Future Utilization of the Research Reactor IRT in Sofia after its Reconstruction

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Objectives of the Reconstruction

The research reactor IRT-2000 (IRT) in Sofia to the Institute for Nuclear Research and Nuclear Energy (INRNE) was built and put into operation in 1961. It was temporarily shut down in 1989 for improvement. The reconstruction of the IRT is being carried out under the decision of the Council of Ministers of Republic of Bulgaria from 2001. The strategy for sustainable utilization considers the IRT as a national base and aims to satisfy the society needs for:

- education of students and training of graduated physicists and engineers in the field of nuclear science and nuclear energy,
- implementation of applied methods and research,
- development and preservation of nuclear science, skills, and knowledge.

Reconstruction parameters

The IRT Technical Design is being in process of elaboration. The IRT will bereconstructed into a reactor:

- of thermal power 200 kW;
- with low enriched with uranium-235 fuel (LEU);
- with six vertical and seven horizontal experimental channels;
- one of the horizontal channels will be used for medical Boron Neutron Capture Therapy (BNCT) application.

An up-to date system for monitoring the IRT site has been built through the EC PHARE programme under the project “Innovation of the Radiation Monitoring System” and “Technical Assistance” for 2002-2005. The radiometric laboratory is equipped with two modern high resolution gamma spectroscopy systems, two ultra-low-level alpha/beta systems, wide range of portable beta, gamma and neutron probes; two aerosol monitors and system of 35 individual electronic dosimeters for individual dosimetry control. Samples taken out not only from reactor building but also from the IRT surrounding area (sanitary-protection zone) are to be measured there.

The research reactor will use LEU fuel IRT-4M. The replacement of the high enriched, with 36% uranium-235 (HEU) fuel IRT-2M with LEU fuel, below 20%, is in accordance with the current requirements of the security of transportation and storage of nuclear and other radioactive materials. This work is being carried out with the support of the US Department of Energy in the frame of the RERTR program for conversion from HEU to LEU fuel.

Preliminary three dimensional neutron transport calculations with MCNP code [1] for reactor core arrangement with LEU, together with BNCT channel regarding the constructional (geometry and material composition of the BNCT beam collimator and filter) design have been carried out (Fig.1). The BNCT Beam Tube Design has been done the same as the USA MIT tube design. The BNCT channel will supply epithermal neutron flux of about 5.109 n/cm2s. In the other experimental channels the maximal fast neutron flux will be about 3. 1012 n/cm2s, and maximal thermal flux 8.1012 n/cm2s.

Returning the HEU spent research reactor fuel to Russia where it was originally enriched is being done with the support of the US Department of Energy in the frame of the RRRFR programme. All activities within this program are going on accordingly the co-operation plan.

Utilization

The INRNE together with the Technical University of Sofia have proposed to the Ministry of Education a new program for education of students in nuclear energy. The Nuclear Energy course will be obligatory for obtaining the Master of Science Degree of the Technical University in Sofia. The educational classes refer: types of research reactors, main characteristics and design of the reconstructed IRT, safety assuring and licensing, reactor physics and thermo-hydraulic characteristics determination, accident analyses, fresh and spent fuel management, radioactive waste management and governmental categorization norms and rules. Acquaintance with calculational codes as the MCNP code for neutron transport and criticality calculations, WIMS-ANL code – for preparing of neutron cross sections for diffusion calculation, REBUS code for the fuel burnup calculation, SCALE code system for spent fuel transport and storage devices safety assessment, PLTEMP/ANL code for calculation of thermo-hydraulic steady-state, and PARET and RELAP5 codes – for transients, etc. is planned too. Preliminary acquaintance with the neutron activation analysis and BNCT is included in the educational programme.

Seminars were held nowadays with the first students’ group in the INRNE. Exercises on radiation monitoring were carried out in the renewed and modern equipped laboratory for radiation measurements. After the reconstruction the IRT will be used for carrying out specific training exercises on the reactor: reactor start, manual and automatically control, control rod calibration, delayed neutron group measurements, sub-critical multiplication/shutdown margin measurements, excess reactivity and shutdown margin measurements; reactor-physics measurements of static and kinetic reactor parameters, reactor dosimetry, measurements of the spent fuel characteristics in the hot cells, radiological characterization survey - alpha, beta and gamma measurement techniques, contamination measurement, etc.

