EERRI COALITION AS A PLATFORM FOR CLOSE COOPERATION - AN ENHANCED UTILIZATION OF RESEARCH REACTORS IN CENTRAL AND EASTERN EUROPE

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Abstract

One the most visible trend in nuclear education and training which became visible during the last few years is networking and closer co-operation between universities at national and international level in nuclear education. Research reactors, which are mainly part of a research institute or university, had the same evolution in networking as universities but with a few years delay - research reactors started to create reactor coalitions. The first impulse towards reactor coalitions was done at the IAEA International Conference on Research Reactors: Safe Management and Effective Utilization, held in Sydney in November 2007, where research reactor coalitions and centres of excellence were two of the key topics of the conference. At this conference functioning and future sustainability of such reactor coalitions were widely discussed. As a result of those discussions, the first reactor coalition was established three months later. In the January 2008 the Eastern European Research Reactor Initiative (EERRI) was born in Budapest, Hungary. The EERRI reactor coalition now covers nine research reactors from seven European countries. The main purpose why reactor coalitions have been born is the chance to offer complex services in a wide range of activities which a single reactor cannot offer and synergy benefits from joint efforts of the coalition. The next reasons for coalitions cover sharing the irradiation and experimental capacities, coordination of the reactor operation for potential shutdown one of the coalition reactors, etc. A good example how the reactor coalition could work is the oldest coalition - EERRI. Wide power range and various reactors' use allow EERRI to offer to solve any type of the experimental work usually performed at research reactors from beam experiments through various types of neutron activation analysis, fuel investigation, material science, radioisotope production to education and training. All EERRI activities are focused in the four main areas: Neutron beam applications, Radioisotope production, Fuel and material testing and Education and training. Soon after its establishment, the EERRI in collaboration with IAEA organised and successfully carried out the first two training courses dedicated for the Members States aiming to build their first research reactor. The next two training courses were carried out in 2011.

1. RESEARCH REACTOR COALITIONS

One the most visible trend in nuclear education and training which became obvious during the last few years is networking and closer co-operation between universities at national and international level in nuclear education. Research reactors, which are mainly part of a research institute or university, had the same evolution in networking as universities but with a few years delay - research reactors started to create reactor coalitions.

Research reactor coalitions and centres of excellence were two key topics elaborated at the IAEA International Conference on Research Reactors, held in Sydney in November 2007. At this conference the cooperation and future sustainability of the reactor coalitions were widely discussed. As a result, the Eastern European Research Reactor Initiative (EERRI) was established in January 2008. Soon after establishing the EERRI work started to establish the next two reactor coalitions, further the next four coalitions were already under consideration. The general term “reactor coalition” covers research reactors themselves together with reactor users, e.g. the most important reactor users from universities, research institutions, medicine, industry, etc.

The main purpose why reactor coalitions have been established is the chance to offer complex services in wide range of activities which a single reactor cannot offer and synergy benefits from joint efforts of the coalition. Other reasons for coalitions cover sharing the irradiation and experimental capacities, coordination of the reactor operation for potential shutdown one of the coalition reactors, etc. An excellent example how such a reactor coalition works is the oldest one - Eastern European Research Reactor Initiative [1], [2].

2. EERRI REACTOR COALITION

The First EERRI meeting was held three month after the Sydney's conference in January 2008 in Hungary. Representatives from research reactors from Central and Eastern Europe signed a Memorandum of Understanding where the main goals were defined: "In order to facilitate improved services, to make use of the synergies of regionally neighbouring similar facilities, to harmonise instrument development, and to preserve competence at research reactors." [3]

