary, the ADMS can supply water into the hot condensate chambers (10) of both ACS towers (at a flow rate of at least 1000 m^3/h) using a separate pipeline. The decision is made by the operator after decrease of the liquid level in the hot condensate chamber is under control.

During the first phase of the implementation of recommendations from the Barselina project, a design for the reconstruction of the ADMS was developed. According to this project an auxiliary pipeline 200 mm diameter (11) was installed in 1995 to make it possible to supply water by pumps (5) from tanks (1, 2, 3) directly into the deaerators (9) and the hot condensate chambers of the ACS (10). Installation of the auxiliary pipeline (11) has improved system reliability , as it makes it possible to supply water by:

- pumps (1, 2, 3) directly into the deaerators at a flow rate up to 650 m^3/h,
- ADMS pumps of unit 2 directly into the deaerators of unit 1 at a flow rate up to 1100 m^3/h,
- pumps (1, 2, 3) to hot condensate chambers of ACS of unit 1 and unit 2 at a flow rate up to 750 m^3/h.

7.3 SERVICE WATER SYSTEM

The Service Water System (SWS) employs lake water to provide cooling for the thermo-mechanical equipment of the plant both in normal and accidental regimes. In normal operating regimes the SWS is used for cooling the thermo-mechanical equipment of the plant, the equipment in the auxiliary buildings and as a water supply source for fire fighting systems (see Table 7.9).

7.3.1 General Description

SWS consists of a water intake and a water discharge canal, a lake-side pumping house, and the supply and discharge water lines.

The plant is located on the south bank of lake **Drūkšiai**, which is used as the ultimate heat sink. The water level is 141.6 m above sea level; its surface area of the lake is 49 km^2, its water inventory - 0.4 km^3, average depth is - 7.6 m, maximum depth - 33 m. The water level in the lake is raised ~1.3 m by means of dams. A water level drop could occur only if the dams are destroyed as a result of external impact: an airplane crash, an earthquake or a terrorist act. In this case the minimum water level in the lake will be governed by the elevation of rivers beds, which originate in the lake, and will decrease to 140.3 m above see level. The open water intake and discharge canals are common to both power units, the potential change in the water level is taken into consideration in their design.

There is a population of a double-shell mollusk of a species called "dreissena" in lake **Drūkšiai**, which periodically, especially in summer time, finds its way into the SWS system. In order to secure the system's operability its design provides for a possibility of back-flushing some of the equipment (see Table 7.9) with service water. There is also a connecting 800 mm pipeline between the suction and discharge water pipelines, which is used for back-flushing the SWS water pipelines during an outage.

The lake-side SWS pumping house contains six vertical type centrifugal pumps (2 or 3 are in operation, 2 are in stand-by, and one pump can be taken out for servicing).

A stand-by pump starts automatically if an operating pump stops. The pumps are connected to a 6 kV bus, pump per bus. Technical specifications of the SWPs are given in Table 7.10. The operation of the service water pumps is supported by the pump bearing cooling and lubrication systems and a movable screen flushing system.

From the intake canal water is delivered to the water intake chamber of the Service Water Pumps (SWP). There it passes through strainers and is pumped to a common discharge header. From the header water is supplied to SWS consumers via two 1600 mm discharge pipelines. Each of the water pipelines is capable of providing the full flow rate at the maximum water demand. If the SWS of one of the power units is taken out of service, water can be supplied to the equipment by the operating the SWS of the other unit. Water is supplied to the equipment via two pipelines, each of which is connected either to one of the supply water pipelines or to a part of the ring-circuit pipelines. For maintenance each of the pipelines can be isolated, while the cooling water demand of the SWS consumers is met using the second pipeline. In case of loss of power for internal needs the valves in the discharge pipelines remain in the 'open' state. The suction and discharge pipelines are equipped with adequate instrumentation the readings of which are displayed in the control room. All SWS pipelines and valves are made of carbon steel and designed for a gauge pressure of 0.98 MPa (10 kgf/cm^2).

Table 7.9 presents service water flow rate data to the SWS consumers in the main and other buildings on site at various operating regimes of the power unit. The nominal operating parameters of SWS are presented in Table 7.11.

