EPZ

Clear as a crystal ball...

EPZ
constantly
improving

Content

Introduction

Director's foreword

We produce safe, clean, climate-neutral energy for more than 1.1 million households

Borssele nuclear power plant is one of the safest nuclear plants in the world. This might sound strange for a facility that commenced operations in 1973. Yet it will remain one of the leading plants in the world in terms of safety until 2034 (when it will be decommissioned).

I can guarantee this as director of EPZ, which operates Borssele. **We work safely, or not at all.**

Numerous mechanisms and guarantees ensure that both the plant and the organisation behind it continually improve. The nuclear plant and the organisation are adapted whenever new insights or technologies become available. In this way, we have managed to make the plant a thousand times safer since 1973.

The safety of the plant is maintained by three safety functions that are examined in detail below:

1. the ability to control the fission reaction in all circumstances.
2. the ability to contain radioactivity and radiation in the plant's buildings in all circumstances.
3. the ability to cool the fuel rods in all circumstances.

The plant thus has multiple systems. If one system (or facility) fails, another will take over. We call this 'redundancy': the plant has excess safety systems.

We also maintain our safety culture with the help of external experts and regulators. Our focus on safety cannot and will not ever weaken. Our safety culture also includes many safeguards that keep us alert.

Assessments by our regulators and international sharing of knowledge and experience help us to remain a safe organisation operating a safe facility.

We intend to continue contributing to the safe, climate-neutral generation of power until 2034. This publication explains how.

Carlo Wolters, director EPZ

Policy Statement Nuclear Safety and Radiation Safety

Safety comes first at EPZ. Our actions aim to minimise the impact on people and the environment. To put this into practice, we apply three basic principles:

Safety is our first priority

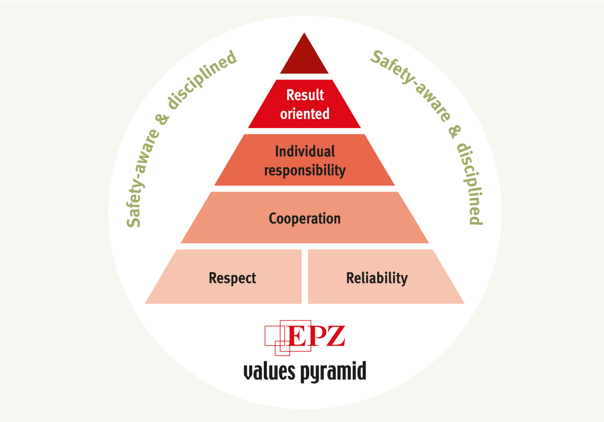
- Safety has the highest priority and always takes precedence above production;
- Safety is visibly present in all our activities;
- We aim to have a high level of organisational knowledge, skills and technology;
- We continually develop and promote our safety culture;
- We have taken the necessary preparations to prevent or limit the harmful consequences of undesired events.

Safety is striving for excellence through continuous improvement

- We work according to the latest insights and compare our safety level with best practices and the latest international standards and guidelines;
- We learn from previous experience. We evaluate our own and international incidents and implement the points for improvement;
- We aim for maximum availability of all systems in our plant and reduce errors to the minimum;
- We comply with the rules and permit requirements that apply to our nuclear power plant;
- Our focus is on resolving anomalies, not on singling out guilty parties.

Safety is about having a proactive attitude

- Our core values determine our behaviour and we hold one another accountable for this;
- When we work, we think about the risks and arrange the work in such a way that a mistake does not lead to an incident;
- We account for the safety of our systems and our way of working and we do so transparently;
- We actively invite inspections, from domestic and international government authorities as well as from colleague organisations, and actively cooperate with them;
- We prepare ourselves for undesirable events, so that we can manage these and prevent or limit harmful consequences.



The Board, EPZ staff and those working for contractors and subcontractors are responsible for implementing this nuclear safety policy and are expected to comply with it, assist one other, hold one another accountable when necessary, and help to prevent and resolve circumstances that may hinder or disrupt the implementation of this policy.

Carlo Wolters, director EPZ

Design

Borssele nuclear power plant

Borssele nuclear power plant was built on the basis of a simple, safe, robust design from the early 1960s. The German technology and the quality of the materials used in the plant enhanced the safety of the basic design. The plant commenced operations in 1973. Every ten years, the state of the art in nuclear power plant design is explored, to establish what safety improvements can be made. In 1983, 1993 and 2003 the safety of the plant was evaluated, and improvements were made. The modifications made in 1986, 1997 and 2006 have retroactively enhanced the safety level of the plant's design. The plant was already safe when it was commissioned in 1973 (10^{-3}), and has since been made a thousand times safer (10^{-6}).

Reactor

A pressurised water reactor like the one at Borssele is an inherently safe design. The physical features of the reactor ensure that the fission process automatically stabilises in the event that parameters deviate too much from the norm. When the reactor power is too high, the temperature in the reactor rises which, in accordance with the laws of physics, causes the rate of fission to drop. This decreases the power level, causing the temperature to drop.
No technical intervention is required. Briefly, this is because the physical properties of the water and uranium are such that the nuclear fission rate drops as the temperature rises. This is known as an inherent safety feature. The nuclear fission process is therefore highly stable and easy to control. This keeps operations simple, reducing the likelihood of disruption.

As long as the core remains submerged in water, damage that could lead to dangerous situations cannot occur. Water is always available for cooling and shielding, thanks to the numerous (redundant) systems and buffers discussed later on.

Watch the video of the nuclear fission process: www.blikindebol.nl/en/design/#animatie

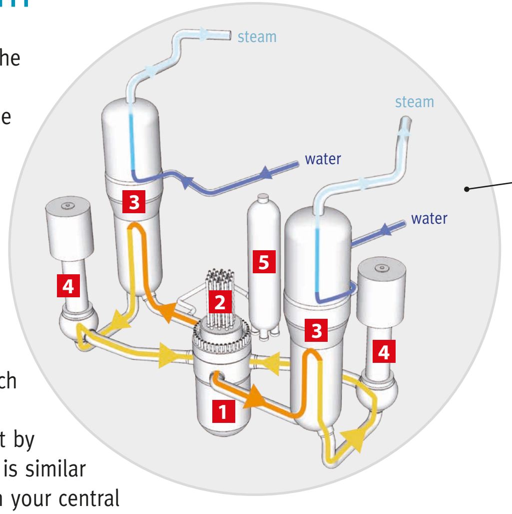
Control rods

The reactor power is controlled by adding neutron-absorbing boron to the water in the reactor. Changing the concentration is a slow process. Rapid changes in reactor power are realised using the **control rods** [2] that hang in the top of the **reactor** [1]. They are operated by staff in the control room. When the control rods are lowered into the reactor, they absorb neutrons, thus reducing reactor power.

The control rods are held in place above the core by highly sensitive electromagnets, which release the rods when they receive the command to do so, or when parameters deviate from the norm.
As soon as the 'hands' release the rods, gravity ensures that they fall into the core. The neutrons are absorbed, and fission stops immediately.

Primary system

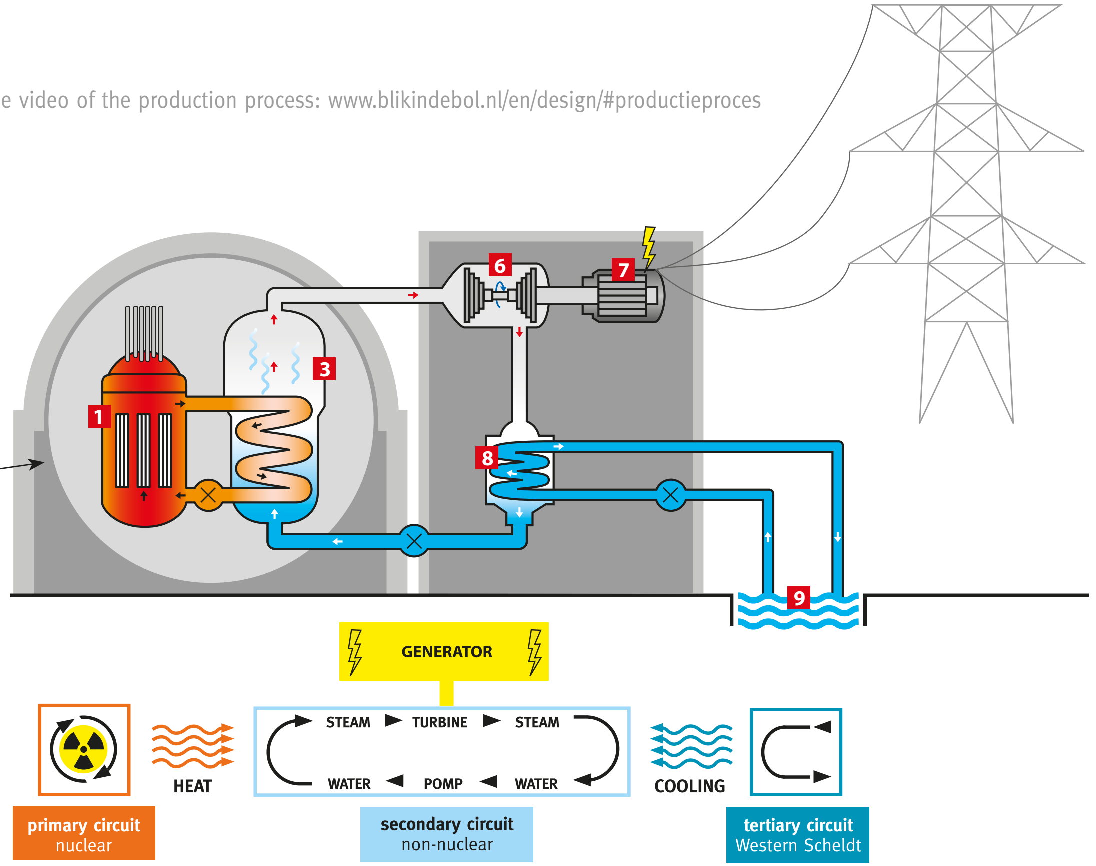
Nuclear fission occurs in the **reactor** [1].
This is controlled using the **control rods** [2].
Coolant ensures that heat is transported to the **steam generator** [3].
The coolant is returned to the reactor by the **main coolant pump** [4].
The coolant is under high pressure, so it cannot reach boiling point. Pressure deviations are levelled out by the **pressuriser** [5], which is similar to the expansion vessel in your central heating system.



Production process

Safely shielded by steel and concrete, the **core** [1] lies at the heart of our plant. Here, heat is produced by the splitting of uranium or plutonium atoms – the reactor fuel.
The heat is absorbed by water in the primary (nuclear) circuit, which circulates through the **reactor vessel** [1] under high pressure.
The heat is used to produce steam in the secondary (non-nuclear) circuit, in the **steam generator** [3].
The steam drives a **turbine** [6] on an axle that drives a **generator** [7]. The power generated is fed into the electricity grid.
The steam condenses back to water in a **condenser** [8]. It is cooled using cold surface water from the **Western Scheldt rivere** [9], which is pumped through the condensers.

Watch the video of the production process: www.blikindebol.nl/en/design/#productieproces



Design

Safety barriers

The nuclear plant has five safety barriers that protect people and the environment from radioactive incidents. The design of the plant is focused entirely on keeping radioactivity within its safety barriers under all process conditions.

Barrier 1: Fuel pellet [1]
The fuel pellet, sintered like porcelain, is the first barrier. Some 90% of the radioactivity remains sealed in the matrix of the fuel (uranium oxide). Only the highly volatile substances (noble gases, iodine, caesium) escape from the fuel pellet.

