Transactions

NEST[et]

NUCLEAR ENGINEERING SCIENCE AND TECHNOLOGY

Budapest, Hungary
4 - 8 May 2008

European Nuclear Society
Rue Belliard 65
1040 Brussels, Belgium
Phone + 32 2 505 30 54
Fax +32 2 502 39 02
E-mail ens@euronuclear.org
Internet www.euronuclear.org

ISBN 978-92-95064-05-8

These transactions contain all contributions submitted by 30 April 2008.

Experimental Facilities for Education and Training

Research Reactor Coalitions - Promoting Nuclear Education and Training

Ira N. Goldman[a], **Pablo Adelfang**[a], **Helmuth Boeck**[b], **Kevin Alldred**[c] **and Nigel Mote**[c]

[a] International Atomic Energy Agency (IAEA), Vienna, Austria

[b] Vienna University of Technology/Atominstitut, Vienna, Austria

[c] International Nuclear Enterprise Group, New Milford, CT and Alpharetta, GA, USA

Abstract. The IAEA, in line with its statute and mandatory responsibilities to support its member states in the promotion of peaceful uses of nuclear energy, has initiated new activities with the objective of promoting formation of coalitions of research reactor operators and stakeholders. The aim of this effort is to promote concrete examples of enhanced regional cooperation, to form networks of research reactors conducting joint research or other shared activities, and to form a voluntary, subscription-based, self-financed coalitions of research reactor operators. The objective is to increase research reactor utilization and thus to improve sustainability at the same time enhancing nuclear material security and non-proliferation objectives.

This paper will describe the Agency's efforts to enhance nuclear education and training in a number of IAEA Member States, including in Europe and Latin America, within the context of the Research Reactor Coalitions Initiative. The paper will recount activities undertaken since the beginning of 2007 to develop coalitions of research reactors to expand nuclear education and training activities, including transfer to developing member states of power reactor operator and other practical training courses that are already successfully implemented at a European research reactor. It will discuss ongoing activities to strengthen and expand nuclear education and training activities through research reactor coalitions involving research reactor operators in Austria, Argentina, Colombia, Jamaica, Mexico, and Russia, and other countriesamong others. It will also discuss how to including facilitate access to research reactor facilities for representatives of of countries and user organizations using nuclear science techniques in countries without research reactors.

1. Background

In order to continue to play a key role in the further development of peaceful uses of nuclear energy, research reactors need to be financially sound, with adequate income for safe and secure facility operations and maintenance, including planning for eventual fuel removal decommissioning.

Over the past several decades, trends in nuclear research have resulted in a more competitive environment for research reactors. In a context of declining governmental financial support, research reactors are increasingly challenged to generate income to offset operational costs, in many cases by seeking commercial sources of income. However, reactors operating at low utilization levels have difficulty providing the service availability and reliability demanded by many potential users and customers, Thus low utilization is itself a significant obstacle to increasing utilization, and thus improving sustainability

To address the complex of issues related to sustainability, security, and non-proliferation aspects of research reactors, and to promote international and regional cooperation, the Agency has undertaken new activities to promote Research Reactor Coalitions and Centres of Excellence. This integrates Agency regular and extra-budgetary funded program activities related to research reactors, national and regional IAEA Technical Cooperation projects, especially “Enhancement of the Sustainability of Research Reactors and their Safe Operation Through Regional Cooperation, Networking, and Coalitions” (RER/4/029) and “Nutritional and Health-Related Studies Using Research Reactors” (RAF/4/020; AFRA IV-12), and is also supported by a grant from the Nuclear Threat Initiative (NTI).

In the area of research reactor coalitions for nuclear education and training, the Agency has developed important contacts and working relationships with institutions involved in the well-established European networks on nuclear education and training, such as ENEN and NEPTUNO, that are discussed in other papers at this conference. The IAEA seeks to use these as models and resources for strengthening nuclear education and training in IAEA Member States in other regions.

The nuclear education and training activities being undertaken in the Research Reactors Coalitions Initiative are also complementary to a variety of other IAEA programmes and activities – such as enhancing nuclear knowledge and knowledge preservation, and for establishing the infrastructure required by potential new nuclear power countries – but the primary objective of this effort is to improve utilization, and therefore sustainability, of research reactors.

2. Concept outline

From the operational perspective, coalitions will facilitate peer group sharing of best practices, improve information availability to members, and reinforce/develop the operating disciplines of safety and quality control. From the business perspective, coalitions will provide support for strategic and business planning and improved market awareness, and so help to increase reactor utilization, generate additional revenues and justify additional governmental support.

From the public perspective, coalitions will have the opportunity to enhance the information available to help retain and build confidence in reactor operation.

A coalition, or network, of research reactors for education and training will share experience and concepts for training methodologies and courses, and allow training courses to be adapted or tailored to specific needs, for example language. It can also match user requirements to the expertise and equipment available within the coalition, potentially including access to, and optimizing the use of, specific capabilities available at different sites within the coalition.

There is not a “one size fits all” solution, coalitions can take several different forms according to the needs and capabilities of their members. Possible coalition variants include bilateral sub-contracting, joint venture or other supply arrangements between pairs of research reactors; informal peer group networks that can share best practice information;, and broad, formal coalitions that are capable of effectively marketing their members’ services and representing their interests in common, as well as setting standards for all members. It is expected that formal coalitions will also facilitate access by non-reactor owning countries/members, with financial subscriptions paid in return for access to reactor services, thus avoiding the new construction or operation of marginally supported reactors.

In most cases, it is envisaged that coalitions will not start with full scope implementation, but rather will develop from relatively modest starting points (e.g. involving two or three reactors/partners), and will evolve by expanding their scope of implementation as the confidence of the members, and their governments, increases. For example, a simple, bilateral backup supply arrangement may grow into an informal network, and eventually become a subscription-based coalition.

3. Concept benefits

A coalition is expected to have both specific and general benefits to participating research reactors. The specific benefits of a coalition will derive from improved strategic and business planning (using IAEA-TECDOC-1212 “Strategic Planning for Research Reactors” as a guide) and joint marketing of the services of its participant reactors (scientific/research activities and commercial products), with the coalition thus able to:

- Optimize the services offered on a geographical basis, and reduce operational costs.
- Make maximum use of expertise or equipment at a particular facilities, and perhaps enable particular facilities to specialize in services in which they could have a “comparative advantage.”
- Use the combined expertise of the participant facilities to best advise and serve their customers. This would help increase customer knowledge of, and access to, the radiation services, and support the customer with a more reliable and comprehensive customer service.
- Improve the utilization and sustainability of individual research reactors, and increase overall levels of demand to the mutual benefit of all market participants (suppliers and customers). Additional reactor utilizations would generate revenues, or help make the necessary justifications for additional local governmental support, thus improving sustainability. The additional funding could assist individual reactors to pay for operational, safety and security improvements.
- Develop a common methodology for calculating costs of reactor services to include spent fuel management and eventual decommissioning liabilities.
- Provide assistance to reactors planning or undergoing conversion from Highly Enriched Uranium to LEU including sharing of experience and planning expertise.
- Address needs of user groups without access to a research reactor in their Member State(s).

4. IAEA Activities and Progress

A. General

The Agency’s role is to serve as catalyst and a facilitator of ideas and proposals. Meetings held by the IAEA in August-September 2006 resulted in preparation of a grant request on research reactor coalitions which was submitted to the Nuclear Threat Initiative (NTI) and approved in October 2006. A parallel Regional Europe Technical Cooperation project was approved in November 2006 by the IAEA Board of Governors.

From October 2006-January 2007, the IAEA conducted informal consultations with a wide number of research reactor operators, commercial entities, research reactor irradiation services users, and other stakeholders. Approximately fifteen “notional proposals” for coalitions covering a range of subjects and virtually all geographic areas were initiated, which became the basis of the Agency’s initial activities in 2007. Following initial discussions with possible participants, several of the notional proposals were further elaborated and then became the basis for exploratory meetings in fall 2007.

From an early stage, a key IAEA partner in this effort has been the Atominsitut TRIGA reactor of the Vienna University of Technology, which is heavily involved in European nuclear education and training networks such as ENEN and NEPTUNO and also has a successful program of nuclear education and training activities for both academic and professional purposes.

B. Coalitions for Nuclear Education and Training

1. Argentina

The IAEA together with the Technical University of Vienna/Atominstitut (ATI) conducted a mission to Buenos Aires, Argentina on 22-23 October 2007 for discussions with the Instituto Dan Beninson (IDB) of the Argentine Atomic Energy Commission (CNEA) on establishing a coalition for nuclear education and training. Agreement was reached on a cooperative relationship between the ATI and IDB and action items were specified. IDB agreed to facilitate provision of Argentine experience in neutron noise and reactor kinetics measurements to ATI. Following the meeting, ATI provided information on its educational programmes and courses (e.g. manuals, schedules, course equipment, target groups). The IAEA made arrangements for the provision of IAEA-developed power reactor simulation codes to IDB. The IAEA will also facilitate the participation in 2008 of an IDB observer at an ATI power reactor operations training course at the TRIGA in Vienna as a first step in assisting IDB to enhance similar courses for nuclear power plant operators in Argentina.

2. Caribbean

An IAEA-ATI mission took place at Centro Nuclear ININ (Instituto Nacional de Investigaciones Nucleares), Mexico on 30-31 October 2007 for discussion of a Caribbean regional research reactor coalition. A preliminary agreement was reached regarding formation of such a coalition between the three research reactors in Colombia, Jamaica, and Mexico. This coalition is intended to serve as a regional resource for nuclear education and training, nuclear science, and analytical services for other countries in the Caribbean region that do not have research reactors. The focus of its activities will be on training and services for neutron activation analysis (especially for environmental applications) and for health physics and radiation protection. A draft "Practical Arrangement" to serve as the legal basis for the coalition is under review by the parties, a reactor operator certification course will be carried out by ININ for Colombian research reactor operators, and Jamaica has formulated a course on neutron activation analysis. It is envisaged that a regional workshop will be held late in 2008 or early 2009 to introduce the capabilities of the coalition to potential regional users.

3. Mexico

An IAEA-ATI mission took place in Mexico on 29 October at Centro ININ for discussions between ININ and the Laguna Verde Nuclear Power Plant. These discussions focused on establishment of practical power reactor operator training courses for Laguna Verde at the TRIGA research reactor at ININ. ATI presented information on the practical reactor operations courses that it presently offers to staff from Slovak, German, and U.K. reactor operators and institutions. A meeting protocol was agreed between the participants, and follow-up discussions later took place between ININ and Laguna Verde. As a result, ININ held a trial reactor operations training course at its TRIGA reactor 26-28 March 2008 for training managers of the Laguna Verde Nuclear Power Plant, and plans to offer the course regularly in the future for Laguna Verde personnel on a contractual basis.

4. Russia

IAEA and Russian experts held exploratory meetings on research reactor coalitions in Dmitrovgrad, Russia on 5-6 September 2007 and in Vienna on 13-14 December 2007. Meeting protocols were concluded that specified a number of possible areas for coalitions among Russian research reactors and/or with research reactors outside Russia, in particular for education in nuclear science and engineering. A mission was organized to Moscow and Obninsk, Russia on 12-14 March 2008 focusing specifically on coalitions for nuclear education and training. Visits took place to nuclear education and training centers and academies in Moscow and Obninsk and discussions were held with the Russian Federal Atomic Energy Agency (ROSATOM) Moscow Advanced Training Institute (MIPK), Moscow State Engineering Physics Institute (MEPhI), and the Central Institute for Continuing Education and Training in Obninsk (TsIPK).

The IAEA encouraged these institutions to collaborate in developing and offering training courses on 'managing nuclear research institutions and research reactors in a competitive environment' for Russian nuclear research institutes, research reactors and nuclear institutions in other Russian-speaking countries. Such training courses would build upon training activities that have already been conducted by these institutions. The IAEA stated that if a coalition of the relevant Russian institutes and other appropriate outside expert institutions were to offer a pilot course on this subject, the IAEA would organize a group fellowship to facilitate the attendance of managers operating Russian-origin research reactors in neighbouring Russian-speaking countries. It was also noted that such a course could serve as an initial step for the development of a future broader “Nuclear MBA” course that is of interest to ROSATOM.

5. Other

An IAEA organized Workshop on Advanced Strategic Planning for Research Reactor Coalitions (Europe region) was held in Vienna from 17-19 December 2007. The final report of the workshop contains suggestions from each of the participants regarding ideas for cooperation and collaboration with other research reactors and for concrete proposals for research reactor coalitions. These include a Nuclear Education and Training Coalition (potentially involving Armenia, Azerbaijan, Austria/ATI, Czech Republic/CTU, and Italy). The IAEA will be carrying out further efforts in 2008 in regard to formation of such a coalition.

The IAEA has also had discussions regarding cooperation with the Jules Horowitz Reactor (JHR) regarding support for training of scientists from countries involved in the JHR project.

5. Conclusion

The IAEA Research Reactor Coalitions Initiative had a promising start during its first full year of formal activity. The IAEA has successfully played the role of “catalyst” and facilitiator of ideas. As a result – and perhaps most importantly – the coalitions concept seems to be gaining international acceptance, with the term frequently used in international research reactor meetings and discussions. As further evidence of this, a number of countries and institutions have formulated and are developing on their own proposals for coalitions.

In particular, a number of cooperative relationships or nascent coalitions are under development to promote and enhance nuclear education and training. It appears that the coalition model can be utilized as yet another tool by the international community to strengthen nuclear education and training and to help develop nuclear scientists and technical staff to meet upcoming human resource requirements in nuclear power engineering, including research and development, nuclear medicine, nuclear safety and radiation protection, etc.

The IAEA will continue to work vigorously in the next years to further develop the cooperative relationships and coalitions for nuclear education and training cited and remains open to other suggestions and proposals from other Member States and institutions.

