

EXTENSIVE UTILISATION OF VR-1 REACTOR FOR NUCLEAR EDUCATION AND TRAINING

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ABSTRACT

The paper presents utilisation of the VR-1 reactor for nuclear education and training at national and international level.

VR-1 reactor has been operating by the Czech Technical University since December 1990. The reactor is a pool-type light water reactor based on enriched uranium (19.7% ^{235}U) with maximum thermal power 1kW and for short time period up to 5kW. The moderator of neutrons is light water, which is also used as a reflector, a biological shielding and a coolant. Heat is removed from the core by natural convection. The pool disposition of the reactor facilitates access to the core, setting and removing of various experimental samples and detectors, easy and safe handling of fuel assemblies. The reactor core can contain from 17 to 21 fuel assemblies IRT-4M, depending on the geometric arrangement and kind of experiments to be performed in the reactor. The reactor is equipped with several experimental devices; e.g. horizontal, radial and tangential channels used to take out a neutron beam, reactivity oscillator for dynamics study and bubble boiling simulator.

The reactor has been used very efficiently especially for education and training of university students and NPP's specialists for more than 18 years. The VR-1 reactor is utilised within various national and international activities such as Czech Nuclear Education Network (CENEN), European Nuclear Education Network and also Eastern European Research Reactor Initiative (EERRI). The reactor is well equipped for education and training not only by the experimental facility itself but also by incessant development of training methods and improvement of education experiments. The education experiments can be combined into training courses attended by students according to their study specialization and knowledge level. The training programme is aimed to the reactor and neutron physics, dosimetry, nuclear safety, and control of nuclear installations. Every year, approximately 250 university students undergo training at VR-1 reactor. Their stay at reactor site means an enormous benefit for their study process.

1. Introduction

The training reactor VR-1, so-called "SPARROW", was commissioned in 1990 at the Department of Nuclear Reactors of the Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague. The reactor is used in education of technical university students, in R&D, in the education and training of specialists in the nuclear industry, and finally in promotional activities within the field of nuclear power.

The education and training is oriented to the reactor and neutron physics, dosimetry, nuclear safety, and control of nuclear installations. R&D has to respect reactor parameters and requirements of the so-called clean reactor core (free from major effects of the fission products). Research at the reactor is mainly aimed at the preparation and testing of new educational methodologies, investigation of reactor lattice parameters, reactor dynamics studies, research in the field of control equipment, neutron detector calibration, etc.

The VR-1 reactor is utilised within various national and international activities. The utilisation of VR-1 reactor at national level takes place within Czech Nuclear Education Network (CENEN). The international co-operation is based mainly on activities realised within

European Nuclear Education Network (ENEN) and Eastern European Research Reactor Initiative (EERRI).

2. Basic Technical Parameters of VR-1 Reactor

The VR-1 Training Reactor (see Fig1) is a pool-type light-water reactor based on enriched uranium with maximum thermal power 1kW and for short time period up to 5kW. The moderator of neutrons is light demineralised water, which is also used as a reflector, a biological shielding, and a coolant. Heat is removed from the core by natural convection. The pool disposition of the reactor facilitates access to the core, setting and removing of various experimental samples and detectors, easy and safe handling of fuel assemblies.