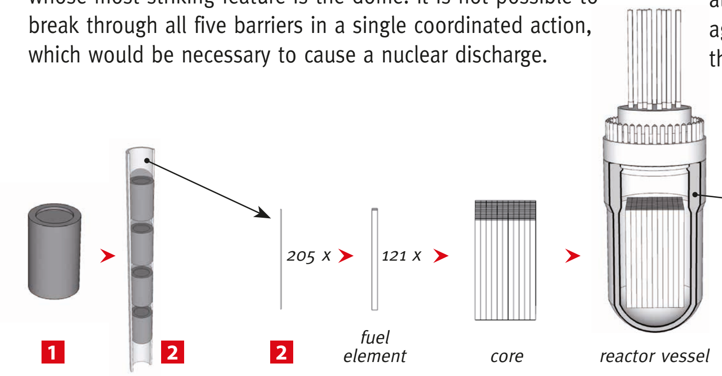
Barrier 2: Fuel rod [2]
The fuel pellets are stacked in a hermetically sealed, gas- and watertight zirconium tube. This fuel rod retains most of the volatile radioactive substances.

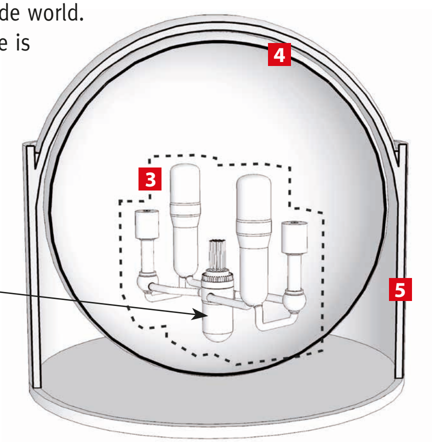
The core consists of fuel pellets sealed in fuel rods. A bundle of 205 fuel rods combine to a single fuel element. The reactor contains 121 of these elements. The core is contained in the primary system, a closed circuit of thick steel pipes, tubes, pumps and pressure vessels. The primary system is housed in bunkers inside the containment building, an airtight steel sphere. All nuclear systems are housed in a concrete structure whose most striking feature is the dome. It is not possible to break through all five barriers in a single coordinated action, which would be necessary to cause a nuclear discharge.

Barrier 3: Primary system [3]
The primary system is a closed circuit through which coolant (conditioned water) is pumped. The water, at approx. 320°C, is pressurised to 155 bars to prevent boiling, hence the name 'pressurised water reactor'. The primary system (reactor vessel, pipelines, steam generators) is made of highly overdimensioned steel parts (several centimetres thick) of the highest quality. Radioactive substances cannot escape.
The primary system is housed in concrete bunkers. The concrete provides radiological protection during operations, and protects the primary system from internal or external threats.

Barrier 4: Containment structure [4]
The primary system is contained inside a steel sphere several centimetres thick, which ensures that radiation cannot escape if an incident occurs. The sphere is a strong airtight structure which can withstand internal gas and steam explosions. This prevents emissions from the primary system to the environment in the event of an accident.

Barrier 5: Reactor building [5]
All systems are contained inside the reactor building, which is instantly recognisable thanks to the familiar concrete dome. The building is the final physical barrier between the primary system and the outside world.
The concrete structure is also the first barrier against external threats.





Preventing nuclear emissions

The nuclear plant's ventilation shaft is often incorrectly referred to as a stack. It is through this shaft that the treated (filtered) air is vented to the external environment.

The air in the containment structure is underpressurised so that, in the event of a leak, air will always flow from the outside to the inside. The underpressure is constantly monitored.
An air treatment system maintains the underpressure and vents any excess (filtered) internal air through the ventilation shaft. This air is constantly checked for radioactivity.
When moving from one chamber to another, staff have to pass through an airlock. The chambers around the primary system (with the greatest underpressure) are hermetically sealed and inaccessible during normal operations. This prevents any radioactive gases or contaminants from escaping the plant unnoticed.

Preventing a hydrogen explosion

In the containment structure (closed steel sphere) at Borssele is a system that immediately converts into water any hydrogen that might develop. The system is passive, and requires no power or controls. It therefore works under all conditions. A catalyst (platinum) in the recombiners ensures a controlled chemical reaction, to rule out the danger of explosions.

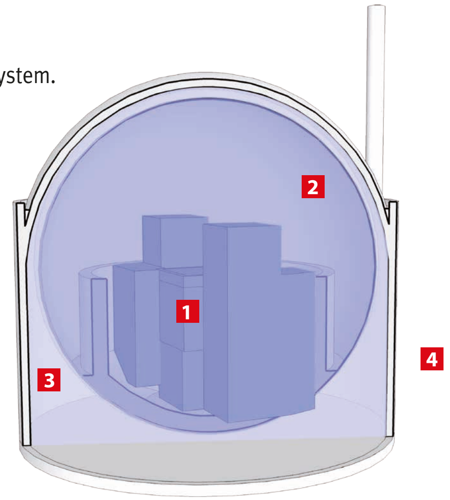
Pressure stages

[1] The greatest underpressure is in the area immediately surrounding the primary system.

[2] The other areas inside the steel sphere have slightly less underpressure.

[3] The space between the concrete dome and the steel sphere has less still.

[4] Ambient pressure.



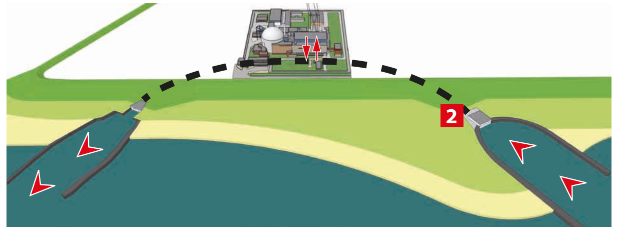
Design

Cooling

Whether a nuclear power plant is in operation or has been shut down for maintenance, the fuel in a pressurised water reactor must always remain submerged, in order to remove the residual heat that the fuel produces due to radioactive decay, and to provide protection from radiation. As long as the core is covered with water, the situation can be controlled.

The plant has several independent systems and water supplies which ensure that the core remains covered with water in all circumstances. The plant also has systems that guarantee that the heat from the core can be discharged to a heat sink in all circumstances. These systems complement or substitute each other.

The nuclear plant has two **main coolant pumps** [1]. These pumps circulate coolant through the primary system while the plant is in operation. If both pumps fail, the reactor automatically shuts down and a process of natural circulation commences, with sufficient capacity to remove the decay heat from the core: without pumps, without technical intervention, simply on the basis of the laws of physics. This is the second major inherent safety feature of the reactor design at Borssele.

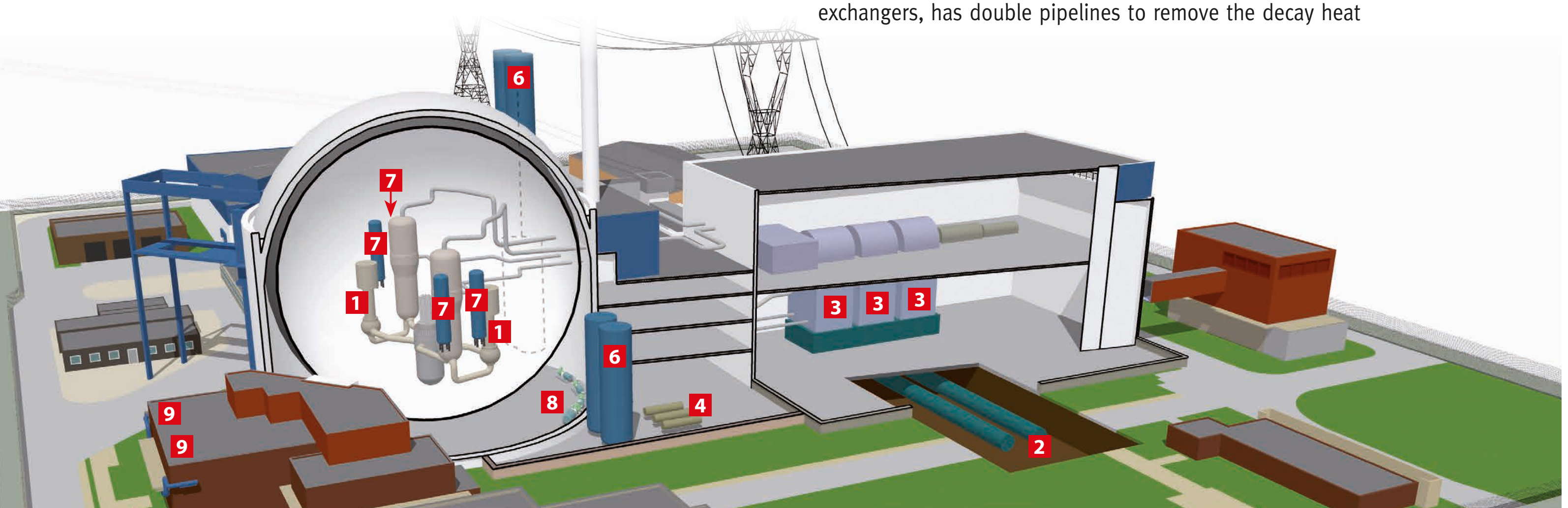


During normal operation and maintenance:

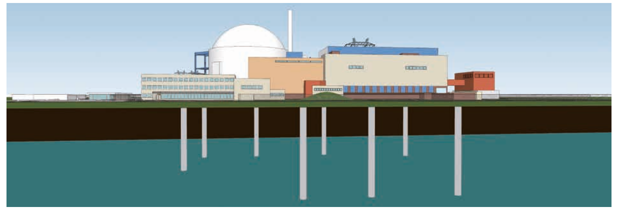
When the nuclear plant is generating electricity, the steam cycle is cooled using water from the Western Scheldt river, which is pumped in via the **cooling water inlet** [2].

Cooling occurs in the **condensers** [3], in which cold surface water ensures that the steam is condensed back into water, after which the steam cycle begins again. This cooling circuit is in fact part of the electricity production system, not the safety system.

When the power plant is not in operation, the core still has to be cooled so that residual heat is removed. Though the chain reaction has stopped, radioactive decay means the core continues to produce heat. The main coolant discharges this heat via the **component cooling system** [4] to redundant cooling water pipes containing water from the Western Scheldt. This cooling chain, consisting of three circuits separated by heat exchangers, has double pipelines to remove the decay heat from the reactor and discharge it to the Western Scheldt during normal operations, or when there is a technical fault. The two redundant trains therefore ensure that heat can be removed from the core.



For the unlikely event that water cannot be taken from the Western Scheldt, in 1997 EPZ installed a back-up system that uses eight deep wells that supply brackish groundwater. Powerful underground pumps pump up brackish groundwater to remove the decay heat.



During cooling water leakage:

These **tanks** [5] top up the water if there is a leak in the primary circuit. The water is used to keep the core submerged. The water reserve is 700 m³, which can be supplied in two ways: under high pressure (110 bar) with a small throughput, or under low pressure (8 bar) with a high throughput, depending on the amount needed (high throughput for a major leak, low throughput for a small leak). The tanks were part of the original design, and have been present on the site since the plant commenced operations in 1973.

The sphere contains **four water tanks (2 x 2)** [6]. In the event of a loss of pressure in the primary system (which indicates there is a leak), the water automatically begins to flow once the pressure drops below 25 bar. The tanks contain a total of 86 m³ of water. This system also dates from 1973.

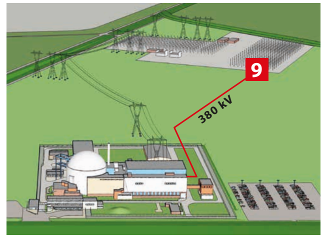
If both water supplies are exhausted, almost 780 m³ of water will have been pumped into the sphere. **Pumps** [7] were fitted beneath the sphere in 1973 to pump the water back to the reactor.