Table 7.9 Service water flow rates to main equipment at t_{cool} = 28 ^{0}C

Equipment	Number	Water flow rates for various operating regimes, kg/s (m^3/h)					
		Nominal	Start-up	Cooling down	Loss of power	Emergency cooldown	SWS maintenance *
Control rod cooling system HEs **	4	833 (3000)	833 (3000)	833 (3000)	417 (1500)	417 (1500)	27.8-1.7 (100-50)
MCP air cooler **	8	133.3 (480)	133.3 (480)	133.3 (480)	-	-	-
MCP oil cooler	8	55.5 (200)	55.5 (200)	55.5 (200)	-	-	-
HEs of IC-1 **	8	166.7 (600)	500 (1800)	1667 (6000)	1667 (6000)	1667 (6000)	1667 (6000)
HEs of IC-2 **	2	215 (774)	215 (774)	215 (774)	215 (774)	215 (774)	83.3 (300)
HEs of reactor metal structures **	2	45.8 (165)	45.8 (165)	45.8 (165)	-	-	-
HEs of spent fuel pool	3	133.3 (480)	133.3 (480)	133.3 (480)	-	-	320
HEs of ACS condenser tray cooling system	8	-	2333 (8400)	2333 (8400)	2333 (8400)	2333 (8400)	-
HEs of fuel cladding integrity monitoring system	2	2.8 (10)	2.8 (10)	2.8 (10)	-	-	-
HEs of the off-gas clean-up system and the Helium Clean-up Plant	5	55.5 (200)	55.5 (200)	55.5 (200)	-	-	-
HEs of air coolers of recirculating facilities (WA67-69)	6	141.7 (510)	141.7 (510)	141.7 (510)	-	-	-
HEs of special ventilation system (WZ51)	2	83.3 (300)	83.3 (300)	83.3 (300)	83.3 (300)	83.3 (300)	-
HEs of special ventilation system (WZ56)	2	27.8 (100)	27.8 (100)	27.8 (100)	-	-	-
HEs of the purification and cooling system pumps	2	5.27 (19)	5.27 (19)	5.27 (19)	5.27 (19)	-	-
MFWP	7	50 (180)	10-50 (36-180)	-	-	-	-
AFWP***	6	6.7 (24)	6.7 (24)	6.7 (24)	6.7 (24)	6.7 (24)	6.7 (24)
Other equipment of buildings "A", "B" and "D"		2.36 (8.5)	2.36 (8.5)	2.36 (8.5)	-	-	-
Other equipment of the turbine hall		486 (1750)	486 (1750)	486 (1750)	486 (1750)	486 (1750)	-
Auxiliary buildings		2193 (7895)	2193 (7895)	2193 (7895)	2193 (7895)	2193 (7895)	2193 (7895)

Total	5444 (19600)	7111 (25600)	6833 (24600)	5278 (19000)	5278 (19000)	2566 (9239)

* Water is supplied from the SWS system of an operating unit
** Equipment designed for back-flushing with service water
*** Now the SWS is used as emergency source of cooling

Table 7.10 Specification of the SWS pump (type 1000V-4/6.3-A)

Number per reactor	6
Capacity, kg/s (m^3/h)	2222-3250 (8000-11700)
Head, kPa (m of water column)	500-421 (51-43)
Minimum suction pressure, kPa (m of water column)	19.6-34.3 (2.0-3.5)
Electromotor capacity, kW	1600
Electromotor voltage, kV	6
Speed, s^{-1} (rot/min)	8.3 (500)

Table 7.11 Nominal SWS operating parameters

Cooling water temperature, ^{o}C (depends on the season)	6-28
Temperature increase in HEs, ^{o}C	7-10
Supply water pressure at the lake-side pumping house, MPa (kgf/cm^2)	0.49 (5.0)
Pressure at discharge, MPa (kgf/cm^2)	0.098 (1.0)

