GSTM Lecture Series
The Fukushima tradegy – is Koeberg next?
Presented by Prof Johan Slabber




UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Graduate School of Technology Management

24 March 2011 • 24 Maart 2011 • 24 Matšhe 2011

Theme and Objective of Lecture

The recent events at the Fukushima Nuclear Plant in Japan that followed the massive earthquake and tsunami have been one of the major focus areas in all the news bulletins up to now. A number of the messages in the media conveyed rather conflicting opinions that served to confuse rather than clarify what was, and still is happening.

This lecture will serve to explain what happened at Fukushima starting from the generic basic principles on which reactor technology is based and will show what is currently happening at Fukushima is rather well predictable given the current boundary conditions surrounding the plant. Some features of the Koeberg Nuclear Power Plant will be explained which will serve to highlight its capability to handle these types of external events.

Date: 24 March 2011
Time: 18:30
Venue: Sanlam Auditorium, University of Pretoria
RSVP: By 23 March 2011 with Chantelle van Rensburg
E-mail: chantelle.vanrensburg@up.ac.za
Tel: 012 420 5179

A map to the venue is attached for your convenience. Please note that due to construction activities on the University grounds you will not be able to access the UP Conference Centre via the Main Gate in Lynnwood Road. Alternative entrances are suggested and indicated on the attached map. Also please note that parking is extremely limited and it is suggested that you arrive timeously.

Summary of Lecture

Background

Nuclear fission power is produced when the nucleus of an element, usually Uranium splits into parts and in the process releases a relatively large amount of energy. In a nuclear reactor this phenomenon takes place in a part of a nuclear reactor called the reactor core. The splitting process in reality forms new combinations of particles that make up the nuclei of the products that result and consequently elements are created that are radically different from the original Uranium. These elements are called fission products and are normally very radioactive. Radioactivity can be seen as the release of excess energy from a very excited nucleus and as the energy is released the degree of excitation decreases. This phenomenon is generally known as radioactive decay. Therefore the release of energy in a fission reaction does come at a price; and the price is the creation of very radioactive fission products. It is a design objective for any reactor to provide successive barriers around the fuel material to inhibit the release of these highly radioactive fission products to the environment. The energy released by the radioactive decay of the fission products is deposited by re-absorption in the core and surrounding structures. When the reactor is operating this heating is less than 10% of the reactor power. However when the reactor is shut down and the fission energy is reduced to practically zero, the heating from the absorption of fission product radiation energy becomes the main source of heating in the core as well as in used fuel elements that might have been discharged from the reactor core.

However during accident conditions where cooling of the fuel is abnormal; there are two sources of heating in the reactor core and used fuel elements that need to be considered. Firstly it is the fission product radiation heating and secondly it is the heating due to an exothermic chemical reaction between the Zirconium in the fuel cladding material and its surrounding environment. In addition to the heat generated by this reaction, in the order of 500 cubic meters of hydrogen per ton of Zirconium oxidized is produced. It is therefore clear that if the fuel heats up to beyond a certain value the integrity of the fission product barrier is challenged by two synergetic heating processes accompanied by the production of an amount of hydrogen depending on the mass of Zirconium consumed in the process.

It is therefore clear that sufficient cooling must be available to keep the fuel elements cold enough to safeguard against degradation of the primary fission product release barrier, in other words the Zirconium cladding, during all modes of operation as well as when the reactor is in a shutdown state.

The Fukushima Incident

In the design requirements of power reactors external events that may have an impact on the safety of the reactor are always stipulated for a specific site.

It is accepted practice to design for an earthquake of a certain magnitude and the possibility of flooding. For sites along the sea this requirement then normally includes tsunamis of certain intensity and flooding elevations.

From the sketchy information released by the Japanese authorities, it is appears as if the tsunami flooded and damaged the cooling water intake equipment and structures of all four reactor units. This could have resulted in a total loss of main heat sink for the heat generated in the cores of three units and the unloaded fuel from the fourth unit as well as older fuel stored in the fuel storage pond of all four units. The heat generated by only the fission products one week after shutdown by one unit is roughly estimated as 6.5 MW. The plants seem to have survived the earthquake and the diesel engines, that need to supply power in the event off a loss of off-site power to the cooling systems, started. Then forty minutes later the tsunami knocked out all off-site power connections as well as the diesels. Batteries took over but died after some hours. With no power they couldn't get water anywhere.

