Appendix-1
Country Reports on Research/Test Reactor and Applications

Australia

In Australia the OPAL reactor first went critical in 2006. Features of the reactor are:

- LEU fuel
- Open-pool design with a power of 20MW
- Demineralised light water provides cooling and shielding
- Heavy water surrounds the core in an enclosed reflector vessel
- The reflector vessel provides a large zone of high thermal neutron flux for irradiation facilities and neutron beam supply
- A cold neutron source

Initial issues with fuel movement and reflector vessel leaks have now been solved and the reactor is operating reliably. Current performance against key objectives is shown below:

Objective	Target (%)	Level Achieved (%)
Reactor Availability	80	77
Reactor Reliability	95	91
CNS availability		63

Key work undertaken utilising the reactor includes:

- Irradiation of U-plates for Mo99 – now at maximum capacity (for the processing plant)
- Silicon irradiations – (27T of Silicon irradiated in FY2011)
- Irradiation of other radiopharmaceuticals
- Neutron Activation Analysis– (Aboriginal rock art & meteorites)
- DNAA – supporting the Uranium mining industry

A thorough operational and maintenance system has been established in order to maintain the reliability and safety of the reactor. Features of this system are:

- Dedicated engineering resources
- Detailed Maintenance Procedures
- Ageing Management

- Maintenance Management
- Spares Management

After the Dai-ichi nuclear power plant incidents, the ANSTO undertook a re-examination of the OPAL Safety Case. As no guide exists for periodic review of Research Reactors, the IAEA guide for Nuclear Power Plants was adapted and used.

OPAL is now operating reliably and predictably and a long term operating plan has been developed which will ensure its continued, safe operation.

Bangladesh

"Study on Current Status of TRIGA Mark II Research Reactor based on its Research and Application"

The aim of this report to present the current status of TRIGA Mark-II RR based on its research and application. Bangladesh Atomic Energy Commission (BAEC) has been operating the country's only research reactor, a 3 MW TRIGA Mark II RR since September 14, 1986 under Natural Convection Cooling Mode (up to 500 kW) and also Forced Convection Cooling Mode (above 500 kW). It is a light water cooled, cylinder shaped pool type research reactor, which uses uranium-zirconium hydride with erbium fuel elements in a circular grid array. It is equipped with a number of irradiation facilities: a) dry central thimble (DCT), neutron beam tubes (tangential, radial piercing, radial 1 and radial 2), pneumatic transfer system, rotary specimen rack (Lazy Susan), thermal column, etc. Since its establishment this reactor has been playing a pioneering role in scientific research and in providing services to the people. For example, the radioisotopes produced in this reactor are being used in different nuclear medicine centers of the country for both diagnostic and therapeutic purposes. With the aim of socio-economic development of the country, the experimental facilities are being used in various fields of research and application. Such as qualitative and quantitative assessment of elements in variety of sample matrices and nuclear data measurements using neutron activation analysis, materials characterization by neutron radiography, materials structural analysis using neutron scattering experiments, production of isotopes, training of manpower, education, etc. To make the TRIGA reactor as beneficial nuclear tool for country through the optimization of its research and areas of application with the help of national and international strategic partners.

Indonesia

1. RSG-GAS reactor has been more than 20 years with varying operating power 15-30 MW has a neutron flux of 2.5 x 10^{14} n.cm-2.s-1, which is equiped with:
   a. Isotope production facilities at the irradiation position inside and outside of the core such as rabbit systems for research and commercial purpose.
   b. 5 out of 6 available beam tubes that can be used as a materials test facility for: Diffractometer for Residual Stress Measurement (RSM), Circle Four diffract. / Texture Diffractometer (FCD / TD), High Resolution Powder Diffractometer (HRPD), Neutron Radiography Facility (NRF), Triple Axis Spectrometer (TAS), SANS Spectrometer (SMARTer), High Resolution SANS Spectrometer (HRSANS).
   c. Testing facility for power reactor fuel element pins on the power ramp test facility (PRTF) which has been tested and will be operated in 2012. This facility illustrates the similarity condition of the loop with 150 bar pressure in safe operation.
   d. Doping silicon production facility that being tested and developed its quality to start up for operation in 2012.
   e. Gemstones coloration facility using gamma radiation that produces the discrete colors of yellow, green, blue, red and brown.
   f. NAA laboratory to analyse the sample from industry, geology/mining, agriculture, health and environment.

