VISIT TO THE MAINTENANCE AND TRAINING CENTER AT PAKS NUCLEAR POWER PLANT

Gábor Náfrádi
Institute of Nuclear Techniques (NTI), Budapest University of Technology and Economics (BME), Budapest, Hungary, nafradi@reak.bme.hu

ABSTRACT

The last official program of the Teaching Physics Innovatively (TPI-15) conference was a visit to Paks Nuclear Power Plant (NPP) in particular to the Maintenance and Training Center (MTC), with approximately 30 participants. The scope of MTC is the preservation of staff competence and training for any new activities in a non-radioactive environment. Besides this work, the MTC offers for the public guided tours for the better understanding of the basic nuclear processes and operational techniques of a modern NPP.

1. HISTORY AND IMPORTANCE OF PAKS NPP

Paks is a small town located in the middle of Hungary on the shore of the river Danube. Here is the Paks Nuclear Power Plant (NPP) [1] located, which operates 4 nuclear units from the 1980's. The type of the units is VVER440-213 [2] which denotes a Russian-designed Pressurized Water Reactor (PWR). The first unit produces electricity since 1982 and the youngest unit is in operation since 1987. The nominal electric power of the reactors was 440 MW, however, through the years the reactor powers have risen to 500 MW. The planned operation time of the units was 30 years, but thanks to the operation lifetime extension programs this period will be expanded by another 20 years [3]. The total power of the four units is 2000 MW, which covers approximately 50% [4] of the Hungarian electricity production and approximately 40% of the electricity consumption. Thus Paks NPP plays a very important and unique role in the Hungarian electricity market.

But why is it so unique? In our world the global warming and the reduction of the emission of greenhouse gases has become a major and urgent global problem. To solve this problem the use of renewable energy sources together with the nuclear power [5] could be the key, since the greenhouse gas emission during the normal operation of these technologies is zero. Modern countries around the world, for example the counties of EU agree that the greenhouse emission should be decreased step by step in the future. The use of nuclear power totally satisfies this modern demand.

To understand this claim we should explain the principles of operation of a NPP. In a NPP the energy is released from a nuclear fission reaction, in the particular case of Paks NPP, where enriched UO_2 is the material of the fuel, the following reaction releases the energy:

$$n + {}^{235}U \rightarrow 2 \text{ fission fragments} + \text{new neutrons} + \text{radiation} + \text{kinetic energy} \qquad (1)$$

The average energy that is released in one fission reaction is about 200 MeV. This energy is distributed as the photon energy and kinetic energy between the released particles. The

kinetic energy of the β particles and the fission fragments will be dissipated in the vicinity of the fission event (in the UO_2 matrix) while neutrons and γ radiation can very easily leave the fission fuel. After the thermalization of the new neutrons they can close the loop causing new fission events. This loop is also called nuclear chain reaction.

The Paks NPP is a PWR reactor which contains a huge amount of water. The water in this system has a double purpose: it is used as a moderator or neutron slowing material and water is also used as a coolant.

The moderator material is essential because only relatively slow neutrons, so-called thermal neutrons can cause easily nuclear fission in the ^{235}U, but the neutrons born in the chain reaction are with relatively high energies (~2 MeV).

As mentioned above, the fission fuel will absorb a great fraction of the released energy, thus it will be heated up, and it will transfer its heat to the coolant, the water. The water is circulated in a closed circuit through the reactor core (so-called primary circuit), where the typical temperatures are around 270 ^oC and 300 ^oC in the inlet and outlet points, respectively. For these high temperatures an increased water pressure is also needed to prevent the boiling of the water in the reactor core. The typical pressure in the reactor core is about 120 bar. The primary circuit can transfer its heat to another closed circuit called secondary circuit via a heat exchanger, so-called steam generator.

The pressure in the secondary circuit is much smaller, therefore a huge amount of hot steam will be generated, absorbing the heat transferred from the primary circuit. The steam drives the turbines and the turbines drive electric generators.

After the foregoing it is clear that NPPs do not produce greenhouse gases, and the clouds which are released from their cooling towers contain only evaporated water. In Paks the cooling towers are missing since the cooling of the closed secondary circuit is solved with fresh water from the Danube.