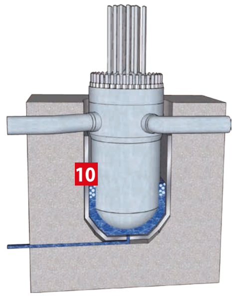
In 1984, after the nuclear accident in Harrisburg (USA, 1979), two extra bunkered water storage facilities (2 x 200 m³) were built at a short distance from the reactor building with their own **emergency power supply** [8], plus a further 400 m³ of water for independent water supply to the steam generators.

After the accident at Chernobyl, a great deal of attention was focused on the safety culture and operation of the process, and many improvements and safeguards were introduced.

Since Fukushima more consideration has been given to incidents on an unimaginably catastrophic scale. A scenario in which the entire Dutch infrastructure has been swept away and society has been so disrupted that external assistance is extremely difficult to provide has been considered:

- A new, additional 380 kV connection to the **national electricity grid** [9] has been installed.
- Extra cooling has been provided for the fuel storage basin.
- A facility for external cooling of the reactor vessel is to be introduced. In an emergency, water can be let into the **empty space between the reactor vessel and the concrete containment structure** [10].
- Extra equipment such as mobile pumps and generators have been purchased, which can be connected at several places in the plant.
- Larger, distributed diesel and water supplies that can be accessed in several ways have extended the period during which the nuclear power plant can manage without external assistance to fourteen days.





Design

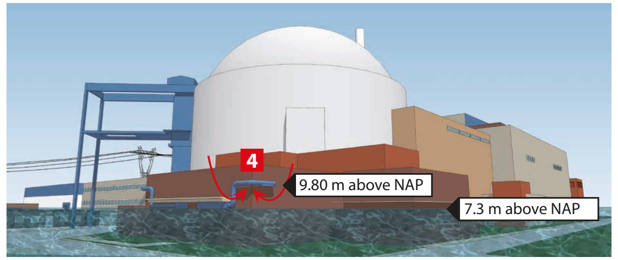
Emergency power

The nuclear plant not only produces electricity, it also uses electricity to control the plant. To ensure that the core remains covered with water at all times and that the decay heat is discharged, active components like pumps are needed, and they are powered by electricity. That is why the plant has been equipped with numerous (redundant) emergency power systems.

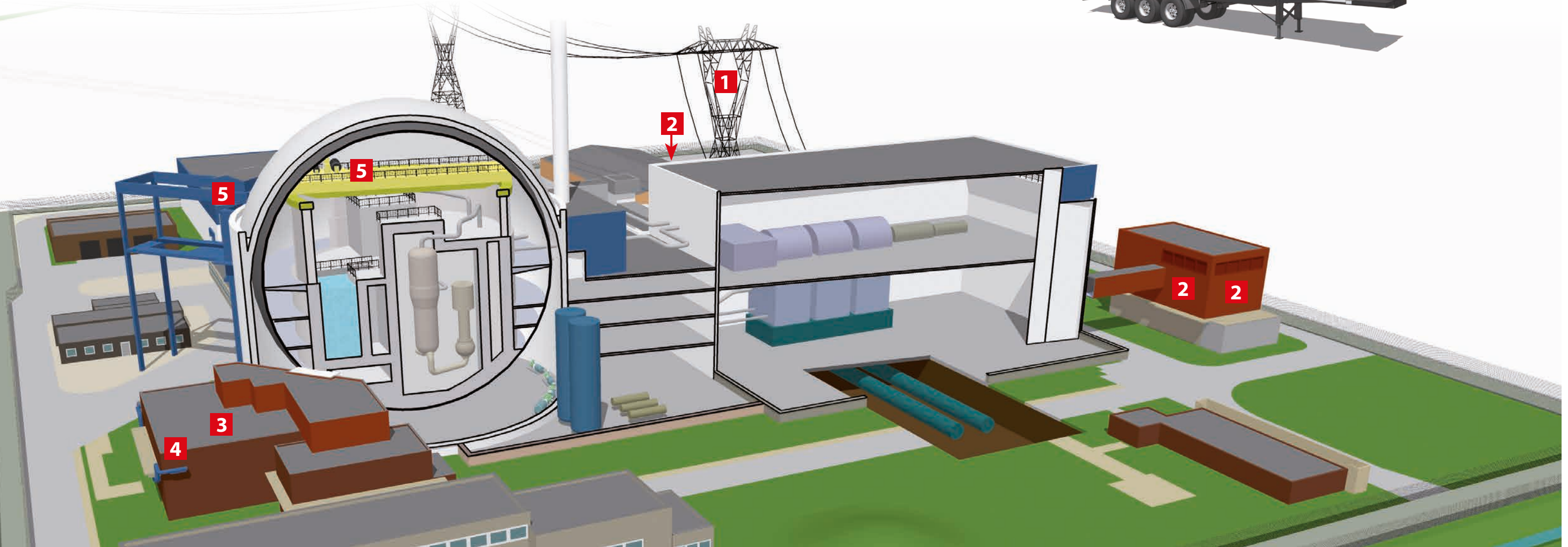
The nuclear plant consumes power from the **national grid** **[1]**. Since this power supply can fail, multiple connections have been installed. High-voltage pylons connect the plant with the public 150 kV electricity grid. Underground cables connect it to the 380 kV national interconnected grid. So electricity can be obtained from two different national grids.

There are three identical 5 MW **diesel power plants** **[2]** around the nuclear power plant. Each of them is highly overdimensioned and can independently supply the electricity needed to discharge residual heat. The diesel power plants in the original design were replaced in 1997 by larger ones housed in different buildings. A review of these plants was launched in 2017.

In 1986, two extra **'station blackout' diesel power plants** **[3]** were built in bunkers. Each of these 1 MW plants can keep the nuclear plant in a safe, controlled state. In 2006 the flood defences were increased from 7.3 metres above NAP (Amsterdam Ordnance Datum) by fitting **'snorkels'** **[4]** to the air inlet to a height of 9.8 metres above NAP.



EPZ also has a mobile 1 MW diesel unit which serves as an additional emergency power supply for operating the plant, and several mobile units for operating smaller auxiliary systems.



Auxiliary shutdown control room

The nuclear plant always shuts down safely and automatically if there is an incident. If the control room (and operator team) is no longer available, the shutdown can be managed from an auxiliary control room (built in 1997). A second team of operators monitor the automatic controls and ensure that everything is safe. They can intervene if necessary.

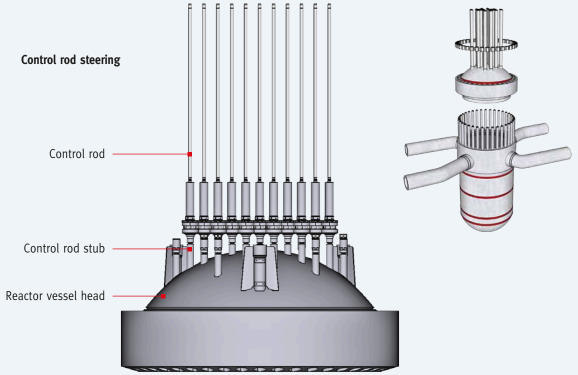
Extreme external events

The nuclear plant has technical means and provisions that protect it under extreme conditions:

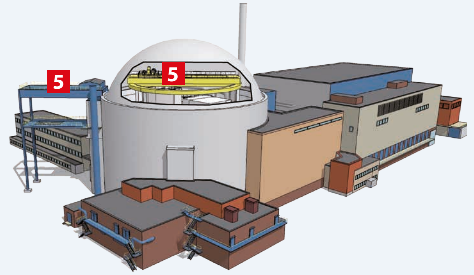
- The flood level for vital components is 9.8 metres above NAP (the major floods in 1953 reached 4.55 metres above NAP).
- Gas cloud detection and ignition on the dike to protect against combustible gas clouds (LPG) escaped from shipping.
- Proven earthquake-resistance in vital components.
- Vital components resistant to aircraft impact thanks to multiple barriers and geographical distribution of vital plant parts.
- Crashtender to fight major flammable liquid fires.

Recent safety investments

Over the past few years many large and small components of the original design have been replaced. In 2017 a new Reactor Control & Limitation System (RCLS) was installed. This system controls and limits the nuclear fission process in the plant.



The safety of the hoisting equipment has also been enhanced. Both inside and outside the plant, **heavy cranes** **[5]** lift heavy transport containers carrying radioactive fuel elements. To further reduce the likelihood of accidents during lifting operations, measures have been introduced to make this equipment even safer.



Maintenance

Nuclear plant maintenance schedule

Every day, more than a hundred people carry out maintenance work and inspections at the nuclear plant. The 'maintenance book' has been compiled on the basis of rules drawn from experience and a method for analysing possible modes of failure and their impact: Failure Mode & Effect Analysis (FMEA).

Because the plant has been in operation since 1973, we know a lot about how it behaves. Since production commenced, the condition of the vital components has been continually monitored. This information and experience allow EPZ to draw conclusions as to what maintenance work is needed. The safety of the plant is the determining factor in maintenance decisions; economic considerations come second.

All maintenance work is controlled through an automated maintenance management system, which generates a plan for preventive maintenance. Corrective maintenance and modifications are scheduled alongside this work.

Maintenance and safety

Modes of failure and their potential safety implications have been defined for each component that is safety relevant (FMEA). The probability of failure times the impact equals the risk. Maintenance measures are planned on the basis of risk.

EPZ uses Probabilistic Safety Analysis (PSA) technology for this purpose. This 'living PSA' – also known as 'Safety Monitor' – allows the impact of maintenance work on the core melt frequency (once in almost a million years) to be calculated. If several safety-relevant components are shut down, the core melt frequency rises slightly. EPZ has a strict operating limit for preventive maintenance, so the organisation remains fully aware of the safety implications of maintenance work.

Operating conditions	Core melt frequency	Operating limit
theoretically achievable core melt frequency during normal operation	Once every 435,000 years	
theoretically achievable core melt frequency including planned maintenance	Once every 415,000 years	3% increase relative to theoretically achievable core melt frequency
1 production year with all practical operating conditions	Once every 400,000 years	7% increase relative to theoretically achievable core melt frequency

Actual maintenance work

Actual maintenance work itself is surrounded by many safeguards. The automated maintenance management system manages preventive maintenance and inspections in a weekly schedule. Operators who detect faults or defects during operations or control rounds enter a corrective maintenance request in the system.
A file is created on every piece of planned maintenance, setting out what maintenance actually needs to be carried out, followed by instructions for the maintenance worker. One important aspect of the file is the risk identification, which looks at the process risks, and at the risks to worker health and safety and the environment. Nuclear activities are performed on the basis of the ALARA principle: the radiation dose received must be As Low As Reasonably Achievable.

Quality and safety are guaranteed by statutory rules and procedures. A 'permit system' is in place that allows the work to be monitored, to ensure it is safe. Nuclear activities are carried out according to procedures, and subsequently verified and evaluated.

During the annual outage, when fuel elements are replaced, 'downtime maintenance' is performed. Preparations for this work are made throughout the year, and the work itself is carried out by a team of hundreds of technicians (both internal and external) in just a few weeks.

Before a maintenance job is actually carried out, a pre job briefing is held at which all concerned discuss the work once more. This is the moment for critical questions and for resolving anything that is not entirely clear. The work permit issued by the shift supervisor is checked.

Finally, a last-minute risk analysis check is carried out on the workfloor to establish whether the conditions are as agreed. Then the maintenance technicians set to work, using a checklist which stipulates what checks have to be performed when. Sometimes, a more senior employee must carry out an explicit check or give permission before work can continue.

Effectiveness of safe maintenance

When maintenance work is done, two tests are performed. One is the 'static' requalification, an assessment performed on the basis of measurements. A functional test then follows as the component is brought back into operation under controlled conditions. EPZ performs analyses and evaluations to continually improve its maintenance performance.

