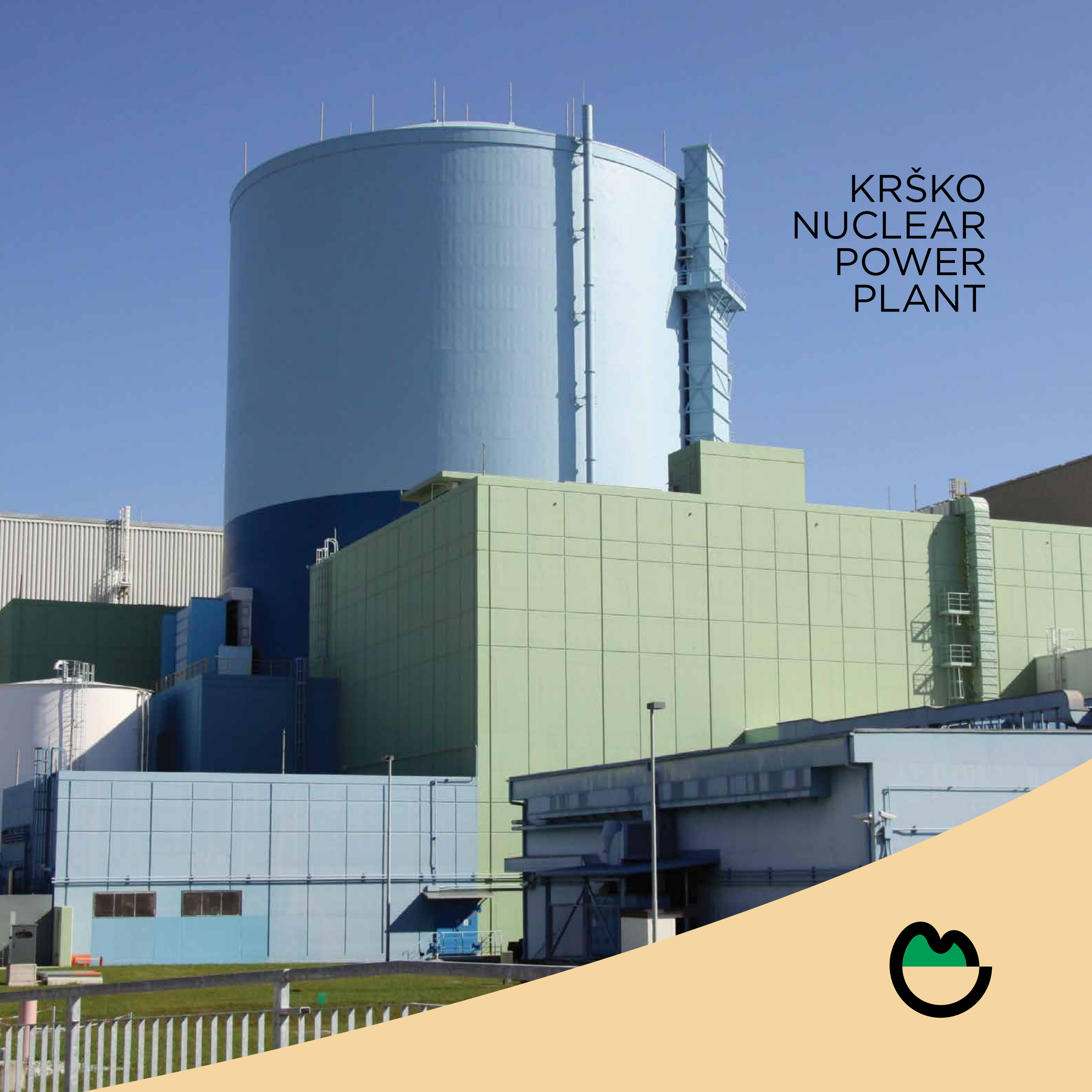


KRŠKO NUCLEAR POWER PLANT

KRŠKO NUCLEAR POWER PLANT

The Krško Nuclear Power Plant is equipped with the Westinghouse pressurised water reactor with the thermal power of 1994 MW. The plant is connected with the 400 kV transmission system to cover the needs of major consumers of the Republic of Slovenia and the Republic of Croatia. Following steam generators' and turbines' replacement, and power uprate, the plant output has increased to 702 MW net. In years without outages, it produces close to 6 billion kWh of electrical energy; in years with outages, it produces around 5.4 billion kWh. The planned annual electric power production amounts to 5 TWh.

The Krško Nuclear Power Plant is located on the left bank of the Sava River in the industrial zone of Krško town. The access to the plant is provided by means of the industrial road linked to the regional road Krško – Brežice. The plant also has an industrial railway line, which connects it with the Krško Railway Station.

The mission and responsibility of the plant are safe and stable plant operation, competitive production of electrical energy and favourable public opinion.

The Sava River - a means of cooling the plant

Main Control Room

ERECTION OF THE KRŠKO NUCLEAR POWER PLANT

After the Krško basin had been selected as a candidate site for Nuclear Power Plant, the working group of the Republic of Slovenia Business Association for Electric Power Resources in collaboration with Slovene Electric Power Utilities and research institutes carried out first researches during the period from 1964 to 1969.

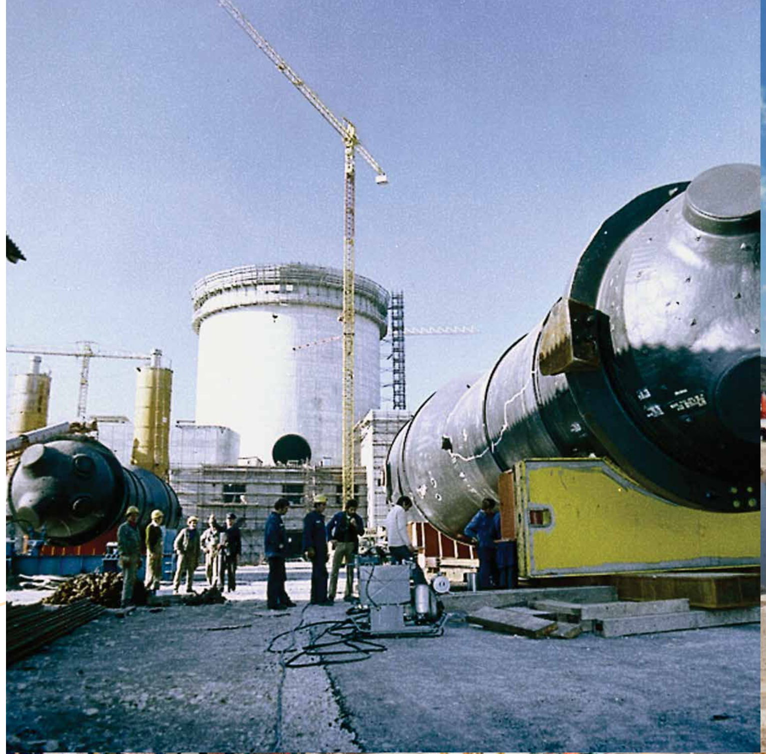
Following the proposal given by Slovene and Croatian electric power utilities in 1970, the Governments of Slovenia and Croatia signed an agreement on joint construction of nuclear power plant to cover the increasing needs for electric power in both Republics.

