TECHNICAL INFORMATION ON RINGHALS

VATTENFALL

Contents

We take electricity for granted

Electricity is a self-evident commodity today. It provides us with light, heat and energy for driving various machines and equipment. For our society to perform satisfactorily, reliable and safe availability of electric power is essential and will continue to be so in the future.

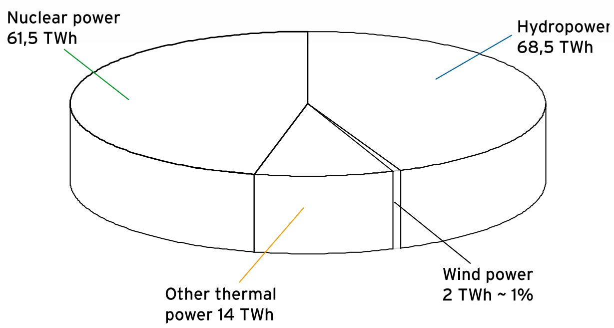
The Ringhals nuclear power plant is the largest Nordic electricity producer. During one year, the electrical energy generated by Ringhals is sufficient to supply six cities the size of Gothenburg, or almost 20% of Sweden's electricity consumption.

At Ringhals, we focus on the future, on the environment and on safe and reliable energy supply to all consumers – which is why we pursue continual research and development.

Heavy demands are made on us, but the demands we make on ourselves are probably even heavier. We consider it vitally important for our operations always to be pursued in a safe and controlled manner.

Ringhals is part of Vattenfall, which is one of Europe's leading energy conglomerates. Vattenfall generates electricity and heat, and supplies energy to several million customers in the Nordic countries and in northern Europe.

Electrical energy generation in Sweden



The electric power year 2008

Solar radiation is an important prerequisite for all life on Earth. The Sun is also the origin to most of the energy sources we use today. The Sun keeps the Earth's water circuit in motion, which enables us to produce electricity, for example, by means of flowing water. Solar energy is also stored in growing vegetation and in coal, oil and gas. The typical energy sources we use today are oil, coal, natural gas, hydropower, wind and nuclear power.

Nuclear power and hydropower are the base

Around half the electrical energy we use in Sweden is generated by nuclear power. Nuclear power plants generate a constant quantity of electricity around the clock. Hydropower stations that can quickly adjust their outputs are also used for matching the power generated to changes in electricity consumption. Oil-fired power stations that can be started whenever necessary are available as stand-by power. Sweden also has around 1200 wind turbines that together account for just over 1 percent of the electrical energy generated.

How we generate electricity

Heat is generated in a nuclear power plant by splitting uranium atoms. This splitting is known as fission.

When a neutron is projected onto a uranium atom, the atom core is split and new neutrons are released. These, in turn, can split other atoms, and a chain reaction is then under way. Nuclear fission liberates heat that can be used for generating electricity in a nuclear power plant.

There are two reactor types in Ringhals – a Boiling Water Reactor (BWR) (R1) and Pressurized Water Reactors (PWR) (R2, R3 and R4).

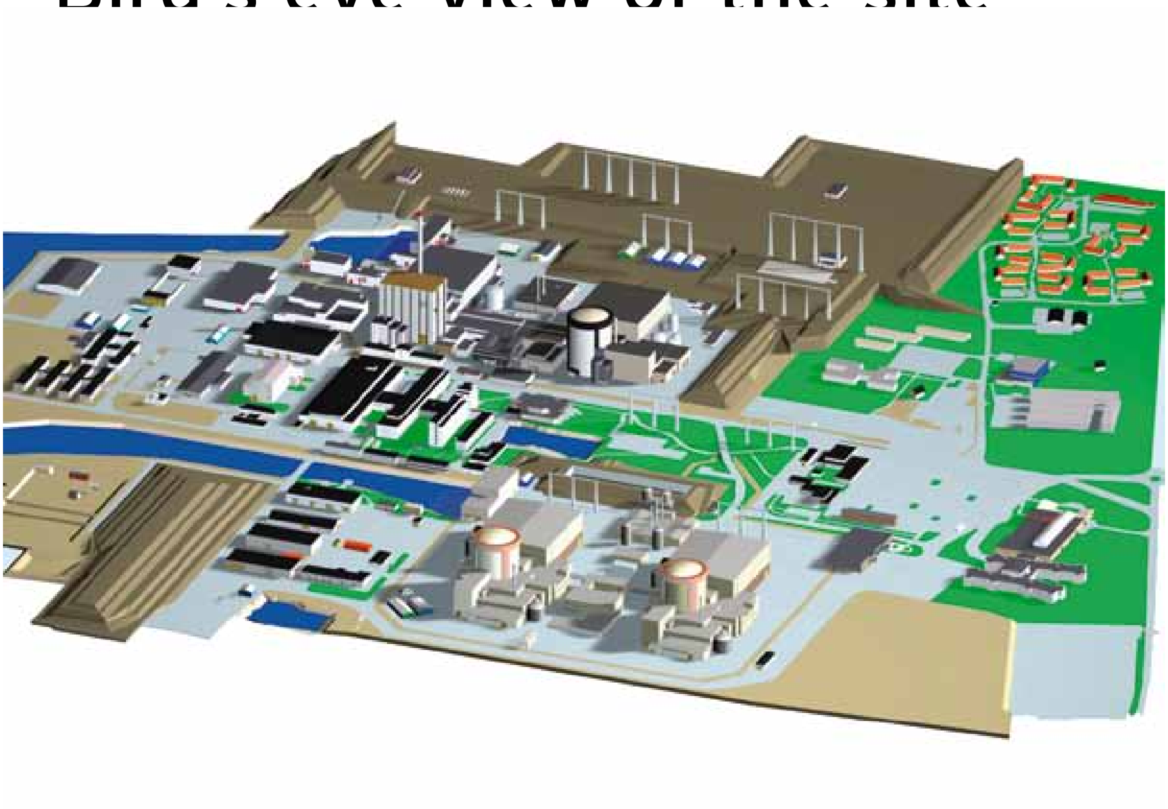
In the boiling water reactor, water is heated in the reactor pressure vessel until boiling occurs. The reactor pressure vessel contains enriched uranium fuel enclosed in metal tubes. The tubes are mounted in bundles known as fuel elements. The core consists of a large number of such elements surrounded by water. In the boiling water reactor, the water is boiled to produce steam. The steam is piped directly to a turbine plant and causes the turbines to rotate and drive the electric generator.

In the pressurized water reactor, the pressure is so high that the water does not boil, in spite of its temperature being several hundred degrees Celsius. The hot water is pumped through the tubes of large heat exchangers – known as steam generators – in which water that has not been in contact with the core is evaporated. The process is then similar to that in the boiling water reactor. The steam is supplied to the turbine, the shaft of which drives the generator that generates electric power. After it has flowed through the turbines, the steam is discharged into condensers. Sea water is pumped through a large number of tubes in the condensers. When the steam comes into contact with the cold tubes, it condenses and is converted back into water. This water is then pumped back to the reactor or the steam generator.

In the process, 60-70 tonnes of uranium are consumed every year. In addition, around 800000 cubic metres of fresh water are used every year. During full-load operation, 170 cubic metres of sea water flow through the four plants every second.

The sea water temperature rises by around 10 degrees Celsius on its path through the condensers.

Bird's eye view of the site



3 = Hotel reception
4 = Hotel area
5 = Gymnasium hall
8 = Kantarellen Restaurant
9 = Health centre
10 = Office buildings
13 = Central stores
14 = Mockup building

Beginning of construction	1969
All units at full power:	January 1984
Annual energy generated:	Approx. 28 TWh
Total net output:	3669 MW
Area of power plant site:	1.5 square kilometres
Number of employees:	Around 1550

Ringhals 1

Net output (elec.)	855 MW
Reactor type	Boiling water
Reactor supplier	Asea-Atom
Turbine supplier	English Electric
In commercial operation	January 1976
Reactor	
Thermal rating	2 540 MW
Operating pressure	7 MPa
Steam temperature	286 °C
Steam flow	1228 kg/s
Number of fuel elements	648
Number of control rods	157
Generators	
Manufacturer	English Electric
Generator voltage	19.5 kV
Grid voltage	400 kV
Turbines	
Number of turbines	2
Speed	3000 rpm
Cooling water flow (sea water)	2x21 m^3/s