Maintenance engineers analyse performance indicators such as:
- mean time between failures, a method for comparing the reliability of parts;
- increase in core melt frequency, the safety impact of maintenance;
- mean time to repair, including call-out time and delivery time for spare parts.

Evaluations consider a range of questions: what went well and what could have been done better, what did we find and is there likely to be any follow-up maintenance? The findings are recorded and any irregularities communicated to those responsible.

This structured approach provides a constant overview of where improvements can be made. This is followed by actual measures, including:
- changes to operating instructions;
- changes to maintenance procedures;
- modifications to the plant;
- improvements in employee skills.

Spare parts management

EPZ keeps a stock of spare parts for critical components. Vital components of safety systems, pumps and control systems are subject to proactive management. Ageing processes are also managed. EPZ therefore not only knows what it has in stock, but also the condition of each part.

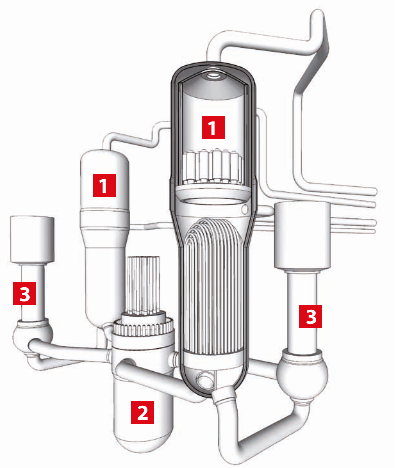
Maintenance

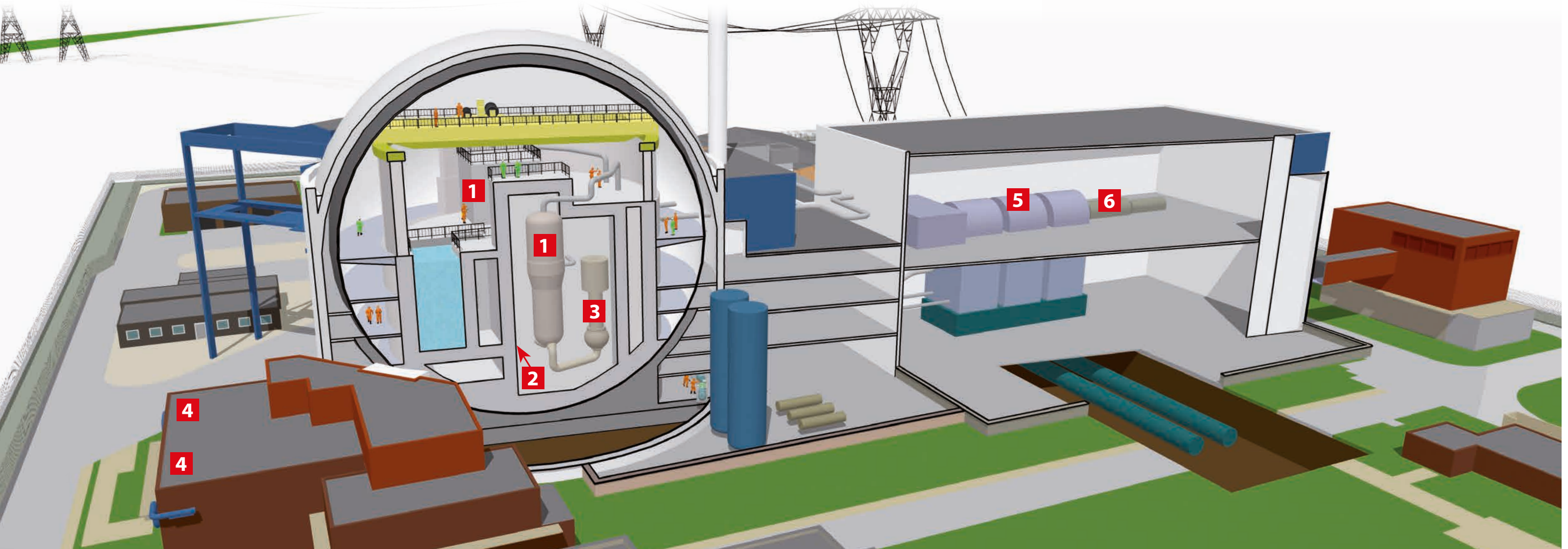
Prescribed inspections

Borssele nuclear power plant is to remain in operation until 2034. EPZ has shown that it is possible to do this safely, and the government has issued a permit for the purpose. The permit prescribes thirty extra inspections to monitor the integrity of the plant up to 2034 (in-service inspections). The reactor vessel and cover have already been closely inspected for hairline fractures, and this inspection is repeated regularly. Welds and bolted joints and parts of the primary (nuclear) system that are subject to heavy loads are also regularly inspected. This takes the form of a visual inspection, with underwater cameras, for example, or use of the eddy current or ultrasound technique. The inspections are performed by a specialist firm. The results are assessed by the government.

The steam generators

The two **steam generators** [1] are huge heat exchangers housing thousands of pipes. Here, heat from the primary system is transferred to the steam cycle that generates electricity. The condition of the steam generators is permanently monitored for leakage from the primary to the secondary side. Once every three years all the tubes in the steam generator are subject to eddy current testing to establish the thickness of the tubes and whether there are any cracks in them. If a tube is not up to standard, it is capped. In recent years, 2% of the tubes have been capped. The steam generators are up to 115% overdimensioned, so this has no impact on efficiency or safety.





The reactor vessel

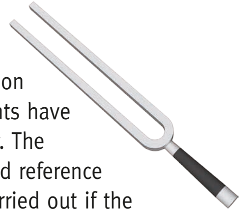
The **reactor vessel** [2] is the only component in the nuclear plant that is virtually impossible to replace. Thanks to the material used in its construction and the almost uninterrupted production (constant temperature), the vessel is in top condition. Every five years it is visually inspected using cameras. Welds, transitions between different materials and connections to the primary system are closely examined using ultrasound and x-ray techniques to detect any imperfections, such as the onset of a crack or thinning of the wall. Inspection intervals for all components are determined on the basis of the importance and the load to which they are subject, but the entire system is inspected at least once every ten years. The programme is evaluated regularly, and coordinated with the regulator (ANVS).

Maintenance of emergency diesel power plants

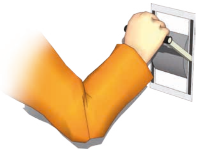
The three large 5 MW **emergency diesel power plants** [4] installed in 1997 are being overhauled from 2017. One new diesel plant has been purchased so that the other three can be overhauled in turn. The plant will thus still have access to full emergency power capacity.

Vibration monitoring of key components

The two **main coolant pumps** [3] have preventively been fitted with vibration monitoring equipment. Any change in the vibration pattern indicates bearing play or imbalance, and an alarm is triggered. The **turbine** [5] and **generator** [6] are also fitted with vibration monitors, even though these components have no direct implications for nuclear safety. The measurements are compared with stored reference data, and preventive maintenance is carried out if the results suggest it is necessary.



Functional testing

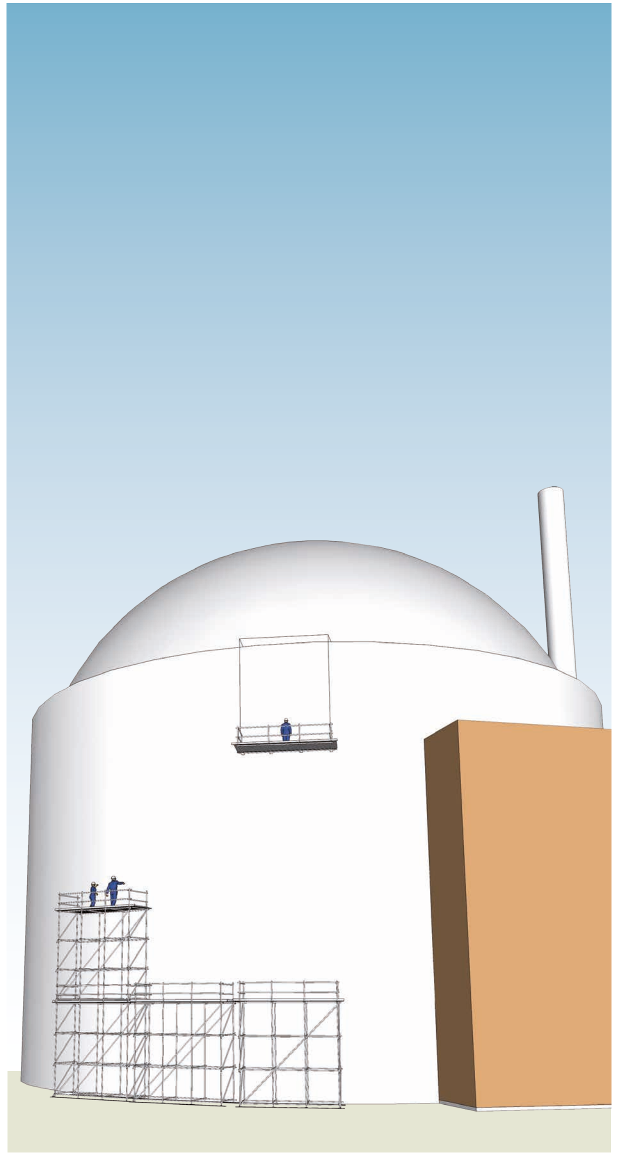


Systems (and their redundant counterparts) are tested daily, weekly, annually or every three years to ensure they are in good working order. Strategies and procedures have been drawn up for the tests. If irregularities are detected, the systems are calibrated, repaired, overhauled or replaced. Inspections are performed using equipment like temperature sensors and signal converters. Are the measured values correct and are they correctly converted to an electrical signal?

Noise detectors

Noise detectors have been fitted at strategic points in the primary system. They allow EPZ to detect loose parts, among other things.
Sensors have been fitted to or near pressure vessels, pipelines and moving components. As soon as any unusual sounds are detected, the cause is investigated and implications for safe operation are identified. Alarms are real-time: the noise measured is analysed immediately and compared with reference values.

Maintenance



Containment structure

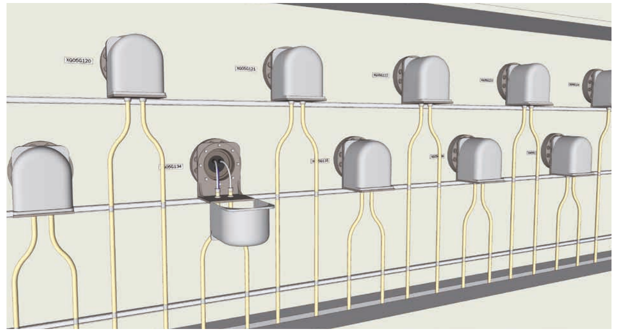
The steel sphere housing the nuclear plant's primary system is tested for leaks every ten years. The sphere is overpressurised by 1 bar and the pressure is monitored over many hours. This test was last performed in 2016, and the results were successful.

The concrete dome is also inspected regularly, and major maintenance work is carried out every fifteen years. The last time was in 2016.

Detecting leaks

Cable lead-throughs for monitoring and control equipment in the steel sphere are regularly checked for leaks using helium, a small atom, which is pumped into the equipment or component.

Special equipment on the outside detects whether any helium leaks out.



Radiological protection

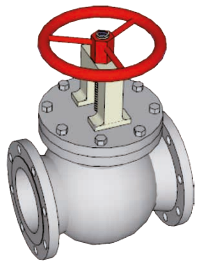
Over a number of years, EPZ has gradually lowered its internal dose limit for radiation. This forces all radiological workers to think about reducing their radiation dose systematically in all their activities. Effective planning and preparation, and the help of the radiological protection department, have reduced the normal daily radiation limit of 500 microSieverts by a factor 10, to 50 microSieverts.

