NUCLEAR EDUCATION AND TRAINING COURSES AS A COMMERCIAL PRODUCT OF A LOW POWER RESEARCH REACTOR

H.BÖCK, M.VILLA, G.STEINHAUSER
Vienna University of Technology/Atominstitut
Vienna
Austria
boeck@ati.ac.at

1. INTRODUCTION

The TRIGA II Vienna reactor was constructed during the period of 1959 to 1962 and designed for basic and applied research in the field of academic university training. At that time most of the TRIGA reactors were built in a power range between 100 to 250 kW with a standard set of scientific irradiation facilities; equally the TRIGA Mark II is equipped with the following devices :

— 5 reflector irradiation tubes;
— 1 central irradiation tube;
— 1 pneumatic transfer system (transfer time 3 s);
— 1 fast pneumatic transfer system (transfer time 80 ms);
— 4 neutron beam holes;
— 1 thermal column; and
— 1 neutron radiography facility.

In the irradiation tubes of the reflector region, ten containers can be irradiated simultaneously. In the central irradiation tube, samples up to 38.4 mm in diameter can be exposed to neutrons at a neutron flux density of 10^{13} $cm^{-2}s^{-1}$, while the pneumatic transfer system allows the transfer of materials to be activated into the reactor from a chemistry laboratory and back again after the required period of irradiation without the experimentalist having to leave his working place. The four neutron beam tubes permit extraction of neutron beams of all energies into the reactor hall for the purpose of neutron and solid state physics experiments. The thermal column is used to extract neutrons with a thermal spectrum into the reactor hall. Unlike the beam holes, the space between the reactor core and the hall is in this case filled with graphite to slow down the neutrons.

The neutron radiography facility is used to investigate components by neutron irradiation, a method similar to X ray radiography. However, neutrons show especially hydrogen or neutron absorber material in solid matter. All these scientific devices have been used extensively during the past 48 years resulting in about 1000 MS and PhD graduates as well as approximately 3400 refereed publications and numerous conference contributions. During the past eight years, an increasing demand for practical training in the nuclear field was observed, which will be described in the following chapter.

2. COMMERCIAL TRAINING COURSES IN THE NUCLEAR AREA

During the normal academic curricula at the Vienna University of Technology (VUT) two practical courses are offered as eligible courses for students which are:

— Practical Course on Reactor Physics and Kinetics; and
— Practical Course on Reactor Instrumentation and Control.

Each course covers about 30 hours of practical work including experimental preparation, measurement, data evaluation and final reporting. In the early days, all the textbooks were only available in German, but two decades ago and due to many foreign guest scientists, the textbooks were also translated into English. As the Atominstitut is the closest nuclear facility to the IAEA, many fellows from all over the world have spent several weeks or months at the ATI during their training. Having returned to their home institute, they promoted the capabilities of the ATI, which resulted later in requests of bilateral cooperation, expert services or further training.

In the late 1990s, additional EU projects were initiated concentrating on the formation of nuclear staff for new reactor programmes. This period coincided with a lack of students in the 1980s and the retirement of the reactor staff of the 1960s. The need of educating and recruiting qualified nuclear staff was imminent, and the demand increased for qualified training places with a training reactor.

At that time the Atominstitut was ready to fill the gap and to offer its services by applying acquired knowledge and experience with practical training courses. The content of the two major courses was flexible to take the special requirements and the nuclear background of the course participants into consideration, therefore the overall course can be tailored exactly to the group's special interests.

3. EXAMPLES OF EXPERIMENTS

Following is an overall list of exercises which may be combined to meet the training groups' interests:

1. **Thermal neutron flux measurement:** Thin Au foils are irradiated in the TRIGA core at 10 W radially and vertically, both Cd-covered and uncovered. From this Cd contrast measurement, the radial and axial neutron flux distribution is determined.
2. **Influence of void coefficient on reactor power:** At 10 W reactor power a small container with different air volumes is pulled axially through the reactor core while the reactor is in automatic operation mode. The influence of volume and position in the core on reactivity is determined.
3. **Critical experiment:** Ten fuel elements are removed from the reactor core and consecutively reloaded; the neutron count rate is measured after each step. At each step, measurements are performed with all control rods up and then down. Criticality is reached with all control rods up after the reloading of five fuel elements.
4. **Control rod calibration:** One control rod is calibrated by removing it stepwise from the critical core and measuring the resulting reactor period. From the in-hour equation the respective reactivity value is determined.
5. **Reactivity values of fuel elements in different core positions:** While the reactor is on automatic control with 10 W, from each of the five fuel ring positions one fuel element is removed. The loss of reactivity is compensated by the movement of the regulating rod. From the rod position difference and using the rod calibration curve, the reactivity value of fuel elements in different core positions can be determined.