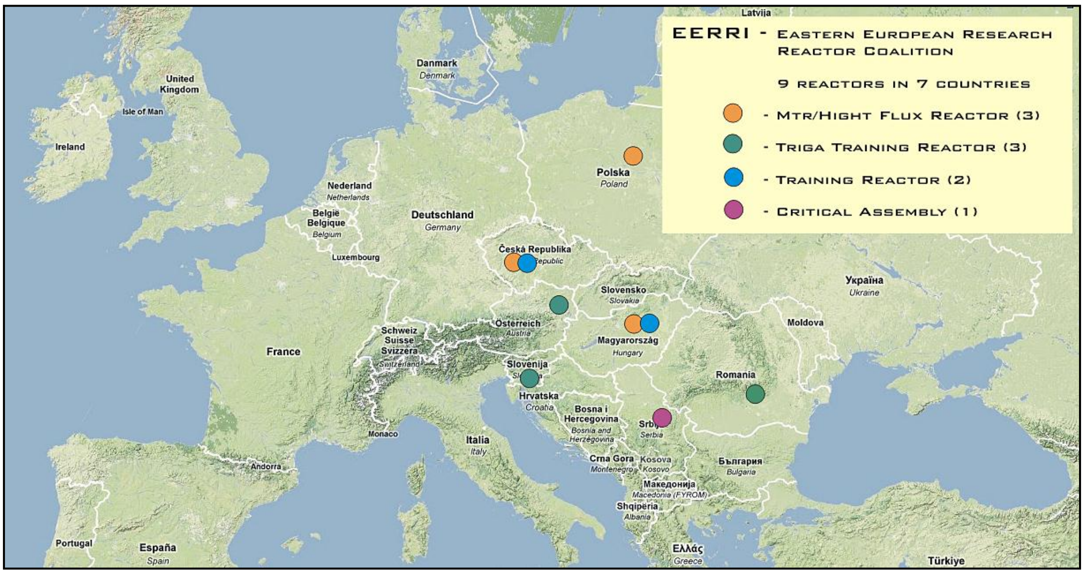

FIG. 1. EERRI — Eastern European Research Reactor Initiative [1].

TABLE 1. EERRI - EASTERN EUROPEAN RESEARCH REACTOR INITIATIVE [1]

Country	Reactor	Licensee	Power	Reactor type
Austria	TRIGA	VUT/ATI Vienna	250 kW	TRIGA Mark II
Czech Republic	VR-1	CTU in Prague	1 kW	Training reactor
Czech Republic	LWR-15	NRI Rez	10 MW	MTR
Hungary	BME-TR	BUTE Budapest	100 kW	Training reactor
Hungary	BRR	KFKI Budapest	10 MW	MTR
Poland	MARIA	IAE Otwock	30 MW	MTR
Romania	TRIGA	ICN Pitesti	14 MW	TRIGA-SSR
Serbia	RB	Vinca Belgrade	0 W	Critical assembly
Slovenia	TRIGA	IJS Ljubljana	250 kW	TRIGA Mark II

It is evident that EERRI has a big potential of hosting nine reactors from seven countries (see TABLE 1.): three of them are MTR / High flux reactors (MARIA, BRR and LVR-15), three are TRIGA reactors (ATI, IJS, ICN), two are training reactors (VR-1, BME-TR) and one is a critical assembly (RB). EERRI can offer really a wide range in reactor power from zero Watts to dozens of MW. Due to the TRIGA reactors EERRI can also offer both steady state and pulse mode operation. The wide power range and various reactor utilization programs allow EERRI to offer and to solve any type of experimental work usually performed at research reactors from beam experiments through various types of neutron activation analysis, fuel investigation, material science, radioisotope production to education and training. All EERRI activities are focused in the four main areas [3]:

- Neutron beam applications;
- Radioisotope production;
- Fuel and material testing;
- Education and training.

3. NEUTRON BEAM APPLICATIONS

During the first EERRI meeting it was agreed that the cooperation in the field of neutron beam experiments appears the most promising area to be organised because neutron beam experiments are performed at any research reactor. Representatives of all reactors agreed to start the harmonisation of neutron beam experiments at each EERRI reactor. The first step in the harmonization process was to review the existing neutron beam facilities and develop an instrument database. A questionnaire was circulated among the research reactor managers. Based on the submitted data an inventory of the neutron beam instrument was established.

The facility inventory contains large number of beam instruments operated by the EERRI research reactors: 9 diffractometers, 5 small angle scattering instruments, one reflectometer, 6 spectrometers and 10 other types of beam instruments. The capabilities and scientific use of the beam instruments are also involved in the inventory (an example part of the EERRI database of the beam instruments is shown in *FIG. 2.*).

Abbrev.	Instrument Full Name	Facility
Diffractometers		
D-H5	Two axis neutron diffractometer at beam H5	MARIA
DIR1	High resolution crystal powder neutron diffractometer	TRIGA (ICN)
HOKAN6	Medium-resolution powder diffractometer	LVR-15
KSN-2	Two axis powder diffractometer	LVR-15
KSN-2	Two axis powder Diffractometer	LVR-15
MTEST	Material Test diffractometer	BRR
PSD	Powder diffractometer with position sensitive detector	BRR
SPN100	Multipurpose double axis diffractometer	LVR-15
Texdif	Multipurpose double axis diffractometer	LVR-15
TKSN-400	Multipurpose double axis diffractometer SPN-100	LVR-15
Small angle neutron scattering instruments		
MAUD	High resolution small angle neutron scattering diffractometer	LVR-15
SANS	Small angle neutron scattering instrument	TRIGA (ICN)
S-H3	Small angle neutron scattering diffractometer	MARIA
S-H4	Small angle neutron scattering diffractometer at beam H4	MARIA
Yellow submarine	Small angle neutron scattering instrument	BRR
Reflectometers		
PREF	Polarised neutron beam reflectometer	BRR

FIG. 2. EERRI database of beam instruments (part of database, September 2010, [5]).