2. BATAN in cooperation with PT Batan Teknologi improving the production facilities of 99Mo and other medical/radiopharmaceuthical isotopes to give the better services to end user. In this way Batan Teknologi will provide the communication channels to all related parties.

3. PT Batan Teknologi provides its services to meet national need, but also provide opportunity for the state- neighboring countries and international parties to use the services mentioned above. As the information source to come in our services, please achieve in following address: http://www.batan.go.id/prsg and E-mail: prsg@cbn.net.id for irradiation and isotope production services; http:// www.batan.go.id / ptbin and bsn@batan.go.id to the beam tube utilization. Available service for training in reactor operation and samples irradiation can obtain more information on http://www.batan.go.id/pusdiklat and pusdiklat@batan.go.id.

Japan

The JMTR is a light water moderated and cooled, beryllium reflected tank- type reactor using LUE silicide plate-type fuels. Its thermal power is 50 MW, maximum thermal and fast neutron flux is 4 x 10^{14} $cm^{-2}s^{-1}$. First criticality was achieved in March 1968, and its operation was stopped from August, 2006 for the refurbishment. An investigation on aged components (aged-investigation) was carried out for tanks in the primary cooling system, heat exchangers and so on, in order to identify their integrity. Refurbishment works have been finished by the end of the FY2010. However, seismic influence evaluation for the JMTR because of the 2011 Tohoku Region Pacific Coast Earthquake is on going with directions of the government. The JMTR will be re-started promptly after the end of the seismic influence evaluation.

Corresponding to the user's irradiation request, new irradiation facilities, such as irradiation test facilities for materials/fuels of LWRs, production facilities for medical radioisotopes, are being installed.

After the refurbishment, the JMTR will be operated for a period of about 20 years until around FY2030. Operation plan after the refurbishment is 7 cycle operation per year that means total 210 days per year by reducing periodical inspection and preparation periods for irradiation samples and so on.

A conceptual design study of the next generation research and test reactor is performed in parallel to the refurbishment work of the JMTR. The conceptual design study was planned in order to contribute to nuclear human resources development in Japan and Asian countries.

New JMTR would be one of kernel materials testing reactor in Asia, and contributes to the formation of the base for the nuclear power introduction into Asian countries. Application of the new JMTR utilization started from March 2010 by the JMTR website (http://new-jmtr-ussj.jaea.go.jp). Foreign users are also welcome to use the JMTR facilities.

Kazakhstan

Nuclear reactor WWR-K is a light water tank-type research reactor commissioned in 1967. The reactor operated at 10 MW thermal power for 20 years until its temporary shutdown in 1988 for safety upgrades. After re-commissioning in 1998, it operates at 6 MW power by cycles of up to 30 days duration.

The reactor has several dozens of irradiation channels with thermal neutron flux 10^{12} to 10^{14} $n\cdot cm^{-2}\cdot s^{-1}$ and is equipped with hydraulic and pneumatic rabbit systems, neutron radiography facility, gas/vacuum loop facility, and a critical assembly which allows modeling of the reactor core, precise measurement of neutronic characteristics of in-core devices, and verification of neutronic calculations.

Current activities at the reactor are:

- *Material testing.* Irradiation testing of various materials and components is a traditional application of WWR-K reactor for many years. A list of materials studied includes mainly pure metals, alloys and stainless steels and new materials as a candidates for fuel or reactor constructional material
- *Neutron activation analysis.* Traditional NAA with small specimens (0.1-1.0 g) is used at WWR-K for a long time. Recent development is analysis of large specimens (10-100 g) which simplifies sample preparation and provides more precise data for wider range of microelements in both geological and environmental samples.
- *R&D for transmutation doping of Silicon.* Several irradiation positions were evaluated in respect to neutron transmutation doping of silicon ingots with ± 5% homogeneity. Vertical channels (diameter 100 mm and 200 mm) in water reflector are suitable for irradiation of 3-inch and 6-inch silicon ingots, respectively. Irradiation equipment is much simpler than for tangential channel. Acceptable radial homogeneity is provided by rotation of ingot. Axial (vertical) flattening of neutron flax is reached by installation of a profiled neutron absorber around the irradiated ingot. Estimated irradiation time is about 2 days for 40 cm high silicon ingot.
- *R&D for BNCT.* Experiments on formation of neutron beam suitable for boron neutron capture therapy (BNCT) were carried out at one of radial horizontal channels. In order to reduce a gamma dose rate and a share of fast neutrons in the beam, three filters were installed: lead blocks in core periphery, lead screen in the region of biological shielding, and beryllium oxide filter after lead screen.