Ringhals 2

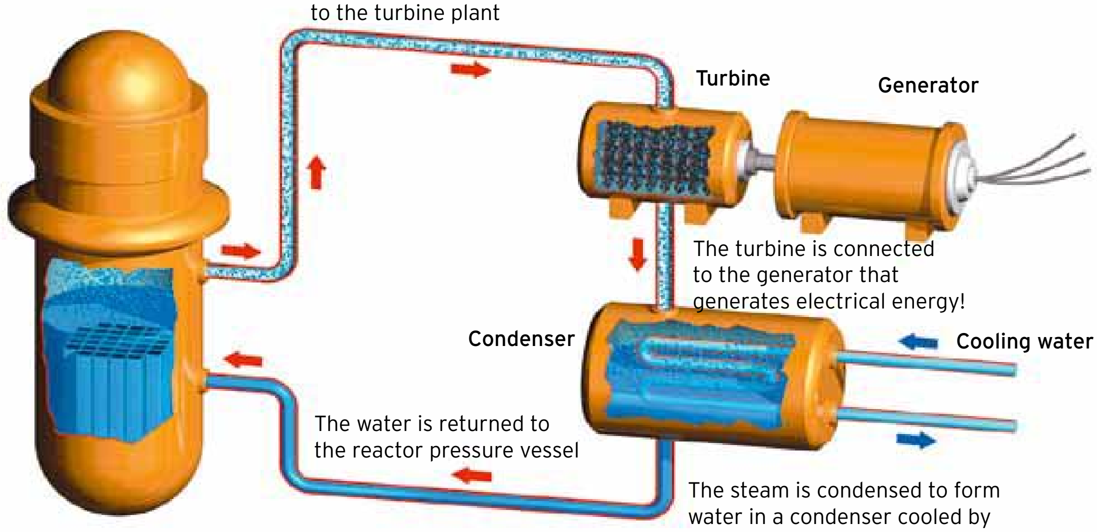
Net output (elec.)	866 MW
Reactor type	Pressurized water
Reactor supplier	Westinghouse
Steam generators	Siemens AG/KWU
Turbine supplier	Stal-Laval Tubin AB
In commercial operation	May 1975
Reactor	
Thermal rating	2652 MW
Operating pressure	15.5 MPa
Steam temperature	276°C
Steam flow	1413 kg/s
Number of fuel elements	157
Number of control rods	48
Generators	
Manufacturer	Asea
Generator voltage	19.5 kV
Grid voltage	400 kV
Turbines	
Number of turbines	2
Speed	3 000 rpm
Cooling water flow (sea water)	2 x 17.5 m^3/s

Ringhals 3 & 4

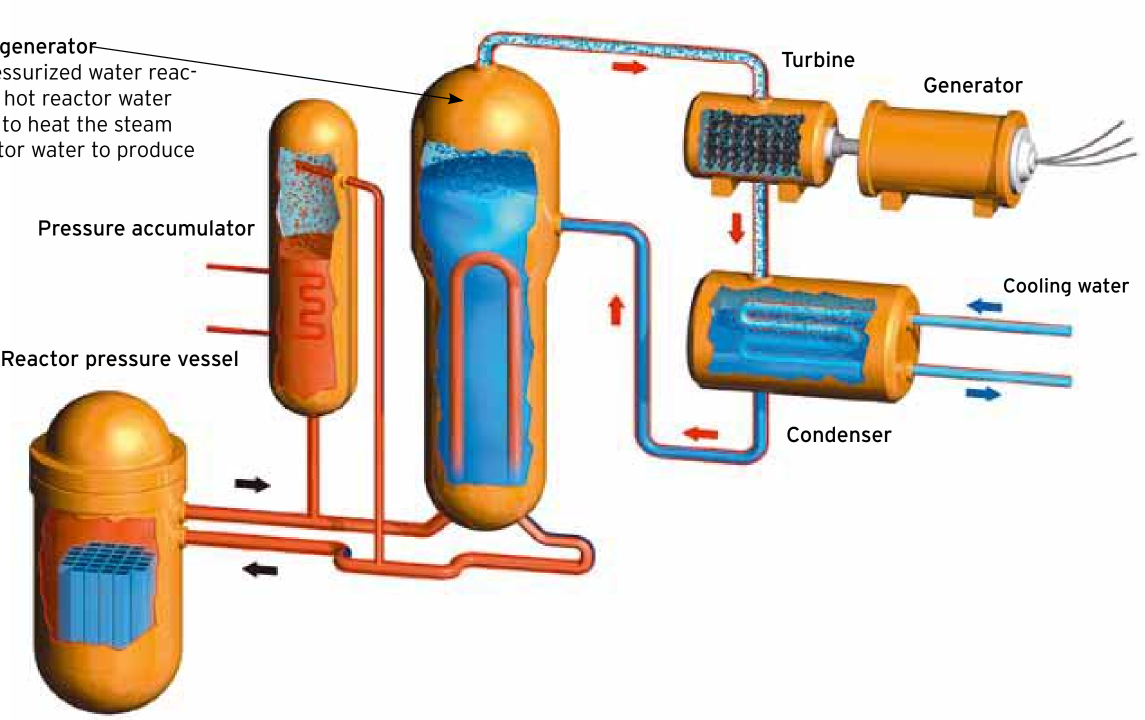
Net output (elec.)	R3: 1043 MW, R4: 935 MW
Reactor type	Pressurized water
Reactor supplier	Westinghouse
Steam generators	Framatome/Siemens AG (R3), Westinghouse (R4)
Turbine supplier	ASEA STAL AB
In commercial operation	R3 September 1981 R4 November 1983
Reactor	
Thermal rating	R3: 3144 MW, R4: 2775 MW
Operating pressure	15.5 MPa
Steam temperature	276 °C
Steam flow	1521 kg/s
Number of fuel elements	157
Number of control rods	48
Generators	
Manufacturer	Asea
Generator voltage	21.5 kV
Grid voltage	400 kV
Turbines	
Number of turbines	2
Speed	3000 rpm
Cooling water flow (sea water)	2 x 22.5 m^3/s