FUTURE OPERATION OF THE 37 YEARS OLD HUNGARIAN TRAINING REACTOR

DR. ATTILA ASZÓDI
Budapest University of Technology and Economics, Institute of Nuclear Techniques
Műegyetem rkp. 9, H-1111 Budapest – Hungary

ABSTRACT

At the Budapest University of Technology and Economics a pool type training reactor of 100 kW nominal power has been operating since 1971. The Institute of Nuclear Techniques as the operator of the reactor and the reactor itself play an important role in the higher nuclear education and research in Hungary. The first generation of the reactor staff was retired during the last few years therefore a special program was started for renewing the operational and educational staff. In 2006 and 2007 the Periodic Safety Review had to be done. The paper describes the facility itself and the recent actions in human resource management and knowledge management, and also the new safety analysis methods which were applied during the recent Periodic Safety Review.

1. Introduction

The share of the four Paks NPP units in the Hungarian electricity production is 38%, which properly indicates the importance of nuclear energy in Hungary. In the early 60's, one decade prior to the start of the construction of the Paks NPP, the country began to prepare for domestic nuclear technology and the preliminary steps for commissioning of the training reactor were also taken. The construction at the Technical University of Budapest was started at the end of 1966 and was finished in 1971, the first criticality was reached in the same year in May. The training reactor has been successfully serving Hungarian nuclear expert education and technical education of physicists, engineers and teachers for the last 37 years.

Hungary prepares for extending the lifetime of the four VVER-440/213 type units at the Paks site; if this project succeeds, those units will finish the operation between 2032 and 2037. Discussion on possible construction of new nuclear units in Hungary was recently started. Both lifetime extension and construction of new units require continuous nuclear expert supply. The training reactor may provide a good basis for this purpose. On the other hand the further operation of this facility for the next two decades requires renewal of different technical systems and the generation-change of the operating and educational personnel.

In 2006 and 2007 the Periodic Safety Review (PSR) was carried out in the training reactor. In June 2007, the Hungarian nuclear safety authority issued the operating license for the next 10 years based on the PSR report. During the PSR study the safety of the reactor was re-evaluated, the development of a new 3D neutron kinetics code was started, and modern Computational Fluid Dynamics (CFD) methods were applied for performing the safety analyses of the special (aluminium-coated, magnesium and uranium-oxide mixture filled) EK-10 fuel for LOCA and RIA transients.

2. The training reactor

The training reactor is operated by the Institute of Nuclear Techniques (NTI) of the Budapest University of Technology and Economics (BME). The training reactor is a Hungarian designed pool-type reactor located at the university campus (see Fig. 1.).

The reactor core is made up of 24 EK-10 type fuel assemblies, which altogether contain 369 fuel pins. The fuel is 10%-enriched uranium-dioxide in magnesium matrix. The UO_2-Mg mixture is inside a 1.5 mm thick aluminium cladding, the active length is 50 cm. The total

mass of uranium in the core is approximately 29.5 kg. The horizontal reflector is made of graphite and water, while in vertical direction water plays this role. The highest thermal neutron flux – $2.7*10^{12}$ n/cm^{2}s – was measured in one of the vertical irradiation channels.
Seven neutron measurement channels are used for reactivity control and power regulation. The detectors are ex-core ionization chambers, two of which operate in pulse mode in the start-up range, four operate in current mode and one is a wide range detector. In all power ranges two independent doubling time and power level signals can initiate automatic reactor trip.
The reactor is only operated when student laboratory exercises or research activities require it. Operation at 100 kW power level for many hours is quite rare; usually it occurs once a week during the semesters. This results a very low burn-up: only 0.56% of the initial ^{235}U content has been used up and 3.4 g ^{239}Pu and 12.3 g fission products have accumulated. Therefore, there has been no need to replace any of the fuel assemblies since 1971. Strict water chemistry regime has been maintained in the reactor pool in the last four decades, therefore no corrosion problem of the aluminium surfaces has been observed during the annual visual inspections.
The training reactor is the scene of reactor operation exercises for undergraduate and graduate students and also serves as neutron- and gamma-radiation source. Irradiation of different samples can be carried out with two pneumatic dispatch systems, with 20 vertical irradiation channels and 5 horizontal beam tubes. The reactor has radiochemistry, neutron- and reactor physical laboratories, as well as laboratories for radiation protection measurements. Extensive research work is going on in the institute and at the training reactor too.

Figure 1. The reactor building and the reactor core at nominal 100 kW power

3. Education in the training reactor

The most important part of the undergraduate education is supporting the education of engineering-physicists at the BME. The NTI holds the nuclear-related courses of the engineering-physicist faculty. The main fields of the courses are reactor physics, thermal hydraulics, nuclear safety, radiation protection, nuclear measurements and instruments and radiochemistry. The education of other engineering faculties (mechanical, chemical, electrical) is also supported by the NTI. The NTI performs educational activities for other Hungarian universities as well.
Due to the transformation of the Hungarian higher education, the former university education strategy will be transformed into the two-cycle BSc and MSc educational concept. The former engineering-physicist education will be replaced with the Physics BSc and MSc education (Faculty of Natural Sciences) with an increased number of students. The Nuclear Engineer specialization of the Energetic Engineer BSc-education (Faculty of Mechanical Engineering) has increased the number of students since 2006 as well. The starting of nuclear related engineering MSc course is in progress too.
The main fields of the post-graduate education are the PhD school and the post-graduate training course for nuclear reactor engineers. The NTI hosts the reactor-physical and nuclear

technical parts of the Physics PhD School of the Faculty of Natural Sciences. There are about 10 PhD students – with state-financed or self-financed scholarship – engaged in research activities at the NTI.
In addition, the post-graduate nuclear reactor engineering training has an increasing popularity. In 2006 a record number of students (36) applied for and was admitted to the training. The number of students increased due to the planned extension of the operating license of the Paks NPP. The nuclear reactor engineer education has a 40-year history at the NTI, but the interest in the course fell down following the start of the commercial operation of the Paks NPP units. The training program has an essential role in the lifetime-extension project since the number of the well-trained professionals is decreasing significantly due to retirement at the NPP, authorities and technical support organizations.
The institute participate also in the ENEN (European Nuclear Education Network Association), aim at the integration of the European nuclear education. The first and most successful course of the ENEN is the Eugene Wigner Course for Reactor Physics Experiments, the main emphasis of which is to perform reactor physics experiments to enhance the knowledge of the students in nuclear engineering and reactor safety [1]. Three research- and training reactors in three different countries (Vienna – Austria, Prague – Czech Republic, Budapest – Hungary) are concerned with this course. The 21 day long course was first started in 2003. In the last 4 years 58 participants from 12 countries accomplished the course. The participants are mainly MSc students but PhD students and young experts can be found among them as well.

Some typical measurement exercises in the training reactor (see Fig. 2.):

- Neutron activation analysis
- Determination of thermal neutron flux in the reactor core using neutron activation analysis
- Determination of the thermal neutron flux axial distribution in the core
- Investigation of delayed neutron parameters, determining of uranium concentration in samples
- Reactor operation exercise
- Measurement of the void coefficient and the control rod reactivity worth
- Measurement of thermal neutron diffusion length in graphite
- Criticality experiment
- Measurement of gamma- and neutron dose rate

The utilization of the training reactor and its laboratories is quite high due to the different education programs. Beside the regular university education there are about 2 to 3 thousands of secondary school students visiting the reactor annually, which helps the secondary school teachers in the basic nuclear physics education.

The reactor is used, among others, in the following research fields:

- Activation analysis for radiochemistry and archaeological research
- Analysis of environmental samples
- Determination of uranium content of rock and other samples
- Biomedical applications (BNCT)
- Nuclear instrument development and testing
- Experiments in reactor physics and thermal hydraulics
- Development and testing of neutron tomography methods for safeguards purposes
- Development of noise diagnostic methods
- Investigation of radiation damage to instruments/equipment
- Radiochemical analysis of different samples supporting the Hungarian Atomic Energy Authority in fight against illicit trafficking of nuclear and radioactive materials.

Figure 2. Student exercise in the control room and with the pneumatic dispatch system

4. Human resource management and knowledge transfer

The colleagues who were participated in the start-up of the reactor and assured the safe operation of the reactor during the first three and a half decades are now retired or preparing to retire. Their replacement requires a special program which has been planned and was implemented in the last 3 years. In the most important positions the number of employees was doubled in 2 years in order that the young colleagues could work together with the experienced ones day-by-day. This ensures the most effective transfer of special operational and maintenance knowledge. The young experts have successfully obtained their licenses for reactor operation and they are able to operate the reactor alone.

For a more effective technical knowledge transfer a modern, computer-based 3D CAD model has been developed based on the 40-45 years old drawings. This has been proved to be effective from more viewpoints:

- differences between many old drawings and the implementation have been revealed;
- the young employees could learn reactor construction in a more effective manner through the problems arisen during the development of the 3D CAD model;
- there are up-to-date drawings which may be continuously updated according to the future modifications of the reactor.

A long-term technical development plan was also outlined to ensure the extended operation of the reactor.

5. Renewal of the technical systems

During the last 3 years the following main actions were made at the training reactor:

- Refurbishing a part of the ventilation system;
- Renewal of the pneumatic dispatch system;
- Restoration of the classroom in the reactor building;
- Application of state-of-the-art 3D reactor-physical and thermal hydraulical simulations in the safety analyses;
- Building of a new document archive for old and new safety reports, procedures, manuals, research reports and books;
- Development and use of a modern intranet site serving general information source for the reactor operators and the collective of the institute;
- Actions for the conservation of collective knowledge.

6. Periodic safety review

In 2006 and 2007 the Periodic Safety Review (PSR) was carried out for the training reactor. The volumes of the Periodic Safety Review report [2]:

0. General Evaluation
1. General Description of BME Training Reactor
2. Equipment Qualification
3. Safety Analyses

4. Aging Management Program
5. Safety Performance
6. Use of Operational Experience and Research Results
7. Procedures
8. Organization and Administration
9. Human Factors
10. Radiological Impact on the Environment
11. Investigation of Compliance with the Hungarian Nuclear Safety Regulations
12. Emergency Response Plan of BME Training Reactor
13. Utilization of BME Training Reactor and its Experimental Equipments
14. Experimental Results

We have very limited information about the material, thermo-physical, mechanical and geometrical properties of EK-10 type fuel elements which were produced in the sixties in the Former Soviet Union. Although the previous safety analyses made in 1997 contained detailed power excursion and LOCA calculations, these calculations were based on several uncertain thermo-physical and mechanical parameters.

For this reason we recalculated the behaviour of the EK-10 fuel rod in the worst case power excursion accident and LOCA scenarios. The thermal-hydraulic processes were investigated by the three dimensional CFX code and the connecting stress analyses were performed with the COSMOS FEM code.

To reduce the effect of the thermo-physical and mechanical parameters' uncertainty from the calculations, we are planning to develop an experimental apparatus to measure the thermal conductivity, specific heat capacity at constant pressure, density and thermal expansion coefficient of UO_2-Mg fuel as a function of temperature.

Based on the above described PSR the Hungarian Atomic Energy Authority has issued the operating license for further 10 years. However, different safety enhancement activities and further analysis have to be made in the next 3 years. During the PSR the development of a new 3D neutron kinetics code was started, and modern Computational Fluid Dynamics (CFD) methods were applied for the safety analyses of the special (aluminium-coated, magnesium and uranium-oxide mixture filled) EK-10 fuel for LOCA and RIA transients.

7. Summary

In the paper a general overview of the activities at the Hungarian Training Reactor was given. The replacement of the reactor staff and the critical systems were started in the last years. After the Periodic Safety Review in 2006 and 2007 the following main steps are planned for the near future:

- Renovation of the radiation monitoring system and the connected data acquisition computer;
- Reconstruction of the safety and control rod drives;
- Renewal of the nuclear measuring chains;
- Preparation for spent fuel transportation and possible replacement of the core;
- Refinement of the decommissioning plan;
- Further analyses for Design Basis Accidents, further developments of safety analysis methods and codes;
- Enhancements of operational manuals and regulations.

The further operation of the training reactor at least until 2027 is planed.

References

[1] Dr. Csaba Sükösd: The "Eugene Wigner Course": an example of international cooperation, Workshop on Managing Nuclear Knowledge, 22-26 August 2005, Trieste (Italy)

[2] Dr. Aszódi Attila, et al.: Periodic Safety Report of the BME NTI Training Reactor, January 17., 2007, BME NTI Report, 500-045-I/2007

THE CZECH NUCLEAR EDUCATION NETWORK ASSOCIATION (THE ROLE OF TRAINING REACTOR VR-1 IN NUCLEAR EDUCATION IN THE CZECH REPUBLIC)

KATOVSKÝ K., KOBYLKA D., MATĚJKA K.

Department of Nuclear Reactors, Czech Technical University in Prague,
V Holešovičkách 2, 180 00 Prague, Czech Republic;
Tel: +420 283 072 387, Fax: +420 284 680 764, E-mail: karel.katovsky@fjfi.cvut.cz

The paper is dedicated to the memory of Prof. Karel Matějka, Ph.D., the founder and the first president of the Czech Nuclear Education Network Association, the training reactor VR-1 project leader and the founder and head of the department, who unexpectedly deceased on the 13th March 2008 at Prague.

ABSTRACT

In according to present European and worldwide activities, Department of Nuclear Reactors initializes an idea of CENEN – "Czech Nuclear Education Network", national institution which aims its effort to nuclear education in Czech Republic. Association is based on principles of ENEN – "European Nuclear Education Network Association" founded as part of 5th European Framework Programme. The main objective of the CENEN (as well as ENEN in European level) is the preservation and further development of a higher nuclear education and expertise. This idea should be realized through the co-operation between Czech universities involved in education and research in the nuclear engineering field, research centres, nuclear industry and regulatory body. CENEN promotes and further develops the collaboration in nuclear engineering education of academicians, engineers and researches; ensure the quality of nuclear engineering education and training.