The statutory annual limit is 20 milliSieverts. At 3 milliSieverts averaged over five years, EPZ's internal limit is almost seven times lower than that permitted by law.

Maintenance of components

The nuclear plant has some 900 valves that control processes like injection systems and cooling systems.

The quality standards for the maintenance of these valves are directly proportional to their relevance to safety. In other words, maintenance of valves in the nuclear cycle is subject to more stringent requirements than that of valves in the steam cycle.

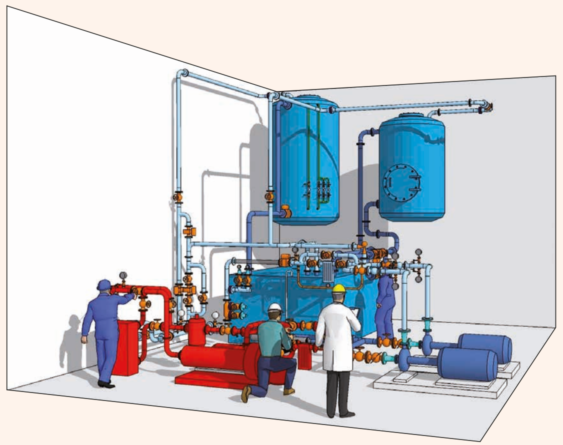


Working practices simulator

In the working practices simulator part of the plant has been recreated as a training environment in which various situations can be rehearsed. Water is pumped through the simulated plant, and it also has the same filters, seals, pumps and measuring and control equipment as in the real plant, in the same colours and with the same features.

The working practices simulator allows staff to be trained in all working practices, from preparatory work to implementation and discussion. It offers huge potential for training, from performing simple checks to discovering radiation hotspots and performing all kinds of tasks. Instead of sitting in a classroom listening to what they should do if they encounter an oil leak, operators are actually confronted with a 'real' oil leak. Around eighty such variables have been built in, which can be used in different combinations for training purposes.

The working practices simulator helps reduce the number of technical faults as a result of human error related to working practices.



Operations

The control room

The atmosphere in the control room is calm, allowing the staff to focus their full attention on the process. All meetings (shift changes, team meetings) are functional.

To ensure the plant operates safely under all circumstances, four staff are on duty in the control room at all times: a shift supervisor, a deputy shift supervisor, a reactor operator and a turbine operator. They all have specific duties. The space is therefore divided into four quadrants, each manned by an operator with his or her own tasks and responsibilities. Each of these responsibilities comes with its own instruments and, in one case, documents. The turbine operator has everything he needs to hand in his quadrant, to prevent him having to walk back and forth, ensuring that the situation in the control room remains as quiet and orderly as possible. All documents are concentrated around the deputy shift supervisor. All the necessary information – including procedures and technical information – are available on paper, and also in digital format.

The operator team

The nuclear power plant is in continuous operation. It is operated from the control room, which is manned round-the-clock in shifts. EPZ sets high standards for the staff who operate the nuclear plant from the control room. They have at least a professional degree (‘HBO’ level) and are selected for qualities such as ability to cope with stress and ability to work in teams.

When they join EPZ, staff receive eighteen months’ full-time training, including ten weeks at the simulator in Essen, Germany, which simulates all kinds of normal and abnormal conditions. Operators also receive four weeks’ theoretical teaching in nuclear physics at NRG in Petten, as well as practical training in the form of internships in various parts of the company. After eighteen months they take an exam administered by the regulator ANVS. If they pass, they are authorised for two years, after which they are reassessed.

Operators receive continuous training throughout their career. They take a four-week refresher course every year, two weeks of which are spent at the simulator. Every time an employee is promoted, he/she receives further training, which can last as long as a year.

Engineers work outside the control room, in the plant itself, under instruction from the staff in the control room. They have secondary vocational qualifications in a technical subject, and complete six months’ internal training after joining the organisation.

All staff (in the control room and in the plant) have the necessary skills and tools stipulated in documents like Human Performance Tools and Management Expectations. These documents are updated whenever new information becomes available, and checks are carried out to ensure the staff’s knowledge and skills are kept up-to-date.

Shift supervisor

Oversees the procedural side of operations. Is responsible for nuclear and general safety and commercial operations during his watch. In the event of a technical fault or unusual circumstances, the **shift supervisor** [1] takes the appropriate measures to ensure reactor safety and coordinates actions in and around the plant.

Deputy shift supervisor

Assumes an independent position to ensure that daily operations comply with procedures.
The **deputy shift supervisor** [2] sits beside a bookcase full of written procedures describing normal operations, and procedures to be followed in unusual circumstances.

A special panel allows the deputy shift supervisor to monitor the nuclear plant’s critical safety functions, including conditions in the primary system, the functionality of the containment structure and conditions in the reactor.

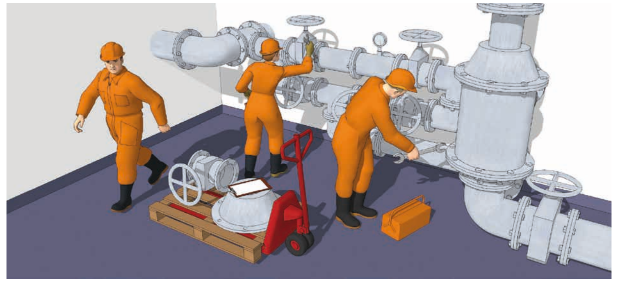
Reactor and turbine operators

The **reactor operator** [3] monitors the reactor operations. He checks the automatic controls during normal operations, and ensures that any technical fault is dealt with in accordance with the prescribed procedures. If necessary (and prescribed), he intervenes.

The **turbine operator** [4] monitors electricity production by the turbine and generator. This, in principle, is the non-nuclear side of normal operations. The turbine operator ensures that any technical fault is dealt with in accordance with the prescribed procedures. If necessary (and prescribed), he intervenes.

Shift engineers

The shift engineers receive instructions from the control room. They monitor the plant and carry out instructions, tests and inspections.



Operations

Firefighters

The commander is a full-time professionally qualified firefighter. The shift of the nuclear plant and the security organisation each provide members of an initial response team who are qualified firefighters. The regional fire service also arrives within ten minutes.

In the event of a major fire, EPZ has a crashtender with foam extinguisher of the type used at airports.

Procedures

EPZ has opted for the best of both worlds:

- German hardware, the best available nuclear technology, both then and now. German technology is based on automatic operations, keeping the human intervention needed to a minimum.
- Operating procedures that originated in the USA. The American philosophy assumes that humans should always be able to intervene if the situation requires. When and how is precisely defined in procedures. The most important thing is that staff always have the right information, continually monitor automatic operations and only intervene in predefined situations according to a prescribed procedure.

In short: the plant can be shut down safely without human intervention but, if necessary, humans will intervene. In every situation, it must be possible to re-establish a safe situation, either automatically or manually.

Operational discipline

The operator team works on the basis of:

1. **Peer checking:** team members never take decisions and actions on their own.
2. **Specific communication techniques:** how and when to give an instruction, how to communicate it.
3. **Pre-job briefing:** before deciding or doing anything, staff discuss the procedure and desired results. This is the moment to clarify any confusion or ask critical questions.
4. **Self-checks:** staff always check the result of their own work and communicate this to their colleagues.
5. **Situation awareness:** staff are trained to be continually aware of the result of their actions and decisions.
6. **Calm in the control room:** the shift supervisor ensures that there is peace and quiet in the control room.

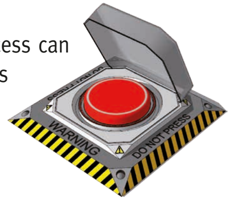
Emergency response team

The shift supervisor can call up the emergency response team at the touch of a button. A duty roster ensures that 18 officials from a range of disciplines are on call at all times.

In the event of an alarm, the emergency response team gathers under the management of the on-duty Site Emergency Director, who takes over all responsibility and authority for managing the facility and taking any action needed. The operation of the nuclear plant remains the responsibility of the shift supervisor, who communicates with the Site Emergency Director. The SED ensures that the emergency response plan is implemented.

Tasks are clearly allocated in the emergency response team. A policy team is formed, and a liaison is sent to the authorities. Strategies, procedures and flows of information are used to categorise the situation, to establish how serious the fault is, and what measures are appropriate.
The emergency services and authorities are contacted via the national emergency response network. Clear arrangements have been made with the authorities concerning how serious incidents should be dealt with. Regular drills are held, including drills for responding to terrorist attacks.

The 'emergency stop button'



In all circumstances the nuclear fission process can be stopped with one touch of a button. This releases the control rods into the reactor to absorb the neutrons, immediately bringing the chain reaction to a halt.

The automatic control system can also decide to immediately shut down the reactor (SCRAM) if certain parameters or events make it necessary. The emergency button does not then need to be operated manually.

Standby shift

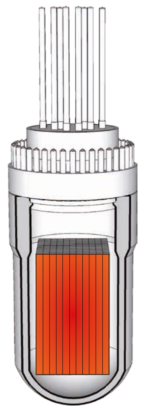
In extreme cases, a standby shift can be called up. There is an auxiliary shutdown control room which can take over control of the nuclear plant if the normal control room becomes unavailable for some reason.

Operating experience

The shifts are backed up by a support department elsewhere on the complex. Staff from this department provide support on operational matters.
Staff work full-time on the improvement of processes, procedures and fault analysis. Faults and failures are analysed and documented. Faults at nuclear plants in other countries are also examined and their implications for operations at Borssele analysed. In this way, we are able to constantly improve our operational experience, and keep it up to date. This allows us to anticipate malfunctions and keep them to a minimum.
When failures do occur, we learn from them. And we share what we have learnt with our fellow operators in other countries.

Operations

Maintenance downtime



A reactor core always continues to produce residual heat, even when it is no longer critical. The fuel in the reactor keeps producing heat due to radioactive decay, even though the chain reaction (nuclear fission) has stopped.

The core must therefore also continue to be cooled during any shutdown. The cooling water both shields against radiation and absorbs excess heat. So even if the main systems have to be opened up, auxiliary systems which are operated from the control room are in operation.

The nuclear plant has several cooling systems (see Design, page 8) that operate independently. They never shut down simultaneously. The plant's technical specifications set out which cooling or other auxiliary systems have to be available.

Outage periods are always meticulously prepared for, both for commercial reasons (they must be kept as short as possible), and for reasons of safety, because a balance must be struck between maintenance and operational requirements. Safety is always the main priority. Responsibility for nuclear safety lies with the outage department during the outage period.

Extra safety precautions

EPZ remains abreast of the latest international developments in safety, and compares Borssele with the 'state of the art' at other nuclear plants. Every ten years we conduct a major survey to establish how we can improve safety at the plant even further. Surveys in 1983, 1993, 2003 and 2013 led to modifications, each making the plant around ten times safer. Thanks to the improvements made every ten years, the plant is currently a thousand times safer than it was in 1973.

The organisation is continually improved on the basis of the results of audits performed by the IAEA and WANO, the international industry association for nuclear plants. The latest insights into Human Performance are applied to permanently maintain and test our safety culture. Lessons learned and best practice from all over the world are assessed to establish their added value for Borssele, and then adopted.

Conservative & Operational Decision Making

In the control room, the rule is that all decisions must be taken conservatively. In the event of a defect, staff in the control can always return the nuclear plant to a familiar state by following set procedures. In unusual operational circumstances, EPZ uses special decision-making techniques.

In the event of technical faults or defects found during maintenance, a permanent group of specialists (or their deputies) meet to take decisions in a transparent manner. They analyse and compare data from different perspectives, then identify cause and effect and possible solutions and alternative solutions. They then take a well-considered decision.

Simulator

Besides the working practices simulator for maintenance staff, EPZ also has a simulator at the Kraftwerkschule in Essen, Germany, where control room staff train to operate the plant. This prepares them for all process conditions, both normal and abnormal.