Future plans are related to expansion of these activities, in particular for testing of prospective nuclear fuel for advanced reactor systems, and conversion of the reactor to low enriched uranium fuel.

Korea

Hanaro is a multi-purpose research reactor in Korea. At the time of completion of reactor construction, 1995, there were no utilization facilities except irradiation holes and beam tubes installed in the reactor assembly. Now the floor of reactor hall is packed with various neutron beam instruments and the irradiation holes are filled with targets for the radioisotope production. During a first decade since 1995, Hanaro equipped thermal neutron instruments one by one according to the plan of national R&D. From 2006 large scale utilization facilities, Fuel Test Loop(FTL)and Cold Neutron Source(CNS), were started to install to support new research areas and completed the installation in 2009.

Hanaro has several thermal neutron beam instruments consist of high resolution power defractometer, neutron radiography facility, ex-core neutron irradiation facility, and residual stress instrument, etc. For the irradiation of materials and fuels, FTL and capsules are used. Neutron transmutation doping facility also is provided. In the cold neutron research laboratory, new instruments like 40m SANS are being installed and some instruments that had been in the reactor hall were moved to use the cold neutron beam.

KAERI (HANARO) has a program for supporting users to utilize the facilities from national and foreign countries. And Korea provides various aids to the foreign countries like scholarship and trainings.

HANARO can provide the utilization facilities to Member countries according to the programs. But the financial support for living in Korea by the FNCA will be needed to implement this cooperation.

Malaysia

Malaysian Nuclear Agency (Nuclear Malaysia) has been operating PUSPATI TRIGA Mark II Research Reactor since it was commissioned in 1982. It has a nominal power of 1MW with maximum thermal neutron flux of (1.777±0.031) x 10^{13} n.cm^{-2}.s^{-1} located at the central thimble at the center of the reactor core. Among the facilities are in-core dry tubes, wet central thimble and the rotary rack for isotope production for medical and radiotracer purpose, as well as neutron activation analysis (NAA). Of the four existing beam ports, two are already used for Small Angle Neutron Scattering (SANS) and neutron radiography (NR). Besides these, feasibility studies to undertake various developments such as prompt gamma neutron activation analysis (PGNAA), new neutron radiography at the tangential beamport and the development of the thermal column for boron neutron capture therapy (BNCT) has been carried out.

Generally, the reactor is used mainly for training in reactor operation, production of radioisotopes for medical and industrial use, as well as research and development (R&D) in neutron beam application at SANS and NR. Since the magnitude of the neutron flux and flux distribution had posed some limitations to the enhancement of the reactor utilization, expansion of neutron application for advance research is relatively limited. However, there had been plans and efforts to enhance the usage by increasing the number of neutron application facility as well as to improve the existing setup.

Although several collaborative projects with the institutions of higher learning to develop new facilities are currently being undertaken, we also faced some challenges in managing the reactor, such as:-

Issues faced	Description	Status
Operation factor	Loss of expert manpower	Experienced reactor operator move to another agency
	Reactor upgrading: 3 MW	Provision not approved
	Console upgrading: analog to digital	Over-budget tender
	Procurement: MPR	Provision not approved
Technical	Ageing: I&C, console	Low reactor availability
Safety Assessment	Probability Safety Assessment (PSA)	On-going: licensing requirement
	Deterministic Safety Analysis (DSA)	On-going: licensing requirement

Mongolia

It is predicted that Mongolian energy demand will increased as much as 2-3 times by year 2030. Nowadays dominant part of the electricity demand in Mongolia is provided from the conventional fuel as raw coal so that it is also being the main reason for air pollution of Mongolia. On the other hand, uranium ore exploration and investigation are intensively developing in Mongolia in recent years. Therefore Nuclear energy law and the implementation program for utilization of nuclear energy and radioactive minerals were approved in 2009.

According to the implementation program a pre-feasibility study of research reactor (RR) is developing. RR will be used in short- and middle-lived medical isotope production, activation analysis of geological and environmental samples and in possible studies on material science as well as education and training.