1. Introduction

The Czech Nuclear Education Network Association was established on 5th May 2005, as a voluntary academic association developing education and training in nuclear engineering in the Czech Republic. The CENEN has 12 academic members – departments of Czech technical universities offering nuclear education and 4 associated members – institutions of Czech nuclear industry, research and development, and legislative offering practical experiences and professional excellence. Association progress is still in developing phase, main goal is knowledge and education materials exchange, experimental facilities for education sharing, collaboration framework definition; members are preparing first joint summer/winter school of nuclear engineering in 2008 now. At the present date the CENEN academic members are The Czech Technical University in Prague (specializing in nuclear reactor theory, dosimetry, nuclear chemistry, waste management, nuclear heavy machinery and mechanical engineering, and power electrical equipments for NPP's), The University of West Bohemia in Plzen (nuclear mechanical and power electrical engineering), The Brno University of Technology (NPP's operation, nuclear mechanical and power electrical engineering), The VSB-Technical University in Ostrava (nuclear mechanical engineering), and The Institute of Chemical Technology in Prague (nuclear chemistry and waste management). The associated members are The Nuclear Research Institute at Rez plc (leader in Czech nuclear R&D), The CEZ plc (energy producer, operator of two Czech NPP's), The SKODA JS plc, member of the OMZ group (nuclear heavy machinery producer and NPP's designer), and The State Office for Nuclear Safety (state regulatory body). The CENEN organization is shown in figure 1.

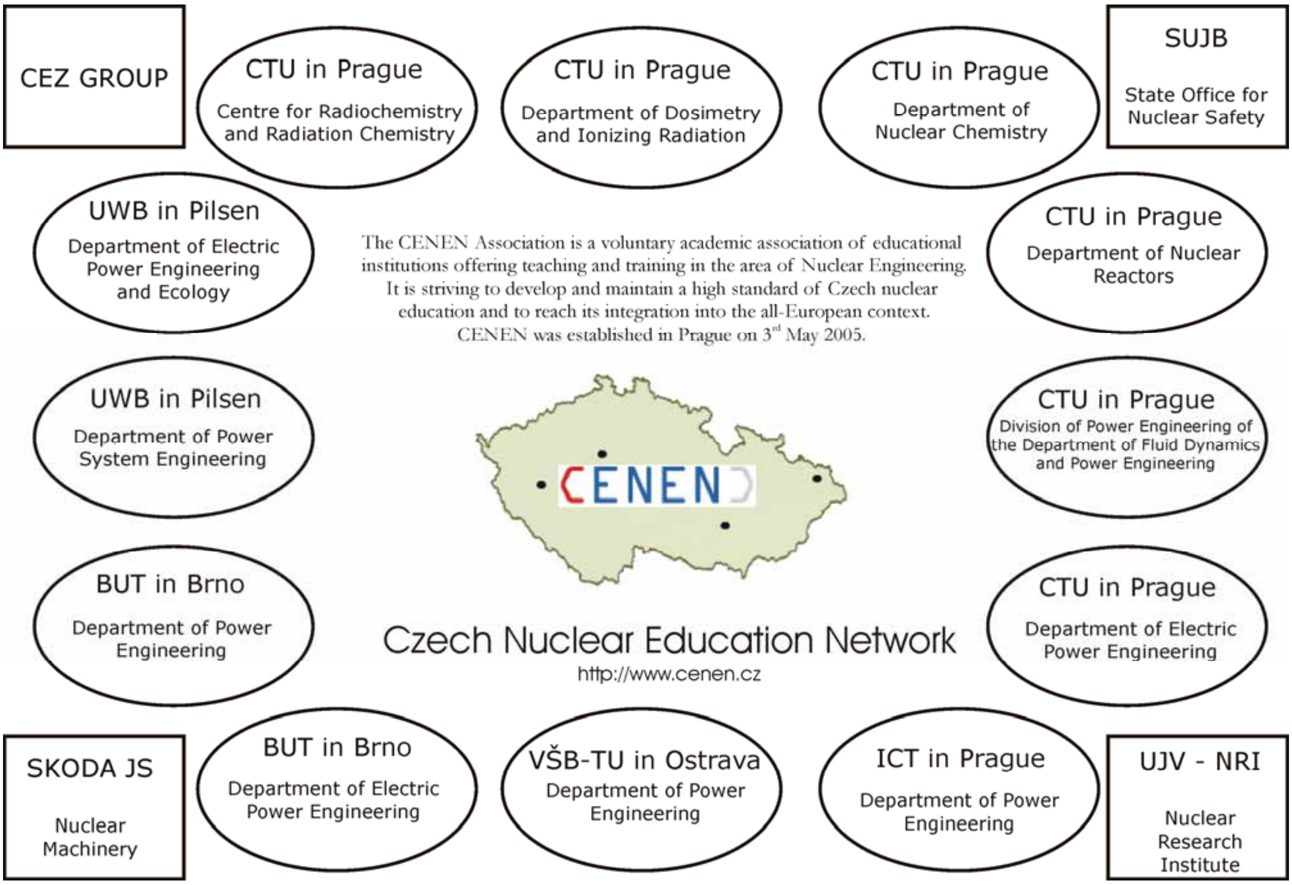

Fig.1: Scheme of the CENEN organization

2. The VR-1 reactor

Present basis of CENEN collaboration is in common utilization of the training reactor VR-1, which is operated by the Czech Technical University in Prague, Department of Nuclear Reactors. The VR-1 reactor has been in utilization from 3rd December 1990. It is a pool zero power reactor and is based on the Czech project using Russian IRT fuel. Maximal thermal neutron flux is 1E8 $n.cm^{-2}.s^{-1}$. There is no burn-up of the fuel. However, during its operation the fuel was two-times changed. In the middle of 90's IRT-2M fuel was changes to IRT-3M fuel, both with 36% of enrichment. In 2005 within the RERTR programme fuel was renewed to IRT-4M type with 19.7% of enrichment. The VR-1 was the first completely converted research reactor on the world with this type of fuel. After the 2005 there were two years of modernization. New independent power measurement and operation power measurement systems were installed. Both systems are completely digital. New technology systems, dosimetry and monitoring systems, as well as security and HMI were put into the operation. The area for students was enlarged, so seven groups of two or three students can measure simultaneously. Special devices for students' exercises and tasks were also innovated - there are new devices for study of dynamical properties of reactor, void coefficient, delay neutron fraction measurement, etc. The reactor VR-1 was ceremoniously reopened on 3rd December 2007 by the President of the Czech Republic Prof. Václav Klaus. In January 2008 the reactor was approved by state regulatory body to the next 10 years of operation.

3. The role of VR-1 in the education within CENEN

For students from CENEN institutes (as well as for some other universities from Czech Republic, Slovakia, and Germany) are prepared courses of Reactor theory introduction, Research reactors operation, Reactor Dosimetry, Neutron and gamma dosimetry, Reactor dynamics, and other specialized courses. Courses may long for a day as minimum (two experimental exercises) or for couple of days. The specialized courses include reactivity measurement using various methods, void coefficient measurement, delayed neutron fraction measurement, neutron spatial distribution, reflector studying, etc. Students are also using the VR-1 for their Bachelor or Master Degree theses. Each year are served approximately 250 university students. The VR-1 reactor is also one of nuclear facilities where students perform their measurements during well-known Eugene-Wigner

Reactor Course. Training reactor VR-1 also serves as general public education device, training facility for future specialists of the CEZ's NPP's, and as a research reactor for irradiation and R&D.

Fig.2: View of the VR-1 reactor hall during ceremony of reopening after innovation

4. The CENEN plans

Essential aim of CENEN is increase attractiveness for nuclear engineering studies; open studies for wider number of students and incorporate Czech nuclear education into European network. Future objectives should be also definition of Czech Master of Science Degree in Nuclear Engineering (like European nuclear M.Sc. standard), promotion of exchange of students and teachers participating in the frame of CENEN network, and establishment of mutual lectures and training courses. Activity in founding national education network is also motivated by successful work of BNEN. The CENEN plans organize first summer school for students this year. The one week intensive course will be full of lectures and seminars from various very special nuclear topics. Students should obtain information which is not provided during standard lectures. The CENEN project partners also plan to share experimental facilities which provide regional universities, they are creating internal database of lectures, exercises, students' theses, mentors, peer reviewers, books, educational materials, etc. Partners plan to participate in European projects like ENEN, collaborate with Russian universities and research centres. Emphasis should be in cooperation with specialists from associated members, professionals from research and industry.

UTILISATION OF RESEARCH REACTORS IN EDUCATION AND TRAINING PROGRAMS ORGANISED BY THE ATOMIC ENERGY COMMISSION

F. FOULON
Atomic Energy Commission, Saclay Research Center, National Institute for Nuclear Science and Technology, Nuclear Engineering Training Unit, 91191 Gif-sur-Yvette, France
B. ALVADO
Atomic Energy Commission, Saclay Research Center, Department of nuclear reactors and facilities, Osiris reactor exploitation service, 91191 Gif-sur-Yvette, France

ABSTRACT

As a part of the French Atomic Energy Commission (CEA), the National Institute for Nuclear Science and Technology (INSTN) is a higher education institution that provides to engineers and researchers a high level of scientific and technological qualification in all disciplines related to nuclear energy applications, including nuclear reactor theory and operation. The adopted strategy is to complete theoretical courses and training courses on simulators by experimental work carried out on research reactors. We present here the utilisation of CEA research reactors for training courses organised by the INSTN.

1. Introduction

As a part of the French Atomic Energy Commission (CEA), the National Institute for Nuclear Science and Technology (INSTN) is a higher education institution under the join supervision of the Ministries in charge of Education and Industry. It has been created in 1956, when France decided to launch a nuclear programme, in order to provide to engineers and researchers a high level of scientific and technological qualification in all disciplines related to nuclear energy applications, including nuclear reactor theory and operation. Since 1956, the adopted strategy is to complete theoretical courses and training courses on simulators by experimental work carried out on experimental facilities located either at the INSTN or more generally on the CEA research Centres.

We present here this strategy and the utilisation of CEA research reactors for training courses on nuclear reactor operation. This use is illustrated by two experiments that are carried out on ISIS reactor as a part of a global program that include the control of sub-criticality during fuel loading, the approach to criticality, the control rod calibration, the measurement of rod worth by the rod drop technique, the study of the temperature effects, the role of the delayed neutrons, exercises on reactor operation and control, the operation of the neutron detection systems, and radioprotection measurements.

2. INSTN mission and strategy

The INSTN mission is to disseminate the CEA knowledge and know-how qualification in all disciplines related to nuclear energy applications amongst academic and scientific institutions as well as industry. The INSTN headquarter is located at the Saclay CEA Centre, 20 km South of Paris. It also has four branches set up in the CEA centres located at Grenoble, Cadarache Valrhô-Marcoule, and Cherbourg-La Hague.

Yet in 1956, a one year specialisation course, so called “Génie atomique”, was launched in order to provide engineers with a high level of qualification in nuclear engineering including reactor physics. This specialisation course has contributed to the qualification of up to 140 engineers per year since 1956. The number may exceed 150 engineers in the next years due to the strong need in nuclear engineers in the French industry.

In order to contribute to the development of the INSTN activities, between 1956 and 1960, it has been established that the institute should be equipped with experimental facilities in order to give students and future operating personnel a comprehensive understanding of the nuclear physics. It was also decided to use some of the experimental reactors on the different CEA research Centres to enlarge the INSTN capability.

3. Use of experimental reactors

For nuclear reactor engineering, the INSTN strategy included the fabrication of two facilities at the INSTN headquarter in Saclay. The headquarter was then successively equipped with a sub-critical assembly (URANIE) in 1956 and with an Argonaut reactor (ULYSSE) in 1961.

URANIE was constituted by a hexagonal assembly of 217 elements (natural uranium with a total mass of 2,5 tonnes) placed in a vessel filled with water and equipped with AmBe neutrons sources and neutron detectors. This facility was used until the 80's for neutron experiments in sub-critical states

ULYSSE reactor is an Argonaut type reactor with a nominal power of 100 kW that was especially designed for training courses. It was constructed between January and June 1961 and was started up in July 1961. From this date it was mainly used for training courses and experimental purposes until the decision to shut down the reactor, after more than 40 years of operation, was taken in 2003. At this time, the leading strategy of completing theoretical courses with training course was confirmed and it was decided to transfer the teaching activities to another experimental reactor, so called ISIS and located on the CEA Saclay Centre.

ISIS reactor is an open core pool type reactor with a nominal power of 700 kW. From 2004 until 2006, ISIS reactor, went through a major refurbishment of the control system in order to adapt the reactor to the educational and training activities (see "Training courses on ISIS reactor at Saclay research center, B. Alvado & F. Foulon, in this conference proceeding). This refurbishment included the development of a supervision software used to display different screens showing the evolution of chosen reactor parameters for each type of experiment done on the reactor. For training activities, the maximal power was limited to 50 kW according to its license renewed in 2006. After the restart of ISIS reactor in 2006, ULYSSE reactor was definitively shut down in February 2007 and the training activities were transferred on ISIS reactor in March 2007. Figure 1 shows the control room of the ISIS reactor were the training courses are carried out.

In parallel to this evolution of the training activities at the Saclay Centre, other experimental facilities have been used to carry out training courses on other CEA research Centres. In Grenoble, SILOETTE reactor, with a power of 100 kW, was used for training from 1973 until 2001, when the reactor was definitely shut down. In Cadarache, EOLE and MINERVE reactors, which are low power reactors (≤ 100 W), are still in use for training courses in the frame of the INSTN missions.

Thus, today three reactors are being used for training courses in the frame of the INSTN missions : ISIS reactor in Saclay and EOLE and MINERVE reactor in Cadarache. In 2007, about 100 training courses have been conducted on these reactors. Courses are typically carried out with a group of up to 10 persons and have a duration of 3 hours.