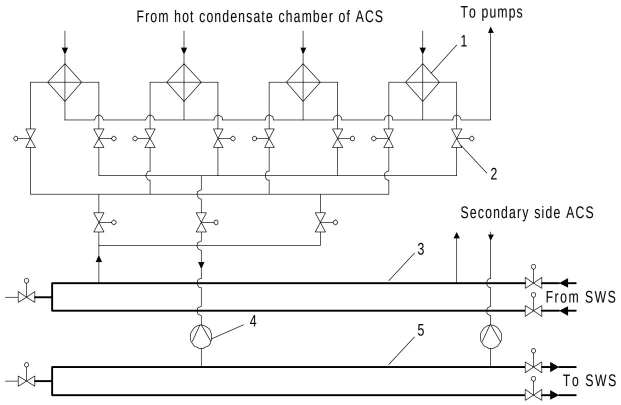

Fig. 7.3 Flow diagram of the HEs of the ACS condenser tray cooling system SWS
1 - heat exchanger, 2 - valve, 3 - ring circuit for water supply, 4 - flow meter, 5 - ring circuit for water discharge

SWS is a safety relevant operation system, which also performs auxiliary (support) safety functions in emergencies. SWS provides cooling for the safety equipment (diesel-generators, HEs of ACS condenser tray cooling system and HEs of the AFWP sealing system) under normal and abnormal conditions. In case of an accident which leads to the loss of SWS, the reactor must be immediately scrammed by pressing the AZ-1 button (emergency protection). At nominal reactor power at least 4 SWPs must be operable, 2 pumps may be tagged out for maintenance. In case of a reduced redundancy of SWPs the full power operation of the unit is allowed for no longer than 2 hours.

7.3.2 HEs of ACS Condenser Tray Cooling System

HEs of the ACS condenser tray cooling system are intended to remove heat generated by steam passing through the ACS condensation pools. A continuous service water supply is provided by a ring-circuit of 1200 mm diameter water pipelines, and later via two 600 mm diameter pipelines for each group of four HEs (Fig. 7.3). The service water is discharged from each HE group via a 600 mm diameter pipeline into a discharge water ring-circuit. When the temperature of the water in the ACS condensation pools exceeds 35 ^{o}C, or an Emergency Core Cooling System (ECCS) signal occurs, the normally closed discharge valves are opened automatically, and service water is supplied to cool the ACS HEs. If necessary the valves can be opened manually, either locally or from the main control room.

7.3.3 Diesel Generators Cooling System

Service water is supplied to Diesel-Generators (DG) via three 800 mm diameter pipelines connected to the main SWS water pipelines. Service water is used to cool the water of the DG internal, the DG circulating oil and air. Three DGs of each power unit are supplied from the SWS water pipeline of unit 1, while the other three DGs are supplied from the SWS water pipeline of unit 2. Such an alignment allows a prompt switch-over if the SWS of one of the units becomes inoperable. Supply of service water is initiated automatically following start-up of the DG. In case of a loss of service water the DG remains available for 7 min.

7.4 INTERMEDIATE CIRCUITS

Intermediate Circuits (IC) are intended for:

- removal of heat from MCC equipment to ensure its availability in all modes of unit operation (the heat is rejected to the service water system),

- prevention of radioactivity release to the environment from equipment connected to the primary circuit (IC interpose an additianal barrier against release of activity from the equipment to the environment via the service water).

There are two independent intermediate circuits:

- intermediate circuit for Purification and Cooling System (PCS) water additional coolers IC-1,
- intermediate circuit for MCC equipment IC-2.

IC-1 should provide heat removal from the primary circuit during reactor cool down (as one stage in the decay heat removal process) and permanent cooling of MCC water in the additional coolers of the PCS. Before being directed to the bypass filters, the water is cooled down to a temperature below 50°C.

IC-2 provides cooling water for the following components:

- bearings and seals of ECCS pumps,
- coolers of the MCP seals,
- heat exchangers of the MCP shaft sealing system,
- coolers in the Fuel Claddings Integrity Monitoring system (FCIM), drum separators, primary circuit piping and PCS piping, hydrostatic bearings of the MCP,
- heat exchanger of the MCC high pressure sensors,
- heat exchangers of the cutting machine which is employed for reducing the height of fuel clusters before transfer to the storage pool,
- heat exchangers of the AFWPs seals.

The main safety related task of the IC-2 system is to ensure availability of the ECCS pumps, AFWPs and MCP.