The decision to construct a nuclear power plant was expedited by the fact that both Republics lacked conventional power resources. The investors of the plant were Savske elektrarne, Ljubljana and Elektroprivreda, Zagreb. Their Investment Team carried out preparatory works, officially invited tenders and selected the most auspicious one.

In August 1974, the two investors entered into a turnkey contract with the American company Westinghouse Electric Corporation for the supply of equipment and the construction of the 632 MW Nuclear Power Plant. So, the main contractor was Westinghouse; the designer was the American company Gilbert Associates Inc., while the works were entrusted to Slovene and Croation companies.

On 1 December 1974, Josip Broz Tito – the then President of the former Yugoslavia – laid the foundation stone for the Krško Nuclear Power Plant. Civil works were carried out by Gradis and Hidroelektra, and erection works by Hidromontaža and Đuro Đaković.

The Republic of Slovenia and the Republic of Croatia participated equally in providing financial resources.



STRUCTURES

All principle structures of the Nuclear Power Plant are located on a solid reinforced concrete platform, which is situated upon the Pliocene sandy-clay sediments of the Krško basin. The platform of the Krško basin forms solid and seismically safe foundation. The structures are designed and constructed to resist anticipated earthquakes in this area free from major damages.

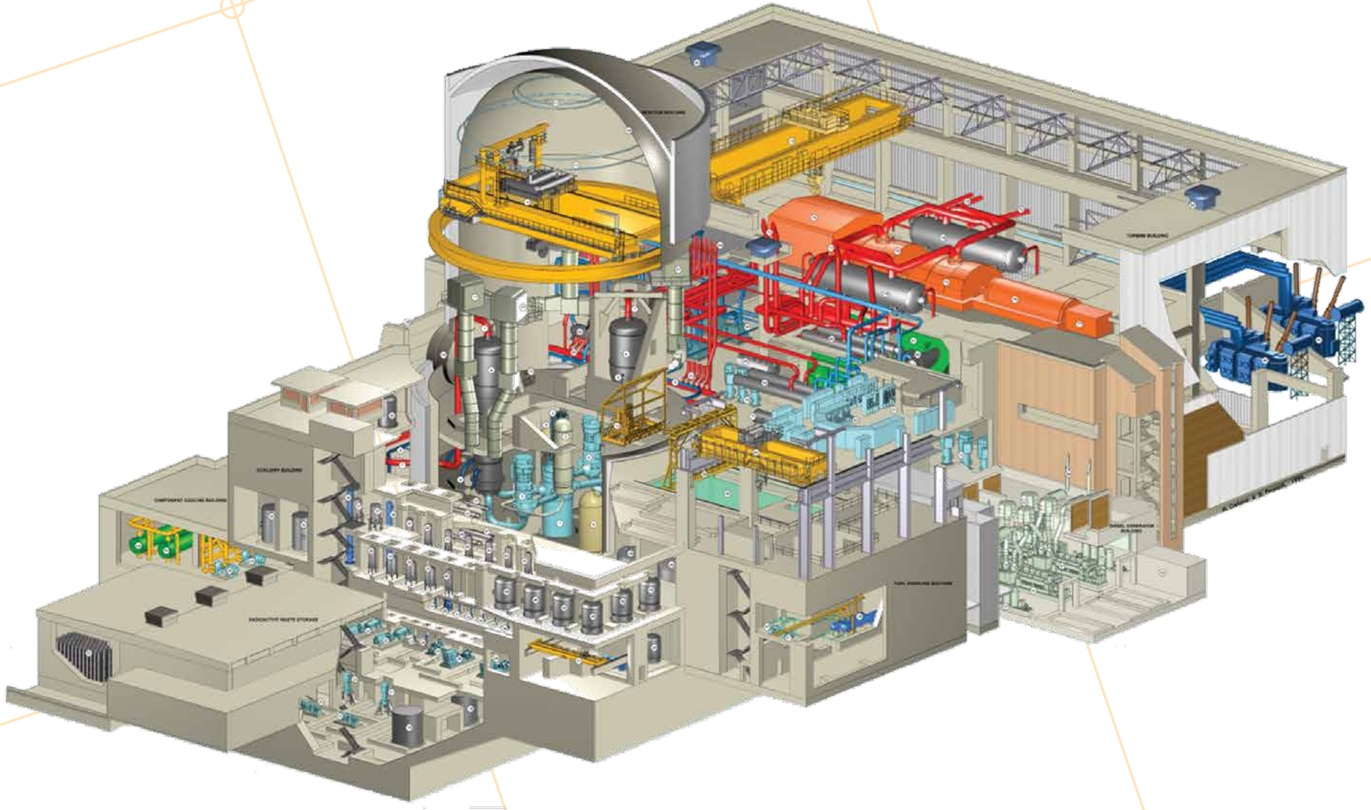
The Reactor Building, where the Reactor Coolant System and Safety Systems are installed, consists of the inner cylindrical steel shell and the outer reinforced concrete shield building. The Containment Airlock is equipped with sealed passage chamber with double doors. Numerous piping and cable penetrations are double sealed. Adjacent to the Reactor Component Cooling Building, Fuel Handling Building, Diesel Generator Building and Turbine Building are located.

Cooling water and Essential Service Water intake structures are located on the Sava River bank above the Sava River dam. Cooling water discharge structure is below the Sava River dam. In addition, Cooling Towers of a draft multi-cell type are provided for cooling circulating water in case of low water flow of the Sava River.

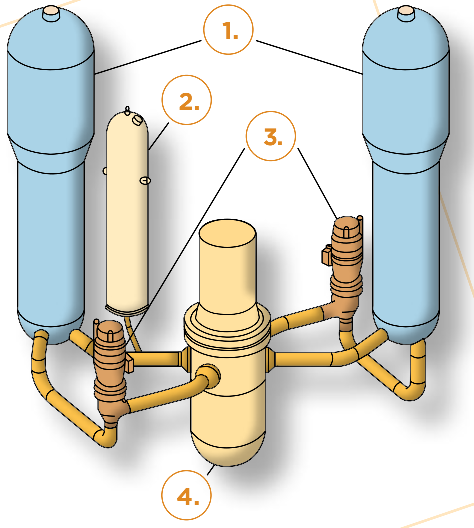
Solid Waste Storage is located on the south-western side of the plant; administration building with workshops and the switchyard are located on the north side, at the plant entrance. In the western part, two bunkered buildings with systems and equipment further increase the power plant's resistance to unlikely extreme and other events.

Adjacent to the bunkered buildings is the Spent Fuel Dry Storage (SFDS).