The reconstruction of the IRT includes an arragement for a BNCT facility. Combating a major disease – cancer, is one of the priority themes of the EC FP7 within the pillar “Translating research for human health”, corresponding to a major political and strategic choice of the European Union. This is also a response to the expectations of society for increasing the quality of life, at national as well as at European community level. BNCT is a form of radiotherapy that has the potential to selectively kill the cancer cells embedded within normal tissue. It uses B-10 isotope, which emits two short-lived high-energy particles when irradiated with a beam of thermal energy neutrons. Due to very short (cell dimension) path of the particles the treatment is lethal to cancerous cell containing the B-atoms, but has a much less damaging effect on the surrounding normal tissue. Treatment using BNCT is mostly applied on head and neck, malignant melanomas and brain tumours, particularly glioblastoma multiform, and liver as well. The current worldwide practice in BNCT is to irradiate the patients with neutron beam from reactor.

Feasibility studies within the national network of the Medical University of Sofia, the National Centre of Radiobiology and Radiation Protection, the Institute of Experimental Pathology and Parasitology and Institute of Electronics of the Bulgarian Academy of Sciences, the National Centre of Radiobiology and Radiation Protection, and the Faculty of Physics of Sofia University are carried out. Transfer of knowledge with institutes, experienced in BNCT as EC JRC, Petten, the Netherlands, VTT, Finland and NRI-Rez, the Czech Republic, is in process of an establishment. Human, social and economical results due to the BNCT for patients from Balkan region are expected. As advantage it could be considered the good infrastructure connections with the Oncology Hospital that is located of about 3 km from IRT.

Neutron Activation Analysis (NAA) is planed to be developed. It is a sensitive analytical method for the determination of elements and their traces (nanograms) in various types of samples and specimens, in metals and inorganic compounds, in animal, plant, and fish products, soil, river waters and sea sand, rain and snow, rocks, cosmic materials, archaeological objects, medicine, and police inquest. NAA is the widely used and beneficial application of the research reactors worldwide. It is estimated that approximately 100 thousand specimens are analyzed each year. The material under investigation is irradiated with neutrons. The element whose content is to be determined is activated and its half-life could be of several minutes to several days.

The hot cells available at IRT allow the organization of radioisotope production and particularly of some radioisotopes (Br-82, Na-24, Ar-41, La-140, and K-42) for the industry and medical application in vivo and in vitro.

Study of various defects in the crystal metal lattice produced by irradiation of metal specimens will be carried out. Investigation on reactor steel embrittlement will be used for development of a model for prognosis of NPP VVER reactor pressure vessels lifetime.

Positron beam could be obtained from irradiation of appropriate targets with thermal neutrons or hard fission gamma rays. Positrons can be used as particle probes, suitable to detect materials defects with dimensions smaller than a micrometer.

The development of a metrological system for testing and calibration of instruments needed for measurements of neutron/gamma fluxes as well as of radiation field monitors for measurements of dose received is planned. Such a metrological system will guarantee uniformity of the neutron/gamma measurements in the country.

Development of neutron radiography will give an effective method of non-destructive testing that allows imaging of defects in a variety of objects (electronic, mechanical, military). The neutron beam penetrates a specimen, attenuates depending on the element contents, and interacts with a neutron absorbing screen. As a result a secondary radiation is produced that create an image is obtained on a special device.

Other conditions

Besides the financial support by the Bulgarian governmental budget from 2001 the IRT has the IAEA support through the project BUL/4/014 “Refurbishment of the Research Reactor”. IRT-2000 reconstruction activities, training courses for Bulgarian young specialists in the Technical University of Prague, Czech Republic, and RIAR in Dimitrovgrad, Russia, participation in proper workshops and conferences, various missions of the IAEA experts to the IRT have been carried out under this project.