Table 7.12 IC-1 conditions

Parameter	Value
IC water flowrate during normal operation, kg/s (m^3 /h)	333 (1200)
IC water temperature in the inlet of IC-1 heat exchanger, °C	25-35
IC water temperature in the outlet of IC-1 heat exchanger, °C	15-20
Pressure in the discharge of IC-1 pumps, MPa (kgf/cm^2)	0.343 (3.5)
Level in IC-1 expansion tank, mm from the top	800-1150

Table 7.13 Technical specification of heat exchangers of IC-1 and IC-2

Parameter	IC-1	IC-2
Heat exchanger type	tubes-in-case, with straight tubes, horizontal, with fixed tube grids	
Number per reactor	8	2
Inner diameter, mm	1200	1200
Length of tubes, m	6	4
Tube material	Steel st.20	Steel st.20
Outer diameter of the tubes,mm	20	20
Number of passes through inner space of heat exchanger	1	1
Configuration of tube bundle	triangle	triangle
Heat transfer surface, m^2	641	427

Table 7.14 Technical specification of pumps of IC-1 and IC-2

Parameter	Value
Circulation pump of the IC-1, IC-2 (type - Ah500/37)	
Number per reactor (for IC-1)	8
Number per reactor (for IC-2)	3
Capacity, kg/s (m^3/h)	83-194 (380-700)
Discharge pressure, MPa (kgf/cm^2)	0.372-0.441 (3.8-4.5)
IC-2 pump of water pressure increase for FCIM coolers (type - Ah20/18)	
Number per reactor	2
Capacity, kg/s (m^3/h)	4.2-6.9 (15-25)
Discharge pressure, MPa (kgf/cm^2)	0.118-0.196 (1.2-2.0)
IC-2 pump of water pressure increase for refueling machine (type - VK-2/26)	
Number per reactor	2
Capacity, kg/s (m^3/h)	0.75-2.22 (2.7-8)
Discharge pressure, MPa (kgf/cm^2)	0.196-0.59 (2.0-6.0)

7.4.1 Intermediate Circuit of the PCS Water Final Coolers IC-1

IC-1 includes a circulation circuit which consists of the following:

- 8 heat exchangers, where IC water is cooled by service water (taken from the lake),
- 8 pumps, which provide circulation of coolant in the circuit,
- expansion tank, which is intended to provide required pressure in suction lines of the pumps.

Nominal parameters of IC-1 are presented in Table 7.12.

Technical specifications for the main equipment are presented in Tables 7.13, 7.14.

During power operation of the unit, 2 pumps and up to 4 IC-1 heat exchangers are in operation. During reactor startup 4 pumps and 4 heat exchangers are in operation. During reactor cooldown 6-7 pumps and 8 heat exchangers of the IC-1 are available for the forced circulation mode operation of the IC-1. Control for the starting and shut-off of pumps, opening and closure of valves (except maintenance valves) is provided from the main control room. Service (lake) water flow rate is adjusted manually using valves in the outlets of the heat exchangers. The adjustments are made employing readings from service water flow meters installed in each heat exchanger and temperature meters installed in the IC-1 outlets of heat exchangers.

Service water pressure in the heat exchangers is higher than pressure of IC-1 water, this prevents ingress of IC-1 water to the lake in case of leaks in the heat exchangers tubes.

In case of loss of off-site power, IC-1 operation does not change.

7.4.2 Intermediate Circuit for MCC Equipment IC-2

IC-2 includes a circulation loop which consists of the following components:

- 2 heat exchangers, where IC-2 water is cooled by service water (taken from the lake),
- 3 main pumps, which provide circulation of water in the loop,
- 2 auxiliary pumps, which are intended to increase pressure of IC-2 water and to supply water to FCIM coolers,
- expansion tank, which is used to provide required pressure in the suction lines of the pumps.

Nominal parameters of IC-2 are presented in Table 7.15. Technical specifications for the main components are presented in Tables 7.13, 7.14, 7.16.