Diagrammatic arrangement

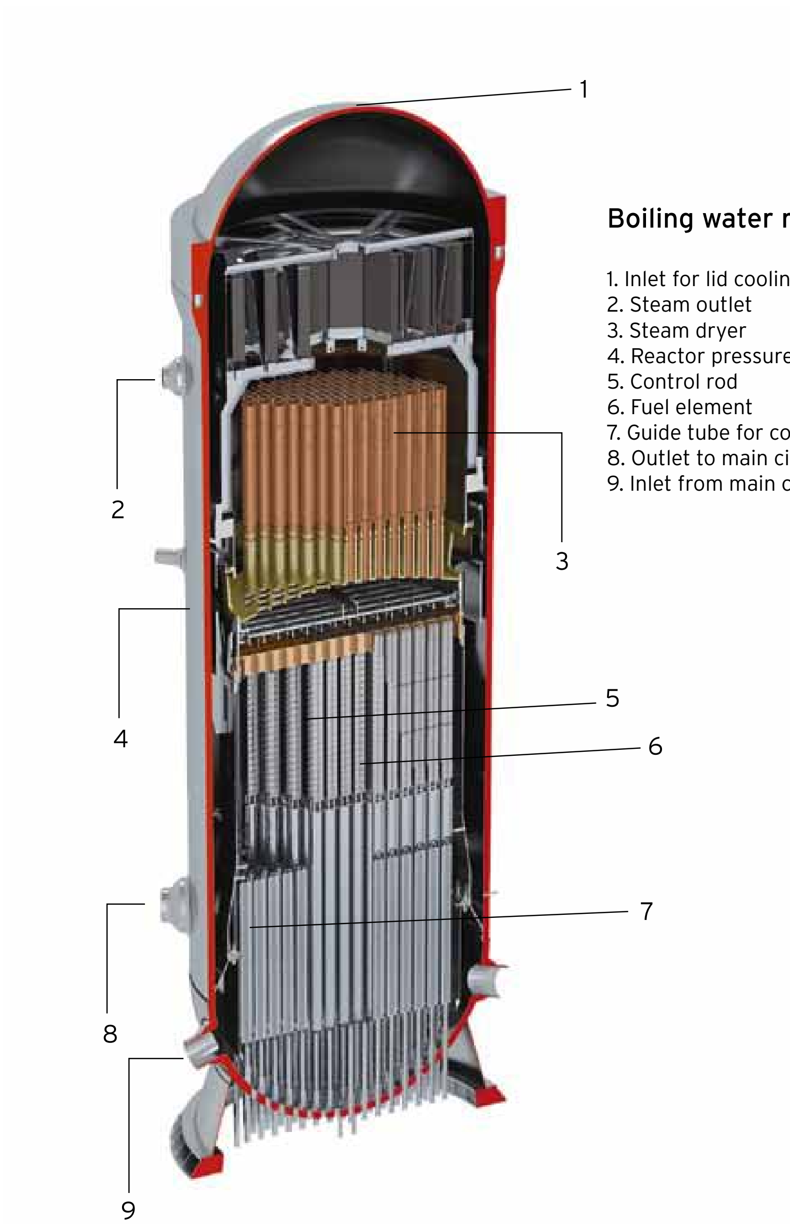
Ringhals 1 boiling water reactor



Ringhals 2, 3 and 4 pressurized water reactors

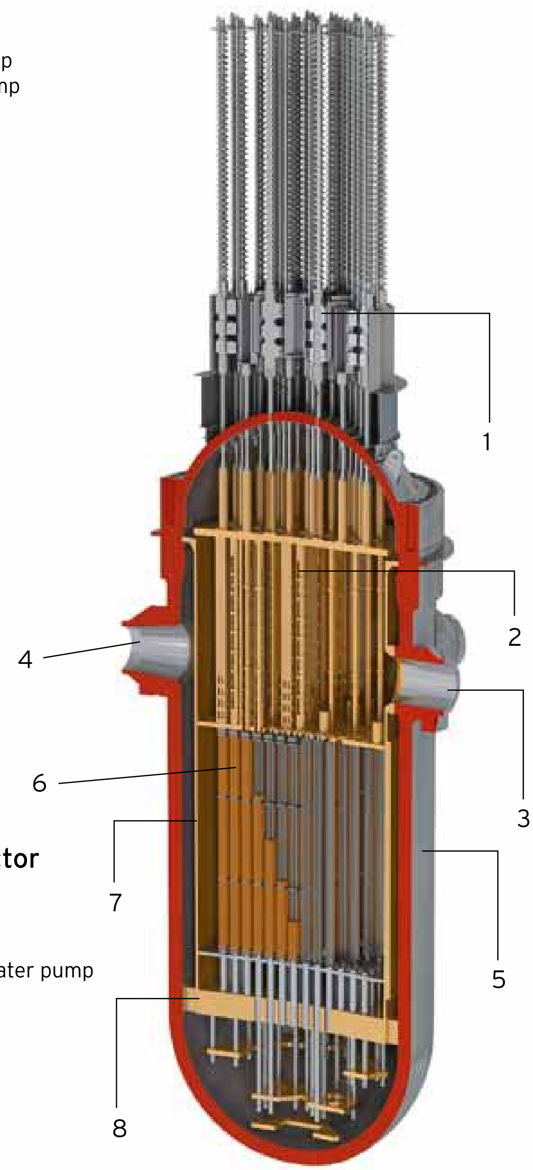


REACTOR



Boiling water reactor

1. Inlet for lid cooling
2. Steam outlet
3. Steam dryer
4. Reactor pressure vessel
5. Control rod
6. Fuel element
7. Guide tube for control rod
8. Outlet to main circulation pump
9. Inlet from main circulation pump



Pressurized water reactor

1. Control rod drive
2. Control rod
3. Inlet from reactor cooling water pump
4. Outlet to steam generator
5. Reactor pressure vessel
6. Fuel element
7. Thermal protection
8. Lower core plate

General

	R1	R2	R3	R4
Reactor thermal output, MW	2540	2652	3144	2775
Number of circulation circuits	6			
Number of cooling circuits		3	3	3
Internal reactor cooling water flow, kg/s	11500	13159	12860	12860
Operating pressure, MPa	7,0	15,5	15,5	15,5
Cooling water inlet temperature, °C		289	284	284
Cooling water outlet temperature, °C		323	323	323
Steam flow, kg/s	1228	1413	1521	1521
Steam pressure, MPa	7,0	5,95	6,0	6,0
Steam temperature, °C	286	276	276	276
Feed water temperature, °C	173	210	221	221

Main components

Reactor pressure vessel

	R1	R2	R3, R4
Weight, tonnes	650	327	330
Total height, m	21,5	13	13
Inside diameter, mm	5950	3990	3990
Wall thickness, mm	150	200	200

Circulation pumps

Type	Totally enclosed centrifugal pumps		
Number of pumps	6		
Flow, m³/s	2.53		
Head generated, m	34.3		

Reactor cooling water pumps

Type		Vertical single-stage pumps	
Number of pumps		3	3
Flow, m³/s		5.72	5.66
Head generated, m		78	81.2

Facts

Steam generators

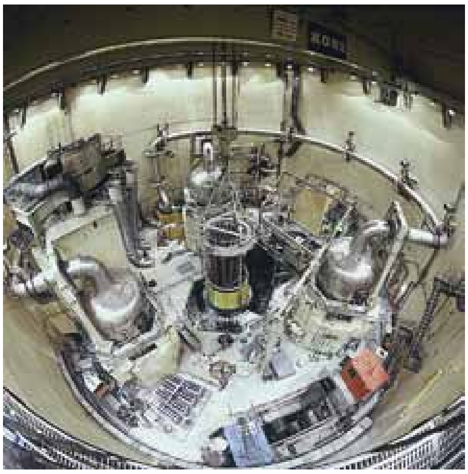
	R2	R3	R4
Number of steam generators	3	3	3
Number of U-tubes per steam generator	5130	5428	4674
U-tube material	Alloy 690 TT	Alloy 690 TT	Alloy 600 MA
Weight, tonnes	293	351	308
Total height, m	19	20,6	20,6
Operating pressure on shell side, MPa	5,95	6.0	6.0
Heat transfer area, m^2	5105	7155	4459
Steam flow, kg/s	479	507	507

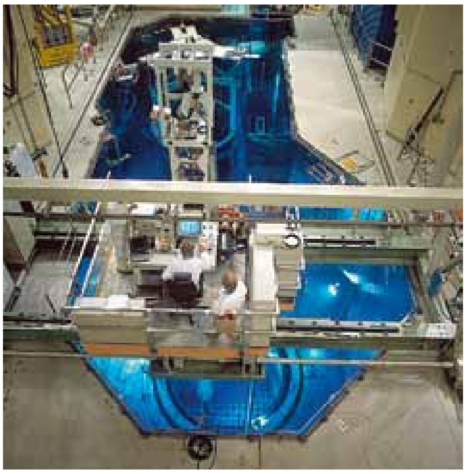
Fuel elements	R1	R2	R3, R4
Number of fuel elements in the core	648	157	157
Fuel weight per element, kg of UO_2	193	513	523
Number of fuel rods per element	64/100/96	204	264
Canning material	Zr-2	Zr-4	Zr-4
Fuel pellet diameter, mm	8,19	9,11	8,19

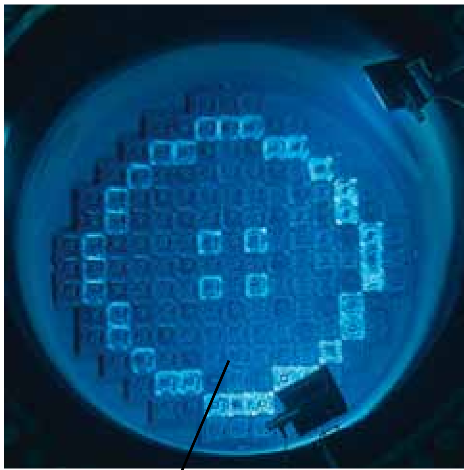
Control rods

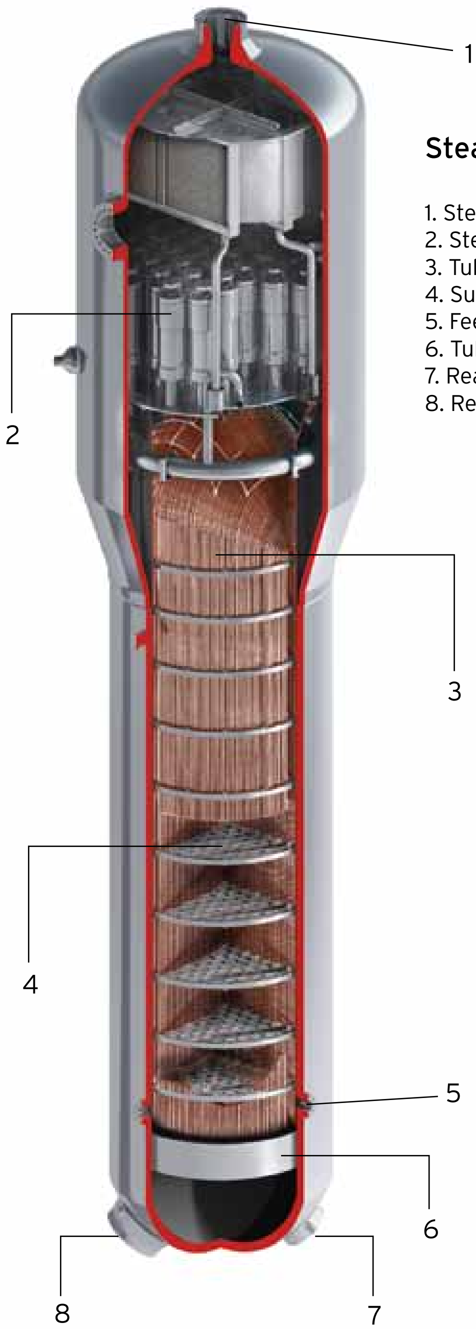
Type	Cruciform blades	Bundles of 20 rods	Bundles of 24 rods
Number of rods	157	48	48
Type of drive	Electro-hydraulic	Magnetic	Magnetic

The fuel in the reactor consists of enriched uranium. Uranium 235 is used for light water reactors. The figure 235 stands for the number of neutrons and protons in the atom core. Natural uranium contains only 0.7 percent of uranium 235. The content is increased to around 3% by enrichment.