SCHEMATIC CROSS-SECTION OF THE PLANT



REACTOR COOLANT SYSTEM

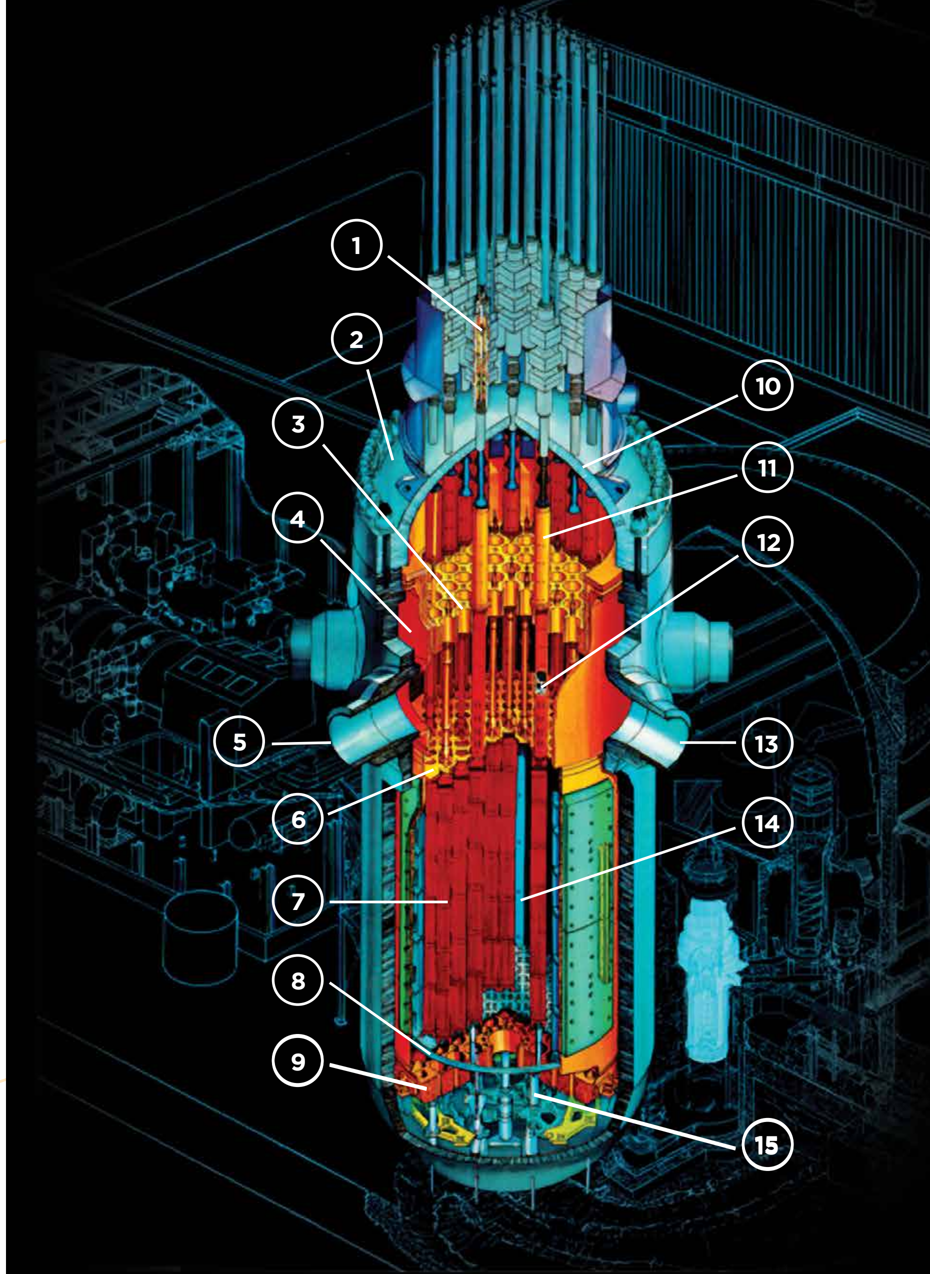


1. Steam Generators
2. Pressuriser
3. Reactor Coolant Pumps
4. Reactor

Westinghouse pressurised water reactor with two cooling loops consists of the reactor vessel with its internals and head, two steam generators, two reactor coolant pumps, pressuriser, piping, valves, and of reactor auxiliary systems. Demineralised water serves as reactor coolant, neutron moderator and for dilution of boric acid solution. In the steam generator the reactor coolant gives up its heat to the feedwater on the secondary side of the steam generator to generate steam. Reactor coolant pressure is maintained by the pressuriser, which is supported by electrical heaters and water sprays, which are supplied with water from the cold legs of the reactor coolant.

Data necessary for reactor control and reactor protection is provided by measuring the neutron flux, reactor coolant temperature, flow rate, pressuriser water level and pressure detectors.

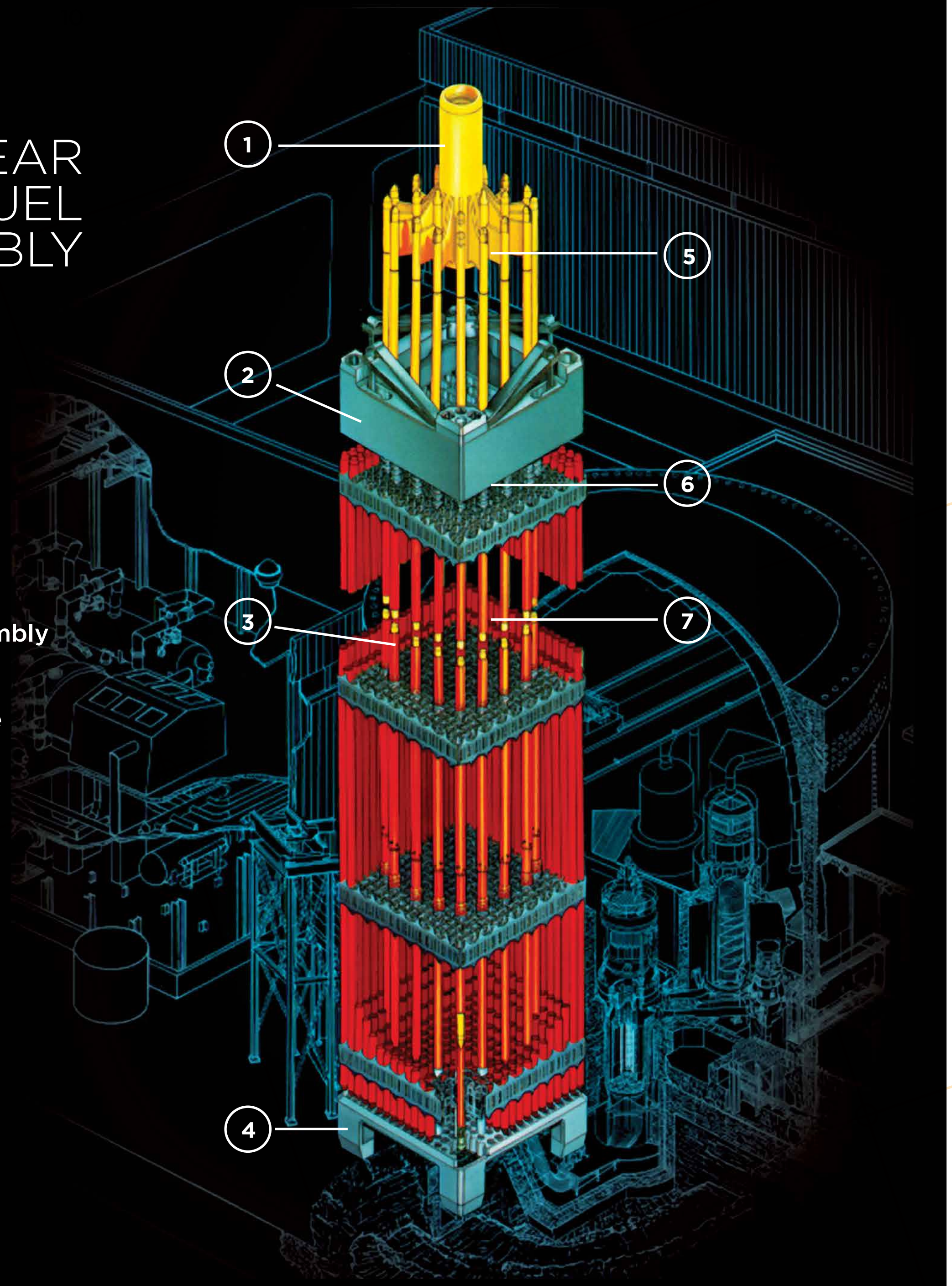
Reactor power is regulated by control rods. The control rod drive mechanisms are attached to the reactor vessel head. Long-term core reactivity changes and core poisoning with fission products are compensated by means of boric acid concentration change in the reactor coolant.