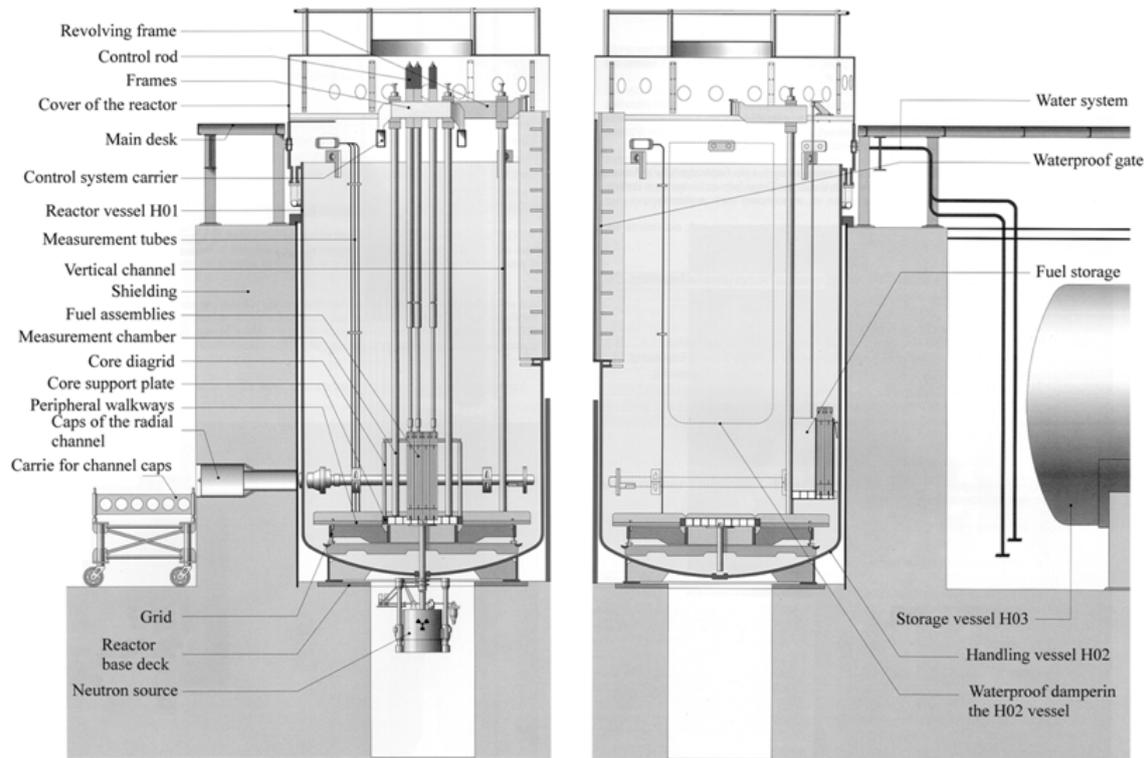


Fig 1. Cross section of VR-1 reactor

Reactor has been successfully converted from the highly enriched uranium (IRT-3M, enrichment: 36 % ^{235}U) fuel to the low enriched uranium (IRT-4M, enrichment: 19.7 % ^{235}U) fuel in 2005 [1]. The reactor core contains 17 to 21 fuel assemblies IRT-4M, depending on the geometric arrangement and kind of experiments to be performed in the reactor. The core is accommodated in a cylindrical stainless steel vessel - pool, which is filled with water.

The cadmium control rods serve the reactor control and safe shutdown. Construction of all the rods is identical, but they differ in their functions (safety, compensation or control) according to the connection with the control and safety system.

Digital control equipment consists from control and safety system, signalling system, connecting system, and neutron source control. The Am-Be neutron source is used to start up the reactor. It ensures a sufficient level of the signal at the output of the power measuring channels from the deepest sub-criticalities, and thus guarantees a reliable check of the power during the reactor start-up.

The reactor is equipped with several experimental devices [3]; e.g. horizontal, radial and tangential channels used to take out a neutron beam reactivity oscillator for dynamics study and bubble boiling simulator. Basic technical properties of the VR-1 reactor are summarised in Table 1.

Rated Power	1 kW (thermal), 5 kW for short time period
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Neutron Flux	2 - 3x10 ⁹ /cm ² .s
Fuel	IRT-4M type, ²³⁵ U enrichment 19,75 % (imported from Russia)
Reactor Vessels (pools)	made from stainless steel vessel diameter 2 300 mm vessel height 4 720 mm wall thickness 15 mm
Reactor Shielding	above core: water layer 3 000 mm side: water layer about 850 mm + concrete 950 mm
Temperature	20 °C (according to the ambient temperature)
Core Cooling	natural convection
Pressure	atmospheric
Control Rods	5-7 control rods: 3 safety (shut-down) rods, 0-2 experimental rods (according to the core configuration), 2 control rods
Operating Power Measurement	four wide-range non-compensated fission chambers
Independent power Protection	four pulse corona boron counters
Neutron Source	Am-Be, 185 GBq, emission rate of 1.1 . 10 ⁷ s ⁻¹