Table 7.15 IC-2 conditions

Parameter	Value
IC water flowrate during normal operation, kg/s (m^3 /h)	111-139 (400-500)
IC water temperature in the inlet of IC-2 heat exchanger, °C	25-30
IC water temperature in the outlet of IC-2 heat exchanger, °C	15-20
Pressure in the discharge of IC-2 pumps, MPa (kgf/cm^2)	0.44 (4.5)
Level in expansion IC-2 tank, mm from the top	800-1150
Service water flowrate during power operation, kg/s (m^3/h)	194 (700)

The intermediate circuit IC-2 operates continuously regardless of the operation mode of the unit. One main IC-2 pump and one IC-2 heat exchanger are active during normal operation. Auxiliary pumps for increasing the pressure of the water coming to FCIM are switched off during normal operation, and IC-2 water comes through the bypass pipeline from the discharge header of the main IC-2 pumps. If the pressure provided in the discharge header by running the main IC-2 pump is not sufficient to supply water to coolers of the FCIM, then one or both auxiliary pumps are started. Regulation of service (lake) water flow rate is made manually using valves in the outlets of the heat exchangers. Adjustments are made according to the measurements provided by service water flow meters installed in each heat exchanger and temperature meters installed in the IC-2 outlets of heat exchangers.

Pressure of service water in the heat exchangers is higher than pressure of IC-2 water, this prevents ingress of IC-2 water to the lake in case of tube failure.

In case of loss of off-site power, IC-2 operation does not change.

The radioactivity of IC-1, IC-2 water and service water is monitored. Water quality ranges are presented in the Table 7.17.

The IC-1, IC-2 circuits are filled and makeup water is supplied using primary grade water from the expansion tanks (makeup is provided automatically).

7.5 FISSION PRODUCT REMOVAL AND CONTROL SYSTEM

Fission products from the core region can penetrate into the compartments which surround the MCC piping and components in various ways. Special venting systems are employed to lower the radioactive background in these compartments. If the air temperature rises above 70 °C, it is cooled by the heat exchanger. If fission products are

Table 7.16 Main components connected to intermediate circuit IC-2

Components	Number of components (per reactor)	IC-2 water flowrate for components, kg/s (m^3/h)
ECCS pumps	6	1.39 (5)
Coolers of MCP sealing	8	2.22 (8)

Heat exchanger of the system for MCP shaft sealing	2	2.22 (8)
Coolers of the system of sampling from drum separator	8	5.56 (20)
Coolers of the system to sample water from hydrostatic bearings of MCP, primary circuit, purification and cooling system	5	5.56 (20)
Coolers of the FCIM system	4	0.139 (0.5)
Coolers of MFWPs and AFWPs sealings	13	1.11 (4)

Table 7.17 Water quality in IC-1, IC-2

Parameter	Value
pH	6.0-10.0
Mass concentration of Cl, μg/dm^3	100
Conductivity, μSm/cm	3.0
Mass concentration of iron, μg/dm^3	2000
Radioactivity, Bq/kg (Cu/kg)	7.4 ($2.0 \cdot 10^{-10}$)

detected, the air is forced through filters. The filtered air is vented to the environment from the 150 m high venting stacks. The most contaminated gases are gases from the circuit employed to cool the internal cavities within the core block. These gases (helium-nitrogen mixture) are treated by a special gas-discharge cleaning system.

7.5.1 Reactor Gas Circuit and Vented Gas Cleaning System

The purpose of the gas circuit of the RBMK-1500 reactor is to provide the helium-nitrogen mixture (about 10 % nitrogen) used for cooling the internal reactor cavities. Pressure of the gas mixture is 0.5 - 2 kPa. Gas circulation improves heat removal from the graphite stack (see Subsection 4.2.1), control rods and reflector cooling channels, as well as protects graphite stack from oxidation at high temperature conditions. The pressure of the inert gas mixture between the fuel channel and the graphite stack serves as an indication of the leak tightness of fuel channels. A rupture of a fuel channel is diagnosed by the appearance of water steam in the released gas mixture. Gas contaminated by radioactive steam is removed from the gas circuit. The inert gas also protects the reactor metal structures from corrosion.
The gas circuit includes [58]:

- monitoring the integrity of the reactor channels system,
- gas supply of the circuit auxiliary equipment,
- helium cleaning equipment,
- released radioactive gas cleaning system.