REACTOR VESSEL

1. Control Rod Drive Mechanism
2. Reactor Vessel Head
3. Upper Support Plate
4. Core Barrel
5. Outlet Nozzle
6. Upper Core Plate
7. Fuel Assemblies
8. Lower Core Plate
9. Support Plate Forging
10. Thermal Sleeves
11. Control Rod Assembly Conduit
12. Control Rod Assembly Drive Shaft
13. Inlet Nozzle
14. Diffuser
15. In-core Nuclear Instrumentation Guide Thimbles

NUCLEAR FUEL ASSEMBLY



1. Control Rod Assembly
2. Top Nozzle
3. Control Rod Guide Thimble
4. Bottom Nozzle
5. Absorber Rod
6. Grid Assembly
7. Fuel Rod

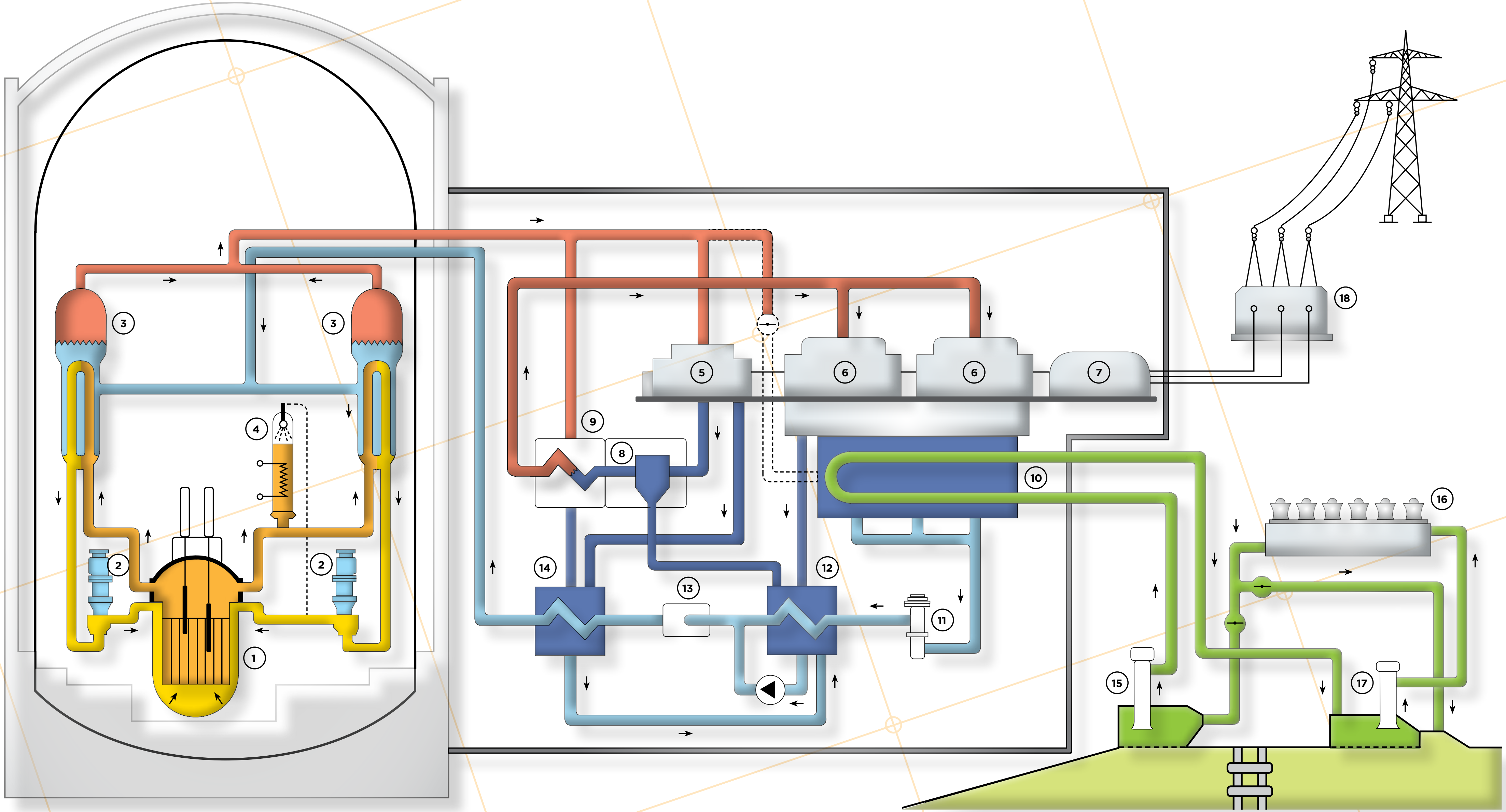
NUCLEAR FUEL

The reactor core is composed of 121 fuel assemblies. Each fuel element consists of fuel rods, top and bottom nozzles, grid assemblies, control rod guide thimbles and instrumentation guide thimbles. Fuel rods contain ceramic uranium dioxide pellets welded into ZIRLO tubes. Uranium oxide fuel is shaped into sintered pellets and enriched with the uranium 235.

During outage – every 18 months – almost half of the fuel assemblies is replaced by fresh ones. Fresh fuel assemblies are kept in the Fresh Fuel Storage. Spent fuel elements are kept and cooled under water in the Spent Fuel Pit.