Simulator training is mandatory, and operators whose performance is below standard may lose their qualifications.

The KCB control room simulator plays a key role in the training of control room staff at a nuclear power plant. Besides normal operations, staff are above all taught to respond to undesirable situations caused by faults and incidents.

The control room simulator can simulate any situation at any moment, including undesirable ones. It became operational in 1997. Since it became operational, both major and smaller modifications have been made, to ensure that the current state of the plant can be simulated as well as possible. The turbine controller was for example changed when a new turbine was installed in 2007.

Ageing Management

Ageing Management

Borssele will remain in operation longer than envisaged when it was constructed. It has been shown on the basis of international guidelines drawn up by the International Atomic Energy Agency (IAEA) in Vienna, with input from Dutch regulator ANVS, that safety is still assured. The IAEA organises special peer reviews of plants that are planning long-term operations. Borssele is regularly reviewed in this connection. In 2013 the permit allowing the plant to continue operating until 2034 was finalised.

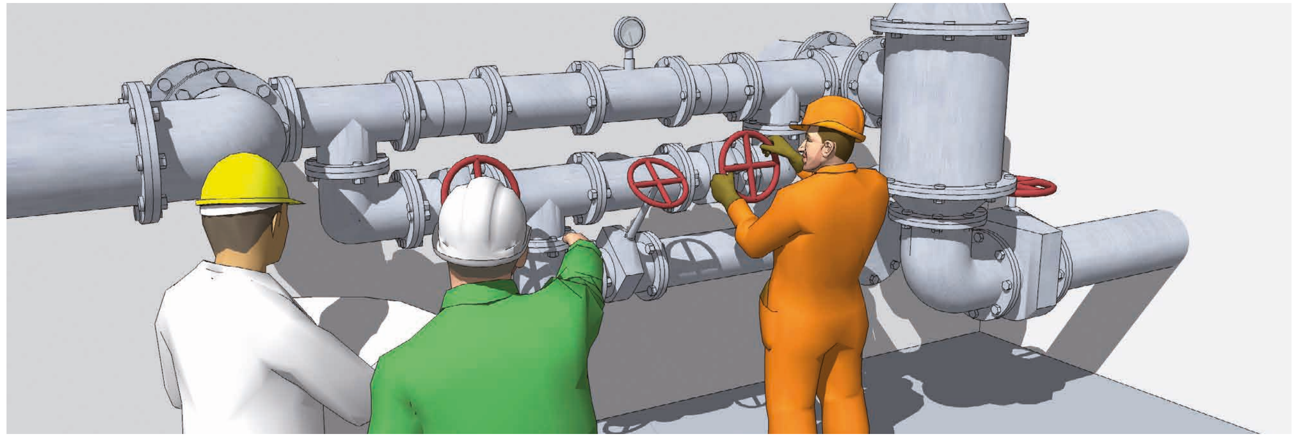
Ageing management at EPZ focuses both on technological ageing and on materials degradation. In time, materials degrade due to long-term use (physical ageing). In addition, technology is constantly evolving, and 'old' technology is no longer taught at colleges and universities. A plant may need to be modernised for either of these reasons. Now that Borssele is to remain in operation twenty years longer, measures have been taken to demonstrate that ageing can be managed up to 2034, with all the necessary safeguards. In many cases, this was a simple matter: the plant was designed to cope with much heavier loads than actually occur. In some cases, additional measurements and calculations have been performed. In all cases, EPZ demonstrated that the integrity of the components is guaranteed until at least 2034.

EPZ manages ageing with specific control measures: regular preventive maintenance, inspections to determine the status of components and, above all, operating the plant in such a way that physical ageing is kept to a minimum. Eventually, aged components are replaced.

AMAT Review

An IAEA Ageing Management Assessment Team (AMAT) can visit EPZ to assess the situation at the request of the regulator (ANVS).

If necessary, AMAT can give suggestions as to how ageing management at EPZ can be improved even further.



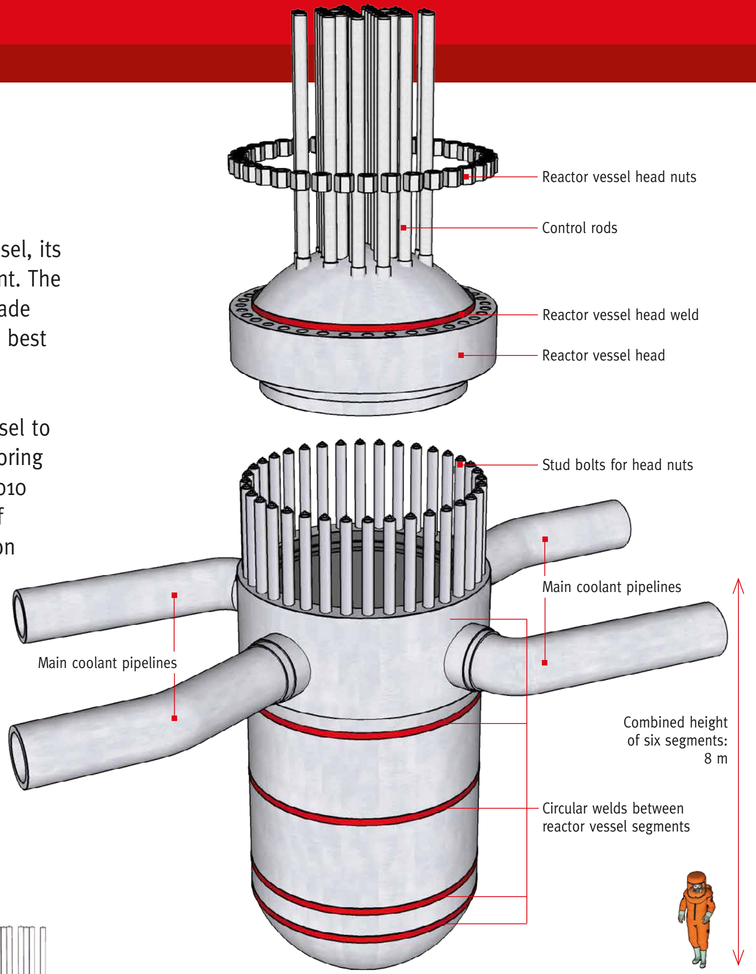
Reactor vessel

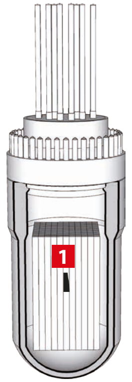
Since it is virtually impossible to replace the reactor vessel, its quality determines the lifespan of the entire nuclear plant. The vessel at Borssele – one of the best in the world – is made of high-quality steel that is 20 cm thick on average. The best materials available were used in its construction.

The impact of neutron radiation can cause a reactor vessel to lose its elasticity, posing a risk of fracture. EPZ is monitoring this process very closely. During maintenance work in 2010 steel samples were taken from the vessel. The results of the analysis can be used to determine how much neutron radiation the vessel has received to date.

The fact that Borssele is run at constant load operation means that there have been far fewer temperature fluctuations than envisaged. Clever management of the core has also ensured that there has been less neutron irradiation of the reactor vessel than assumed in its design.
As a result, the plant can safely be kept in operation until 2034. If the load remains the same, the vessel could even last for more than a hundred years.
In 2012, in response to problems at Belgian nuclear plants, the quality of the steel at Borssele was thoroughly investigated. Even after forty years of production, it is better than would be required of a new plant.

In 2007, **non-irradiated test rods** [1] from the reactor vessel were placed around the core. Here, extra high neutron and temperature loads cause accelerated ageing. This test will end in 2018, and the results should allow EPZ to demonstrate that the reactor vessel can be used safely until 2034, and possibly longer.



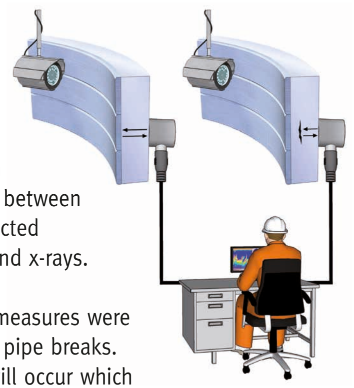


Technical specifications

Volume	: 72 m³
Weight of head	: 45,000 kg
Total weight	: 230,000 kg
Height excl. head	: 8 m
Height incl. head	: 10 m
Internal diameter	: 3.81 m
Wall thickness	: 18 to 36.5 cm

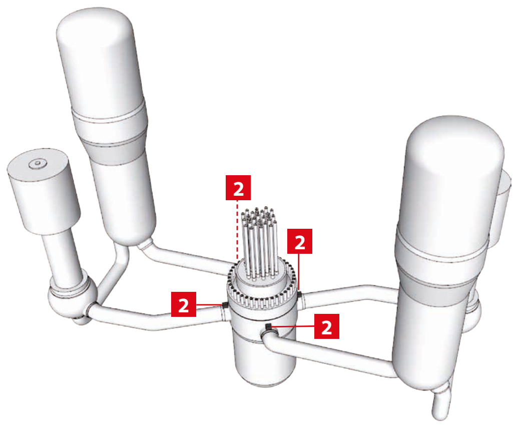
Ageing Management

Primary circuit



The primary circuit cools the core. If a pipe breaks, the core will no longer be cooled. To prevent this from happening, welds and joins between different materials are inspected annually using ultrasound and x-rays.

In 1997 ‘leak-before-break’ measures were taken to exclude the risk of pipe breaks. If a pipe degrades, a leak will occur which will be detected using a special leak detection system. The plant can then be safely closed down. Even though the possibility of a pipe break has been ruled out by the ‘leak-before-break’ measures, the plant is designed in such a way that, if a break were to appear, reactor shutdown and core cooling are ensured.

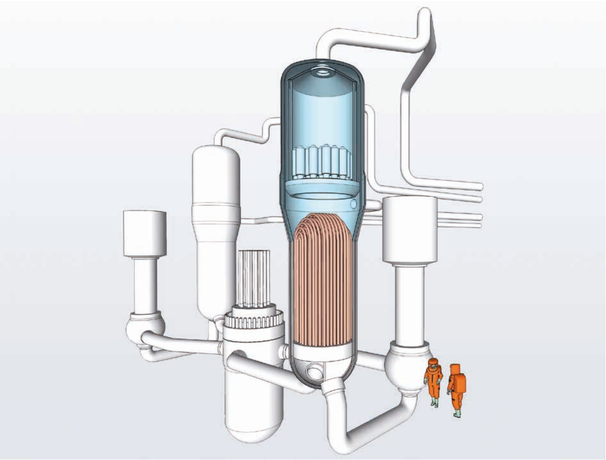


Vital points in the primary circuit are being monitored by **thermocouples** [2] since 2010. They record any load changes as a result of changes in temperature. The data can be used to draw ‘real-time’ conclusions about fatigue in the primary circuit.

Steam generator

In the steam generator the primary heat is transferred to the steam cycle which generates electricity. Thousands of tubes transfer the primary heat to the secondary system. A majority of the tubes are individually inspected once every three years. If any major defects are found, the tubes are capped and others take over their job. The steam generator at Borssele is overdimensioned, and the margin is more than enough to continue operations until 2034.