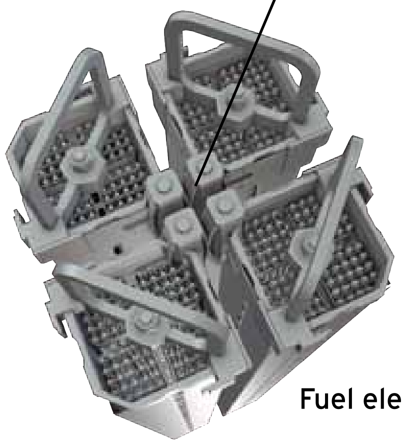






Steam generator

1. Steam outlet to the turbines
2. Steam dryer
3. Tube bundles
4. Support plate
5. Feed water inlet
6. Tube plate
7. Reactor cooling water inlet
8. Reactor cooling water outlet

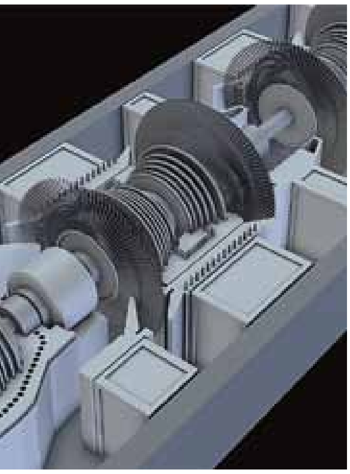


Fuel element

Uranium

Uranium is the fuel used for nuclear power and is one of the heaviest elements on Earth. Uranium was contained in the dust ejected during the explosion of stars when the Earth was created. Uranium is therefore common in the Earth's crust. The concentration of uranium in Sweden is not sufficiently high to make it economically attractive to mine uranium at its present prices. Uranium ore is mined principally in Canada and Australia, but also in Namibia, South Africa, Kazakhstan, Uzbekistan and Russia.

Uranium is an element that is rich in energy. One kilogram of uranium contains as much energy as 90 tonnes of coal. Every uranium pellet emits as much energy as around 800 litres of diesel oil. A nuclear reactor contains around 15 million pellets.



Steam makes the turbine spin

The turbine converts thermal energy into mechanical energy. The steam generated in the reactor impinges on the turbine blades and causes the shaft to rotate.

The turbine plant consists of a high pressure turbine, low pressure turbine, reheater, condenser and generator.

At Ringhals, two turbine units are connected to each reactor. Each turbine unit consists of a high pressure turbine and three low pressure turbines mounted on the same shaft as the generator.

Steam from the reactor plant flows to the centre of the high pressure turbine, and it then expands and its volume increases towards the turbine ends. The steam pressure drops from around 6 MPa* at the turbine inlet to around 0.64 MPa at the outlet. At the same time, the temperature drops from 280°C to 165°C. The steam will now have delivered around 40% of its energy.

After flowing through the high pressure turbine, the steam continues to the reheaters, where it is dried and reheated before flowing to the low pressure turbines. The steam pressure at the low pressure inlets is around 0.6 MPa and the temperature is around 260°C.

Condenser

On leaving the low pressure turbines, the steam is drawn down in to the condenser. The pressure will now have dropped to 4 kPa*, and the temperature is around 30°C. The steam is condensed on the outside of the condenser tubes through which sea water flows. From the condenser, the condensate is pumped back to the reactor plant, where it is again used to generate steam.

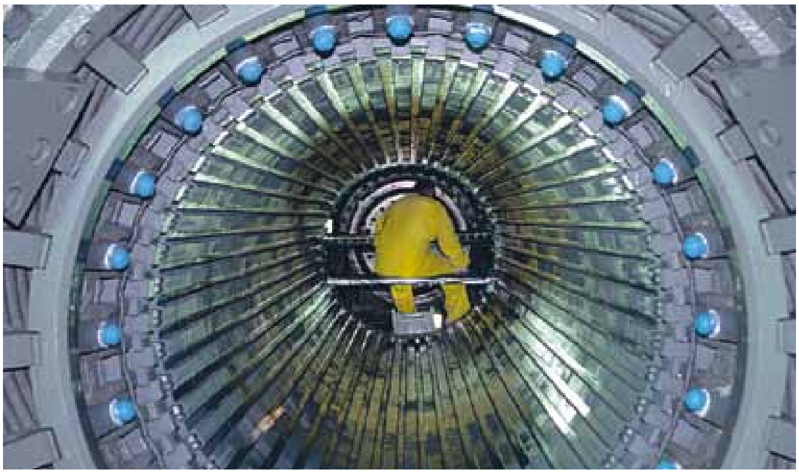
On its way back to the reactor plant, the condensate is reheated in a number of heat exchangers. This takes place at the same time as the water pressure is raised in two stages by means of condensate and feed water pumps.

The sea water used for condensing the steam to water is returned to the sea and its temperature is then around 10°C higher than when it was pumped in.

* *MPa= megapascal*
* *kPa= kilopascal*

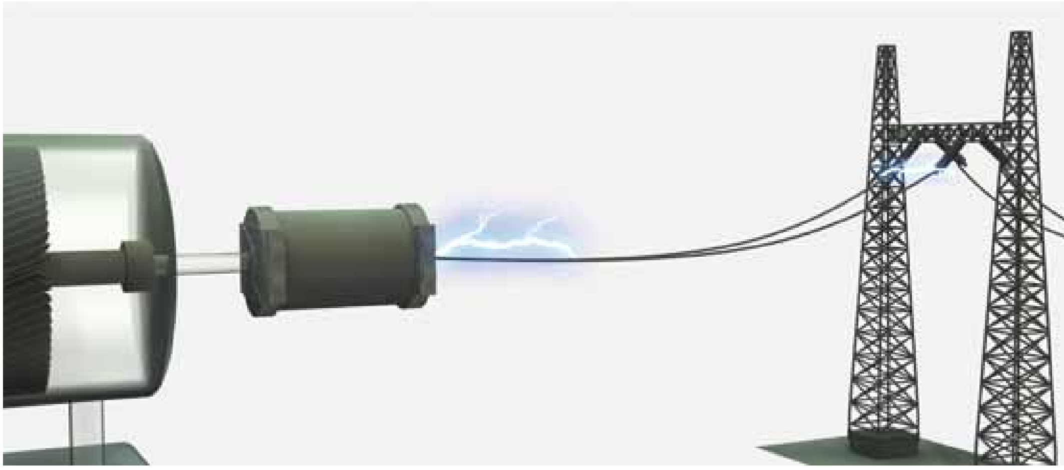
Turbine plant

	R1	R2	R3	R4
Net output	855	866	1043	935
Steam flow, kg/s	2x614	2x727	2x760	2x760
Moisture content of primary steam, %	0,04	0,025	0,001/0,19	0,001/0,19
Steam data				
Pressure/temperature at high pressure turbine inlet, MPa/°C	6,6/286	5,9/275	6,3/279	5,9/275
Pressure/temperature in the condenser, MPa/°C	0,0042/30	0,004/28	0,004/29	0,004/29
Turbine speed, rpm	3000	3000	3000	3000
Condenser cooling water Flow, m^3/s Temperature rise, °C	 2x22,0 10	 2x17,5 10	 2x22,5 10	 2x22,5 10
Number of cooling water pumps per turbine	6	3	4	4
Total length of turbine plant, m	50	40	42	42



Electrical equipment

	R1	R2	R3, R4
Generator			
Manufacturer	GEC	ASEA	ASEA
Number of generators	2	2	2
Terminal power, MW	2x430	2x430	2x430
Rated voltage, kV	19,5	19,5	21,5
Rated output, MVA	470	506	577
Stator cooling	Water	Water	Water
Rotor cooling	Hydrogen	Water	Water
Main transformers			
Number of transformers	2	2	2
Rated voltage, kV	20,5/438	20,5/438	22,6/438,5
Rating, MVA	500	500	550
Local transformers			
Number of transformers	2	2	2
Rated voltage, kV	19,5/6,8	19,5/6,8	19,5/6,8
Rating, MVA	40/25	40/25	50/25
Diesel generators			
Number of diesel generators	4	4	4
Engine manufacturer	SACM	SACM	NOHAB
Nominal output, Kw	2750	2750	2750
Rated voltage, kV	6,9	6,9	6,9
Rating, MVA	3,44	3,44	3,45
Speed, rpm	1500	1500	1000



The generator is an energy converter

The generator mounted at the end of every turbine shaft converts the kinetic energy of the turbines into electrical energy at a voltage of 20 000 volt. The electricity is delivered to the Swedish grid across a transformer in which the voltage is stepped up to 400 000 volt.