After a few years, the spent fuel is transferred to multi-purpose canisters, which are then placed in robust casks where passive cooling is ensured.

During refuelling, fuel assemblies are removed from the reactor through flooded transfer canal penetrating the containment vessel into the Spent Fuel Pit. During refuelling, the reactor is open and the reactor cavity is flooded. The refuelling machine removes the spent fuel assemblies from the reactor core and replaces them with the fresh ones. Fuel assemblies remain in the rector core at least two fuel cycles.



FUNCTIONAL DIAGRAM

1. Reactor
2. Reactor Coolant Pumps
3. Steam Generators
4. Pressuriser
5. High Pressure Turbine
6. Low Pressure Turbines
7. Generator
8. Moisture Separator
9. Reheater
10. Condensers
11. Condensate Pumps
12. Low Pressure Heater
13. Feedwater Pump
14. High Pressure Feedwater Heater
15. Circulating Water Pumps
16. Mechanical Draft Multi-cell Cooling Towers
17. Cooling Tower Circulating Pumps
18. Transformer

TURBINE GENERATOR AND ELECTRICAL SYSTEM

The steam generators generate saturated steam, which drives the turbine. In the double-flow high-pressure turbine the steam expands to 0.8 MPa. Then the steam flows through moisture separator and through reheater into double-flow low-pressure turbine where it expands to 5 kPa. After the steam is condensed in the condensers, the feedwater pumps return it through the heaters into the steam generators.

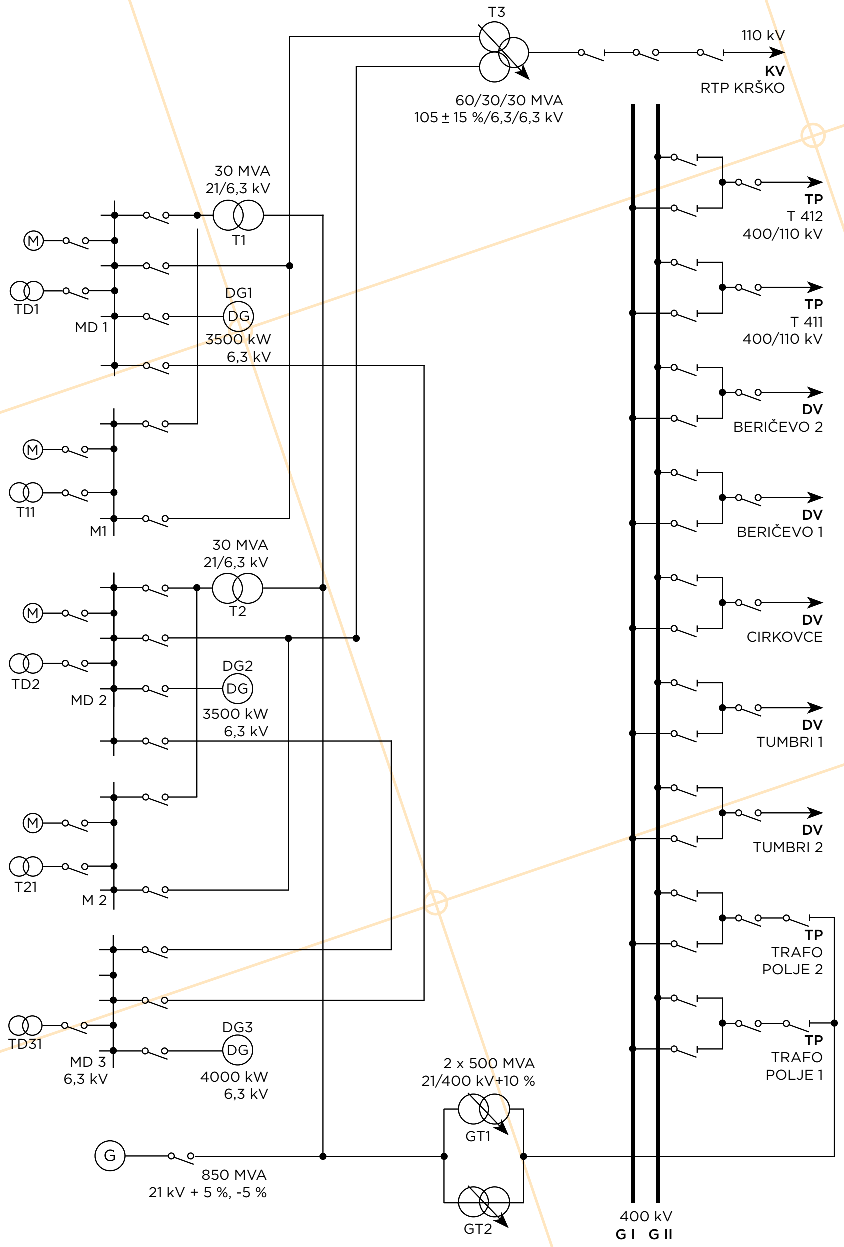
The power of the three-phase generator is 850 MVA, its cos fi 0.876, and the voltage 21 kV. The generator rotor is cooled with hydrogen and the stator is cooled with water. The exciter is brushless.

When the Sava River flow exceeds 100 m^3/s, the condensers are cooled by means of direct river water trough flow. In case of lower river flow such cooling is combined with cooling towers, so that at the lowest flow rates a small amount of water is drawn from the Sava River, while the remaining water is circulated by cooling water discharge into the Sava River. The Sava River temperature may increase for 3°C maximum and must not exceed 28°C in a mixing point.

The Krško Nuclear Power Plant is connected to the 400 kV transmission system through the 400 kV switchyard. Electric energy flows from the generator through two main transformers to the 400 kV switchyard. Then it continues through one transmission line towards Maribor and two transmission lines towards Ljubljana, through two transmission lines towards Zagreb and through buses to the distribution and transformer station – Krško TS 400/110 kV.

The plant is supplied either from its generator or 400 kV transmission system. In case of the 400 kV transmission system failure, the electric power is supplied through the 110 kV cable from the Krško TS 400/110 kV. The backup supply of electric power is assured from the Brestanica Gas-steam Power Plant, which is 7 km away from the Krško Nuclear Power Plant. The Brestanica Power Plant can cut-off all other consumers and supply the power only to the Krško Nuclear Power Plant.

In addition, the plant is provided with three diesel generators, each with rated power of 3500 kW, which serve as an independent emergency electric power source for essential plant systems and are able to respond in 10 seconds already.



