Eskom | Powering your world

GENERATING ELECTRICITY AT A NUCLEAR POWER STATION

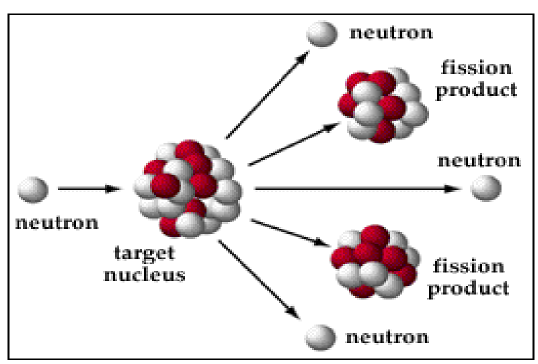
When the word ‘nuclear’ is heard, people often think of atomic explosions or the Fukushima disaster. However, thirty one countries around the world have been operating nuclear power plants for more than sixty years. Nuclear power forms an integral part of electricity production and industrial infrastructures. 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 11% of the world’s electricity needs. Koeberg Nuclear Power Station, situated in the Western Cape, provides 4.2% of South Africa’s electricity needs.

The atom

Everything around us is made up of millions of small building blocks called atoms. The air we breathe, our clothes, bodies, etc. are 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 plum - is a nucleus containing tiny particles called protons and neutrons. Even smaller particles called electrons move in random circles around the nucleus - like planets around the sun. Electrons have a negative electrical charge and protons have a positive electrical charge. Neutrons have no electrical charge. Streaming atoms with neutrons can cause the nucleus of certain atoms to become unstable and split (nuclear fission). Uranium, used at a nuclear power station, is an element with such atoms.

Fission

In a nuclear power station atoms are split during a process called nuclear fission which 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 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 nuclear fuel used in a nuclear power station is uranium. Pure uranium is a silvery, shiny, hard, heavy metal. Uranium production in South Africa is a byproduct of gold and copper mining.

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 a certain fission rate (chain reaction), the uranium is processed in an enrichment facility to increase the concentration to 4.4% for use at Koeberg.

Operating method

Koeberg uses a three-loop system (primary loop, secondary loop and tertiary loop). 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 fission is transferred from the primary to the secondary loop.

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 system is closed. There is no contact with the secondary or tertiary loops.

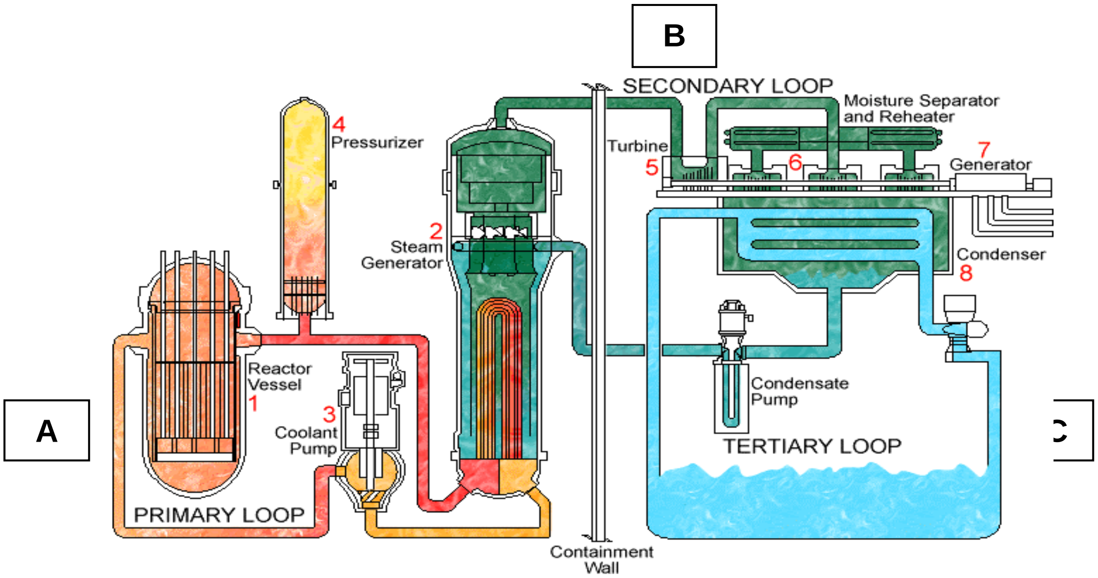
B. Secondary loop

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

The generator produces 940 MW (sent out) of electricity. 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 the Koeberg Power Station:

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

Reactor vessel (1)

The reactor vessel is 13 m high and 25 cm thick. Inside the reactor vessel is the nuclear fuel where fission takes place. All internal surfaces of the vessel are clad with stainless steel to avoid corrosion.

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.

The control rods: The control rods contain material that regulates the rate of the chain reaction. If they are pulled out of the core, the reaction starts or speeds up. If they are inserted, the reaction slows down or stops. A boron solution is added to the coolant to slow down the reaction. Boron is eradiated out of the system to speed up the reaction.

The coolant: A coolant, i.e. water, is pumped through the reactor to carry away the heat produced by the fission process. This is comparable to the water in the cooling system of a car, which carries away the heat, built up in the engine.

The moderator: A moderator, also the coolant water, slows down the speed at which neutrons travel. This reduction in speed actually increases the opportunity to split the U-235 atoms, which release heat and radiation energy.

Steam generator (2)

The steam generator is designed to withstand the changes from cold to hot operating conditions. Particular care has been given to corrosion conditions. The reactor water flows through a series of u-tubes inside the steam generator. Once the water has given off its heat it leaves the u-tubes and is returned to the reactor. There are three steam generators in each of Koeberg's units.

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

Pressuriser (4)
The pressuriser maintains the primary loop pressure within prescribed limits. When the pressure has to be increased, electrical heaters are automatically switched on and a certain amount of water is turned to steam. When the pressure has to be decreased, cold water is sprayed through sprayers located in the top of the pressuriser, which condenses a part 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 rate of 1 500 revolutions per minute (rpm). As the steam expands through the various stages of the high-pressure turbine, the steam pressure and temperature 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. The turbines are connected by means of a shaft to a generator. Koeberg's turbines are the largest in the Southern Hemisphere.

Generator (7)
Each generator can produce a maximum of 970 MW of electricity. The combined output of Koeberg's two units is 1940 MW (sent out). The length of the generator is 14 meters. A stator and a rotor make up the generator. Each of the two generators is coupled to the high voltage indoor switchyard (increases/decreases voltage) via transformers.

Condensers (8)
After the steam has been used to drive the turbine, it flows down into the condenser where a third circuit, utilising seawater, pumped in at a rate of 40 tons per second (40 000 litres per second) per unit cools and condenses the steam back to water. The condenser is designed to ensure that the steam or water, called the condensate, does not come 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).
Select the "About electricity" and "Facts and Figures

Produced by: **Corporate Affairs Division: Communication and Stakeholder Management**
NU 0001 Revision 10 (March 2018)