The Ringhals generators are water cooled, except the generator of Ringhals 1, which is hydrogen cooled.

Out of the electricity generated by Ringhals, around 5% are used for in-house power demand.

Various stand-by power systems are available for meeting the power demand in the event of a blackout. Every plant has four stationary diesel generators for stand-by power generation in the plant. In addition, a mobile diesel generator can be switched in the event of outage of one of the stationary diesel generators.

Who runs the plant?

The nuclear power plant is run from the control room in which the operations are managed by a shift charge engineer who leads the work of the shift team. In addition to the shift charge engineer, the shift team consists of three control room operators who are responsible for the turbine and rector sections. In addition to these persons, there are four station technicians who are responsible for the operation of the turbine- and auxiliary systems. The station technicians also do the rounds of the plant in order to take measurements and carry out checks.

The control room personnel receives continual training in full-scale simulators in Ringhals for R1, R2 and R3–R4. A simulator is a copy of an actual control room and is used for simulating various conceivable events, under control of computers.

Mobile diesel generator	
Engine manufacturer	Nohab
Nominal output, kw	2835
Rated voltage, kv	6,9
Speed, rpm	1000



In a safe way

Safety always has priority in a nuclear power plant. The safety work at Ringhals is aimed at preventing operating disturbances, avoiding an operating disturbance developing into a breakdown, and minimizing the consequences if a breakdown should nevertheless occur. In spite of these strict demands, breakdowns sometimes do occur and people make mistakes. The plant therefore has various systems that keep track of possible faults.

A nuclear power plant must be designed so that radioactive substances will not be released in an uncontrolled way. Even in a major breakdown, the reactor containment must remain intact and if the core is damaged, it must be kept cooled and covered with water.

The uranium fuel is a ceramic material with a high melting point (2800°C). It is extremely insoluble in water and air. The fuel is also enclosed in gas-tight tubes made of Zirkaloy, which is a strong alloy reminiscent of stainless steel. The third barrier is the reactor pressure vessel that has walls made of 15-20 centimetre thick steel. The reactor pressure vessel is enclosed in a massive building made of steel and concrete – the rector containment. This contains water sprinklers designed to cool the interior and bind the radioactive substances released from the fuel in the event of an accident. The containment also provides good protection against external damage.

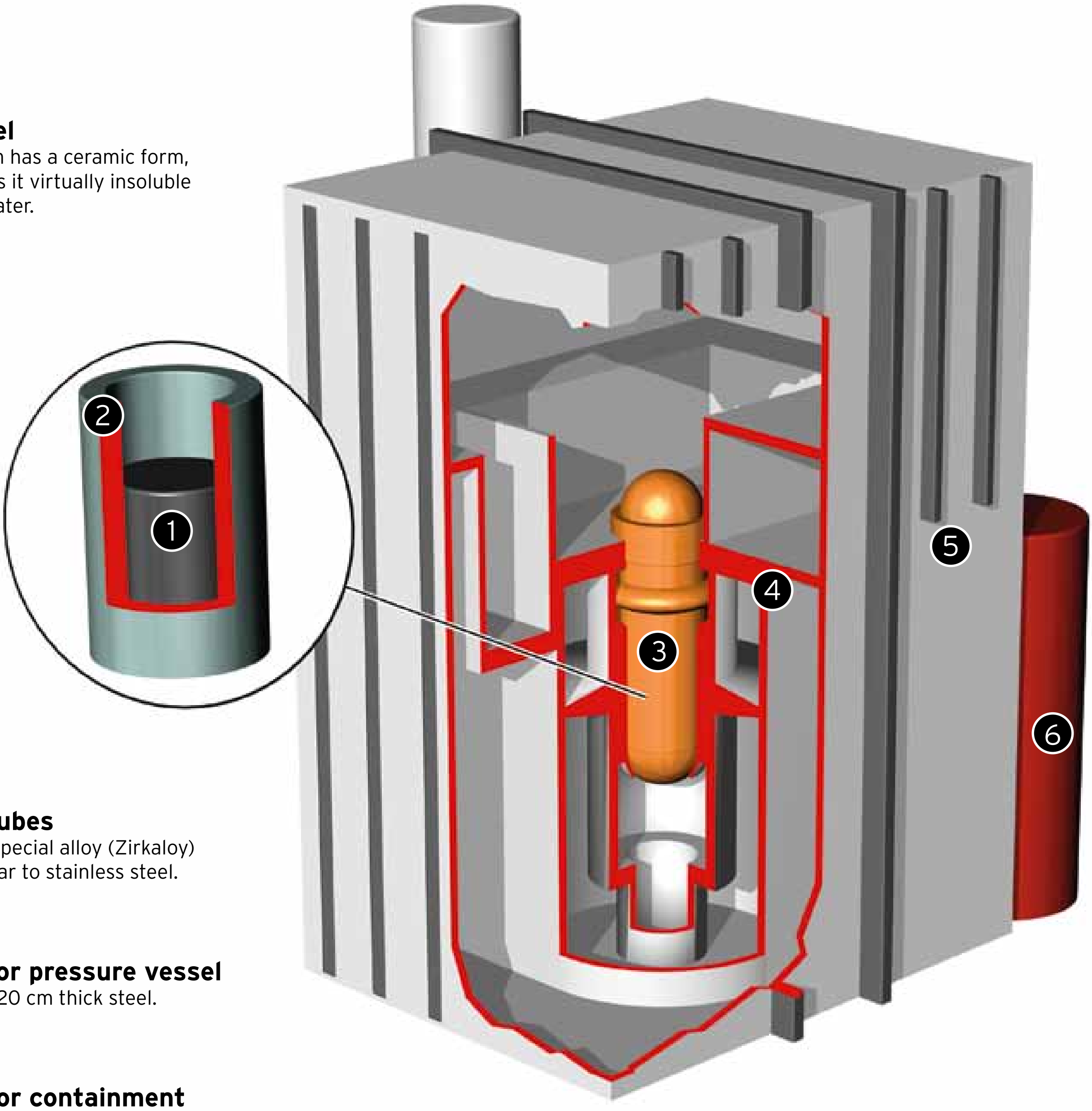
The Ringhals reactor containments are equipped with safety filters for pressure relief. In order to protect the reactor containment against excessive internal pressure in the event of a breakdown, steam and gas can be released through the filter without harmful quantities of radioactive substances being emitted. The gases and steam are discharged through a system of nozzles submerged in water. Water droplets are formed in the nozzles and these effectively separate impurities by collision. The purified gases are discharged through a dehumidifier to a ventilation stack.

Training is an important part of the work

In order to manage operating disturbances and unexpected events, the operations personnel at Ringhals undergo an extensive training programme matched to their duties and the requirements of the authorities. Theoretical studies are interspersed with knowledge checks and training on simulators. The Nuclear Safety and Training Centre (KSU), which is the Swedish nuclear power plant centre for training and simulator exercises, is responsible for the training work.

An extensive major exercise at one of the Swedish nuclear power plants is carried out at regular intervals in order to keep up the breakdown preparedness. The Protection against Accidents Act and the requirements of the authorities, mainly those of the Swedish Radiation Safety Authority (SSM), require that the nuclear power plants have an organization and a plan for breakdown preparedness. This must be included in the general plan of the county administrative board, which also coordinates preparedness between municipalities, country councils and authorities. Various exercises are carried out to keep a check on the standard of preparedness. In addition to major exercises, minor exercises are also carried out at nuclear power plants every year.