ON LINE DIAGRAM

- G — Generator
- GT — Main Transformer
- DG — Diesel Generator
- Circuit Breaker
- Disconnect Switch
- M — Motor
- Unit Transformer
- Auxiliary Transformer

G, M, MD	Buses
DV	Transmission Line
GT, T, TD	Transformer
KV	Cable
RTP	Krško TS 400/110 kV
TP	Transformer Bay

RADIOACTIVE WASTE AND ENVIRONMENTAL PROTECTION

During the Nuclear Power Plant operation gaseous, liquid and solid waste is produced. The plant is provided with the Gaseous Waste Processing System which consists of two parallel closed loops with compressors and catalytic hydrogen recombiners and of six decay tanks for compressed fission gases. Four of the tanks are used during normal plant operation, while the remaining two are used during reactor shutdown. The capacity of the tanks is adequate for more than one-month gaseous waste hold-up. Within this period the majority of the short-lived fission gases decay, while the remaining gases are released into the atmosphere under favourable meteorological conditions. Automatic radiation monitors in the ventilation duct prevent uncontrolled release when the radioactive gas concentration exceeds the permissible level.

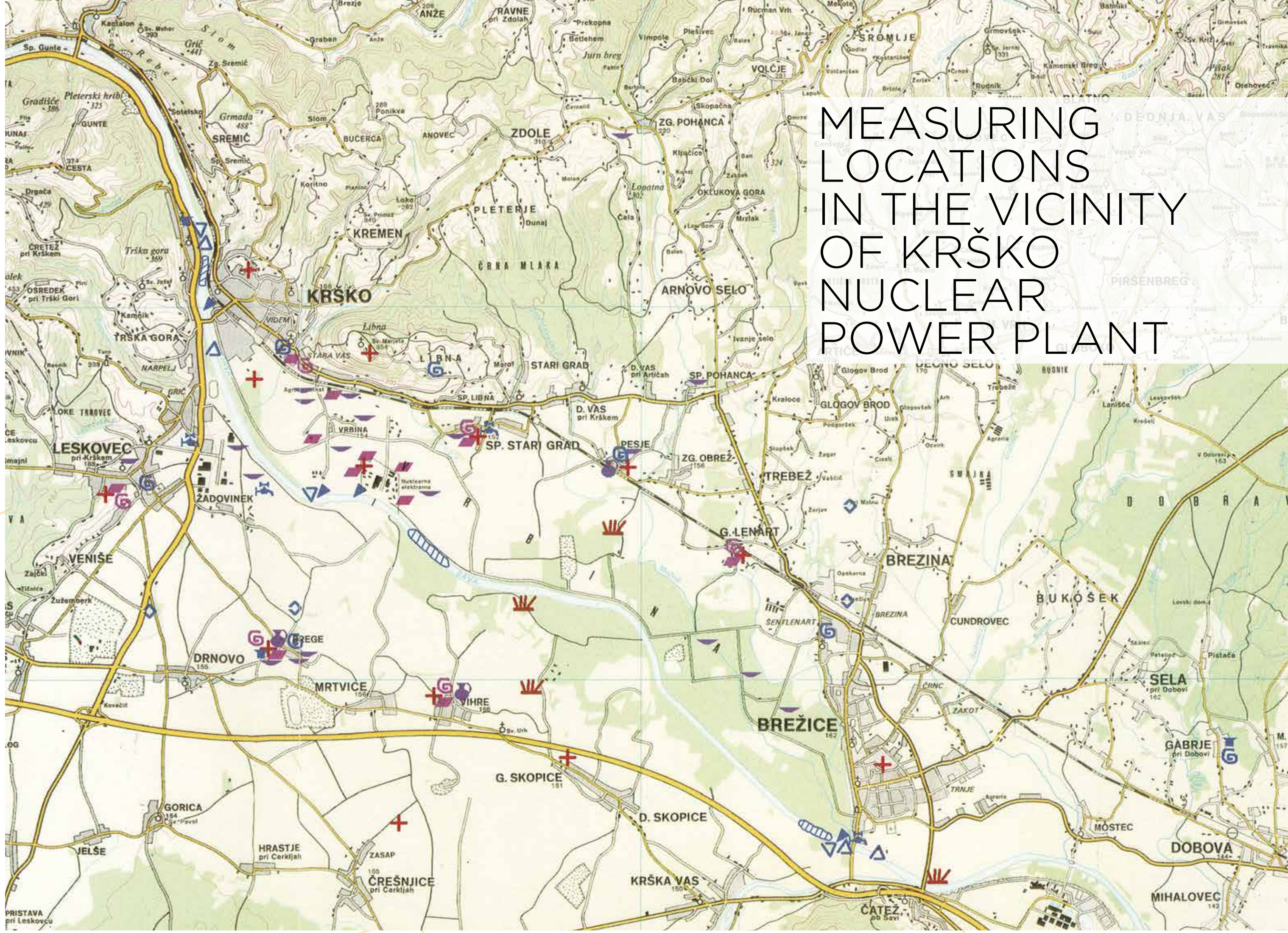
Liquid radioactive waste is purified in the Liquid Waste Treatment Facilities consisting of tanks, pumps, filters, the evaporator, and two demineralisers. The blow-down water from the steam generators is purified separately. The radioactivity of the water discharged into the Sava River is considerably below the maximum permissible concentration.

All solid radioactive waste, generated during the plant operation, maintenance activities and servicing is collected in the Solid Waste Storage. Used ion exchangers, evaporator concentrates, used filters, and other contaminated solid wastes, as paper, towels, working clothes, laboratory equipment, and various tools are major solid wastes. Solid waste is compressed and encapsulated into 208-litre steel casks. These casks are temporarily kept in the Solid Waste Storage within the plant area. Combustible radioactive waste is sent for incineration to an external contractor, thus ensuring volume reduction.

Modern Waste Treatment Facilities and continuous off-site radiological monitoring ensure that off-site radiation during the plant operation is less than 0.1 per cent of the dose received annually from natural background and artificial sources.

The offsite radiological monitoring is being carried out since 1974 already and comprises surveillance of 50 locations in local land environment. The following media are regularly monitored: air, waters, precipitation, suspended matter, deposits, biota of the Sava River and underground waters. Dose calculations are compared to natural external dose rate and atmospheric deposits from preoperational monitoring. All the measurements are being carried out during the plant operation as well.

MEASURING LOCATIONS IN THE VICINITY OF KRŠKO NUCLEAR POWER PLANT



- Permanent Dose Rate Monitors
- Fish
- Sediments
- Water Pumping Station
- Tap Sample
- Aerosol Pumps
- Vaseline Lubricated Plates
- Precipitation
- Iodine Pumps and Filters
- Food
- Milk
- Soil
- Monthly Water Sample
- Single Water Sample

TECHNICAL DATA

NUCLEAR POWER PLANT

• Reactor Thermal Power	MW	1994
• Gross Electrical Output	MW	737
• Net Electrical Output	MW	702
• Engineering Minimum	MW	35
• Heat Consumption	kcal/kWh	2560
• Thermal Efficiency Factor	%	36

CONTAINMENT

• Height	m	61
• Inside Diameter	m	32
• Outside Diameter	m	38
• Steel Shell Test Pressure	MPa (at)	0.357 (3.62)

REACTOR VESSEL

• Outside Diameter	m	3.69
• Height	m	11.9
• Wall Thickness	m	0.168
• Empty Vessel Weight	t	327
• Vessel Weight with Internals	t	436