2. THE ROLE AND MISSION OF THE MAINTENANCE AND TRAINING CENTER

The Maintenance and Training Center (MTC) [6] is located at the Paks NPP site. The MTC is a unique place where the workers of the NPP can be trained and prepared for any kind of work in a non-radioactive environment since 1997. The spectrum of these trainings is very wide, from the occupational safety and health (OSH) trainings to the specialized maintenance works everything takes place here. But the MTC fortunately offers even more, there is the possibility for visitor groups to participate in guided tours. These tours introduce every aspect of the work on a real nuclear unit from the clothing and proper use of work protection techniques to the detailed working scheme of motors, pumps, armatures. Moreover, from the point of view of a visitor the MTC provides a unique opportunity to see and touch (or even crawl inside) a full-scale (original) steam generator and a reactor core. The reactor core contains every part of a real reactor except the nuclear fuel assemblies so the reactor tank, reactor shaft, control rod drives etc. These original reactor equipment were transported to Paks from a built but never used nuclear unit in Poland. During the guided tours the visitor can listen short presentations and they can ask questions according to their field of interest. While this is a non-radioactive facility of the NPP, it is ideal for visitors, where they can really see and learn how large and complex an NPP is. For a layman the visit of the MTC is advised after the visit of the Visitors Center.

3. THE ADVANTAGE OF A VISIT AT MTC IN PHYSICS EDUCATION

The traditional way of teaching nuclear physics or nuclear techniques in Hungary is mainly based on strong theoretical education or hands-on trainings with small isotope sources, but there is no chance for real application-oriented training, or to experience the real industrial scale of modern nuclear facilities. This is also the situation in high school even during the higher educational training (except for a few specializations). However, Hungary is in a special situation because there are 6 nuclear reactors in operation: 4 NPP units at Paks and two smaller reactors at Budapest. There is an Experimental Reactor at the Hungarian Academy of Sciences (HAS), Centre for Energy Research (EK) and the Training Reactor at the Budapest University of Technology and Economics (BME).

For nuclear physics and technology education the training on the two units at Budapest is essential, however, these facilities cannot introduce the industrial scale applications to the students. Therefore, even for university students it is a great opportunity to visit the MTC and experience the real industrial environment for their own. This type of visit is periodically organized for mechanical engineers and physicists, where Hungarian students and also students from abroad (Slovakia, Brazil, Vietnam) can participate.

For high school students the visit of the MTC can be even more beneficial. Many physical education topics are related to NPP and the electricity production process, for example mechanics, thermodynamics, nuclear physics, electrodynamics, etc. During a visit it is easy to demonstrate how physics is working in real life applications from all of the above mentioned topics.

4. DESCRIPTION OF A VISIT

For the visit a prior appointment is necessary, which can be done through the Information and Visitors Center of the NPP. It is recommended to devote at least 2-3 hours or more for a visit if a visit to the Information and Visitors Center or to the Museum of Nuclear Energy is also included. Visiting groups over 16 year of age can visit the power plant's operational area as well, then a longer time is needed. The standard maximum size of a visiting group is 40 people, this group size is ideal for a secondary school class. Catering can be organized at the NPP's canteen.

During a visit in the MTC the visitors can look at some 1:1 scale original primary and secondary circuit components, the same types that are in use at the Paks NPP: The visit includes a hands-on experience with the steam generator and the reactor vessel. The guides who are active trainers at the maintenance center kindly answer any kind of NPP- or MTC-related questions. During the tour teaching aids, nameplates of components and even film screening helps the better understanding of the ongoing physical and operational processes of the NPP. The attendance is free of charge.

5. SAFETY ISSUES TO EXPERIENCE

The safety issues used in a nuclear power plant have significantly high importance during the operation. This is one of the keys to the operation without accidents, incidents or malfunctions. Nuclear power plants use the concept of defense in depth, which means every system is redundantly installed and the reactors are inherently safe. To understand this concept visitors can see every safety barrier to prevent the release of radioactive materials to the environment. The first barrier is the fuel ceramics matrix, which retains fission products in the fuel itself. The second barrier is the fuel cladding, which encloses the fuel in zirconium-alloy tubes. The third barrier is the primary circuit itself, and the last barrier is the airtight reactor building called box or containment. To experience these safety concepts is useful even

if the students won't choose a related profession in the future, because generation of fear and rumors increasingly appear in the media.

SUMMARY

During the last day of the TPI-15 conference a visit to Paks NPP, in particular to the Maintenance and Training Center took place, where the participants could experience the advantages of such a training center in physics teaching on their own. During a few hours of guided tour several physics area are brought up in the explanation of the basic operational processes of the NPP which can be extremely fruitful for secondary school students. This type of visit is ideal to experience the complexity of an industrial facility but keeping always in foreground the underlying physical processes and the most important aspects of nuclear safety.

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An areial view of the Paks NPP with river Danube in the background (source: [1])

The main buildings of the Paks NPP (source: [1])

Vessels in the NPP that the visitors can touch or even crawl inside (source: [1])