1. The fuel
The uranium has a ceramic form, which makes it virtually insoluble in air and water.



2. Fuel tubes
Tubes of a special alloy (Zirkaloy) that is similar to stainless steel.

3. Reactor pressure vessel
Made of 15–20 cm thick steel.

4. Reactor containment
Metre-thick concrete with cast-in steel membrane.

5. Reactor building
The reactor building surrounds the reactor pressure vessel and reactor containment.

6. Safety filters
Special filters arrest at least 99.9% of the radioactive substances.



Radiation is all around us

Radiation has always been present in the human environment. It originates from outer space, the Sun, and radioactive substances in the ground and in our own bodies. During the past century, we have developed methods for creating radiation and putting it to use for research, medical care and industrial applications.

At a nuclear power plant, a great deal of the safety work is concerned with radiation protection. It is important to ensure that radioactive substances will not spread in the plant and out to the environment.

Ionizing radiation

Ionizing radiation is radiation with higher energy than visible light, and infrared and ultraviolet radiation. This includes, for example, radiation from radioactive substances and X-ray radiation. This radiation is so high in energy that it tears away electrons from the atoms it passes and converts them into ions (charged atoms).

Ionizing radiation is classified into four groups – alpha, beta, gamma and neutron radiation. See the box to the right.

Radiation protection at a nuclear power plant

A great deal of work is devoted at a nuclear power plant to protecting the personnel and surroundings from ionizing radiation originating from radioactive substances in the reactor.

Several protection systems, known as barriers and filters, are provided all the way from the time when the fuel comes into the nuclear power plant, is used in the reactor, and is finally disposed of as waste.

Radiation at a nuclear power plant can be shielded by centimetre-thick lead, decimetre-thick concrete, or two metres of water. Some examples are as follows:

- In the reactor building, lead mats are used for shielding radiation from pipes, conduits, etc.
- The reactor containment consists of metre-thick concrete.
- The spent fuel is stored in pools, under 10 metres of water.

Various zones

A nuclear power plant is divided into zones, and the division is dependent on the radiation level. The zones are known as controlled areas.

The personnel always change their clothes when entering a controlled area. This is done regardless of whether entry is for carrying out repairs, reading instruments or cleaning.

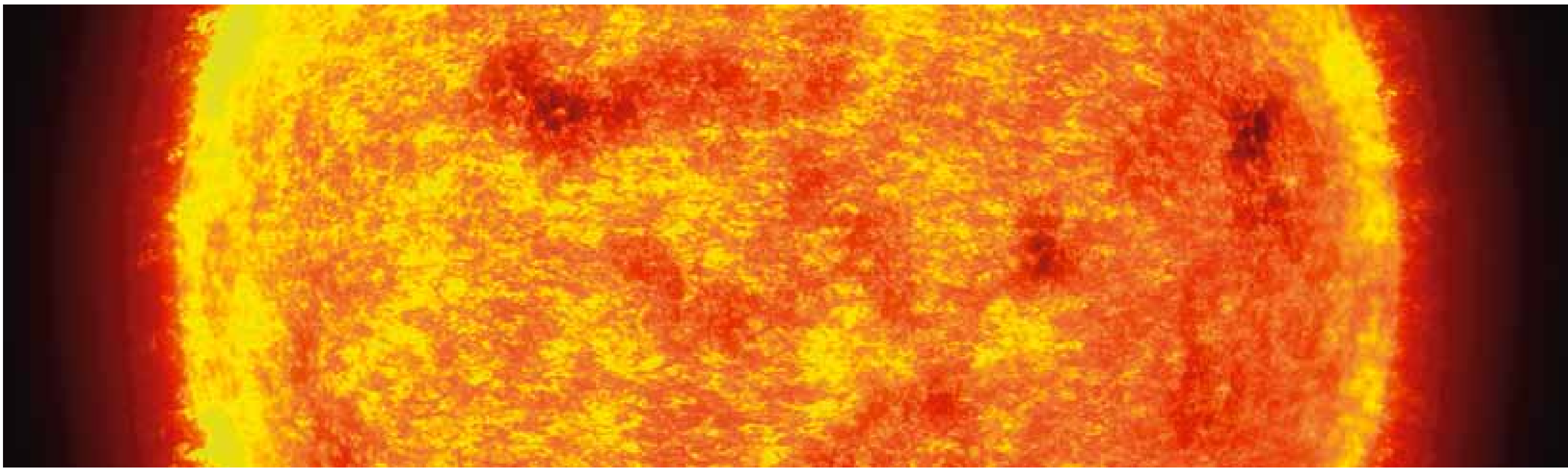
Everyone working in the plant has a dosimeter that records radiation. Moreover, an additional dosimeter is used on which the radiation level can be read directly.

Radioactivity can be washed away

Every time a person leaves a controlled area in which radioactivity may be present, he or she passes a frame monitor. This is used to check that the person does not carry any radioactive particles.

If a measurement is positive, the person must wash, which is usually confined to the hands, and the check is then repeated.

The clothes used inside a controlled area are washed in special laundries at the nuclear power plant.



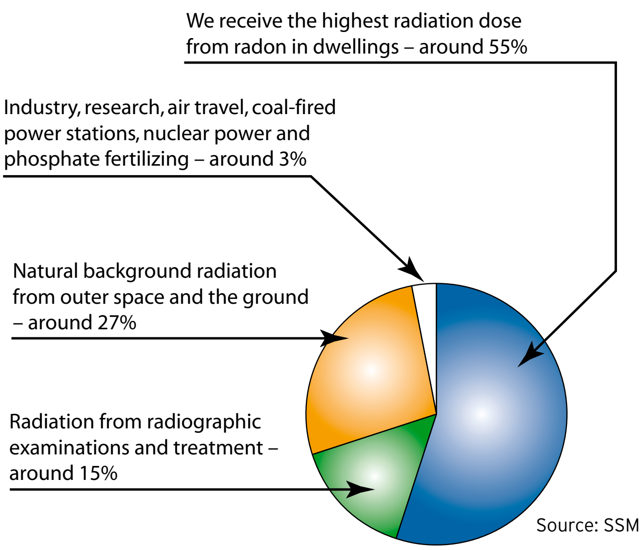
Ionizing radiation

Alpha radiation
Large and heavy positively charged particles. Reach only a few centimetres into the air. Can easily be stopped, e.g. by the skin or by thin paper.

Beta radiation
Electrons that are lighter than alpha particles. Have a range of about 10 metres in air. Stopped by thick clothes or spectacles.

Gamma radiation and X-ray radiation
Related to visible light but contains more energy. Gamma radiation has a longer range and higher penetration capacity than alpha and beta radiation. It is stopped by a layer of lead several centimetres thick, 100 mm thick concrete or 2 metres of water. X-ray radiation is stopped by a few millimetres of lead, such as the lead collar of the dentist.

Neutron radiation
Consists of neutrons that are released in nuclear fission. Neutron radiation occurs as long as a nuclear reactor is in operation, but ceases as soon as nuclear reaction ceases. Is stopped by water.



Radiation doses

Radiation doses are measured in millisieverts, mSv. Every Swede is subjected to an average of 4 mSv from natural background radiation, radiation in dwellings and medical interventions. For work with ionizing radiation, the Swedish Radiation Safety Authority (SSM) has set an upper limit – 50 mSv during one year and a total of 100 mSv over a 5-year period. The average dose in Swedish nuclear power plants is around 3 mSv. The collective dose is measured in man-sievert, man-Sv. The collective dose for a plant corresponds to the total of all radiation doses measured at the plant during one year.

Examples of radiation doses

Dental X-ray	0,01 mSv
Round trip by air across the Atlantic	0,1 mSv
Abdominal X-ray	1 mSv
Radiographic treatment for brain tumour (local dose)	50 000 mSv

Radiation doses per year

Emissions from Ringhals (immediate neighbours)	0.000026 mSv or 0.5% of the permissible limit value (2008)
Radioactive substances in our own bodies	0,2 mSv
Nuclear power worker (in a radiation environment)	2-3 mSv
Air hostess	5 mSv
Action level for radon house	8 mSv

Focus on the environment

At Ringhals, we work continually towards reducing the environmental impact of our operations. This applies to fields such as dangerous waste, chemicals, ordinary waste, water treatment, cooling water discharge, and emissions of radioactive substances. Our aim is to limit the quantities and to reuse or recover as much material as possible.