The EERRI harmonisation should be continued in the future and the cooperation in the area of beam application can be extended to the user system to develop similar system in all EERRI members if applicable. The harmonised web-pages describing instruments capabilities can be a possibility to promote the access to EERRI beam facilities. The instrument development can also be an important field in this regard; it has good potential for substantial collaboration.

The collaboration among the EERRI members can be enhanced by organising special events like training school and/or workshop. The Central European Training School on Neutron Scattering (CETS) has been organized by the FKFI Budapest Neutron Centre. The school provides insight to the neutron scattering techniques and includes hands-on-training at the Budapest Research Reactor beam facilities. The program of the school has been shaped during the last decade to serve the regional neutron community. The last school, in 2010 was also utilized to introduce relevant neutron scattering facilities to other EERRI members.

The latest EERRI activity in the field of neutron beam applications was workshop “Concerted Actions in Research and Applications with Neutron Beams in Europe” organized by the IAEA with collaboration of KFKI in the summer 2011. The workshop aimed to strengthen the cooperation in the field of beam research and applications. It examined the current status of the beam facilities and discussed the future trends in neutron sciences and application. 39 participants from 14 countries attended on the meeting. The participants acknowledged that the meeting was a useful and successful event regarding to its outcome.

4. RADIOISOTOPE PRODUCTION

The primary mission of radioisotopes production is to prepare certain commercially unavailable radioisotopes to distribute to the nuclear medicine community and industry, and to perform research to develop new radioisotopes desired by nuclear medicine investigators. In conjunctions with this mission performs service irradiations, sells by-products and explores opportunities for new products and radioisotope applications as needed.

Radioisotopes production making service for different sectors of economic and science constitute an important ongoing activity of many national nuclear programs. Radioisotopes, formed by nuclear reactions on targets in reactor as well as cyclotrons, require further processing in almost all cases to obtain them in a form suitable for use. Production of radioisotopes includes many economic aspects: as necessity to analyze international market prices, access the market situation and contact potential users to assess the potential customer base before making this a major part of their strategic plan for the facility.

Isotope production received emphasized attention at the EERRI meetings. Among all EERRI members four reactors i.e. MARIA, BRR, LVR-15 and TRIGA (ICN) are main radioisotopes producers. Others reactors have possibility to offer service on small-scale or occasional isotope production. It was noted that the isotope business in several of the EERRI members are operated by institutes or organizations that are separate from the research reactor and that the research reactors simply irradiate targets at the request of the isotope producer, receiving only nominal income for supplying the neutrons. Therefore, isotope distribution and business is competitive and not transparent. Economic and business problems were highlighted during EERRI meetings.

To build on the existing momentum, to ensure sustainability, and to achieve the envisaged goals of EERRI coalition, consideration needs to be given to further strengthening of cooperation and especially joint action. Representatives of MARIA, BRR and LVR-15 reactors discuss EERRI objectives with their respective isotope organizations and will suggest enhancement of cooperative mechanisms in order to strengthen coordinated isotope supply from EERRI organizations. The EERRI coalition should development of specific capabilities and skills in business development and stakeholder management. The coalition can share, or even pool, expertise in business development, thereby leveraging the individual capabilities of the institutes without requiring significant new budget commitments. This should be supported by training activities in strategic planning and business development as part of the IAEA input to the coalition.

The isotope production as a one of base EERRI activities is coordinates by IAE Otwock with the close collaboration with other reactors. The coordinator collects information on reactor operating and shutdown schedules, as well as availability of irradiation space, which will be posted and updated on the EERRI website and made available to isotope production organizations. Intensification of cooperation between EERRI members parties engaged in isotope production for medicine purposes is supported by:

- Coordination of reactor operating schedules;
- Capabilities of research reactors - periodically update technical data, operation schedules, maintenance periods;
- Joint radioisotope production: available irradiation space, needs and offers;
- Closer cooperation with radiopharmaceuticals producers and international organizations;
- Integration with other European and Global initiatives;
- Financial support of regional production centres.