Tab 1. Basic technical properties of the VR-1 reactor

3. Education and Training at VR-1 Reactor

The training reactor VR-1 is principally used for training of students from technological universities and specialist from Nuclear Power Plants. Training is aimed to areas such as reactor physics, neutronics, dosimetry, reactor operation, nuclear safety and I&C systems. Depending on the curriculum and orientation of individual users, the training is performed in the regular weekly schedule or in the form of batch courses two to five days long. The specific content of the courses is compiled according to the requirements of the users. The courses and experiments are available in three levels:

- demonstration;
- basic;
- advanced.

The demonstration level is intended for basic understanding of physical phenomenon, which is applied during the experiment and participants are rather passive observers. In the basic level, participants actively take part in the experiment, and independently evaluate acquired data. The advanced level is designed for in-depth study of the issue and requires a deeper theoretical knowledge of participants and their active participation in the preparation of measurements, during the experiment and interpretation of acquired values. A chosen phenomenon or process is often analysed using several different approaches or conditions. Currently, over 25 experiments are prepared at the reactor [3]. The most frequent experiments are the following:

- basics of neutron detection using gas detectors;
- determination of gas detectors dead time;
- analysis of neutron detectors properties for reactor I&C;
- measurement of delayed neutrons;
- determination of neutron flux density distribution by tiny gas detectors,
- determination of neutron flux density distribution by activation detectors (Au foils, Cu wires);
- reactivity measurements (e. g., Rod Drop, Source Jerk, Positive Period);
- control rods calibration (e. g., by Inverse Count Rate);
- analysis of various materials impacts on reactivity;

- criticality approach and critical experiment;
- study of nuclear reactor dynamics;
- start-up, controlling and operation of nuclear reactor;
- bubble boiling simulation and its impact on reactivity;
- short-time instrumental neutron activation analysis.

The less frequent, specialized experiments aimed at determination of kinetic characteristics (e.g. neutron lifetime, effective delayed neutron fraction), selected analytical methods for the environment protection or extended experimental courses of digital control systems.

4. Utilisation of VR-1 Reactor within National and International Cooperation

VR-1 reactor as a specialized training facility of the Ministry of Education, Youth and Sports, is in addition to students of Czech Technical University in Prague open to students from other universities in the Czech Republic (more than five Czech universities). Majority of reactor training for students from the Czech universities takes place within the scope of CENEN (see Fig 2). Every year 150-200 students from Czech universities undergo training at VR-1 reactor. Student's stay at reactor site means an enormous benefit for their study process.

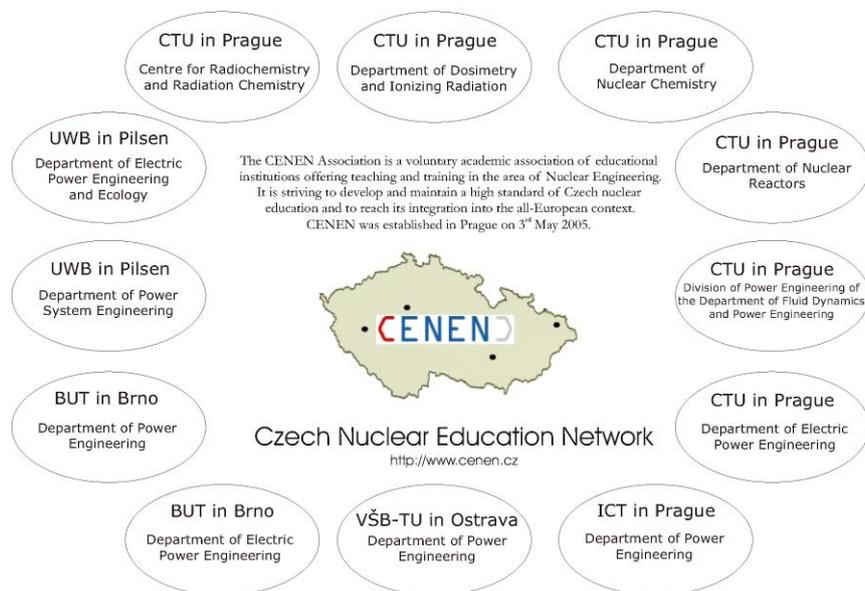


Fig 2. Scheme Diagram of Cooperation within CENEN Framework

The reactor is frequently used for training of NPP's specialists as well. The users are both from Czech NPPs (Dukovany and Temelín) and Slovak NPPs (Jaslovské Bohunice and Mochovce). Approximately 5 courses for NPP's staff take place at VR-1 reactor per year.