Our work on environmental issues is important for creating a good environment and meeting the demands made on us. Ringhals has been registered in the Eco Management and Audit Scheme (Emas) since 1999, and has been certified to ISO 14001 since 1998. A certificate offers proof that we meet a number of requirements made on our internal environmental work. Our environmental management system is part of our quality system. Electricity from Ringhals has Environmental Product Declaration (EPD), which means that the environmental impact of everything from uranium mining to terminal storage is defined. For further information on EPD, visit www.vattenfall.com.

Environmental targets at Ringhals

Ringhals takes decisions annually on the environmental targets for the coming year, as an element in guiding the operations. The environmental targets are classified into four areas. In-house environment that includes matters such as radiation doses to the employees. Outdoor environment that includes matters such as waste management. Emissions of radioactive substances to the atmosphere and water. Organizational matters that cover relations with the authorities, and improvement work.

As regards the target for a safe radiation environment, for example, the emissions from Ringhals to the atmosphere and water recipients conform to the requirements of the authorities with a very comfortable margin. The emissions from Ringhals to the immediate neighbours are far below the specified limit values and are equivalent to less than one thousandth of the dose from natural radiation sources.

Inspection programme

The environmental impact of Ringhals is regularly checked by biological recipient checks by the National Board of Fisheries, by the inspection programme of the County Administrative Board, and by the radiological measurement programme of SSM. The inspection programme is based on our taking samples, analyzing them and reporting the results to the authorities by environmental reports and environmental inspections.

The radiological environmental inspection programme covers the collection of samples on land and in the water around Ringhals. Samples are taken of vegetation, animal products, sediment, algae, molluscs and fish. The test results are checked by SSM.

Environmentally tested operations

Ringhals is the first nuclear power plant to have commissioned environmental testing of the whole of the operations. Environmental testing is a very good way of gaining a complete picture of the environmental impact of the entire operations in order to be able to continue the environmental improvement work.

The court judgement obtained in the spring of 2006 makes a number of requirements on our operations, in addition to those we have already received, on how Ringhals could improve its environmental work. One of the requirements was that Ringhals should reduce the noise caused by the operations.

You can find out more about our environmental testing by visiting our home page at www.vattenfall.com/ringhals.

Annual emissions to the atmosphere and water

The emission quantities of substances with the highest environmental impact are presented below.

Emissions to atmosphere

Substance	Contribution
Radioactive substances	Around one thousandth of the natural dose to the immediate neighbours
Greenhouse gases (carbon dioxide,and sulphur hexa-fluoride, refrigerants)	Less than one ten thousandth of Sweden's total emissions
Acidifying substances (sulphur dioxide and nitrogen oxides)	Less than one ten thousandth of Sweden's total emissions
Over-fertilizing substances (ammonia)	Less than one ten thousandth of Sweden's total emissions

Emissions to water

Substance	Contribution/ content in cooling water channel
Radioactive substances	Below one thousandth of the natural dose to the immediate neighbours
Over-fertilizing substances (ammonia)	Less than one tenth of the natural content in the sea
Boric acid	Around one hundredth of the natural content in the sea
Chlorine	Very low content, 0.1 ppm (parts per million)

Our use of cooling water and local heating of the sea also have an environmental impact.

We look after the waste

Operation of a nuclear power plant gives rise to radioactive waste that must be dealt with in a safe manner. The handling employed depends on the form and radioactivity content of the waste. Radioactive waste is classified into three groups – high-level, intermediate-level and low-level radioactive waste.

High-level radioactive waste

High-level radioactive waste consists of spent fuel elements and certain other components from the reactor plant. Around 20% of the fuel are changed during the annual shut-downs. The fuel removed is highly radioactive and emits heat. It must therefore be provided with radioactive shielding and be cooled in water pools. The spent nuclear fuel is stored for at least one year at Ringhals before being placed in containers of special design and shipped by the specially built vessel Sigyn to Clab (Central intermediate storage facility for spent nuclear fuel) at the Oskarshamn nuclear power plant. High-level radioactive waste is stored here until the time comes for terminal storage, after 40 years of intermediate storage.

Intermediate-level radioactive waste

Intermediate-level radioactive waste consists mainly of filters, ion exchange resins and scrap. Ringhals uses filters and ion exchange resins for treating water in systems that contain radioactive substances and contaminants. The waste is mixed with concrete and is cast into steel plate or concrete containers. The containers are transferred to the terminal storage facility for radioactive operating waste (SFR) located at the Forsmark nuclear power plant.

Low-level radioactive waste

Low-level radioactive waste consists principally of low-level radioactive ion exchange resins, scrap pipe parts, tools, insulating materials, overalls and waste such as plastic, paper and cables. Waste and other soft materials are compacted into bales. Scrap and other hard materials are tightly packed in boxes or containers. Ion exchange resins are dewatered in ”Bigbags” of special design. The low-level radioactive waste is dumped either in SFR or in the Ringhals underground storage facility.

The Swedish Radiation Safety Authority (SSM) make demands on the handling of waste. Conformance to these demands is checked by inspections.

SKB

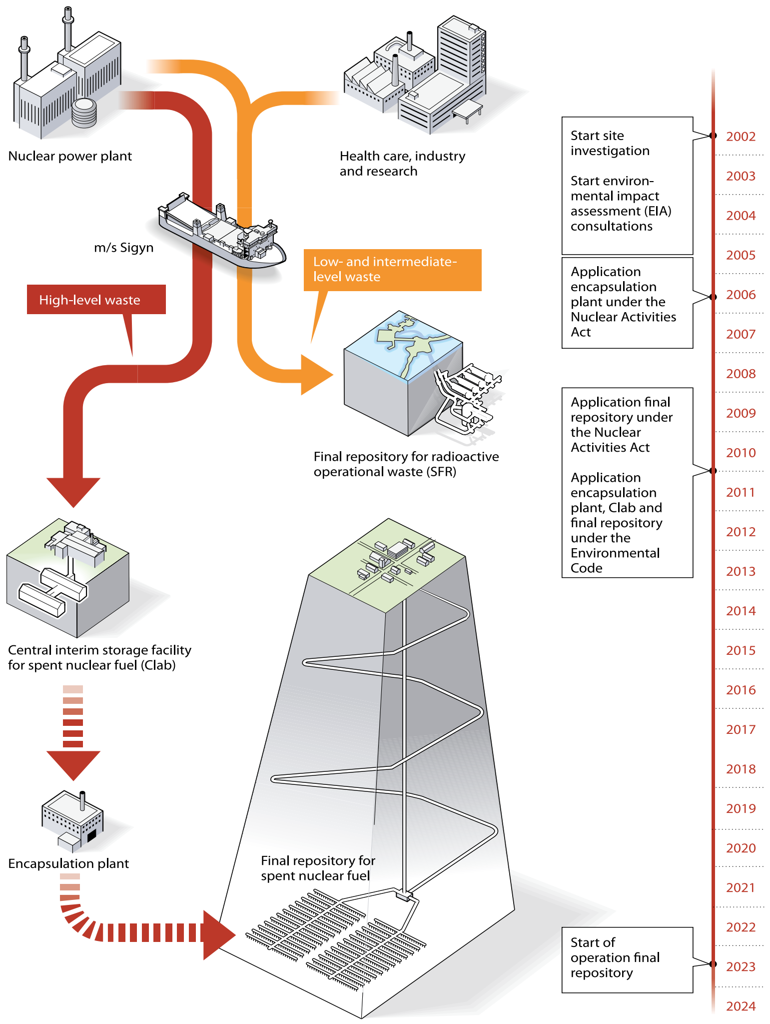
The Swedish Nuclear Fuel Handling Company (SKB) is entrusted with the task of taking care of the radioactive waste from Swedish nuclear power plants. The power plants pay annual fees into a special fund – the Nuclear Waste Fund –, which is intended to finance the planning and construction of waste storage facilities.

Terminal repository in bedrock

SKB is planning to build a terminal repository in Forsmark for all spent nuclear fuel, which will isolate the fuel for a long period of time – at least 100 000 years. This demands a stable environment in which any changes takes place extremely slowly. The terminal repository will be built 500 metres down into Swedish bedrock. The fuel will be enclosed in copper canisters with cast iron inserts. The canisters will be surrounded by bentonite clay that will serve as a buffer to absorb any small movements that may occur in the rock. The clay also prevents water from flowing around the canister.

The repository will require no monitoring or inspection by generations to come.