Figure 1 : Photographs of the control room of ISIS during a training course showing the control board of the reactor (left) and the projection of the supervision screen used to follow the evolution of the reactor parameters.

The training courses are addressed to a wide range of public including students from universities and from engineer schools, operators of research reactors (qualification of reactor personnel), professionals with interest in reactor theory and operation (operators, researchers, regulators, engineers, administrative staff), as well as teachers from undergraduate schools. For the later, this contributes to a diffusion of the knowledge and interest in nuclear sciences amongst the students at an early stage in undergraduate schools.

Depending on the trainees and on the associated pedagogic goals, the persons are following from 3 to 18 hours of training courses on nuclear reactors, either to have a global understanding and demonstration of reactor operation, or to study in details the various aspects of reactor operation. Two experiments carried out on ISIS reactor are presented in paragraph 4.

Future trend shows a strong increase in the need of engineers and operating personnel specialised in reactor theory and operation. Only in France, it is estimated that more than 5000 young students will have to be specialised in nuclear engineering for the need of the French nuclear industry in the next 10 years, increasing the need for training courses on experimental reactors.

4. Experiments carried out in training courses

We will review in this paragraph two experiments that are carried out in the frame of the INSTN educational and training activities. For each experiment emphasis is given on the safety of reactor operation.

- Control of the sub-criticality during fuel loading

The evolution of the counting rates N on the low level neutron detection systems is recorded during core loading with the last four fuel elements. The evolution of the inverse of the counting rate 1/N (when the neutron density is stable due to the neutron source) as a function of the number of fuel element is shown in Figure 2. The quantity of U5 and the position of each element added in the core are also indicated. On the left part of figure 2, the core configuration including the element position is given. The evolution of the neutron density is observed with a neutron detector in position BN1 (see Fig. 2).

According to the neutron kinetics, in the presence of a neutron source, the neutron density N in the sub-critical state reach an equilibrium that depends on the core reactivity ρ. Thus we have 1 / N ∝ - ρ / Sθ_c, with S the neutron flux of the source and θ_c the neutron lifetime at criticality.

1/N being proportional to - ρ, with ρ negative, the reactivity of the core is increasing and approaching zero (critical state) by negative values (since the reactor is still sub-critical) by the addition of the fuel elements. The observed 1/N variation strongly depends on the characteristics and position of the fuel elements.

The addition of the fuel elements in positions 31 and 21 induces a larger increase of the core reactivity seen by the detector placed in BN1 than the addition of elements in positions 84 and 82. This results form proximity effect : BN1 is much close to positions 31 and 21 and thus is more sensitive to the increase in neutron density by the addition of those two elements.

The curve also shows that the decrease in 1/N is not proportional to the mass of U5 added to the core. In fact the core is constituted with both new elements with a mass of U5 of about 457 g (n° 31 and 84) and used elements (n° 21 and 8 2) with burn up exhibiting values up to about 10^5 MWJ/T. The addition of the used elements not only results in an increase of the core reactivity, which is proportional to the mass of U5 introduced, but it also results in a modification of S in the previous equation. In fact we observe the increase of the S term contributes to a stronger decrease of 1/N than the addition of U5.

From the safety point of view, it is show that the criticality can be reached only by the addition of fuel elements. Since fuel elements have usually varying characteristics, criticality could be reached if the fuel loading plan is not correctly followed. Thus the evolution of the neutron density, through the neutron detection systems has to be strictly followed and analysed during fuel loading to detect any abnormal evolution of the core reactivity. This analysis has to take into account both the fuel element characteristics (mass of U5, burn up, position to the Be reflector) and the relative position of the neutron detection system to the fuel elements.

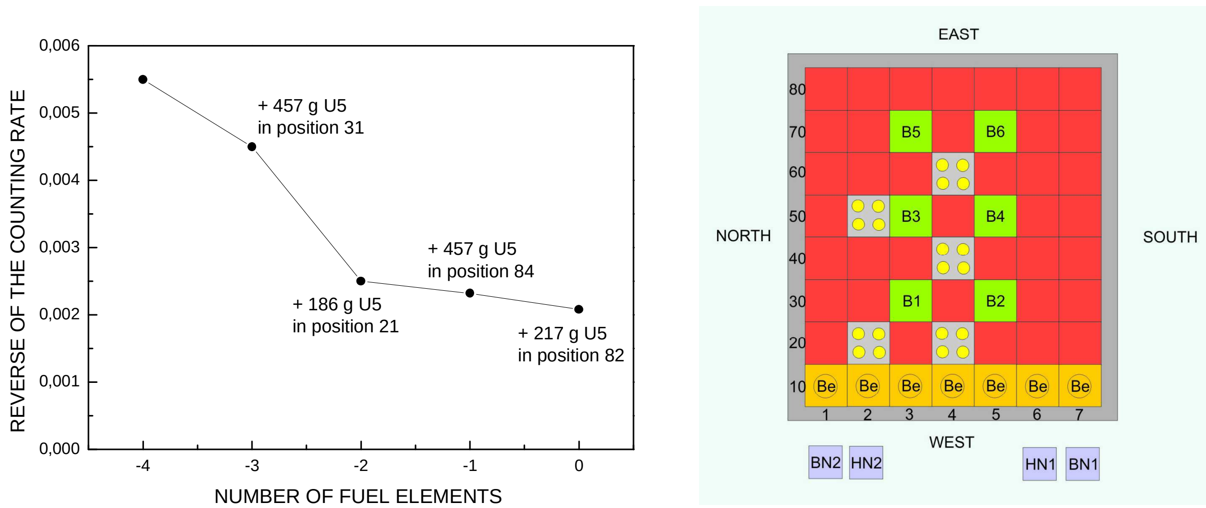

Figure 2 : Evolution of the reverse of the counting rate (when the neutron density is stable due to the starting neutron source) as a function of the number of fuel element missing in the core, and core configuration on the right hand side.

- Measurement of rod worth by the rod drop technique

The global worth of a rod can be measured by the rod drop technique. The reactor being critical with the rods B2 and B5 in their upper position (safety rods), B3 and B4 in the bottom position, B6 in its critical position and the rod B1 in its upper position, the rod B1 is dropped.

Following the drop the evolution of the neutron density in the core is recorded using the neutron detection systems BN1 and BN2.

From these measurements and using curves established from the neutron kinetic equations the global worth of the rod is found. Figure 3 shows the calculated curves giving the ratio $n(t)/n_0$, i.e. the neutron density at the instant t after the rod drop divided by the initial neutron density, as a function of the rod worth and for different time intervals after the rod drop (2 s, 4 s, …). From the data recorded on detection systems BN1 and BN2, the $n(t)/n_0$ values are reported in this figure. The global worth of B1 is then established : about 1190 pcm, seen from position BN1, and about 1790 pcm, seen from BN2 position.

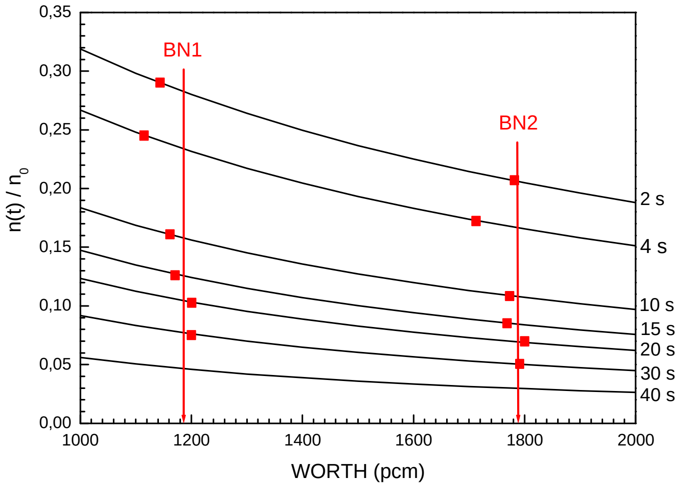

Figure 3 : Calculated curves giving $n(t)/n_0$, as a function of the rod worth, for different time intervals after the rod drop (2 s, 4 s, …) ; experimental data obtained on BN1 and BN2 detection system after B1 rod drop.

The B1 rod worth seen from position BN1 is lower than from position BN2 because BN2 is closer to the rod B1 so that the drop of B1 induces a larger modification of the neutron density around BN2 than around BN1. Thus the real global worth of B1 for the whole reactor core, i.e. the global worth is not affected by proximity effects, is closer to the value measured by BN1 than by BN2. Repeating B1 rod drop with B2 rod in its lower position, i.e. lowering the neutron density around B2 and thus BN1 before the rod drop, would have contributed to even decrease the global worth seen by BN1. From a practical and safety point of view, this experiment shows that the apparent global worth of a rod strongly depends on core configuration and on the position from which this worth is seen.

5. Conclusion

Since 1956, the National Institute for Nuclear Science and Technology provides to students, engineers and researchers a high level of scientific and technological qualification in nuclear reactor theory and operation. From this date, the adopted strategy is to complete theoretical courses and training courses on simulators by training courses carried out on CEA research reactors. The experience gained over more than 50 years show that this approach brings tremendous benefits. For students that can carry experimental work on research reactors, training courses on a reactor gives a great and unique opportunity to get an insight in the reactor kinetics and to get further interest in this domain of science and technology. For all trainees including the reactor personnel and regulators, the training courses ensure a practical and comprehensive understanding of the reactor operation and contribute to their qualification in this domain. Training courses also contribute to an improvement of the safety of the reactor operation especially when empathies are given to the impact of each operation and effect on the safety of the reactor operation, both in normal and incidental situations.

THE IAEA NETWORKS FACILITATING TRAINING AND DEMONSTRATION OF DISPOSAL AND DECOMMISSIONING TECHNOLOGIES

S. HOSSAIN, B. NEERDAEL, P. DINNER
Department of Nuclear Energy, International Atomic Energy Agency
Wagramer Strasse 5, P.O. 100, 1400 Vienna – Austria

ABSTRACT

Since 2001, the IAEA has been successfully operating the IAEA Network of Centres of Excellence for Training in and Demonstrations of Disposal Technologies in Underground Research Facilities (URF Network), which is showing to be a very effective and efficient vehicle for training of professionals in the field. Several Member States with operational underground research facilities have come together in a Network and are offering the use of their facilities for joint training and R&D activities to countries having less advanced programmes.

Using this positive experience of “networking” international efforts, the IAEA is planning to improve its response to the growing number and complexity of requests from Member States by introducing similar Networks in other activity areas. The International Decommissioning Network (IDN), launched in September 2007, is expected to play a pivotal role. Another Network to bundle international efforts in low level waste disposal area is also currently being developed.

1. Introduction

A continued focus of IAEA activities is to support Member States to secure and sustain human resources for the nuclear sector, by both replacing retiring staff and building new capacity. To fulfil one of its statutory functions the IAEA assists Member States, particularly developing ones, in their efforts to build and sustain nuclear know-how and training in all areas of nuclear technology for peaceful purposes. Emphasis is being placed on innovative approaches to facilitate the transfer of information and expertise among Member States in order to improve the response of the IAEA to the growing number and complexity of requests from the member States – at a time of budget and staff constraints.

Since 2001, the IAEA has been successfully operating the *IAEA Network of Centres of Excellence for Training in and Demonstrations of Disposal Technologies in Underground Research Facilities* for high level waste and spent nuclear fuel. In the frame of this Network, Member States with advanced geological disposal programmes and operating underground research facilities are offering the use of their facilities for joint training, research and development activities to countries having less advanced programmes. Experiences gained in the operation of these underground research facilities, and through associated experimentation and demonstrations are being transferred to the participating Member States through hands-on work in these facilities. This “networking” mechanism is showing to be a very effective and efficient vehicle for training of professionals in the field. Using this positive experience of networking international efforts, the IAEA is planning to introduce similar Networks in other activity areas, e.g. decommissioning and disposal of low level waste.

2. Network for Training in and Demonstration of Disposal Technologies in Underground Research Facilities (URF Network)

2.1 Background

The international community has been studying the geological disposal concept for almost 50 years. However, worldwide, there is only one geological disposal facility for long-lived radioactive waste that is in operation. For the last decades waste management specialists have been agreeing upon that geological disposal is the preferred option for the management of high level and long lived radioactive waste and spent nuclear fuel. Recent progress provides increasing assurance to the waste management community that sound technical solutions underpinned by good scientific investigation are available. Most of the technologies required for geological disposal have been developed, and work is continuing to complete the development of those technologies that still need to be demonstrated to assure that disposal can be effected. However, establishing public confidence in geological disposal is an important concern. Member States faced with the radioactive waste disposal issue are at various stages in the process. Some have selected favourable sites, have well-developed research programmes in underground facilities and have been given official government approval, backed by the public, to advance towards the establishment of a geological repository. Other countries are still in the earliest stages of site identification and discussion of the issue with the public. The development of underground facilities, in several countries, has been contributing towards moving from the theory to the practice.

In 2001, under the auspices of the IAEA, several Member States in which underground research facilities were operational came together in a *Network of Centres of Excellence for Training in and Demonstration of Disposal Technologies in Underground Research Facilities (URF Network)* and offered the use of their facilities for joint training, research and development activities with other Member States. These underground research facilities are extremely expensive to build and operate, and depend on international collaborations for funding. Historically, these collaborations had been between Member States with advanced waste management programmes. The IAEA-based Network embraces countries which have not got the resources to establish underground facilities to do the research needed to develop confidence in the concept of geological repositories for radioactive waste.

2.2 Objectives of the URF Network

Although, as stated above, geological disposal programmes in Member States are in various stages of development, construction of a geological repository for high level and spent fuel waste is not contemplated for at least a few decades in almost all cases. The IAEA URF Network is being developed with this time frame in mind, i.e. starting without delay, in order to assist lesser developed Member States, in a few decades to establish the broad and robust network of international expertise needed to ensure the efficient development of safe nuclear waste disposal systems worldwide.