REACTOR COOLANT

• Chemical Composition		H_2O
• Additives		H_3BO_3
• Number of Cooling Loops		2
• Total Mass Flow	kg/s	9021
• Pressure	MPa (ata)	15.41 (157)
• Total Volume	m³	197
• Temperature at Reactor (Vessel) Inlet	°C	287
• Temperature at Reactor (Vessel) Outlet	°C	324
• Number of Pumps		2
• Pump Capacity	m³/s	6.3
• Pump Driving Power	MW	5.22

STEAM GENERATORS

• Material		INCONEL 690 TT
• Number of Steam Generators		2
• Steam Pressure at Steam Generator Outlet	MPa (at)	6.5 (63.5)
• Steam Temperature at Steam Generator Outlet	°C	280
• Feedwater Temperature at Steam Generator Inlet	°C	219
• Total Steam Mass Flow	kg/s	1088
• Steam Generator Height	m	20.6
• Steam Generator Weight	t	345
• Number of U-tubes in Steam Generator		5428
• Total Heating Surface	m²	7177
• U-tube Outside Diameter	mm	19.05
• U-tube Thickness	mm	1.09

REACTOR CORE

• Equivalent Diameter	m	2.45
• Equivalent Height	m	3.66
• Equivalent Radial Thickness of the Reflector	m	0.15
• Equivalent Axial Thickness of the Reflector	m	0.10

NUCLEAR FUEL

Number of Fuel Assemblies		121
Number of Fuel Rods per Assembly		235
Fuel Rod Array in Fuel Assembly		16 X 16
Fuel Rod Length	m	3.658
Clad Thickness	mm	0.572
Clad Material		ZIRLO™
Fuel Chemical Composition		UO_2
Pellet Diameter	mm	8.192
Pellet Height	mm	9.8
Total Weight of Nuclear Fuel	t	48.7

CONTROL RODS

Number of Control Rod Assemblies		33
Number of Absorber Rods per Assembly		20
Total Weight of Control Rod Assembly	kg	52.2
Neutron Absorber		Ag-In-Cd
Percentage Composition	%	80-15-5
Diameter	mm	8.36
Density	g/cm³	10.16
Clad Thickness	mm	0.445
Clad Material	Steel SS	304

ENGINEERED SAFETY FEATURES

• Passive Safety Injection System:		
No. of Pressure Vessels/Accumulator Tanks		2
Volume of Each	m³	36.4
• Active Safety Injection System:		
HP Safety Injection (SI)		
No. of Trains		4
No. of Pumps		2
Pump Flow Rate	m³/s	0.044
LP Safety Injection (RHR)		
No. of Trains		2
No. of Pumps		2
Pump Flow Rate	m³/s	0.14
• Energency Core Cooling Actuation Time	s	40

TURBINE GENERATOR

• Maximum Power	MW	737
• Steam Flow Rate	kg/s	1090
• Fresh Steam Inlet Pressure	MPa (at)	6.42 (63)
• Fresh Steam Temperature	°C	280.7
• Turbine Speed	rad/s (rotation/min)	157 (1500)
• Steam Moisture at High-Pressure Turbine Inlet	%	0.10
• Condenser Pressure (Vacuum)	kPa (at)	5.1 (0.052)
• Average Condensate Temperature	°C	33
• Number of Feedwater Pumps		3
• Feedwater Pump Capacity	%	50
• Generator Rated Power	MVA	850
• Rated Voltage	kV	21
• Generator Rated Frequency	Hz	50
• Cos fi	ø	0.876
• Regulated Range	%	+5-5

TRANSFORMERS

• Main Transformers:		
Rated Power	MVA	2 x 500
Voltage Ratio	kV	21/400
Load Tap Changing	%	+-10
Impedance Voltage	%	12.8/12.5
• Unit Transformers:		
Maximum Permissible Continuous Power	MVA	2 x 30
Voltage Ratio	kV	21/6.3
Impedance Voltage	%	10
• Auxiliary Transformer:		
Maximum Permissible Continuous Power	MVA	60
Voltage Ratio	kV	110/6.3/6.3
Load Tap Changing	%	+-16
Impedance Voltage	%	12