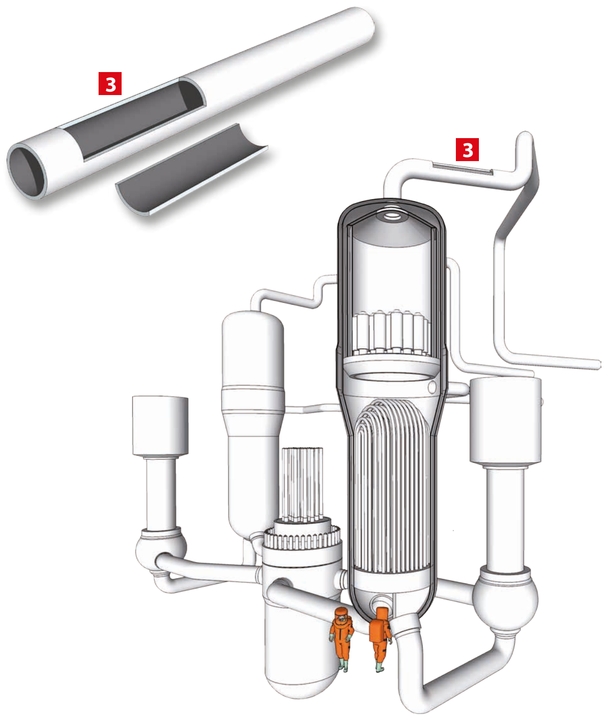
The two steam generators are also among the best in the world. The steam generators in most pressurised water reactors have been replaced, or are due to be replaced, because of cracking due to primary water stress corrosion. These cracks form under the influence of primary water in the steam generator tubes, which are made of a nickel alloy. In most nuclear power plants, the pipes are made of Inconel 600, which has been found to be susceptible to water stress corrosion. The steam generators at Borssele are made of Incoloy 800, however, which is not susceptible to primary water stress corrosion cracking.



Water chemistry

To prevent corrosion in the secondary (non-nuclear) systems, demineralised water containing chemical additives is used in the water/steam cycle. Phosphate chemicals were used originally, but they raised the probability of damage to the **tubes in the steam generator** [3].

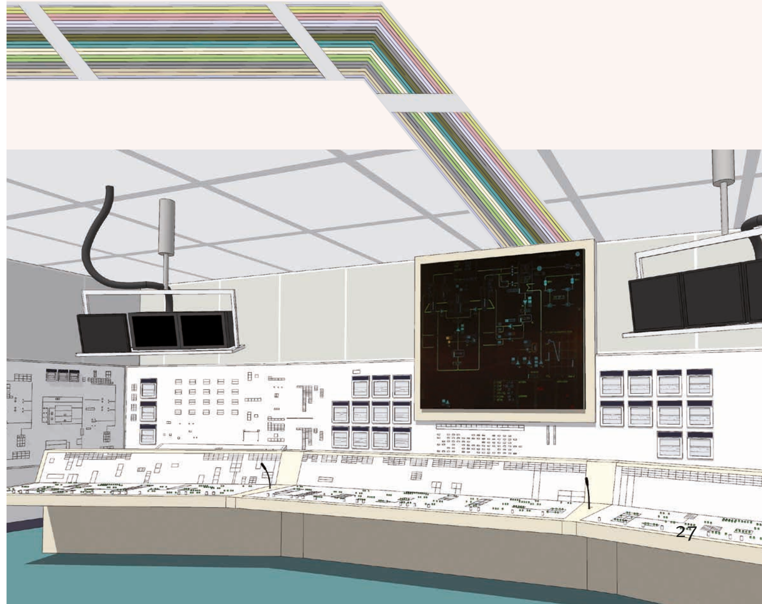
Once the steel condensers were replaced with titanium, it was possible to switch to All Volatile Treatment (AVT) chemicals. This halted the corrosion process in the steam generators, as regular extensive inspections of the tubes have shown.



Equipment and cables

Accident-proof monitoring and control components must continue to work in the event of an accident. Long-term exposure to radiation and high temperatures can cause insulating material to become brittle, which raises the likelihood of short circuits. Measures are taken to manage the ageing of equipment and cables.

Monitoring equipment has been fitted to track environmental conditions over one or more annual cycles. This information can be used to calculate the residual life of the electrical, instrumentation and control components with the help of a ‘residual life database’. Components and cables that will not last until 2034 are replaced.



We work safely or not at all

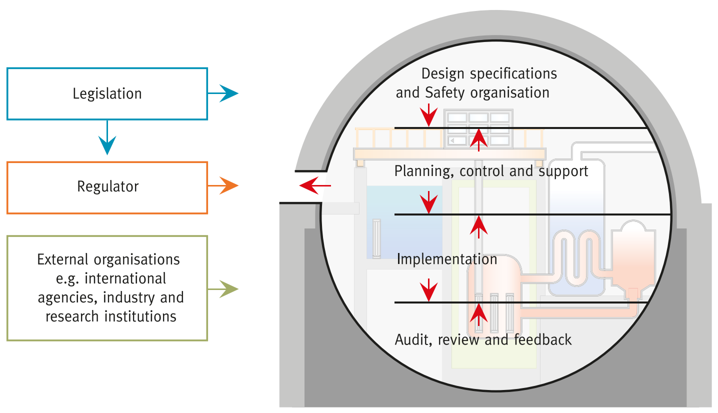
The safety of a nuclear power plant is determined in part by the safety culture in the organisation. People's behaviour affects efforts to minimise safety risks. Safeguards in place both inside and outside the organisation allow work to be performed safely, and encourage a process of constant improvement. There is internal and external supervision, and within the organisation people are accustomed to giving feedback to each other about the importance of working safely.

Safety principles at the nuclear plant are based on the IAEA Safety Standards, whose main priority is to protect the population and the environment from nuclear risks. The standards apply to the installations, use of materials and processes. All precautions are designed to prevent any accidents and incidents that give rise to an uncontrollable situation, escalation of an existing situation or to radioactive emissions.

Safety has been systematised at Borssele:

- Working methods comply with international standards.
- These rules have been incorporated into procedures.
- Practical training focuses on behaviour and compliance with the rules.
- Best practice at other nuclear plants is examined, and knowledge is shared.
- There is workplace supervision (both internal and external) of compliance and performance. National regulators and international audit teams regularly visit Borssele.
- These inspections are not without consequences. Rules and procedures are improved if new information becomes available or shortcomings are identified.

Internal and external safeguards

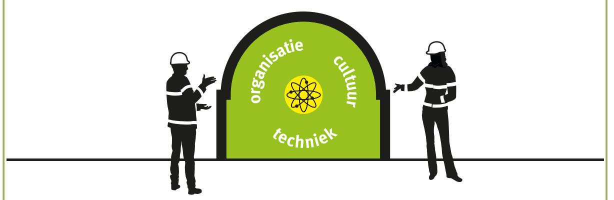


In addition, the 'soft' side of safety culture has been made as tangible as possible in the form of 'Management Expectations', which set out in a clear and accessible way what is expected of everyone. Any member of staff may be called to account for their nuclear safety responsibilities. Training and coaching are provided, both individually and in groups.

Continuous improvement at Borssele nuclear power plant

The process at a nuclear power plant can have a major impact if it is not properly controlled. EPZ is fully aware of this fact, and of the special responsibility it entails: to guarantee the best possible protection for people and the environment from the potentially damaging effects of nuclear fission. This responsibility is encapsulated in the concept of nuclear safety.

Nuclear safety at EPZ



Nuclear safety is the protection of people and environment from harmful effects of a radioactive release and ionizing radiation.

At EPZ we do that by constantly improving our technology, organisation and culture.

Risk and safety

The terms 'risk' and 'safety' lie at the core of our safety culture. At a nuclear power plant, risk comes in the form of the chance of dying or falling ill due to exposure to radiation. We seek to constantly reduce this risk by continually reducing the chances of exposure to radiation.

The industry, the government and scientists all make huge efforts to achieve this, using a whole range of measures: legal, technical, infrastructural and behavioural. The driving force behind this is risk tolerance (how much risk do we want to accept?) and risk perception (how do we view the risks, or how do we perceive safety?). These are dynamic factors, subject to constant change.

For an example of changes in risk tolerance, we need look no further than road safety. Major risks that were regarded as normal in the past are now no longer acceptable. In 1972 there were 3000 road deaths a year. Now there are around 650, even though there is much more traffic on our roads. Reduced risk tolerance has been the driving force behind measures that continually reduce risk.

Just like on our roads, risk tolerance in respect of the nuclear industry has steadily declined continually. This has prompted us to continually improve safety at our nuclear plant. Over the years, society has come to regard safety associated with nuclear plants differently. The need for measures to reduce risk is driven not only by the potential number of victims, but also by the impact on society as a whole. An accident at a nuclear plant may not disrupt society, or lead to unacceptable economic and environmental impacts.

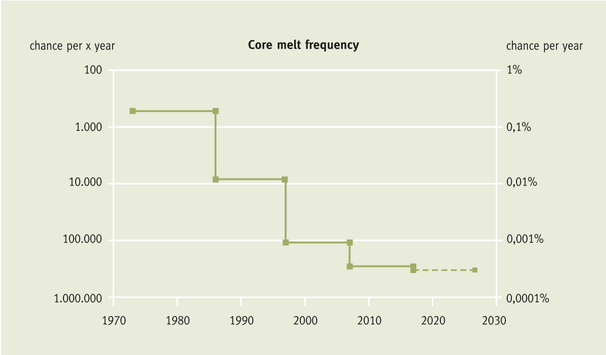
Technological progress has had a positive impact on safety. Advanced sensors and data communication have made road traffic safer. Things like seatbelts, airbags, movement sensors, design changes, GPS and other forms of communication have improved road safety over the past few decades. Because our risk perception has also changed, we no longer feel safe in a car built in the 1960s that does not have these features. In the same way, the safety of the nuclear plant has grown as the public interest in reducing risk has grown.

Safety Culture

Continuous safety improvements

Under pressure from growing safety awareness, technological advances and experience have been fed back into the nuclear plant for decades, reducing the risks step by step. Safety is never 'finished', and can always improve. At EPZ we call this 'continuous improvement'. The result of this process can be seen in the development of the EPZ organisation and the layout of Borssele nuclear power plant. Safety has increased at all levels. The organisation has grown from approximately 130 staff in 1973 to some 350 now. Many of these extra employees work on safety at the plant: more analysts, more specialist technical support, more firefighters, larger operational teams etc. All these staff have to meet much stricter training and qualification requirements than in the 1970s.
The layout of the plant has also changed radically over the decades, with the introduction of redundant systems, new barriers and safety systems. If one safety system fails, an extra system will take over.

Thanks to all the physical and organisational measures, the chances of a nuclear incident that impacts on people and the environment have been reduced by about a thousand times over the past 40 years.



Authority for Nuclear Safety and Radiological Protection (ANVS)
The ANVS monitors whether nuclear safety and radiological protection in the Netherlands comply with the highest standards, establishing rules, issuing licences, ensuring they are complied with and taking enforcement measures when necessary. The establishment of the ANVS in 2015 pooled all the expertise needed to perform these tasks. The ANVS reports to the Minister of Infrastructure and the Environment, who reports to parliament every year. Under normal operations, an ANVS inspector is present two days a week on average for monitoring purposes. During 'downtime', an inspector will be present every day. The ANVS generally monitors on site, and checks the work being done at the plant. It verifies that licences are being complied with, whether technical specifications and procedures are correct, and whether any alterations being made to the plant are permitted. Alongside this technical work, the ANVS also monitors organisational structures and processes, safety management, human behaviour, improvement management and safety culture. The ANVS also closely monitors all deliveries and removal of radioactive substances.

International Atomic Energy Agency (IAEA)
International supervision of the nuclear plant is the responsibility of the International Atomic Energy Agency (IAEA), which has a membership of 136 countries. This autonomous organisation, part of the United Nations, is tasked with ensuring that nuclear energy is used safely and for peaceful purposes. The agency has the right to inspect the nuclear plants of its member states. The ANVS can also invite the IAEA to conduct an inspection or give a second opinion.