The most important objectives are the following:

- To encourage the transfer and preservation of knowledge and technologies. While participation in current URF activities is the primary interest for some Member States and will be a benefit to all, many other Member States, especially developing countries, would need assistance for earlier phases of geological disposal studies.
- To supplement national efforts and promote public confidence in waste disposal schemes. Topical workshops and seminars may be organized, addressing important issues like monitoring and retrievability. Such activities could also be valuable in providing specialists new in this field with an understanding of both technical and non-technical issues that influence waste disposal technology.

- To contribute to the resolution of key technical issues. Member States can suggest any key technical issues of common interest as proposal for cooperative projects.

Thus, the URF Network provides a mechanism to ensure that Member States are appropriately aware of the latest state-of-the-art international technology in geological disposal. The Network helps to ensure that, as necessary, Member States have access to professional persons who are trained in the relevant disciplines, and part of an international community that serves as a platform to discuss matters of general concern. Thereby, the general public in each Member State should be assured that their professionals are both familiar with and capable of applying the appropriate technology to their own projects concerning the geological disposal of high level waste and spent nuclear fuel.

2.3 Membership

The Network consist of

- *Network Members,* who are owners of unique facilities in Member States, which can be recognized as Centres of Excellence having demonstrated high quality research and have offered their facilities to be part of the Network; and
- *Network Participants,* who come from any interested Member State, with or without an established programme for geological disposal but aware of the necessity of its implementation as solution for their high level or spent fuel waste.

The membership of the core group (who are Members) is dynamic, according to programme's development in Member States and availability of underground or even surface facilities. Since 2001, the core group of the Network has expanded from two facilities in Belgium and Canada at the beginning to include now almost all underground facilities and some supporting surface facilities in the following Member States:

- *Belgium* (HADES URF in Boom Clay Strata; SCK-CEN),
- *Canada* (Underground Research Laboratory – URL; AECL),
- *France* (Underground Test Facility, Tournemire; IRSN),
- *Germany* (Deep Disposal in Abandoned Iron Ore Mine Konrad; DBE Technology),
- *Sweden* (Äspö Hard Rock Laboratory; SKB),
- *Switzerland* (Grimsel Test Site in Granite and Mon-Terri URL in Clay Stones; NAGRA),
- *UK* (Geoenvironmental Research Centre; Cardiff University) and
- *USA* (Yucca Mountain Project, the Waste Isolation Pilot Plant and LBNL; US-DOE).

Recent inclusions of the Network are IRSN (France) and DBE Technology (Germany). Discussions are currently on-going to extend the Network further in 2008 to other Agencies, e.g. ANDRA (France) and JAEA (Japan). The underground research facilities allow for work to be carried out in major geological media, e.g. clay, crystalline, salt and tuff, in which geological repositories for radioactive waste are expected to be developed. These are complemented by well-equipped surface institutions in which desk and laboratory studies are carried out.

For those Member States with less well-developed infrastructures, there is the opportunity for their nationals and programme participants to undertake work in any or several of the Network's Centres of Excellence. Network Participants are regularly asked to express their needs over a period of several years. Being a long-term project, Participants' needs can be addressed over a long period of time consistent with a country's nuclear waste management programme. So far twenty-two Member States have taken advantage of the opportunities that the Network provides.

2.4 Role of the IAEA

The IAEA's Nuclear Energy Department coordinates and facilitates the activities of the Network and, otherwise, acts as Secretariat to the Network, including maintaining records of its activities in a web based platform. The IAEA promotes interactions between Network Members and Participants and coordinates the offers from Network Members with the needs expressed by Network Participants. In this respect the IAEA organizes annual Project Review Meetings in which Network Members and Participants report on their activities and define future action accordingly. The Network Members usually meet in a preparatory meeting ahead of the Project Review Meeting to discuss the proposals made by the IAEA Secretariat and the action plan.

The Department of Technical Cooperation of the IAEA plays a major role in supporting per year 2 to 3 training courses for 10 to 15 participants each and some fellowships and scientific visits for candidates from developing Member States hosted by the Network Members. In general, the Network Members provide both physical facilities and the experienced personnel for the training at no cost to the IAEA. This also provides trainees and fellows with a flexible and interesting learning experience and allows them to become more familiar with technologies, concepts and approaches of other countries.

Whenever possible, appropriate linkages between the Network and other IAEA implementation tools like the Coordinated Research Programmes are established to optimize approaches and resources. Cooperation is also looked for with activities of other international or regional programmes, e.g. those of EC.

2.5 Current status and future outlook

Till now, more than 150 candidates from over 20 countries have taken part in 12 training courses and many fellowships and scientific visits organized in Belgium, Canada, Czech Republic, Finland, Germany, Hungary, Sweden, Switzerland and USA. Three more courses will be provided in the second half of 2008 in Canada, Japan and UK.

Initially, the courses focused on the historical developments of underground facilities and on the associated fundamental scientific and technological aspects of geological disposal. Both the Participants and Members of the Network have subsequently agreed that the courses should be extended to include subjects such as numerical modelling and its development and validation through underground work and, more generally, aspects of societal acceptance in the development of geological waste disposal programmes. Further topics in this direction, e.g. performance assessment, site characterization, etc., have been suggested by Network Participants as response to a recent questionnaire survey. Currently, based on these responses and the offers of the Network Members, detailed programme for training and fellowship during the period 2009 – 2011 is under development.

The positive response by Member States to the activities of the URF Network over the past five years has demonstrated that the Project is providing important benefits that are not available through other avenues. Given the renewed interest in development of nuclear power, a declining availability and adverse environmental effects of traditional hydrocarbon resources, and rising international demand for energy, it is desirable that the Network Project should continue to build on what has been a very promising start. Continuation of the Network is entirely consistent with the IAEA mandate to ensure the safe and sustainable application of Nuclear Energy. Also the Network Project can contribute to the recognized requirement for nuclear knowledge maintenance and management.

Further information on the Network and its activities is available at the following website:
http://www.iaea.org/OurWork/ST/NE/NEFW/wts_network.html .

3. The International Decommissioning Network (IDN)

3.1 Background

Based on the success achieved with the International URF Network, a second network built on the same principles was launched by the IAEA Departments of Nuclear Energy, Nuclear Safety and Security, and Technical Cooperation during the General Conference in September 2007. It was followed by a Technical Meeting held at the IAEA in October, where the Terms of Reference, modus operandi and 2008 programme of work were finalized.

The need for this Network stems from the large number of nuclear installations, including power reactors, research reactors and many other fuel cycle facilities that have already ceased activity or are approaching the end of their operational lifetime and will need to be soon decommissioned. Many of these facilities are small and widely distributed geographically, e.g. more than 250 ageing or shut down research reactors. Appropriate steps need to be taken to prepare for their future decommissioning. In developing Member States, decommissioning programmes are often influenced by the availability of resources, i.e. knowledge, experience, infrastructure, funding capabilities and consequently, decommissioning strategies need to be tailored to cope with those constraints.

Those working in the decommissioning field have strongly endorsed the value of a more ‘hands on’ approach to the sharing of decommissioning skills and knowledge, particularly between experienced organizations with proven areas of excellence and those facing decommissioning challenges for the first time.

3.2 Mission and Objectives of the IDN

The International Decommissioning Network “strives to render decommissioning timely, cost-effective and safe through sharing information and guidance.”

Primarily organized along regional lines, the IDN aims to assist participants to take full advantage of the Agency’s established mechanisms for Technical Cooperation. In general, the IDN will fulfill the following functions:

- Support decommissioning of nuclear facilities in Member States, particularly those with less developed nuclear infrastructure, by providing access to decommissioning skills, knowledge and projects;
- Provide a mechanism whereby decommissioning organizations may exchange information under the aegis of the IAEA to pursue the promulgation of good practices and the longer term retention of knowledge relevant to decommissioning.
- The IDN will also provide specialist advice and technical guidance on the IAEA’s programme in the area of decommissioning – services such as “peer reviews” – which are expected to expand in response to the expressed needs of the participants.

In recent years the demand for assistance in the field of decommissioning has exceeded the Agency’s ability to respond in a timely and effective manner. In many instances, national organizations require similar types of assistance to get their decommissioning projects underway. A Regional Project in decommissioning, which has served the needs of decommissioning experts in the European Region for the past several years, has provided an excellent model for increasing the help participants can provide to each other. Furthermore, all participants, including those from Member States with developed decommissioning programmes benefit from the “networking” activities, since they also share perspectives and technical experience directly with each other.

3.3 Participation in the IDN

The IDN is open to all Member States and will be of interest to those engaged in or actively planning for decommissioning. The IDN forms a loose coordination "Net" for a number of existing "networks" forming in a sense a "Network of Networks" – for activities both within and outside of the IAEA, e.g. the DeSa Project (for safety assessment) and the R^2D^2 Project (for demonstration of research reactor decommissioning). Regional "hubs" centred around a real decommissioning demonstration project, offer a venue for "Participant" training and other forms of regional cooperation, while receiving assistance from "Members.

3.4 The role of the IAEA

The role of the IAEA follows closely the model established by the URF Network. By acting as a "catalyst" for events, stimulating Members to host events showcasing their unique capabilities and providing regular email "updates" on ongoing or planned activities in the field of decommissioning, the IDN can play an important role to extend the "reach" of regular decommissioning programme activities.

3.5 Current status and future outlook

The work to launch the first "events" under IDN sponsorship ("cost-free" to the Agency), building on an on-going Regional Project has begun in earnest, with initial events open to IDN participants, e.g.:

- Workshop on materials-management and clearance with ENRESA, 16-20 June 2008
- Group Scientific Visit to Mol for "size reduction of components for decommissioning of nuclear facilities", planned for October 2008
- The "Web presence" for the IDN has been established and continues to grow, e.g. through web-pages outlining current activities: http://goto.iaea.org/decommissioning; and click "web update"
- a regular e-mail "update" is issued bi-monthly
- Experiments with "on-line" topical presentations and discussions are being scheduled.

The work programme for the IDN will be reviewed and updated at the Annual Meeting (Forum) of the IDN, 5-7 November 2008. This forum will follow immediately on from a "lessons learned" session on the peer-review of MAGNOX decommissioning currently underway.

Programme evolution needs to consider balance of activities based on interests expressed:

- Emphasis on "Hands on" training and demos
- Highest interest in decommissioning of smaller facilities such as Research Reactors, Fuel Cycle facilities
- Over time, develop activities addressing the particular issues of smaller facilities such as medical or research laboratories
- Focus on topical areas reflecting inputs received (TM)

Also, the planning and hosting of activities needs to focus on regions where there is the greatest expressed interest, viz. Europe and Asia, with "seed" activities being held in Africa and Latin America.

4. International Low Level Waste Disposal Network (DISPONET)

Following the same approach of the two Networks described above, the IAEA is proposing to focus its support for low level waste disposal via a forum (Network) for a prompt, open and efficient transfer and exchange of knowledge gained through learning from the experience of others. The Agency wishes to support organizations, either currently engaged in or actively planning for disposal programmes, through their inclusion in a network to effectively cooperate and coordinate relevant actions.

Exchange of information on the development or the operational experience with existing facilities is expected to build credibility of the national disposal programmes of the recipient participants. The Network will also provide a forum to share approaches to specific issues such as disposal of a typical waste, e.g. graphite, radium and disused sealed sources. All will benefit from the best ideas put forward by the participants in the Network. Merging more informal exchanges together with programmed actions inside the Network is expected to increase the effectiveness and efficiency of the Agency's training and development work.

The Network is being established to increase efficiency in sharing international experience in the application of proven practices for disposal of low and intermediate level radioactive waste. In particular the IAEA intends to:

- coordinate support to organizations or Member States with less advanced programmes for disposal of low level waste, by making available the relevant skills, knowledge, managerial approaches and expertise from Member States with operating disposal facilities;
- organize an expanded range of training and demonstration activities with a regional or thematic focus providing hands-on, user-oriented experience and disseminating proven technologies;
- facilitate sharing and exchange knowledge and experience amongst organizations with advanced designs and disposal facilities in operation; and
- create a forum in which expert's advice and technical guidance may be provided on the Agency's programme in the area of low-level waste disposal.

The following is the tentative schedule to formally launch the Network:

- Consultants' Meeting, Vienna, 21-22 April 2008 to define the TOR, i.e. objectives, scope, method of work and road map of DISPONET, and identify potential Members and Participants.
- Technical meeting, Vienna, 28-30 October 2008 to formally launch DISPONET in presence of both Members and Participants.

5. Overall Observations and Conclusions

The development and increased use of "Network" concepts for training offered in waste management by the IAEA reflects both a response to pressure for more engaging and hands-on activities from Member State organizations, and a recognition that traditional means of offering services "one-to-one" cannot work in the expanding demands of the "nuclear renaissance". Approaches which seek to involve all participants in activities where they have a common interest, and to pursue "cross-cutting" opportunities between the various programme areas of the IAEA is beginning to pay dividends. These results are encouraging to both IAEA staff and colleagues (participants) from Member State organizations

DEVELOPMENT OF PC-BASED NPP SIMULATION PROGRAMS FOR TRAINING AND EDUCATION

DR. ATTILA ASZÓDI, ANDRÁS CSIGE,
DR. GYULA CSOM, DR. SÁNDOR FEHÉR
Budapest University of Technology and Economics, Institute of Nuclear Techniques
Műegyetem rkp. 9, H-1111 Budapest – Hungary

ABSTRACT

PC-based NPP basic principle simulators have been developed for over 15 years at Budapest University of Technology and Economics Institute of Nuclear Techniques (BME NTI) with two main goals: to provide the nuclear engineering education with tools capable to illustrate the fundamental physical processes of an NPP and to serve the regular basic retraining of the technical personnel of the NPP Paks (VVER440/213).
Our latest plant analyser is based on APROS which is a commercially available system code for modelling one-dimensional, two-phase flow processes in nuclear power plants and other industrial facilities.
A detailed APROS model of Paks Unit 3 (VVER-440/213) is under development at the BME NTI since 2000. The model contains the primary and secondary circuit with the emergency systems, the essential control and protection signals and the containment. The model was extended within the frame of a PHARE project, thus making capable to calculate beyond design basis accidents.