Integral part of reactor utilisation is education and training of students coming from abroad. There is close cooperation with Germany (Fachhochschule Aachen), Slovakia (Slovak University of Technology in Bratislava), Sweden (KTH Royal Institute of Technology in Stockholm) and Austria (Atominstitut TU Vienna). Education for foreign students is also organized within the scope of ENEN. Approximately 40 foreign students take part in course at VR-1 reactor per year.

Several courses organised at VR-1 reactor in cooperation with IAEA. Currently there are activities related to EERRI. EERRI was established in 2008 and covers 8 research reactors (see Fig 3) from 6 European countries as an example of regional co-operation between research reactors. Soon after its establishment, the EERRI in collaboration with IAEA organised and successfully carried out the first group education and training course dedicated for the Members States aiming to build their first research reactor. The second

course is already scheduled for April this year. The course will take place at VR-1 reactor as well.

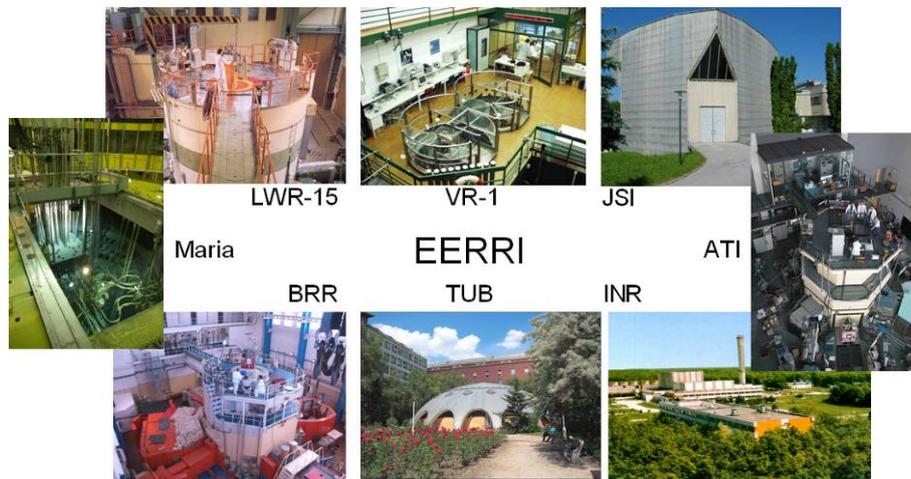


Fig 3 Research reactors utilised within EERRI

(LWR-15 and VR-1– Czech Republic, JSI – Slovenia, ATI – Austria, INR – Romania, BRR and TUB – HUNGARY, Maria – Poland,)

Another important part of the VR-1 reactor utilisation is providing the public information. High-school or university students as well as public visit the reactor. Programme of visit is didactic; containing a lecture, a site visit, performance of a reactor operation and visitors also gather all important aspects of nuclear energy production. More than 1000 visitors come to VR-1 reactor per year.

5. Conclusions

The VR-1 reactor has been used very efficiently for nuclear education and training of university students and NPP's specialists for more than 18 years. The utilisation of VR-1 reactor at national level takes place within CENEN. The international co-operation is based mainly on activities realised within ENEN, IAEA and EERRI. The operator and main user of the VR-1 reactor is the Czech Technical University in Prague; another five Czech universities participate in its use. The co-operation with foreign universities is frequent as well. Every year, approximately 250 university students undergo training at VR-1 Reactor. Further training courses are provided for specialists from Czech and Slovak NPPs. There are five special courses per year. Every year more than 1000 visitors come to VR-1 reactor within informational and promotional activities.

6. References

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