World Association of Nuclear Operators (WANO)
The World Association of Nuclear Operators (WANO) in Paris is the international 'industry association' for nuclear power plant operators which ensures that safety in the sector is constantly improved. All nuclear power plants in the world are members of the WANO.
In peer reviews, experts from nuclear plants all over the world get to inspect each others' plants. The aim is to learn from each other through assessment. Staff at EPZ are encouraged to take part in WANO missions themselves. They regularly visit other nuclear plants as part of a peer review team. The experts base their assessment largely on their own observations in the plant and on interviews with staff. They recommend possible improvements. A peer review is an internal matter. The team leader reports the final conclusion to the management of the plant in question. After two years, a follow-up review assesses whether action has been taken on the points for improvement. A list of all WANO missions can be found on www.epz.nl.

Ten-yearly Safety Evaluations (10EVAs)

One of the obligations stipulated in Borssele's Nuclear Energy Act licence is for a safety evaluation to be performed every ten years. This is common practice internationally. Once every ten years, the nuclear plant is comprehensively screened and assessed against the state of the art in safety and radiological protection. Borssele has undergone four 10EVAs in its lifetime: in 1983, 1993, 2003 and 2013. After evaluation and decision-making, each 10EVA is followed up by a modification project, designed to ensure that the plant continues to meet high national and international standards.

The trend revealed by the four 10EVAs conducted so far is that the emphasis is shifting from hardware improvements to organisational improvements. Each 10EVA makes the plant safer, so Borssele is now much safer than when it was first commissioned in 1973.
A 10EVA takes the form of a self-evaluation that is subsequently assessed by the ANVS, which may stipulate further questions for the company to address. The assessment is conducted on the basis of current (and pending) regulations and the best available technology or organisational insights. The findings are translated into potential improvements which are assessed in terms of their relevance and practicability.

Once the government and the EPZ management have reached agreement on the improvements, a modification project is launched. The most radical modification project carried out to date was that in 1997, when the nuclear plant was modernised and fitted with extra safety devices to such an extent that each subsequent hardware improvement will be less radical than the previous one. It is in terms of human performance that the most gains can now be made.

International knowledge sharing

The international nuclear community is highly focused on sharing knowledge. The philosophy is to learn as much as possible from the experience of others. Operators share details of best practice, and of technical faults and incidents. News services play an important role in this process, and large numbers of nuclear experts attend international conferences in their field. EPZ participates in all initiatives. Well-known organisations like the IAEA, WANO and European Commission also play a key role in gathering and providing access to knowledge and experience.

The EPZ organisation analyses this collective operating experience and assesses whether it is useful for its own operations. If, for example, an earthquake occurs in Japan, Japanese nuclear plants will provide an account of their experiences as quickly as possible. Borssele will then assess the impact on local nuclear plants and draw any lessons for its own situation.

Safety Culture

INES notifications

Since 1990 the nuclear industry has been using the INES scale for reporting nuclear and radiological incidents at nuclear plants, and transport incidents or incidents with radioactive material in hospitals and other organisations. Just as the Richter scale is used to categorise earthquakes, the INES scale is used internationally to indicate the severity of disruptions at nuclear plants. There are seven levels on the INES scale, one to seven. Anything below that is categorised as INES=0, and has no safety significance.

INES ratings
The rating 0 is reserved for defects with no safety significance. INES ratings 1, 2 and 3 are referred to as incidents, which have no impact on staff or the surrounding area. At level 4, safety risks can occur within the plant, because of a release of radioactive substances within a building, for example. From level 5, an accident can have consequences for the immediate surroundings of the plant; 7 denotes a major accident whereby high levels of radioactive substances are released into the environment. Fukushima and Chernobyl were rated 7 on the INES scale.

Common technical faults
Typical faults that commonly occur are defects in the back-up safety systems that come to light during regular testing. Disruptions to operations causing energy generation to be halted for a short time can also occur. Finally, procedural failures may also be reported.

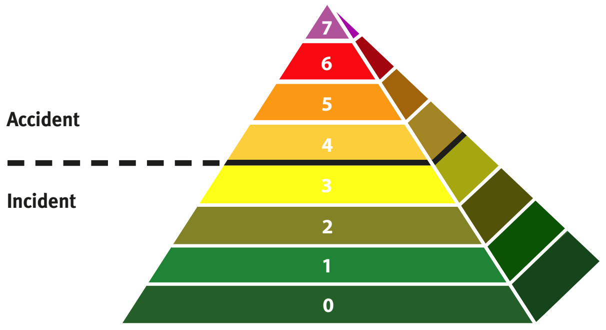
Responsibilities of EPZ and the authorities
EPZ investigates every fault to determine the cause, and how serious it is. On the basis of its own investigation, EPZ proposes the INES rating, and publishes all preliminary INES notifications.

It is however the authorities (the Authority for Nuclear Safety and Radiological Protection) that makes the final INES assessment on the basis of the EPZ report and its own investigation. The ANVS also ensures that improvements are carried out in response to disruptions. It reports every year to parliament on disruptions that have occurred at all nuclear plants in the Netherlands.

What happens after an INES notification?
At EPZ all work processes focus on preventing unsafe situations. The company records and analyses all operational experiences, including all disruptions and incidents, in accordance with international standards. Staff are also encouraged to report incidents internally, even if they seem insignificant. The purpose of this systematic, comprehensive approach is clear: to continuously improve safety, and to learn from mistakes.

EPZ is a member of the World Association of Nuclear Operators (WANO), an organisation to which almost all nuclear plants in the world are affiliated. WANO shares and analyses information about INES notifications and other irregularities. EPZ receives hundreds of reports each year which it analyses for their relevance to Borssele. EPZ also regularly sends reports to the global network itself.

Most notifications at Borssele are INES=0, with no significance for safety. The most serious incident (INES=2) was reported in 1996, when a valve was accidentally left open and went unnoticed for a while. Measures were taken to rule out the possibility of this ever happening again. The general trend at Borssele is downward: the number and severity of INES notifications fluctuates, but is on the decline.
All INES notifications can be found on www.epz.nl.



- 7 Major accident
- 6 Serious accident
- 5 Accident with wider consequences
- 4 Accident with local consequences
- 3 Serious incident
- 2 Incident
- 1 Anomaly
- 0 Defect with no safety significance

Commission for Industrial Safety

The Commission for Industrial Safety is an internal committee of experts from EPZ departments who advise the company's management team on health and safety in the workplace. Their remit concerns traditional health and safety; radiological protection is the responsibility of the Reactor Safety Committee (RBVC). Health and safety is part of the nuclear plant's general safety culture, given the direct link between safe working practices and nuclear safety.

Checks are performed on the workfloor to ensure that staff are using personal protection equipment, and there are regular awareness-raising campaigns. During outages, companies and individual members of staff are given financial incentives to work safely. This helps EPZ keep the number of accidents due to human error to a minimum.

Staff health and safety qualifications

Both internal and external staff at EPZ must be qualified to work at the nuclear plant. EPZ rigorously ensures that contractors also have the required qualifications: a valid VCA workplace health and safety certificate or another prescribed professional qualification.

Competence management

Competence management, launched in 2008, began to take concrete form in 2009, when a system was introduced to assess all 300 staff at the nuclear plant on the basis of 200 competences. Most staff are required to have between five and 15 qualifications. It was found that an average of 91% of EPZ staff meet all the requirements of their job. Nine per cent are receiving extra training in certain aspects, due to the fact that they joined the company only recently, have changed jobs or their certificates have expired.

Safety Culture

Training

Staff at the nuclear plant spend an average of 18 days a year on training. EPZ is keen to train its staff, and to ensure they develop knowledge and personal skills, to meet not only today's challenges but also those of the future. Each year several dozen staff (new to the company or to their current job) take practical training to acquire the necessary knowledge of the plant. Ten or more 'refresher courses' are also held every year, to brush up existing knowledge and teach staff about new issues. EPZ also uses external trainers for refresher courses (from Tractebel, the Nuclear Research & Consultancy Group and Reactor Institute Delft).

Shift operators at the nuclear plant train twice a year at the simulator in Essen, Germany. The facility simulates all potential situations that might occur in a nuclear plant. Simulator training is mandatory under the plant's licence conditions. Besides staff's knowledge of their own field and of procedures, other qualities are also tested. Training includes behavioural competences like analytical skills in stressful situations, teamwork and communication skills.
During simulator training shift operators hone their knowledge of commissioning and decommissioning procedures. This is normally only needed during fuel reshuffles, so only one shift a year gets the opportunity to put their skills into practice. This is not enough to develop a routine, so shift operators also rehearse all kinds of major and minor disruptions to operations and serious accident scenarios. Simulator training focuses particularly on procedures and operational discipline.

Watch the video of staff training at de simulator:
www.blikindebol.nl/en/safety-management/#video

Continuous improvement in human performance

It is not only technology itself that determines safety. The way people use technology also has safety implications. EPZ is keen to establish whether it can make further progress in safety in terms of human performance. The main areas it is concentrating on at the moment are as follows:

Strengthening servant leadership based not on hierarchy and power, but on awareness-raising and staff development. A servant leader creates a safe learning environment in which staff can grow and function at their best. The associated human performance programme allows staff to perform effectively, ensuring the organisation achieves better results. This brings staff performance more into line with management expectations.

And also:
- Ensuring that the high standards for the maintenance of critical systems are also applied to non-critical systems.
- Ensuring that temporary modifications to the plant are properly check for safety.
- Increasing the speed and efficiency of analysis of anomalous events at the plant.
- Strengthening line managers' sense of responsibility for the radiological safety of their staff.
- Further improvements to staff preparations for radiological safety in the event of an accident, and further improvement of accident procedure.

EPZ
constantly improving

List of terminology

PSR (10EVA)
Ten-yearly safety evaluation of the entire nuclear plant, mandatory under national and international nuclear operating licences.
In Dutch called 10EVA.

ALARA
As Low As Reasonably Achievable, for reducing the radiation dose received by staff.

AMAT
The IAEA's Ageing Management Assessment Team.

ANVS
Authority for Nuclear Safety and Radiological Protection.

AVT
All Volatile Treatment.

Benchmark
Independent international committee of experts established by the Dutch government to assess whether the Borssele nuclear power plant is one of the 25% safest nuclear power plants in the West.

On-call duty
Staff carrying communications equipment, who can be called up immediately, and are within a short distance of the nuclear plant.

ERBVC
External Reactor Safety Committee, a group of international external experts who supervise the plant and have the task of preventing the internal experts from developing tunnel visio.

Failure Mode & Effect Analysis
A method for analysing potential modes of failure and their impact.

GRS
Gesellschaft für Anlagen- und Reaktorsicherheit, the German nuclear safety organisation.

IAEA
The United Nations' International Atomic Energy Agency, whose headquarters are in Vienna.

INES
International Nuclear Event Scale.

IVC
Commission for Industrial Safety.

Core melt frequency
The likelihood that the core will sustain damage due to overheating. Calculated using probabilistic methods. Borssele score: once every 10 million years.

Matrix
Ordered system of atoms, material.

Mean Time between Failure
Method for comparing the reliability of components.

Mean Time to Repair
The average length of time to complete a repair, including call-out time and delivery time for spare parts.

Probabilistisch Safety Analysis (PSA)
Probabilistic safety analysis assumes that even unlikely events (and combinations thereof) can occur. The analysis relates single or multiple failure and human error to the realistic chance that they will occur.

Quartile
Quarter of a certain amaount.

RBVC
The (internal) Reactor Safety Committee, consisting of specialists and middle managers from the EPZ organisation. Supervises safety.

Redundant
Excess, more implemented than required.

RESA
ReaktorSchnellAbschaltung.

SALTO
IAEA Safe Long Term Operations peer review team.

SED
Site Emergency Director, leader of the emergency response team.

(micro)Sievert
Unit of measurement for the radiation dose to which a human is exposed over a certain period of time.

State of the Art
Skills and technology of the highest available level.

WANO
World Association of Nuclear Operators, the international industry association which focuses on knowledge sharing and improvements in safety and other performance.

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