1. Historical overview

PC-based NPP basic principle simulators have been developed for over 15 years at Budapest University of Technology and Economics' Institute of Nuclear Techniques with two main goals: provide the nuclear engineering education with tools capable to illustrate the fundamental physical processes of an NPP and serve the regular basic retraining of the technical personnel of the NPP Paks (VVER440/213).
The development of the first simulator called PC^2 was started in 1988 for demonstrating the dynamic processes of the primary circuit. It was followed by an analyser program (STEGENA) for detailed studies on the thermodynamic and thermohydraulic processes going on in the horizontal steam generators of a VVER-440 plant. The next phase in the evolution was the development of a secondary circuit simulator (SSIM) in 1995. This program was written for MS Windows platform. The model describes the dynamic processes of the secondary circuit in quite fine details. The simulation extends for all the main components: steam generators, turbines, condensers and preheaters are all comprehensively modelled.
The latest version of PC^2 was released in 2000 also for MS Windows platform. This program can be used for demonstrating the main reactorphysical processes and the most important thermal-hydraulics processes in the six primary loops for educational purposes.
Elaborate educational conception and student exercises belong to all three simulators. Both the simulators and the educational aids have proven to be useful and effective in the course of retraining at Paks NPP and the nuclear engineering education at the Budapest University of Technology and Economics, as well.

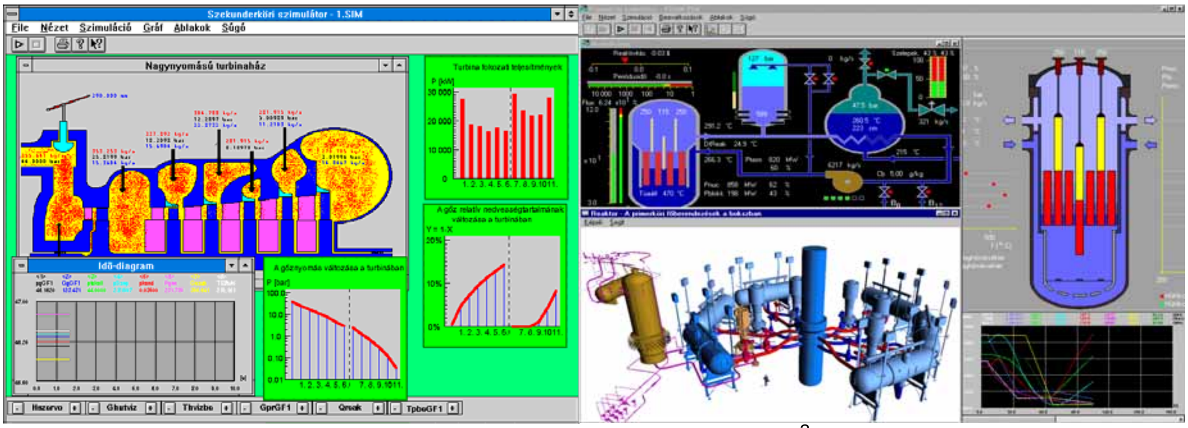

Fig. 1. Typical screens of the SSIM and PC^2 simulators

2. APROS model of Paks NPP

APROS (Advanced Process Simulator [1]) is basically a one-dimensional, two-phase thermal-hydraulic system code, similar to RELAP, ATHLET and CATHARE. Numerical models for one- and three dimensional reactor kinetics, automation and electrical systems, containment processes and core degradation are also available. The code package contains a graphical user interface (GRADES) and pre-built component modules (pressurizer, steam generator etc). APROS is developed by VTT and Fortum in Finland.
A detailed APROS model of Paks unit 3 (VVER-440/213) is under development at the BME Institute of Nuclear Techniques since 2000. The model was extended within the frame of a PHARE project, thus making capable to calculate containment processes and beyond design basis accidents [2].

2.1 DBA model

The model of the primary circuit contains the six primary loops, the reactor pressure vessel, and the pressurizer with the related control and protection signals. The model of the Emergency Core Cooling Systems (ECCS) contains the three independent trains of the active ECCS (high- and low pressure injection system), the four hydroaccumulators, and the related control and protection signals. The model of the secondary circuit contains the six steam generators with their steam- and feed water piping, the Main Steam Header, the two turbo generators, the condenser, the low- and high pressure preheaters, the feed water pumps, and the feed water tanks. The control and protection signals for the secondary circuit were built into the model too, with the auxiliary and emergency feedwater systems.

2.2 Containment model

The containment model of APROS uses a lumped parameter approach. The gas region is homogeneous mixture of non-condensable gases and steam. It was first used for modeling the Loviisa and Olkiluoto units, so the initial validation has been done for Westinghouse-type containment with ice condensers and for a typical BWR containment with a suppression pool. Before modeling the hermetic compartments and the passive pressure suppression system (bubble condenser tower) of a VVER-440/213 plant, the code was validated with EREC experiments.
In the current model of the Paks-specific VVER 440/213 unit the hermetic compartments are described with 24 nodes. The two halves of the steam generator (SG) room, the pump room, reactor pressure vessel cavity and ventilation center were modelled by one node each. Hermetic valve corridors, hydroaccumulator and pressurizer compartments and other smaller dead-ended volumes were modelled as one big “dead-ended” volume connected to both SG boxes. The connecting channel between the bubble condenser (BC) tower and the SG boxes was modelled as two identical nodes (the left and the right channel).
At the units the BC tower has 12 water trays for condensing the steam generated during a LOCA event. The BC tower has 4 air traps for capturing and holding non-condensable gases (3 water trays are connected to 1 air trap). In the APROS model the surface and the volume

of the 12 water trays are considered in 4 water trays. All 4 air traps are modeled in APROS. The BC tower was modeled with 16 nodes: 8 nodes for tower atmosphere and 4-4 nodes for water trays and air traps.

2.3 Severe accident model

The severe accident calculation package of APROS consists of four modules for calculating different physical processes related to fuel damage and core melting [1]. These modules are initialized and started in the model only after the maximum fuel cladding temperature reaches a preset value.

- GENFLO: thermal hydraulic model of the VVER-440 reactor pressure vessel. The calculation takes into account the degraded geometry of the core (swollen fuel pins, relocated fuel pellets etc.). The boundary conditions (pressures in and coolant injections into the downcomer and upper plenum) are provided by the thermohydraulic model of the primary loops.
- SARELO: model for simulating the degradation of the reactor core. This module describes the behaviour of the solid core structures from the solid state via relocation into the molten stage. The model describes the core overheating, oxidation, cladding melting, fuel relocation, control rod melting and finally fuel melting. Initially the materials are solid, but during the transient they can melt. The radiation and conduction heat transfer between zones are simulated. The chemical reaction between high temperature zirconium cladding and steam is also calculated.
- COPOMO: corium pool model simulating the behaviour of the melted core inside the reactor pressure vessel. It calculates transient behaviour of corium first on the core support plate, from which it relocates through the core barrel into the lower plenum of reactor pressure vessel. From corium heat is transferred into the surrounding steel structures of reactor pressure vessel or core barrel depending on the location of the corium. Due to the heat transfer part of the surrounding steel structures may melt and part of the molten corium may become solid again.
- FIPROMO: module for calculating the release, transfer and deposition of fission products. It keeps track of the fission product masses and decay heat production in each node of the simulation model. The fission products are divided into six independent groups depending on their chemical behaviour:

The events after reactor vessel failure (direct containment heating, molten core-concrete interaction) are not modelled in the current version.
The above described model can be used to simulate the whole NPP unit in design basis accidents and even in severe accidents until the molten core penetrates the reactor pressure vessel. The APROS code with the VIPROS visualisation system can be used for safety analysis in the case of design basis accidents.

3. The VIPROS visualization tool

A new visualization program called VIPROS (Visualisation for Process Simulators) was developed for the plant analyzer at BME NTI. VIPROS can use the output data file of any simulation software (RELAP, ATHLET, ASTEC, APROS etc.) for illustrating the thermohydraulic processes by plotting time diagrams and graphical animations. For this reason the VIPROS program is a suitable tool for understanding the complicated thermohydraulic processes, and it can be used not only in research and engineering but in education as well. The code is written in C/C++ using the open source FLTK toolkit. VIPROS is a cross-platform application: it was successfully compiled and run on MS Windows, Linux and Mac OS X. The present version of VIPROS is generated for the visualization of APROS severe accident simulation model of Paks VVER-440/213 unit developed in the frame of the HU2002/000-632-04-02 PHARE project [2].
Examples of VIPROS windows can be seen on Fig. 2 through Fig. 4.

- Fig. 2 shows the temperatures in the primary side (and steam generator secondary side) nodes. The status of the pressurizer (PRZ), Main Coolant Pumps (MCP1 through MCP6), HPIS pumps (TH10, TH20, TH30), LPIS pumps (TJ12, TJ22, TJ32), hydroaccumulators (TH50, TH60, TH70, TH80) are shown in this window. Some information about the secondary side also can be seen here: data about the SG valves, turbine bypass valves (KR), atmospheric relief valves (AR) etc.

- Fig. 3 is very similar to Fig. 2, but it shows void fraction in the nodes instead of the temperatures.
- Fig. 4 shows the temperatures in the confinement system (with numbers and color coding), and the status of the bubble condenser tower.

Complex thermohydraulic processes – which are very difficult to trace in a unit control room, or in a full-scope simulator, or even with time diagrams produced by system codes – can be visualized with VIPROS, for example two-phase flow in the primary loops, opening of loop seals, ECCS water injection, flashing in the core etc.

The APROS-VIPROS system is used for investigating different design basis and beyond design basis accidents (for example loss-of-coolant accidents with different break size and location). It is also used in university teaching.

4. References

[1] APROS documentation, VTT, Finland, 2005.

[2] Ismo Karppinen, Markku Hänninen, Ari Silde, Dr. Attila Aszódi, András Csige, Győző Fejérdy, Mika Harti, Eerikki Raiko. Development of the APROS nuclear plant analyser for the Paks NPP, Hungary. *Final report, PHARE project: HU2002/000-632-04-02*. 2005.

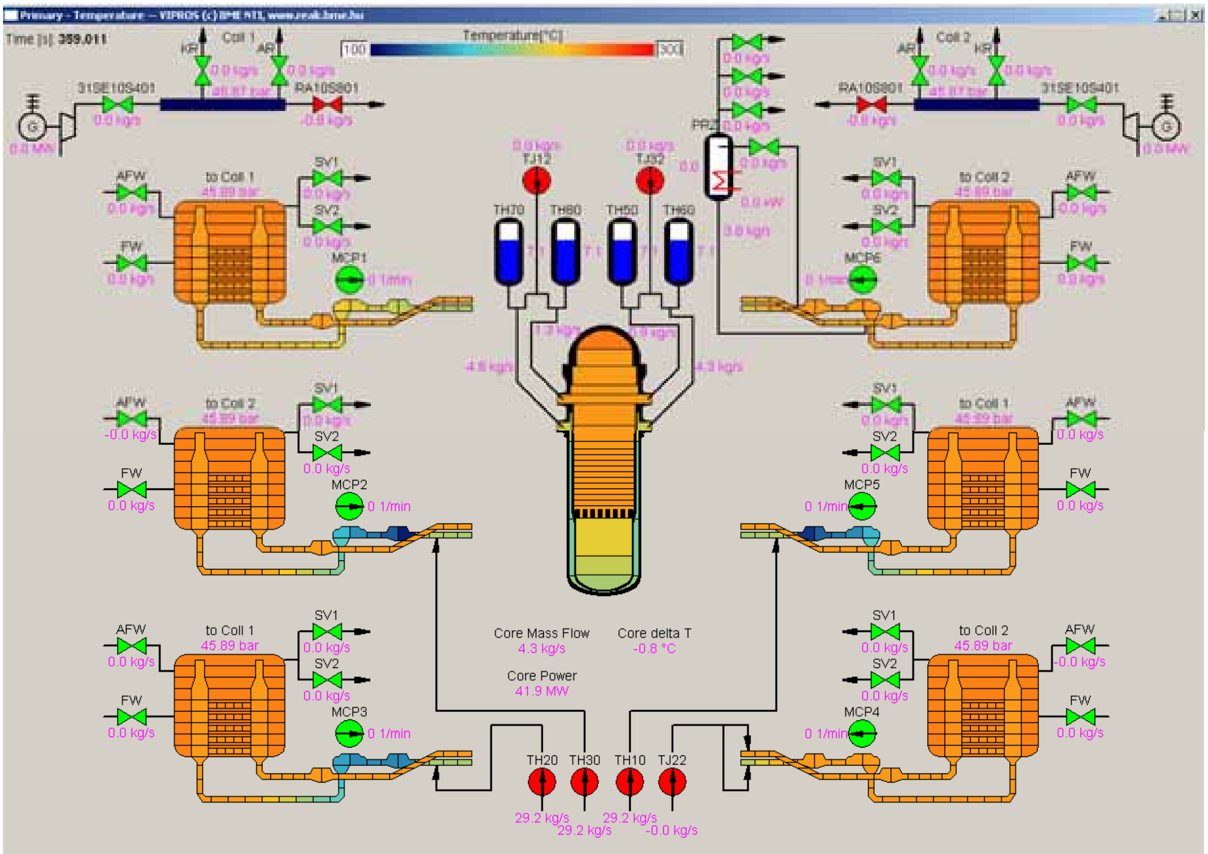

Fig. 2. Example of temperature distribution in the primary circuit nodes (VIPROS)