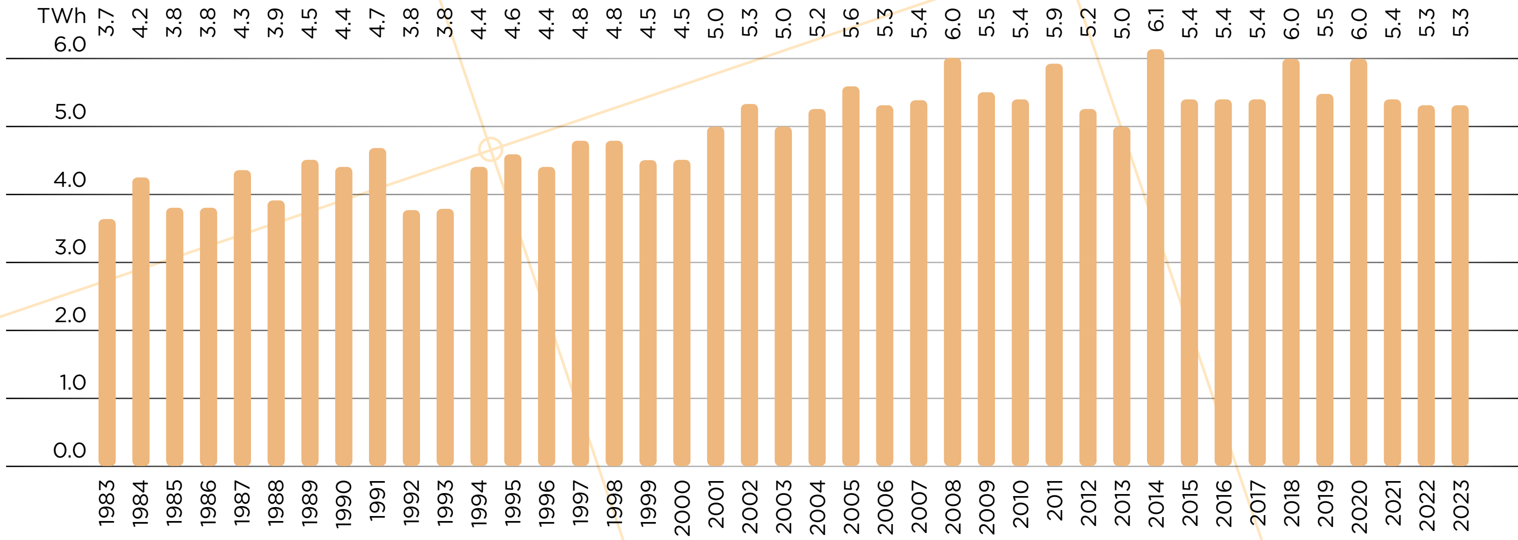
SIGNIFICANT DATES

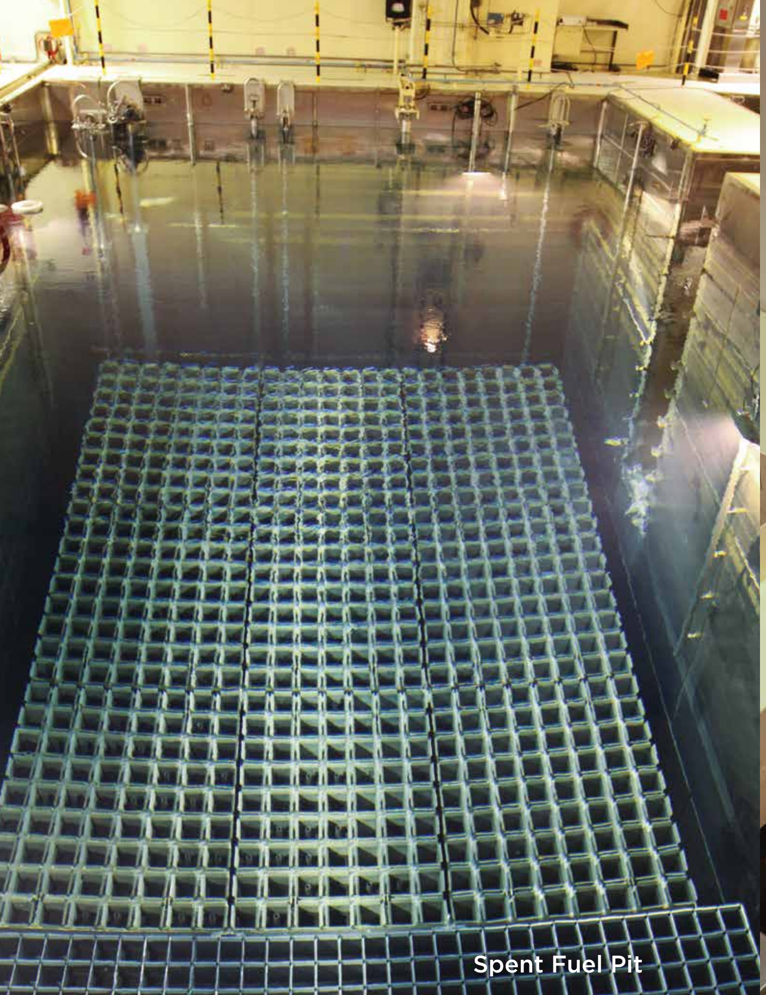
December 1974	Foundation stone laid for Krško Nuclear Power Plant.
February 1975	Start of excavation and construction works on the building site.
October 1977	Start of Turbine Generator installation.
April 1978	Both Steam Generators and Reactor Vessel installed.
November 1979	Essential pressure tests completed.
October 1980	Fuel supplied.
November 1980	Pressure and temperature nominal parameters achieved in the primary system.
May 1981	First phase of test operation. Fuel inserted in the Reactor Vessel.
September 1981	Self-sustaining chain reaction achieved in the reactor.
October 1981	Generator synchronised to the transmission line and the first kilowatts delivered to the Electric Utilities.
February 1982	100% power achieved.
July 1982	Steam Generator Main Feedwater System modified.
August 1982	Start of full-power operation.
January 1983	Start of commercial operation.
July 1983	First yearly outage and refuelling.
February 1984	Operating license issued by the Regulatory Body.
May 2000	Plant Power Uprate and Full-Scope Simulator Construction.
March 2003	Agreement between the Government of the Republic of Slovenia and the Government of the Republic of Croatia on regulating the status and other legal issues related to investments in the Krško Nuclear Power Plant, its utilisation and decommissioning.

April 2006	Replacement of Low Pressure Turbines.
October 2010	Replacement of Generator Stator.
April 2012	Replacement of Reactor Head and Main Generator Rotor.
April 2012	Connection of New Diesel Generator.
October 2013	Reconstruction of Switchyard and Replacement of Main Transformer.
October 2019	Emergency Control Room (ECR)
April 2022	Construction of a fortified (bunkered) protective building with a safety injection pump and an auxiliary feedwater pump with water sources from permanent wells.
January 2023	Construction of the Spent Fuel Dry Storage.

NET ENERGY PRODUCTION AT KRŠKO NUCLEAR POWER PLANT

TOTAL 202 TWh (commercial operation)




Spent Fuel Pit

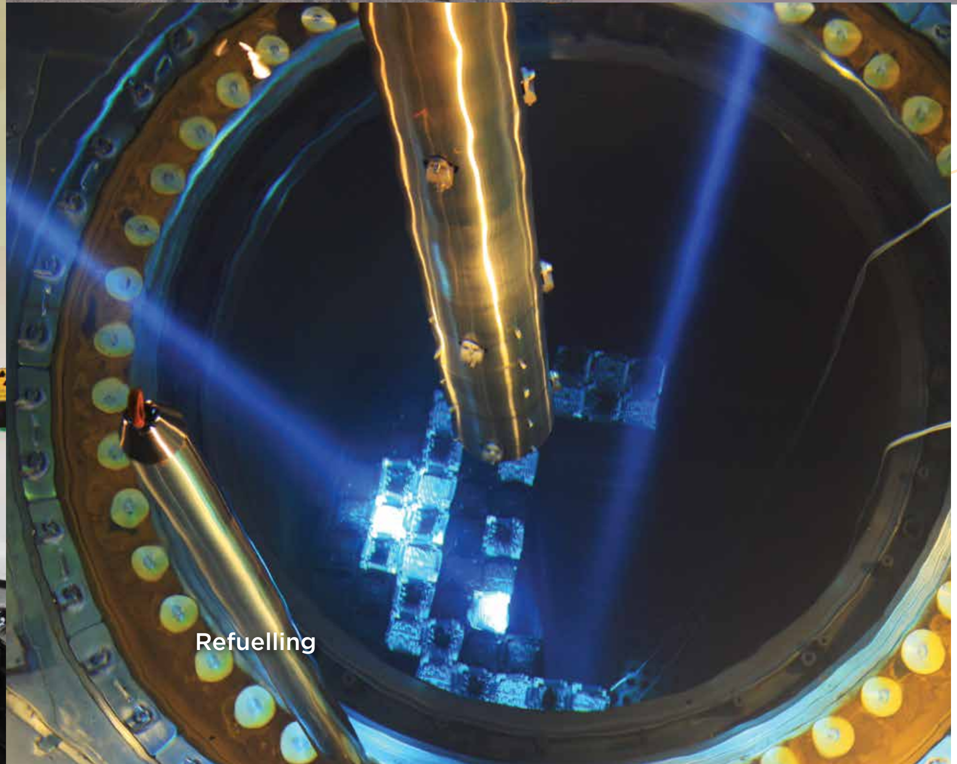

New Fuel Inspection


Switchyard


Turbine Generator


Spent Fuel Dry Storage


Temporary storage of Low and Intermediate Level Waste


Refuelling

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