The project NIK-02/2007 of the Ministry of Education and Science for development of BNCT scientific information system in Bulgaria has started.

Integrated Management System which fulfils the requirements of the standard ISO 9001:2000 for quality and ISO 14001:2004 for environment has been implemented from 2003 and certificated by the Quality Austria. The elaborated procedures follow the safety requirements of the Bulgarian Nuclear Regulatory Agency as well as the Governmental requirements for occupational health and safety, and for security.
The reconstructed IRT is a basis for keeping up specialists with researcher’s approach and skills who are able to give adequate responses to the challenges of complex modern technologies and the associated environmental problems. The reactor will be used for production of isotopes needed for medical therapy and diagnostics; it will be the neutron source in element activation analysis having a number of applications in industrial production, medicine, chemistry, criminology, etc.
Nuclear energy has a strategic place within the structure of the country’s energy system. A new nuclear power plant Belene with two reactors of 1000 MeV will be built. The extremely high requirements regarding nuclear safety call for the availability of scientific and technical potential, and for an adequate culture of safe use of nuclear energy. The acquired scientific experience and qualification in reactor operation is a basis for participation of the country in the international cooperation within the European structures. In that aspect, the operation and use of the IRT brings economic benefits for the country.

Outlook activities

The nearest outlook activities are focused on the final design for refurbishment of the IRT. Involving more young physicists and engineers in the activities of IRT reconstruction and their training to be capable to operate research reactor, to held application works, to conduct the BNCT is one of the most important task that has to be solved for the future utilization of the research reactor IRT. The activities will be developed by strengthening the international collaboration with research reactors for sharing good practices. Closer collaboration with national institutions like universities, hospitals, regulatory agencies, industry, etc. will guarantee the effective utilization of the research reactor.

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References

1. I. F. Briesmeister, Ed., “MCNP -A General Monte Carlo N-Particle Transport Code, Version4C,” LA-13709-M (April 2000)., RSICC ORNL, Code Package, CCC0700, 2000

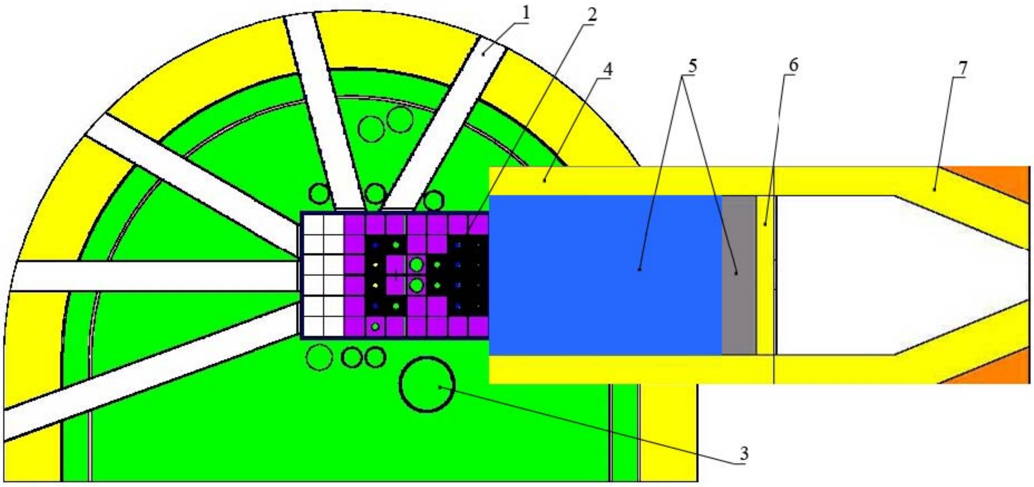

Fig. 1. The MCNP model of the IRT with BNCT tube (MIT tube design): 1. Horizontal channel, 2. Fuel assembly, 3. Vertical channel, 4. Lead reflector (10 cm), 5. Filter/Moderator: Al(81 cm), PTFE (13 cm), Cadmium (0.05 cm), 6. Lead photon shield (6 cm), 7. Lead collimator (15 cm).