6. **Reactor power calibration and temperature coefficient of reactivity:** The reactor is operated at 10 W, and rod positions and water and fuel temperature are noted. Then reactor power is raised to 100 kW, and again the values are noted. From the difference in rod position and fuel temperature the fuel temperature coefficient can be determined. Then the reactor is operated for 90 min only with convection cooling and the increase of water temperature is monitored. Comparing the temperature increase with the value from a previous e-calibration, the thermal reactor power can be determined.
7. **Demonstration of a prompt critical power excursion:** Due to the strong negative temperature coefficient of reactivity, TRIGA reactors allow prompt critical excursion to 1000 times the normal power mode without any damage to the core. This is demonstrated using a pneumatic rod which is removed promptly from the critical core. Typical power levels of 250 to 300 MW are reached for a time period of about 40 ms.
8. **Introduction into typical research reactor instrumentation:** An introduction to the instrumentation of the TRIGA Mark II reactor is given, and towards the end the participants will be able to start up the reactor to various power levels.
9. **Calibration of the nuclear channels:** The nuclear and temperature channels are calibrated according to given procedures, and alarm and scram settings are verified.
10. **Measurement of control rod drop times:** The three control rod drop times are checked according to given procedures, and the individual rod drop time is measured from different rod positions.
11. **Ion chamber operation:** A compensated ionisation chamber (CIC) is used to determine the optimal compensation voltage and to measure the A-V characteristics at different power levels.
12. **Fission chambers:** A fission chamber is used to set the discriminator between gamma and neutron signals and to determine the range of neutrons outside the core.
13. **Self-powered neutron detectors:** A self-powered neutron detector is exposed in the core centre, and its activation and decay is monitored. This allows for determination of the type of emitter material.
14. **NPP Simulator Program (PWR):** Using an IAEA simulator program for PWR type reactors, a cold start up is carried out, followed by power changes and selected incident simulation.
15. **Verification of the radiation level during reactor operation:** Using various radiation detectors the radiation field at different reactor areas are verified.
16. **Control rod calibration in the subcritical range:** The safety rod will be calibrated in the subcritical range by cross-calibration using the reactivity data of the regulating rod. In this case the safety rod is lifted in small steps from the zero position and the count rate increase is measured with a fission chamber.
17. **Safeguards mock-up inspection**
18. **Demonstration fuel handling**
19. **Gamma spectrometry with various fuel samples**

4. INTERNATIONAL COURSES

4.1. Eugene Wigner Course

The Eugene Wigner Course was established in 2005 in cooperation between the technical universities of Bratislava, Budapest, Prague and Vienna. A group of about 15 students was subdivided into four groups, starting together in Bratislava and then rotated among the involved technical universities. During this course they carried out practical work at three different research reactors, including theoretical lectures, and a final examination which was accredited by their home universities with 6 ECTS. During the last two years, financing of this course became very difficult, and the course was stopped, although the feedback from all participants was very positive.

4.2. Training course for the MTR+3I EU project

The Atominstitut took part in the above mentioned EU project together with about 25 other European research centres. The contribution of the Atominstitut was to prepare a practical demonstration training course for future reactor operators. This course took place in March 2009 with five international participants and was successfully accepted as a demo course by the EU.

4.3. Nuclear Technology Education Consortium (NTEC), UK

In 2007, the NTEC coordinated by the University of Manchester inquired if the Atominsitut could offer a one week academic reactor course for NTEC students. The contract was signed and since this time totally six courses (two per year) have been carried out, each course with six NTEC students. The course is credited by NTEC with 6 ECTS.

4.4. NPP staff from Slovakia

For several years, the Technical University of Bratislava has been involved in the re-training of the NPP staff of the NPPs Bohunice and Mochovce. Since Slovakia does not operate a research reactor and Bratislava is very close to Vienna, the Atominstitut was asked to take over the practical part of the training course, which has been performed six times since 2002.

4.5. Belgian Nuclear Research Centre courses

The Belgian Nuclear Research Centre in Mol, Belgium, is requested by the regulatory body to offer a re-training programme for their operators. In view of this task, the Atominstitut was asked to host in total 36 operators divided into six groups of six participants each to perform a course using experiments both from the standard reactor physics and kinetics course as well as from the reactor instrumentation and control course.

4.6. IAEA Junior Safeguards Traineeship Program

The IAEA recruits in regular intervals new safeguards inspectors, however, developing countries have complained that their candidates do not have the prerequisites to apply for this job. Therefore the IAEA initiated as far back as 1984 a biennial 9 month training course for about 6 technicians from developing countries, who are then in a position to apply for a job as safeguards inspector. The first practical part of this course takes place at the Atominstitut for one month every two years. In total about 120 junior safeguards trainees have passed through the Atominstitut.

4.7. Eastern European Research Reactor Coalition (EERRI)

In 2008, the IAEA initiated several research reactor coalition programmes to increase cooperation and utilization of research reactors in various regions. One region is Central and Eastern Europe, and therefore the Eastern European Research Reactor Initiative (EERRI) was created. The Atominstitut is part of this coalition, and one target of this initiative is to offer practical training to young professionals. Since the formation of EERRI two such courses have been carried out; the first course was coordinated by the Atominstitut in cooperation with the Institute Josef Stefan in Ljubljana, Slovenia, the Central Research Institute for Physics (KFKI) and the Technical University in Budapest, Hungary, while the second course was coordinated by Czech Technical University in cooperation with the Atominstitut and the Institute Josef Stefan. More courses are planned for 2011. Participants came from all over the world through IAEA Technical Cooperation projects.

4.8. Selected courses for IAEA Technical Cooperation projects

The Atominstitut hosts IAEA fellows for periods of one month to one year through IAEA Technical Cooperation projects. Since 1983, more than 200 fellows from all over the world have participated at highly specialised training projects. The fellows are attached according to their interest to one of the working groups. Experience shows that after their return to their home institute, long term relations and cooperation between the two institutes result as positive outcomes from these fellowships.

5. CONCLUSION

It has been shown that in particular a small university research reactor can be effectively used not only for standard training courses within the academic field, but it can also be used in a commercially efficient manner by offering education and training experience to other groups as mentioned above. Presently the TRIGA II Vienna reactor could host even more courses than the staff and reactor operation times allow.