The Swedish system



Ringhals radioactive waste in 2008

High-level radioactive waste

Number of fuel elements	123

Low-level and intermediate-level radioactive waste

Less than 1000 m3 annually

Number of terminal packages produced

- 99 canisters
- 152 bales
- 33 cases
- 7 containers
- 20 Bigbags

The m/s Sigyn vessel

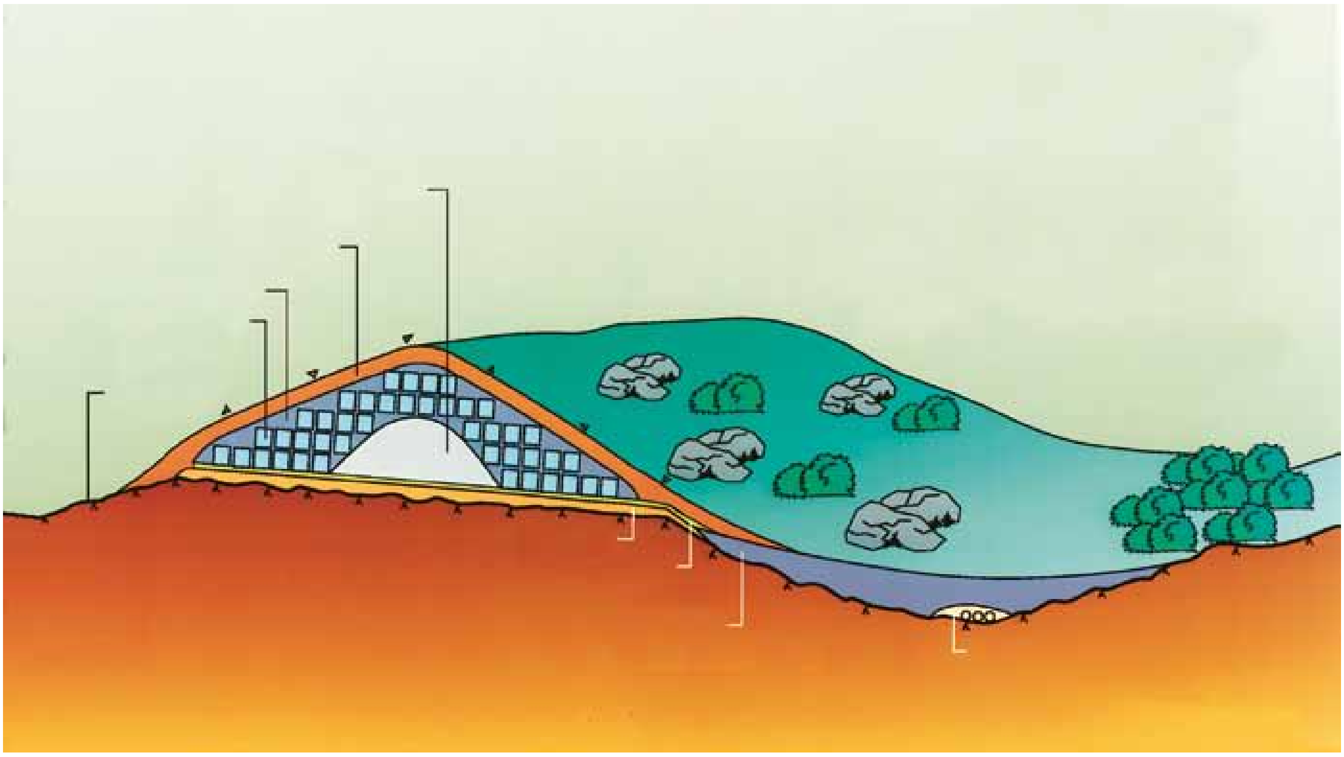
Vessel type	combined roll-on/roll-off and ift-on/lift-off
Length	90.6 m
Beam	18 m
Load-carrying capacity	Approx. 1400 tonnes
Draft at full load	4 m
Country of manufacture	France

Shipping casks for spent fuel

Weight	Approx. 80 tonnes
Capacity	17 BWR or 7 PWR fuel elements
Total length	6150 mm
Total diameter	1950 mm
Material	Steel forging
Produced by	Uddcomb, Sweden

Ringhals underground storage facility

An underground storage facility for low-level radioactive waste has been built on the Ringhals industrial site. This facility consists of two main parts – the waste storage facility and the infiltration bed. Waste that cannot be compressed is located in the centre to ensure that the storage facility will retain its form of a hill. The storage facility is then filled with plastic-wrapped bales and other packages. The entire contents are covered with a draining material, and this is covered with a top layer of moraine. The purpose of the cover is to keep the storage facility dry and provide effective shielding of any radiation. The infiltration bed consists of a mixture of sand, shells and organic materials. The leach water from the storage facility flows through the bed in which substances entrained by the water will be bound and their transport to the sea will thus be delayed. A drainage layer is provided at the bottom of the bed through which the leach water is discharged to sea. The leach water is regularly sampled.



GLOSSARY OF TERMS

Fuel pellet: Small cylindrical piece of compressed and sintered (fused) uranium dioxide included in the reactor core.

Clab: Central intermediate storage facility for spent nuclear fuel. The Clab is located at the Oskarshamn nuclear power plant.

Decontamination: In radiation protection and nuclear technology, denotes the removal of dirt containing radioactive substances. Contamination is the opposite.

Repository: Place where waste is dumped. Rubbish dump in daily parlance.

Dosimeter: Instrument that measures the radiation dose to which a person is subjected.

Eco Management and Audit Scheme: Abbreviated to Emas. The voluntary EU environmental management and environmental auditing ordinance – regulations for companies to guide their environmental work.

Environmental Product Declaration (EPD): This declaration specifies the magnitude of the environmental impact caused by every unit produced. The EPD shows every conceivable environmental impact from uranium mining to terminal storage of the waste.

Exemption: Material that has been in an area in which there are radioactive substances (controlled area) and that, after special measurement, has proved to have such low radiation level that it can be handled without restrictions from the radiation protection aspect.

Half life: The time it takes for half of the radioactive atoms to decay. Every radioactive substance has a specific half life (the radiation is halved).

ISO 14001: International standard for management systems of companies. ISO 14001 is the standard for environmental management. Conformance to a certain standard means that the relevant company can maintain at least the level specified in the standard.

Ionizing radiation: Radiation that contains so much energy that it can ionize materials. This radiation can damage human cells.

Collective dose: Total radiation dose to a group that has been subjected to ionizing radiation. Expressed in man-sievert, man-Sv.

Millisievert: mSv – measure of the radiation dose to a human being. 1 mSv is the background radiation during 1 year.

Radioactivity: Certain substances are unstable and emit ionizing radiation when they decay. The decay is measured in Becquerel, Bq. 1 Bq = 1 nucleus decay per second.

SFR: Terminal storage facility for radioactive operating waste. Located at the Forsmark nuclear power plant. Operating waste includes spare parts that have been irradiated, as well as protective clothing, tools, packaging, measuring instruments and filters.

Sigyn: Special vessel for transporting spent nuclear fuel and other radioactive waste.

SKB: The Swedish Nuclear Fuel Handling Company, which develops methods for and takes care of our radioactive waste. SKB is owned jointly by the nuclear power plants.

SSM: The Swedish Radiation Safety Authority has been a managing authority under the Ministry of the Environment since 1 July 2008, with national collective responsibility within the areas of radiation protection and nuclear safety (Former SSI – Swedish Radiation Protection and SKI - The Swedish Nuclear Power Inspectorate merged in 2008 to SSM - Swedish Radiation Safety Authority).

Radiation dose: Ionizing radiation that may have an effect on the irradiated cells. The amount of radiation per unit of weight is known as the radiation dose.

Radiation: Energy in motion, e.g. light. A distinction is made between ionizing and non-ionizing radiation. Light is non-ionizing.

Studsvik Radwaste: Deals with low-level and intermediate-level radioactive waste in Studsvik. Also works with decontamination, waste handling and demolition.

TWh: Measure of the amount of energy. 1 terawatt hour = 1 billion kilowatt hours.

Uranium: Radioactive metallic element. Decays very slowly.

Noble gas: Noble gases are a group of gaseous elements that, due to their structure, are not included in any chemical compounds.

INFORMATION CENTRE

The Ringhals Information Centre can provide you with information on energy, the environment and nuclear power.

The Ringhals Information Centre is open for visits, and we receive around 12 000 visitors every year.

We shall be pleased to hear from you for more detailed information on guided tours and opening times on +46 20 66 20 10, or else visit our home page at www.vattenfall.com/ringhals.

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ELECTRICITY FOR THE INQUISITIVE

Ringhals AB
SE-43285 Väröbacka
Sweden

Phone: + 46 340 66 70 00
Fax: + 46 340 66 51 84

inforinghals@vattenfall.com
www.vattenfall.com/ringhals

VATTENFALL