The released radioactive gas cleaning system is utilized to clean gas which is collected in the reactor space, helium cleaning equipment, turbine condenser and the back of the refueling machine, cleaning and releasing the cleaned gas to the atmosphere [59]. The released gases are cleaned of iodine, aerosols and inert radioactive gases to a recommended norm. Released gases are transported by two vacuum pumps VVN-1-12 (one pump is in an operational mode, and other is in reserve). The capacity of the pump is 750 m^3/h. Before release the gases are cleaned of radioactive iodine and aerosols in aerosol filters and carbon absorbers. Because aperture cross-sections in separate compartments of the gas delay chambers are large, the gas flow velocity is small and gases are left in the chamber to 10 hours. During this period a majority of radioactive elements are decayed. Just before to getting to the 150 m high venting stack, gases pass through an additional activity reduction chamber. Here released gases are dryed in ceolite filters and radioactive inert gases are cleaned using the absorbers with activated carbon SKT-3.

The block-schematic of the reactor gas circuit with released gas cleaning system is shown in Fig. 7.4.

7.5.2 Reactor Channel Integrity Monitoring System

Reactor Channel Integrity Monitoring (RCIM) system performs reliable integrity monitoring of fuel channels, reflector cooling channels and control rod channels in the reactor.

The reactor channels' integrity are monitored by permanent monitors, measuring temperature and relative humidity of gas pumped through RC. The initial data is processed by ICS "TITAN" and is requested by the computer from all the measuring points with a period of 30 s.

The reactor core is subdivided into 26 zones according to the number of RCIM group valves. Sensing lines connect RCIM group valves with all gas housings of the fuel channels (1661), control rod cooling circuit (235) and reflector cooling circuit (156) channels.

Gas flows coming from the zone sensing lines merge in a single flow in a respective RCIM group valve and can be directed (by switching over the valve positioner) either to the "Venting" header (normal regime), or to the "Enhanced suction" header (an accidental regime to dry the graphite stack and localize moisture in reactor cavity). The flowrate of gas pumped through the channel housings increases from 0.1 m^3/h in the

"Venting" regime to 0.5 m^3/h in the "Enhanced suction" mode depending on the number of aligned RCIM valves (no more than 4 group valves can be aligned at a time).

In order to monitor relative humidity at the reactor cavity outlet there is a zone humidity detector downstream each of RCIM group valves. When relative humidity in a group valve increases to 70 % a "humidity" alarm is sent, and after processing by the plant Information and Computer System (ICS) "TITAN" the alarm is indicated in the MCR.

A thermocouple is installed in each of the sensing lines upstream of the group valve to monitor the gas temperature. If the gas temperature in the RCIM system exceeds 40 ^oC a preventive alarm signal is sent and after processing by ICS "TITAN" the alarm is indicated in the MCR.

When there is a leak from fuel channels, control rod cooling circuit or reflector cooling circuit channels into the reactor cavity, the gas humidity increases and a zone detector triggers. On receiving the "humidity" alarm one or several (up to 4) group valves are switched over to the "enhanced suction" regime. The search for a leaking channel is carried out by monitoring a temperature increase of the gas mixture in a sensing line.