Current problems in international Mo-99 supply were discussed during coalitions' meetings and the EERRI capabilities and proposals of production of fission Mo-99 including LEU target irradiation and possible alternative pathways (such as availability of enriched Mo-98 for (n,γ) Mo-99 production in response to DOE solicitation) has been prepared .

5. FUEL AND MATERIAL TESTING

Fuel and material testing is perspective field of interest of the EERRI coalition, but very difficult for the collaboration. Fuel and material irradiation and its post irradiation examination for current reactors' generation is usually organised on a contract-basis with customer at each reactor and it is significant source of operational incomes. In the last two years the customer requirements of large and expensive experiments in the field material testing significantly decreased. The utilisation of the experimental lops and rigs decrease as well. More easily is to collaborate in fuel and material testing of the Gen IV and fusion reactors where the testing is closely connected with R&D and reactor coalition could take part in various international or national projects and grants. Among all EERRI members four reactors i.e. MARIA, BRR, LVR-15 and TRIGA (ICN) have facilities for fuel and material testing. The EERRI database of irradiation loops/rigs for material and fuel testing was developed as a first step in future collaboration in this field.

6. EDUCATION AND TRAINING ACTIVITIES OF EERRI REACTOR COALITION

In the area concentrated on education and training, the EERRI reactor coalition created the database of educational and training subjects (as an example part of the EERRI database is shown in *FIG. 3.)* and the database of educational and training experiments (an example part of the EERRI database is shown in *FIG. 4.*).

Subject	Reactor	CTU	ATI	IJS	BUTE	KFKI	NRI
Regulatory requirements		yes		yes	yes		
Research reactors management		yes	yes	yes	yes	yes	yes
Research reactors review		yes	yes	yes	yes	yes	yes
Research reactors utilization		yes	yes	yes		yes	yes
Introduction to nuclear physics		yes	yes		yes		
Reactor physics		yes	yes	yes	yes		
Thermohydraulics of research reactors		yes			yes		
I&C Systems		yes	yes				
Maintenance and inspection programs		yes	yes			yes	yes
Fuel management, fuel cycle, fuel burnup				yes	yes	yes	yes
Water chemistry						yes	yes
Waste management					yes	yes	yes
Radiation protection		yes	yes		yes	yes	yes
Emergency procedures		yes			yes	yes	yes
Decommissioning of research reactor					yes	yes	yes

FIG. 3. EERRI database of educational subjects (part of database, September 2011, [4]).

Training Experiment	CTU	ATI	IJS	BUTE	KFKI	NRI
Reactor operation - practical experience	R	R	R	R	-	-
Critical experiment, approach to criticality:						
* full scale experiment - duration 2 weeks	A	-	-	-	-	-
* mock-up experiment - by fuel adding	-	R	A	C	-	-
* mock-up experiment - by moving rod	R	R	R	R	-	R
*	-	-	-	-	-	-
Reactivity measurements:						
* Positive Period method	R	R	R	R	-	R
* Source Jerk method	R	-	-	-	-	-
* Rod Drop method	R	-	-	A	-	-
* Source Multiplication method (Greenspan)	R	-	-	R	-	-
* Noise analysis (Rossi-Alpha methods,...)	C	-	-	A	-	-
* Digital Reactivity meter	C	-	R	C	-	-
*	-	-	-	-	-	-
Control rods calibration:						
* Inverse Count Rate	R	-	-	A	-	-
* Mutual Calibration method	R	-	-	-	-	R
* Positive Period method	A	R	-	R	-	R
* Rod Swap method	-	-	R	-	-	-
* Rod insertion method	-	-	R	-	-	-
*	-	-	-	-	-	-
Study of reactor dynamics:						
* zero power reactor with/without neutron source	R	-	R	R	-	-
* delayed neutrons detection	R	U	-	R	-	-
* thermal effects & coefficients	C	R	R	A	-	R
* void effects & coefficients	R	R	R	R	-	-
* power& thermal effects - pulse operation	-	R	C	-	-	-
* various materials impacts on reactivity	R	R	A	R	-	-
* reactor response to step reactivity changes	-	R	R	-	-	-
* Xe effect	-	-	R	-	-	R
* change of reflector effects	-	-	A	-	-	R
*	-	-	-	-	-	-
R – Routine, A – Advanced, U - Under-construction, C - Considered						

FIG. 4. EERRI database of educational experiments (part of database, September 2011, [4]).

