Koeberg Nuclear Power Station

Generating electricity at a nuclear power station

When the word ‘nuclear’ is heard, people often think of atomic explosions or of the Fukushima disaster. However, thirty two countries around the world have been operating nuclear power plants for more than sixty years. Nuclear power forms an integral part of electricity production and industrial infrastructures. Around the world, scientists use nearly three hundred research reactors to investigate nuclear technologies or to produce radioisotopes for medical diagnosis and cancer therapy. Nuclear energy currently provides approximately 10% of the world’s electricity needs. Koeberg Nuclear Power Station, situated in the Western Cape, produces 4,2% of South Africa’s electricity.

The atom

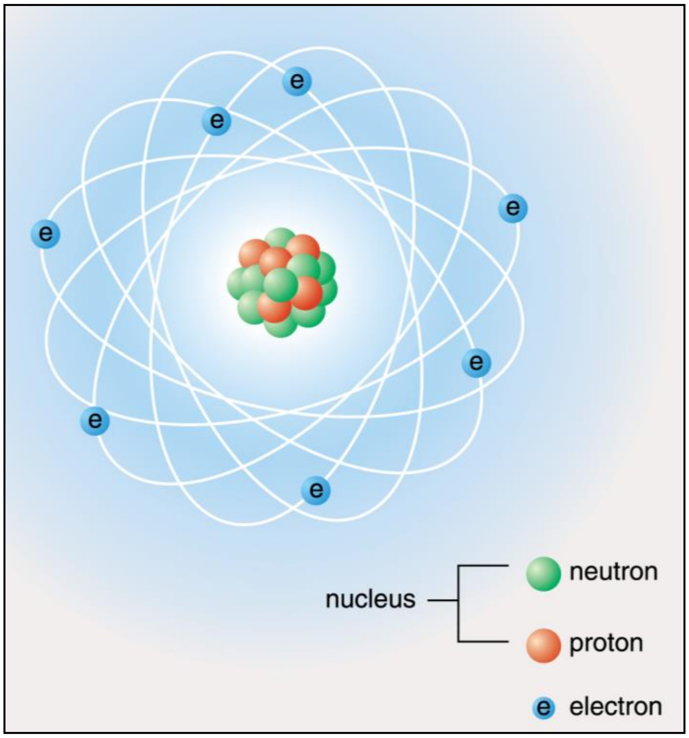
Everything around us is made up of millions of small building blocks, called atoms. The air we breathe, our clothes, bodies, everything is made up of millions of atoms, invisible to the naked eye.

At the centre of each atom - like a pip in the centre of a peach, is a nucleus, containing tiny particles called protons and neutrons.

Around the nucleus, even smaller particles, called electrons, move in random circles - like planets around the sun.

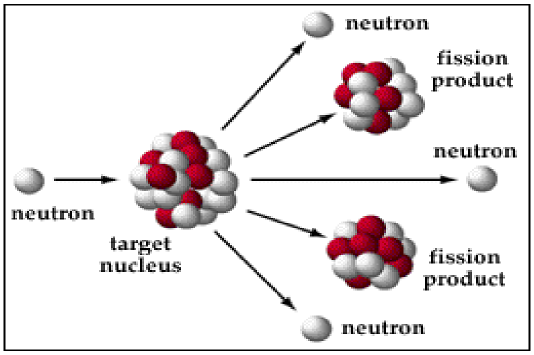
Electrons have a negative electrical charge and protons have a positive electrical charge. Neutrons have no electrical charge.

To start the process of fission, uranium-235 (U235) is bombarded with external neutrons, and when a U235 nucleus absorbs an extra neutron, it becomes unstable and quickly splits into several fragments.



Fission

In a nuclear power station atoms are split during a process called nuclear fission. This takes place in the reactor core. The nuclear fission process releases energy in the form of heat. The heat is used to heat and convert water to steam. To set fission in motion, a source of neutrons (californium) is used to start the process. Thereafter neutrons are obtained from the used fuel already inside the reactor, to sustain the chain reaction. Neutrons strike the uranium atoms, which split and release energy and neutrons. This process will continue and is called the chain reaction.



Uranium

The fuel used in a nuclear power station is uranium, a heavy metal like gold or platinum. When mined, uranium ore is usually found alongside gold and copper.