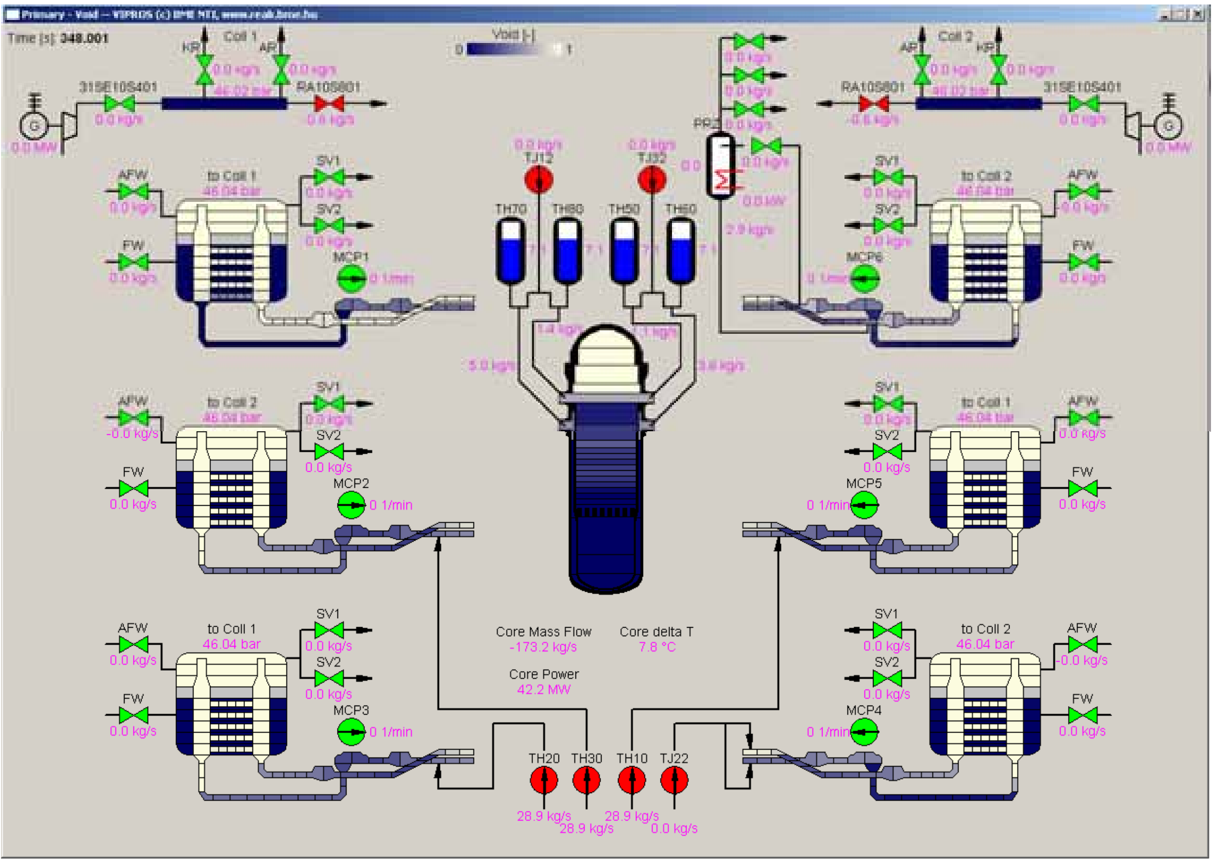

Fig. 3. Example of void fraction distribution in the primary circuit nodes (VIPROS)

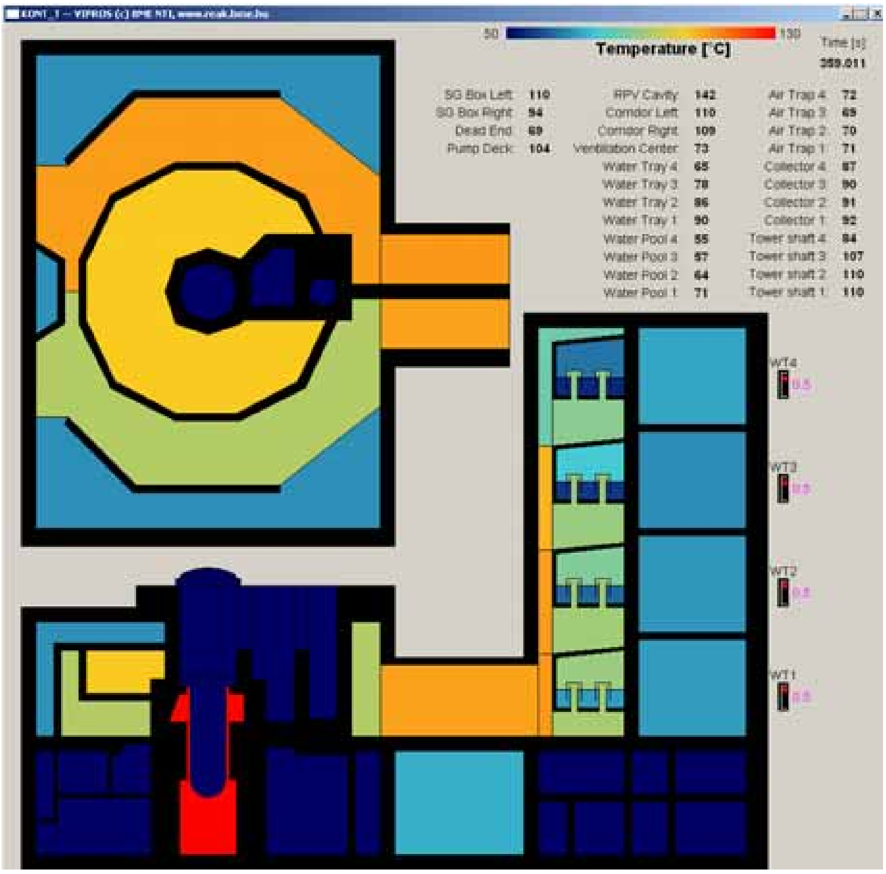

Fig. 4. Temperature in the hermetic confinement rooms (VIPROS)

JOSEF UNDERGROUND EDUCATIONAL AND TRAINING FACILITY

PETR SALÁK, JAKUB JANN
Centre of Experimental Geotechnics, Czech Technical University in Prague
Thakurova 7/2077, 166 29 Prague - Czech Republic

ABSTRACT

The Josef Underground Educational Facility (Josef UEF) is a new multidisciplinary facility employed primarily for the teaching of university students. Other activities include research and cooperation on projects commissioned by the private business sector. Almost 600 meters of renovated underground areas provide a wide range of research opportunities for young scientists involved in underground structures, geotechnics, geochemistry, engineering geology and material engineering. The facility is particularly suitable for work on experimentally oriented doctoral dissertations, students having the choice of either joining research projects currently underway or indeed, initiating their own projects.

1. Introduction

The Josef Underground Educational Facility (Josef UEF) is a new Faculty of Civil Engineering, Czech Technical University in Prague facility which opened in June 2007. The facility is located about 50km south of Prague near the Slapy dam close to the village of Čelina in the Příbram district. The Josef UEF is employed primarily for the teaching of students from the CTU and other universities. Other activities include research and cooperation on projects commissioned by the private business sector. The construction of the facility was inspired by a similar educational facility in the USA and by foreign underground laboratories. The combination of education and research as well as its multidisciplinary approach make the Josef UEF unique not only at the domestic but also at the European scale. The aim of this paper is to inform postgraduate students interested in underground construction, geotechnics and geology about the diverse opportunities provided by the Josef Educational Facility. It is hoped that the authentic underground environment and the various research projects currently underway at the Josef UEF will both provide new information for students and inspiration for dissertation topics.

2. Description of the Josef UEF

The Josef UEF is situated in a former gold exploration gallery. This extensive underground complex is made up of tunnels and galleries with a total length of almost 8km, 600m of which have so far been renovated and are being used for educational and research purposes. It is planned that the rest of the tunnels and galleries will be renovated in the near future. The surface support facility containing cloakrooms, a small lecture room, WC and showers is currently situated in temporary facilities. Modern support facilities including offices for administrative purposes, accommodation, workshops and surface laboratories will eventually be located in a currently disused surface building, plans for the reconstruction of which have already been made. Renovation will commence as soon as administrative and financial circumstances permit. The Josef exploration gallery runs in a NNE direction across the Mokrsko hill rock massif. The total length of the main drift is 1835m, with a cross-section of 14-16m^2. The overlying rock thickness is 90–110m. Two parallel tunnels lead from the entrance portals, each having a length of 80m and a cross-section of 40m^2. The main exploration gallery is connected to various exploration workings by numerous insets, which follow ore formations and provide access to two further levels. 90% of the breakings are unlined. The end of the main gallery is connected to the ground surface by means of an unsupported 110m vent. A plan of the gallery is shown in Fig. 1.

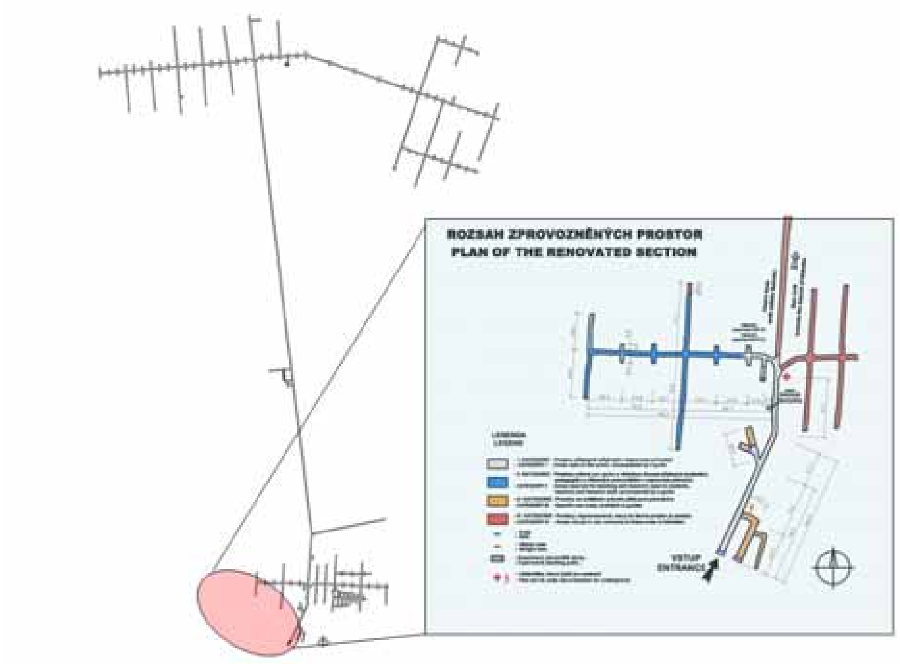

Fig. 1. Plan of the Josef gallery

3. Josef gallery - past and present

The excavation of the Josef exploration gallery commenced in 1981 and the gallery was in operation for ten years. In 1991 exploration of the area ceased and the gallery was closed whereupon it began to deteriorate rapidly. The Faculty of Civil Engineering, CTU realised the potential that this by now somewhat dilapidated underground complex provided for educational and research use and in 2005 an agreement on the use of the gallery for such purposes was signed between the faculty and the Ministry of the Environment which owned the complex. Renovation work, carried out by Metrostav Ltd at its own expense, commenced almost immediately. In February 2007 Metrostav handed the complex over to the faculty. The costs related to the operation of the Josef UEF are funded from the JPD3 European Structural Fund. Teaching programmes commenced at the Josef UEF at the beginning of the academic year 2007/2008. The main goals are to provide students both with practical experience and university courses which satisfy the demands of the commercial world. Besides teaching, several multidisciplinary research projects will commence in 2008.

4. Research

The size of the Josef underground gallery and its geological diversity allow the participation of a wide spectrum of those interested in experimental research. Underground “in situ” research involving direct contact with the rock massif is an important aspect both in the research potential of the Josef UEF and in overall long term Faculty of Civil Engineering planning.

4.1 TIMODAZ

Presently, the Faculty is actively involved in the TIMODAZ project which is supported by the EU's 6th Framework Programme. TIMODAZ is an acronym of the project's title "Thermal Impact on the Damage Zone around a Radioactive Waste Disposal Vessel in Clay Host Rocks". TIMODAZ is an international research project one of the participants in which is the Centre for Experimental Geotechnics, a Faculty experimental facility and the operator of the Josef UEF. The aim of the research is to investigate the effects of long-term thermal load on lining stability; the concept behind the research i.e., to determine the "ideal" form of spent nuclear fuel transformation technology in the mid- to long-term, follows extensive global discussion on this theme. Any eventual spent fuel transformation technology will require the safe removal of spent fuel from deep underground disposal. The extreme long-term functioning of the lining around the disposal vessel is one of the premises for the safe removal of spent fuel canisters from the engineered barrier. The long-term effects of heat could well bring about a severe reduction in the stability of the lining caused either by deterioration in the strength properties of the lining material or by the occurrence of deformations resulting in a collapse in the shape of the lining. The experiment will consist of two physical tunnel lining models which will simulate two extreme cases of the effects of temperature on lining stability:

- An underground silo experiment at the CEG laboratory
- An "in situ" experiment within the Josef gallery

4.2 "In situ" experiment TIMODAZ

This experiment will simulate a thermally loaded lining (90°C) which is not permitted to deform towards the rock massif and which therefore will experience an increase in stress. Long-term continuous measurement performed on the fully-instrumented model will prove whether or not stresses exceeding the strength properties of the lining material are likely to develop within the lining (Fig. 2). A short drift in the renovated part of the Josef gallery (the West Čelina belt) was chosen for the construction and performance of the experiment. The rock environment within which the experiment is being constructed consists of tuffites with a high compression strength (230 MPa). Thermal conductivity is in the range of 3.6 W/mK; specific density is approximately 2740kg/m3.