Soon after establishing the EERRI coalition in the spring 2009, EERRI organised the first training course for IAEA [2]. The six weeks course was focused on participants from non-nuclear countries, who wish to develop nuclear competence and infrastructure as a first step to develop a national nuclear power programme. The course was aimed at young technical professionals with little or no nuclear experience who can work in future at research reactor licensee or at national regulatory body. The first course attended by eight participants from Vietnam, Azerbaijan, Colombia, United Arab Emirates and Estonia, who spent six weeks at the TRIGA reactor in Vienna, Austria and both reactors (BME-TR a BRR) in Budapest, Hungary. Lecturers from IJS Ljubljana, Slovenia took part at the course also [2].

The second EERRI training course for IAEA named „Group Fellowship Training Programme on Research Reactors“ was similar as the first course with minor changes (the content of the EERRI course is shown in TABLE 2.) It was held in the spring 2010 at Vienna (ATI, TRIGA), Ljubljana (IJS, TRIGA) and in Prague and Rez in Czech Republic (CTU, VR-1 & NRI, LVR-15). The second course was attended by eight participants from Jamaica, Brasilia, Azerbaijan, Sudan, Oman and Saudi Arabia [5].

TABLE 2. CONTENT OF THE EERRI COURSE [4]

Module 01	**Technical visits** (minimum of three reactors listed below)
TRIGA Research Reactor in Vienna, TRIGA Research Reactor in Ljubljana, VR-1 Training Reactor in Prague, LVR-15 Research Reactor in Prague, Training Reactor in Budapest, BRR in Budapest	
Module 01	**Introduction** (lectures)
Introduction to Research Reactor (RR), Introduction to RR utilization, Introduction to Nuclear Engineering, Overview of RRs types, Overview of Nuclear Power Plant (NPP) types	
Module 02	**Theory** (lectures and computer based exercises)
Reactor physics of RRs, Introduction to reactor calculations, RRs reactor physics parameters and models, Calculation of RRs safety parameters, Introduction to computer codes – diffusion, transport & Monte Carlo codes, Thermal hydraulics	
Module 03	**Basic reactor experiments** (lectures and practical exercises on RR)
Neutron detection, Neutron flux and distribution measurement at RRs, Reactor kinetics & dynamics (including study of delay neutrons), Critical Experiment, Calibration of control rods, Determination of excess reactivity, Reactivity Measurement methods, Demonstration prompt criticality, Measurement of reactivity coefficients	
Module 04	**Reactor operation** (lectures and practical exercises on the reactor)
I&C Systems of nuclear reactor, Demonstration and practical exercises in RR start-up and operation, Demonstration of fuel handling out of core, RRs maintenance and in-service inspections, Radiation detection and protection – theory & practice, Waste management at RR, Water chemistry in RRs	
Module 05	**Safe operation of RR** (lectures and practical implementation at RR)
IAEA & Regulatory requirements for safe operation of RRs, Code of Conduct for RRs, Safety Analysis Report of RRs, Operational limits and conditions, Emergency preparedness and emergency exercises, Public information / communication, Quality assurance in practice at RRs, Security and safeguards of RRs	
Module 06	**RRs utilization** (lectures and demonstrations at the reactor)
Training of RRs operating personnel, Beam experiments, Material testing & hot cells, Isotope production, Neutron Activation Analysis	

The third EERRI course for the IAEA was held on February and March 2011 and the fourth on March and April 2011. The fifth course will be held in Austria and Hungary (same as the first course) and the sixth one will be held in Austria, Slovenia and Czech Republic (same as the second course). The third course was attended by eight participants from Jordan and the fourth course attended by five participants from Sudan and Philippines. The total number of participants attended the first four EERRI courses is 31 from 11 countries [6]. The fifth course is going to start in November 2011 and the sixth course in planned for the spring 2012.

Such six weeks courses for the participants with little or no nuclear experience focus on all aspects of the research reactor operation covering topics from legislation through theoretical and experimental reactor physics, reactor construction, operation to reactor utilisation (see TABLE 2.) These courses are typical examples of wide range courses, which are extremely difficult to organise by a single reactor institute or single university, reactor coalition can organise these courses much more efficiently.

5. CONCLUSIONS

It has been shown that research reactor coalitions play an important role in training and education to assist nuclear emerging countries in their efforts to gain nuclear experience in many different areas from legal aspects to reactor physics, safety and utilization. The EERRI coalition is an excellent example how such courses can be organised across borders and in cooperation of institutes with different structure.

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