Like many elements, uranium exists in several forms, called isotopes. Isotopes are atoms of an element with an equal number of protons, but different numbers of neutrons in their nuclei.

Natural uranium normally contains different quantities of uranium isotopes. The number of protons is the atomic number of an element, and the number of neutrons, plus the number of protons give, the atomic mass. Some uranium atoms have a mass number of 235, others 238. U235 is the most readily fissionable isotope, but only 0.7% is found in natural uranium.

In order to sustain fission chain reaction, the uranium is processed in an enrichment facility to increase the concentration of isotopes to 4.4% for use at Koeberg.

Operating method

Koeberg uses a three-loop system (primary, secondary and tertiary loops). The primary loop is pressurised to prevent water from boiling. This is done by a pressuriser, hence the name '**Pressurised Water Reactor (PWR)'.** Heat generated from the fission process is transferred from the primary loop to the secondary loop through a heat exchanger. The heat creates steam, which drives the turbo-generators.

In the tertiary loop, the steam is cooled in condensers with cold water from the Atlantic Ocean. The condenser is designed to ensure that the condensate does not come into contact with the seawater. All three water systems are completely isolated from one another, thereby ensuring that no radiation is transferred.

A. Primary loop

Heat is transferred from the water and nuclear fuel in the reactor to the tubes in the steam generators. The water is then pumped back to the reactor. This is a closed system. There is no contact with the secondary or tertiary loops.

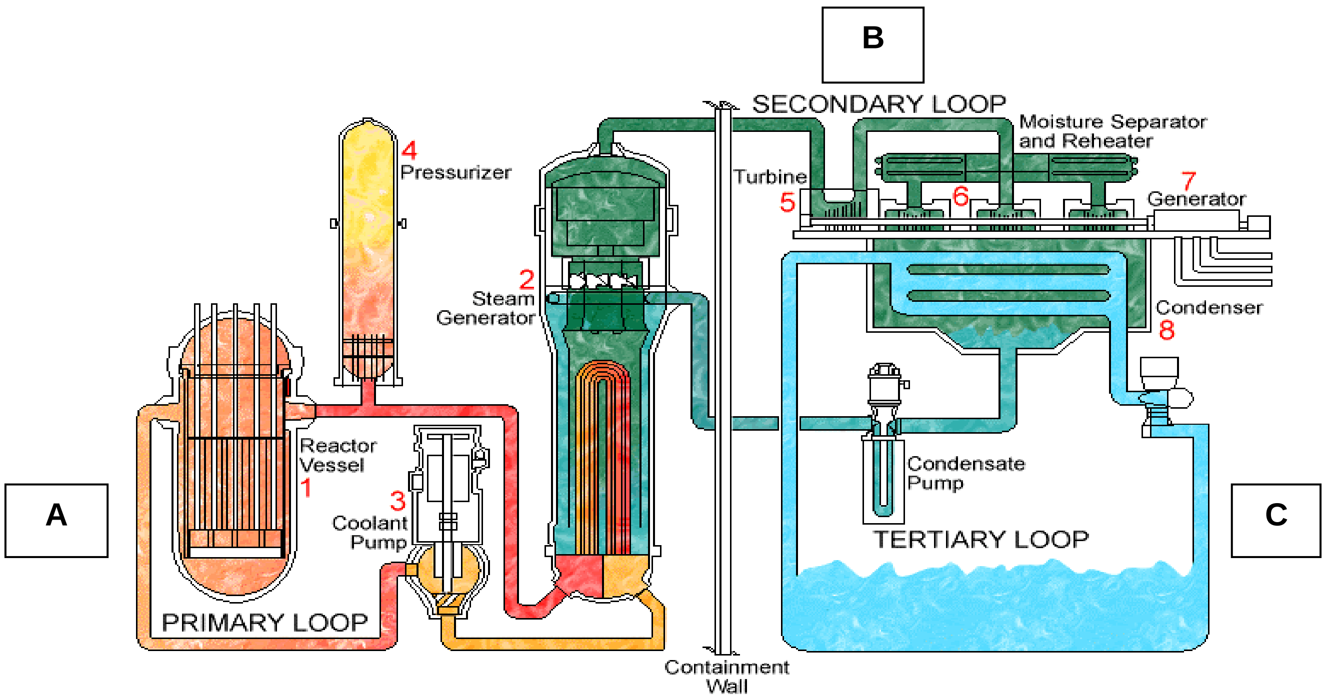
B. Secondary loop

Water is pumped into the steam generators where it is heated to form steam. The steam drives one high-pressure turbine and three low-pressure turbines, which in turn drive the generators.