Fig. 2. Installation of thermometers

4.3 ENEN-II

The Josef UEF is also involved in the ENEN-II project which will consolidate the results obtained by the European Nuclear Education Network Association (ENEN) and partners in the FP-5 ENEN and FP-6 NEPTUNO projects. Work at Josef will expand ENEN involvement into other than nuclear engineering disciplines including radiation protection, radiochemistry, radio-ecology and the geological disposal of radioactive waste, attracting universities and other educational establishments currently active in these fields and by doing so will extend ENEN output from the purely academic to include practical professional training.

5. Teaching

Currently, the Josef UEF's main activity is teaching. In September 2007 the underground complex saw the commencement of regular instruction following specially designed CTU study plans. It is envisaged that over 300 students will take advantage of the Josef facility in the first year of teaching To date, courses have focused primarily on various aspects of underground structures – e.g. underground engineering, rock mechanics, underground urbanism, geotechnics, engineering geology, an introduction to mining techniques and surveying. It is envisaged that the following academic year will see an expansion in the number of courses in cooperation with the Czech Technical University's partner universities (Charles University and Institute of Chemical Technology). In addition to underground structures and geotechnics, students will be able to gain practical experience in geology, mineralogy, geological mapping and applied chemistry. It is planned that the expansion project will be financed from European structural funds. The courses are distinctively practically oriented, thus providing students with a unique opportunity to take real measurements and perform real experiments in an authentic environment. In order to provide support for both the practical and theoretical parts of the various teaching courses several innovative features have been installed in the underground complex with more in the pipeline. The geotechnical features installed to date include:

- a convergence polygon where students have the opportunity to learn and practice measurement techniques and to study their role in the NATM method
- a contact stress measurement demonstration as an element of the wider geotechnical monitoring process
- several blast hole patterns to demonstrate various blasting techniques
- rock and soil bolting and nailing demonstrations
- a replica of an historic wooden tunnel support system
- an exhibition of mining equipment

Student visits to the facility vary according to course requirements and are organized at several levels. A typical first visit to the UEF will aim to provide the student with an initial practical insight into issues involving soil and rock mechanics and underground structures.

As the course progresses, the student returns to Josef for further practical training at which time the number of students is limited allowing each student more tutor time and resources to successfully complete the various demanding tasks involved in the course (e.g. drilling etc.). The Josef Gallery is particularly suitable for experimental work on bachelor and diploma theses. Teaching programs are provided by three Faculty of Civil Engineering CTU departments - the Centre for Experimental Geotechnics and the Geotechnics and Special Geodesy Departments (Fig. 3).

Fig. 3. Practical course of underground geodesy

6. Conclusions

The Josef Underground Educational Facility has ambitions to become a unique European multidisciplinary facility providing high-level practically oriented courses for university students, special training for building company staff and high standard facilities for both domestic and international research projects. A number of outstanding international research projects are to commence in the very near future. The Josef UEF's educational and experimental research activities coupled with the authentic environment provided by the former gold exploration gallery provide an excellent opportunity for postgraduate students involved in underground structures, geology, geochemistry, underground geodesy, rock mechanics, mining engineering etc. to participate in multidisciplinary research projects or to further their own projects and ideas. The full potential of the facility will be realised within the next two or three years by which time the whole of the underground complex will have been renovated. A design project focusing on the reconstruction of the remaining unused underground galleries is currently in the preparation stage. Ambitious underground research projects require suitable surface support facilities. The currently disused two-storey building at Josef, which was donated to the Faculty of Civil Engineering by the Ministry of the Environment, will eventually be converted into a modern surface facility with offices, laboratories, workshops etc. The Josef UEF project has seen support both from representatives of the Faculty of Civil Engineering and the local authority (the Chotilsko municipality). Preliminary agreements with various partner organisations both from the Czech Republic and abroad have already been signed (Charles University in Prague, Institute of Chemical Technology, SCK.C etc.) which, we believe, augers well for the future of this ambitious and unique facility.

7. Acknowledgement

The authors thanks to the Grant Agency of the Czech Republic for allowing them, in the framework of the grant project GA 103/08/1691, to prepare and publish this paper.

7. References

[1.] Morávek, P. (1992), Gold in Bohemian Massif. Czech Geological Survey, Prague, 248 p.

[2.] Morávek, P., Litochleb, J. (2002): Jílove Gold Mines. Regional Museum in Jílové u Prahy, Jílové u Prahy, 187 p.

TRAINING IN NUCLEAR TECHNOLOGY IN AN ANTI-NUCLEAR ENVIRONMENT

H. Böck, M. Villa
Vienna University of Technology, Atomic Institute of the Austrian Universities
Stadionallee 2, 1020 Wien, Austria

ABSTRACT

The 250 kW TRIGA Mark II reactor operated by the Atomic Institute is now the only nuclear facility in Austria. Although Austria follows a dedicated anti-nuclear policy the Atomic Institute enjoys a relative undisturbed nuclear freedom in its nuclear activities. This allows to use the research reactor not only for academic training but also for international training course especially in nuclear technology. Typical examples of periodic training courses are

- Courses for junior IAEA safeguards trainees
- Courses for staff of the NPP Bohunice and NPP Mochovce (Slovak Republic)
- Courses in cooperation with the University of Manchester for NTEC students and junior professionals

The presentation will outline typical training programmes and summarize the experience with international training courses.

2. National Activities

Since its initial operation the Atomic Institute of the Austrian Universities was founded as an inter-university institute where students from all Austrian universities may carry out their post-bachelor specialisation in the fields of

- Neutron- and Solid State Physics
- Nuclear Technology
- Radiochemistry
- Low Temperature Physics
- Radiation Protection
- Nuclear- and Astrophysics
- X-Ray Physics

According to the university curricula students have to enrol a certain number of practical and theoretical courses to be completed with a practical Masters Thesis. Since that time the Atomic Institute of the Austrian Universities offers about 80 theoretical and 10 practical courses within the above fields. Especially two courses on “Reactor Physics and Kinetics” and on “Reactor Instrumentation and Control” attracted many students as they were trained directly at the TRIGA Mark II reactor. The students work in a group of 4-5 students, they have to summarize their results and a written test completes the course which is valued with 3 ECTS. A list of the exercises of the “Reactor Physics and Kinetics” is given below:

- Measurement of the thermal neutron flux density in the reactor core
- Measurement of the epithermal and fast neutron flux density in the reactor core
- Determination of the importance function and the void-coefficient
- Determination of the neutron absorption cross section according to the danger coefficient method
- Measurement of the reactor period
- Radiation protection around a research reactor
- Critical experiment
- Control rod calibration and determination of the core excess reactivity

- Sub-critical safety rod calibration
- Determination of the reactivity value of uranium fuel and graphite elements in different core positions
- Reactor power calibration and determination of the temperature coefficient of the reactivity
- Demonstration of a reactor pulse with different reactivity insertion

A list of the exercises of the "Reactor Instrumentation and Control" follows:

- Introduction into a typical reactor instrumentation
- Reactor safety principles
- Calibration of the nuclear channels
- Measurement of control rod drop times
- Neutron flux measurement with compensated ionisation chambers
- Fission chambers
- Self-powered neutron detectors
- Simulator program for PWR

Further practical courses offered at the Atomic Institute is "Radiation Protection" and "Radiochemistry".

In the years between 1972 and 1978 part of these courses plus some theoretical courses were integrated in the program of a Technical School to train technicians as future staff of the NPP Zwentendorf. After the negative referendum on 5.11.1978 this training was stopped but the regular students training at the Atomic Institute was not influenced.

However the strong Austrian anti-nuclear policy and the Chernobyl accident reduced the number of MS and PHD students in the nuclear field up to about 1995. Since the mid-90ties the number of students in nuclear technology is again increasing due to two facts:

- An increased cooperation with the IAEA
- The decommissioning of the 10 MW ASTRA reactor at Seibersdorf in July 1999

Also during that period bilateral cooperation with Czech Republic and Slovak Republic increased at an university level by student exchange and student group excursions, this fact will be important later in view of trans-national cooperation and knowledge exchange. Since the mid-90ties the Atomic Institute was also heavily involved in public discussions on Eastern European WWEER NPP's as the Austrian Government created a "Nuclear Forum" to support it's anti-nuclear policies against neighbouring countries. The Atomic Institute remained a scientific and technical centre of nuclear competence (1) which was strongly ignored by the Austrian media but highly appreciated as a discussion partner for New EU Member countries.

The strong ties between the Atomic Institute and the IAEA is reflected in many cooperation activities especially in soft- and hardware development for safeguards and security instrument development (2-11). In many projects the IAEA received high quality academic work and the students were supported financially by the IAEA. Some of the students were later employed by the IAEA due to their excellent scientific and technical knowledge.

3. International Activities

As first large international activity in nuclear education the Atomic Institute took part in the ENEN and NEPTUNO projects (12,13). In this context the Atomic Institute produced an extensive catalogue on all nuclear educational activities at European universities (14) which acts still as a very valuable document for follow up projects. Out of these cooperation contacts with other European universities initiated and resulted typically in an international course between four universities (Bratislava, Budapest, Prague and Vienna) called the Eugene Wigner Course which is carried out since 2005. At this course about 15 students and young professionals rotate in groups of 5 between 4 universities carrying out practical exercises at 3 different research reactors. This course is also credited according to the Bologna agreement by the home universities of the students with 3 ECTS.

Another co-operation started in 2007 by signing a contract with the Dalton Institute/University of Manchester. Within the Nuclear Technological Education Centre (NTEC) two groups with maximum 6 students spend a week of practical training in reactor physics and kinetics and in reactor instrumentation and control at the TRIGA reactor of the Atomic Institute.

Further since a few years the Atomic Institute also cooperates with the TU Bratislava in the Slovak retraining program of staff members of the NPP Bohunice and NPP Mochovce. Groups of 4 staff members carry out a selected group of exercises from the above list during 3 days, in addition selected ppt presentation on subjects of interest are included. Another international co-operation is the participation at an EU project called Integrated Infrastructure Initiative for Material Testing Reactors Innovations (MTR+I3) (15) which is concentrated in the preparation of the operation and utilization of the Jules Horowitz reactor. The Atomic Institute has taken over the Work Package Leadership 2 on training of reactor staff in cooperation with Belgium, Czech Republic, France, Greece and Portugal. The program is subdivided into three task which deals with

- Define target groups for training and needs in the MTR field and potential candidates per year
- Training programs within the European Unions, strengths and weaknesses, information from European training programs in nuclear field (academic and practical) such as ENEN, NEPTUNO and Eugene Wigner course (multinational training course between Austria, Czech Republic, Hungary and Slovak Republic supported also by the IAEA)
- Define training programs adapted to the particular needs of the various target groups Integration of the MTR programs in the European training programs. Training program could be delivered in two complementary sites, new sessions dedicated to MTR in existing programs in order to attract young persons in the MTR field.

4. Conclusions

Although the Atomic Institute is located in a strict anti-nuclear environment both politically and supported by continuous negative media information, the Atomic Institute manages to carry out it's international contacts successfully even with an obvious increase during the past decade. It further helps to improve the international relations in the nuclear field by active co-operation even in spite of lack of national support.

References

(1) H. Böck: "Transboundary Risks: The Temelin Case". AIAU 25313, Rev. Jan. 2006, to be published in "Negotiated Risks - International Talks on Hazardous Issues" by Rudolf Avenhaus and Gunnar Sjöstedt (Eds.)

(2) M. Swoboda: "Evaluierung von CdZnTe Detektoren im Hinblick auf deren Einsatz in tragbaren Isotopenidentifikationsgeräten". Diplomarbeit, Vienna University of Technology, June 2000

(3) M. Knabl: "γ-Spektren Katalog mittels CdZnTe-Detektoren". Diplomarbeit, Vienna University of Technology, March 2001

(4) R. Plenteda: "A Monte Carlo based virtual gamma spectroscopy laboratory". PhD Thesis, Vienna University of Technology, June 2002

(5) S. VAUGHN: “Quantitative validation of nuclear safeguards monitoring systems and their simulations”. PhD thesis, Vienna University of Technology, Feb. 2003
(6) G. Hrkac: “Characterization and analysis of NaL(Tl) and BGO crystals and their use in identification of Pu and U-enrichment”. Diplomarbeit, Vienna University of Technology, June 2003
(7) M. Schrenk: “Automatische Erkennung von radioaktiven medizinischen Isotopen bei grenzüberwachenden Strahlungsmessstellen“. Diplomarbeit, Vienna University of Technology, May 2005
(8) S. Karimzadeh: “Behavior of the electronic seals in mixed radiation fields”. Diplomarbeit, Vienna University of Technology, June 2005
(9) J. Budzinski: “Machine learning techniques for the verification of refueling activities in Candu-Type NPPs with direct applications in nuclear safeguards”. University Vienna, June 2006
(10) P. Dominique: “Determination of the activity in containers by external dose rate”: Diplomarbeit, University Vienna, Aug. 2007
(11) S. Hengster: ”Comparison of simulation and measurement of radioactive sources by usage of SuperSYNTH”. In progress
(12) European Nuclear Engineering Network (ENEN): http://www.enen-assoc.org
(13) Nuclear European Platform for Training and University Organisation (NEPTUNO): http://www.sckcen.be/neptuno/
(14) H. Böck, M. Hajek, M. Villa, European Nuclear Engineering Network (ENEN). Working Package 1 (WP1), AIAU 22305, March 2003
(15) Integrated Infrastructure Initiative for Material Testing Reactors Innovations (MTR+I3), EU Contract FI6, Contract Number 036440, Starting Date: October 1st, 2006

European Nuclear Society
Rue Belliard 65
1040 Brussels, Belgium
Telephone +32 2 505 30 54
Fax + 32 2 502 39 02
nestet2008@euronuclear.org
www.euronuclear.org