It is clear from the reports that eventually the power supply was restored to some extent but since a sufficient source of reactor-grade cooling water was unavailable they have decided to use sea water directly on the heated fuel elements and structures. But, the time consumed in getting this operation going seems to have allowed the overheating of the fuel elements and the production of an explosive quantity of hydrogen due to the chemical reaction. From the television footage that was shown it is clear that explosions occurred at the facilities which blew off some cladding material used at the top of these reactors. This does not necessarily imply that the reinforced concrete buildings that act as last physical barrier against release were damaged.

The question now is what can be expected in the days to come? An answer to this question is based mainly on speculation but some clear indicators already exist. The hydrogen explosions suggest that the cladding tubes which are supposed to contain the fission products are degraded. Degradation will most probably result in an increase in the release of radioactivity into the building environment. If the ventilation system is operational then one can expect some degree of filtration and dilution of the concentration of the radioactivity. However some of these radioactive fission products are of a gaseous nature and some are even noble gases. If they manage to maintain cooling for the next months or even years the radioactive releases will diminish, if not …?

The Koeberg Design

All the nuclear reactor facilities in Japan are built close to the notorious "ring of fire". In the case of Koeberg the situation is very different. Although the Cape is seismically very stable Koeberg was designed with substantial conservatism using for the design the Ceres-type seismic event on the 'Milnerton' fault as basis. This fault is nine kilometres off-shore. In addition, the nuclear island which consists of the Nuclear Steam Supply System (NSSS) and fuel building is supported on a large number of aseismic bearings specifically designed to reduce the peaks of horizontal building acceleration during the specified earthquake.

Although no tsunamis have ever been recorded on the West Coast the design of Koeberg included allowance for a three meter tsunami under the assumption that the tsunami coincides with maximum spring tide, a major storm surge and maximum wave height. This resulted in a total height of seven meters above mean sea level. The Koeberg terrace height is eight meters above mean sea level.

As a modification to the plant subsequent to the Three Mile Island accident, platinum-based hydrogen re-combiners were installed in the containment buildings of the two reactors to eliminate possible hydrogen explosions.

What is Radiation?

Radiation is energy carried away from an excited nucleus of radioactive elements. This energy can be carried by energetic charged particles or by electromagnetic radiation. Where this radiation interacts with a medium, energy is deposited. If the medium is a human being then, depending on the nature and quantity of the energy bearing radiation, the energy deposited can damage or kill cells.

The importance of safety in the nuclear industry is generally recognized and except for the use of radiation in medicine, strict standards for radiation exposure have been developed. This is fortunate, because so many of the devices of modern technology, such as accelerators, nuclear reactors, television sets, high-flying aircraft all represent potential sources of radiation exposure. Notwithstanding the accidents that have occurred in nuclear facilities so far, the nuclear industry, has contributed very little in the way of radiation injury either to its own personnel or to the general public.

Prof. Johan Slabber

Professor Johan Slabber is currently working in the Department of Mechanical and Aeronautical Engineering at the University of Pretoria where he is involved in giving the degree in Mechanical Engineering a nuclear flavour. Before joining the University he was the Chief Technology Officer at the company PBMR (Pty) Ltd.

In his earlier career he held the positions of General Manager, Reactor Technology at the Atomic Energy Corporation of South Africa (now Necsa), Chief Systems Engineer at the company Integrators of Systems Technology (IST) where he led a small team which completed the first conceptual systems design of a small Demonstration High Temperature Reactor. In 1994 he joined the Safeguards Department of the International Atomic Energy Agency (IAEA) in Vienna where he completed a contract period of 5 years before joining the company PBMR (Pty) Ltd in 1999.

He holds a Doctorate in Mechanical Engineering from the University of Pretoria and also studied at the Oak Ridge School of Reactor Technology in the United States.

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UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Graduate School of Technology Management

Universiteit van Pretoria • University of Pretoria • Yunibesithi ya Pretoria
Private Bag X20 Pretoria 0028 Suid-Afrika • South Africa • Afrika Borwa
Tel: +27 (0) 12 420 4111

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