The generators produce 940 MW of electricity (sent out). Once through the turbines, the steam is condensed and the water is returned to the steam generator, to start the process afresh.

C. Tertiary loop

Cold Atlantic seawater is pumped through condensers at a rate of eighty tons per second. It cools the steam in two condensers, each with a capacity to cool forty tons per second. The seawater is returned to the ocean.



Components of Koeberg Nuclear Power Station:

1	The reactor	5	High pressure turbine
2	Steam generators	6	Low pressure turbines
3	Coolant pump	7	Generator
4	Pressuriser	8	Condenser

Reactor vessel (1)

The reactor vessel is 13 m high with 25 cm thick walls. The internal surfaces are clad in stainless steel to avoid corrosion. Fission takes place inside the nuclear fuel in the reactor vessel.

The reactor core contains four main elements:

The fuel: Nuclear fuel consists of pellets of enriched uranium dioxide encased in long pencil-thick metal tubes, called fuel rods. These fuel rods are bundled to form fuel assemblies.

Control rods: The control rods contain material that regulates the rate of the chain reaction, or it can be used to terminate the fission process. The rods are lowered into, or raised out of the core, as needed, to control the fission process. At full power output, the control rods are generally removed from the core.

Coolant and moderator: Water is used as a coolant and moderator in a PWR station. It is pumped through the reactor to carry away the heat produced by fission, thereby cooling the reactor and heating the water in the steam generators to produce steam to propel the turbines. Water also acts as a moderator (a medium that reduces speed) to slow down the speed at which neutrons travel. This reduction in speed increases the opportunity for U235 atoms to split, and therefore reduces the size of the reactor and making the process more efficient. Boron, which absorbs neutrons, is also added to control the fission process. The boron concentration used is a function of the number of fissionable atoms in the core as well as the power level needed.

Steam generator (2)
The steam generators are designed to withstand the changes from cold to hot operating conditions. The reactor water flows through a series of u-tubes inside the steam generators. Once the water has released its heat, it exits the u-tubes and returns to the reactor. Each of Koeberg's units contains three steam generators.

Coolant pump (3)
The reactor coolant pumps circulate water (primary coolant) through the reactor vessel and the steam generator tubes. There are three coolant pumps; one for each of the three loops. The pumps ensure adequate cooling of the reactor core.

Pressuriser (4)
The pressuriser maintains the pressure in the primary loop, within prescribed limits. When the pressure needs to be increased, electrical heaters automatically switch on and a certain amount of water is turned to steam. When the pressure needs to be decreased, cold water is sprayed through sprinklers located at the top of the pressurizer. This condenses some of the steam and consequently decreases the pressure.

Turbines (5)
The steam generated by the steam generators drives one high-pressure and three low-pressure turbines at a speed of 1 500 revolutions per minute (rpm). As the steam expands through the various stages of the high-pressure turbine, the pressure and temperature of the steam decreases, and the moisture content of the steam increases. The steam then passes through a set of moisture separator reheaters where excess moisture is removed, before it enters the three low-pressure turbines. A shaft connects the turbines to a generator. Koeberg's turbines are some of the largest in the Southern Hemisphere.

Generator (7)
Each of the two fourteen-metre long generators consist of a stator and rotor. Each produces a maximum of 970 megawatts of electricity (1 940 MW total). The two generators are connected to the high-voltage, indoor switchyard via transformers, where the voltage is increased or decreased.

Condensers (8)

Once the steam has propelled the turbines, it moves into the condenser, entering the third circuit. Water from the cold Atlantic Ocean is used to condense the steam to water. Every second 40 tons or 40 000 litres per second, per unit, enters the cooling system. The condenser is designed to ensure that the steam or water in the secondary loop never comes into contact with the seawater, thereby creating a third barrier between the primary coolant and the environment.

For more information on Eskom related topics see the Eskom website (www.eskom.co.za).
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