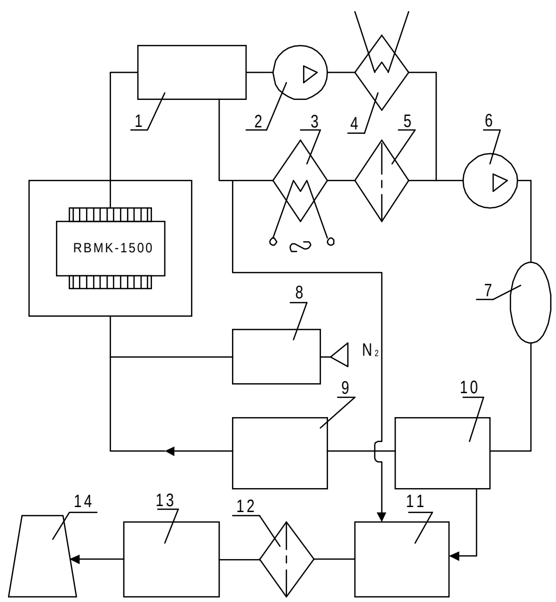

Fig. 7.4 Reactor gas circuit with released gas cleaning system (block schematic)
1 - monitoring the integrity of fuel channel system, 2 - vacuum pump, 3 - electric heater, 4 - gas circuit condenser, 5 - iodine filter, 6 - helium compressor, 7 - receiver, 8 - nitrogen supply and regulating device, 9 - helium-nitrogen supply and regulating device, 10 - gas cleaning unit, 11 - gas delay chamber, 12 - filter, 13 - activity reduce device, 14 - venting stack

7.5.3 Venting System for the Reactor and the MCC Compartments

All compartments in the reactor building are divided into service and non-service compartments. The purpose of the venting system for the reactor service compartments is to:

- provide sanitary-hygiene and temperature conditions in these compartments,
- prevent possible pollution of indoor and ambient air by toxic substances,
- remove excess heat from the compartments with process equipment,
- cooling to concrete structures of the reinforced leak-tight compartments.

The reactor non-service compartments are vented by a special venting system. The purpose of the special venting system is the same as that of the ordinary venting system (which is venting reactor service compartments), but it is intended for non-service compartment. There is a higher probability for radioactive fission products in these compartments, therefore, air from the non-service compartments is cooled and cleaned by filters.

Air venting is performed using venting units VDN-17, VDN-10 and VDN-12.5. These are centrifugal, high pressure units with sinus-shape six-blade rotor ventilators. The ventilator shaft and the electric motor shaft are connected with a bushing. Ventilators differ by the shell structure and capacity.

Air from the compartments, where a lot of heat is generated, are cooled before proceeding to the filters. This is done in air coolers of type VO-267/2510-62-MU-U4. Air coolers consist of ribbed tubes connected by collectors. Service water is used for cooling, the temperature of which is about 25-28 ^{o}C. In the coolers air is cooled to 70 ^{o}C.

Decontaminated air is cleaned in the aerosol filters of type A-17 and D-23KL. These filters are used for air cleaning of radioactive and toxic aerosol products. A very fine polymeric fiber of type FP is used as filtering material. Filters are not regenerated, their filtering materials are not changed, they are permanent.

For cleaning of released contaminated air with radioactive iodine isotope carbon type AUI absorbers are used. The absorbers are vertical, cylindrical-shape devices, where air is filtered through an impregnated carbon type CKT-3 load placed into a special assembly.

In those locations where air supply channels penetrate a fire-prevention partition-wall, they are equipped with fire-resistant valves. In the MCC compartments, air reception channels are equipped with leaktight valves, which shut channels in emergency situation (such as, if the MCC pipelines are ruptured and radioactive steam is released into the compartments). They serve to protect from radioactive steam-gas mixture release to the atmosphere.

Main components of the special venting system structure are characterized in Table 7.18 [60]. All listed systems operate continuously.

Table 7.18 Special venting system structure [60]

Venting system	Purpose of the system	Venting compartments	Air venting capacity, m^3/h
WZ-51	Exhaust from the reactor hall via stab floor with purification at aerosol filters	Reactor hall	48000
WZ-52, 53	Exhaust from NPP rooms with purification at aerosol filters	Spent fuel pool , spent fuel assembly transfer channel. Bottom tank of control rod cooling system. Gas delay chamber in the ACS tower. Rooms of RCIM system	198800
WZ-54	Exhaust from NPP rooms with the following discharge to the stack without purification	Reactor hall. Compartments of feedwater and main steam pipelines. Top tanks of control rod cooling system. Compartments of ECCS pipelines. Compartments of pumps and heat exchanger of IC. ACS tower	400000
WZ-55	Exhaust from NPP rooms with the following discharge to the stack without purification	Compartments of control rod cooling system pipelines. Compartments of IC. ECCS process corridor. ACS tower	300000
WZ-56	Exhaust from PP rooms with double purification	MCC compartments. ACS tower.	39000
WZ-57	Exhaust system of concrete cooling	MCC compartments	105200
WZ-58	Exhaust system of concrete cooling	MCC compartments	105200