Many Mongolians lack knowledge about application of nuclear power so that they have some precaution about nuclear power plants, especially after Chernobyl and Fukushima accidents. So, first of all it is important to introduce a RR. The usage activities of the RR will be transparent to the general public. A confidence of the public will grow on the ability and skills of local professionals to operate nuclear facility. Therefore, introducing RR the general public acceptance of nuclear facility will increase and it will demonstrate that the nuclear power can be one of the energy sources in Mongolia.

The Philippines

The PNRI Research Reactor (PRR-1) is the first and only nuclear research reactor in the country. It was obtained through the bilateral agreement between the Philippines and the United States of America on July 25, 1955. Under the agreement, the United States Government was to provide the research reactor while the Philippine Government was to provide the manpower and the building for the research facility.

The PRR-1 is an open pool general purpose type reactor owned and operated by the PNRI. The PRR-I is located inside the campus of the University of the Philippines Diliman, Quezon City. The PRR-1 became the principal research facility for many research activities in the field of radioisotope production, neutron spectrometry, neutron activation analysis and reactor physics. It was also the training ground for students and new graduates in natural sciences and engineering.

The PRR-1 started operation on August 26, 1963 at 1 MW with a plate type core was operated uneventfully without any major modification for about 15 years. The original instrumentation system and other parts of the reactor became unreliable and difficult to maintain by the late 1970's. The system was modernized in the 1980s replacing the fuel, cooling system and instrumentation system with new components provided by General Atomics. The TRIGA conversion was completed and was successfully restarted at full rated power of 3 MW in 1988.

But before the reactor could resume regular operation, a serious leak developed in the pool liner. The epoxy joint between the thermal column casing and the pool liner had failed and the aluminium liner had a serious corrosion problem.

However, the resumption of reactor operation was prevented due to the following : (a) the remaining original mechanical and electrical components were very old and needed repair; (b) the reactor core container was found not to be leak-tight ; (c) the area around the reactor site had urbanized and the confinement system of the reactor building –

designed and built in the 1960's could not deal with an accidental radionuclide release , even if the system had been in perfect working order; (d) a seismic fault less than 5 km away became suspected by national authorities to be capable of causing severe earthquake.

In 2005, the PNRI formally decided to decommission the reactor and was accepted as a model reactor for the International Atomic Energy Agency (IAEA) Research Reactor Decommissioning Demonstration Project (R2D2).

The R2D2 Project commenced in June 2006 and expected to be completed in six years. Under this project, (a) IAEA will assist the regulatory body in developing its capability to review the necessary approach being proposed by the operator and ensure international safety standards are being appropriately applied (b) Technical assistance will be provided to the reactor operator/owner with the development of the safety documentation and supporting documents for the licensing process to decommission (c) workshops, training courses and hands-on-exercises will be conducted at the facility inviting other Member States to obtain practical experience.

Thailand

The operation of Thai Research Reactor-1/ Modification 1 (TRR-1/M1) is under the responsibility of TINT (Thailand Institute of Nuclear Technology). TINT is founded during governmental reformation in 2006 by separating from Office of Atom for Peace which has essentially become the regulatory body in Thailand. TRR-1/M1 is located in Bangkhen site in Bangkok. TRR-1/M1 was converted from the MTR type research reactor in 1977 to a TRIGA-Mark III reactor. The reactor has been operated at the nominal power of 1,200 kW. There are two types of fuel elements loaded in the core: 8.5% wt. and 20% wt. types. TRR-1/M1 is operated daily from Tuesday to Friday with the total operation time of 46 hours per week, approximately 10.5 month a year which roughly amounts to the burnup rate of 90 MWD/year. The annual shutdown of the reactor takes about 1.5 months including inspection, repair, replacement of spare parts, calibration and performance test. Currently, the safety documents of the reactor are being reviewed and revised to improve the safety of the reactor. Also, the ageing management program of the reactor is being formulated for physical ageing and non-physical ageing issues. The major challenge for TRR-1/M1 at the moment is the uncertainty about fuel supply which may cease production in the future and it is unlikely to find replacements for the fuels.

Vietnam

At present, Vietnam has only one research reactor – Dalat Nuclear Research Reactor (DNRR) - with nominal power 500kW which main purpose is training, radioisotope production, neutron activation analysis and basic research. During operation more than 27 years, the research reactor played a very important role in the nuclear programme in Vietnam including the production of more than 4,000 Ci to serve for treatment and diagnostics of patients, irradiation of about 60,000 different samples for NAA of geologic, crude oil, environment, carrying out many researches and experiments related to fundamental and application on reactor, and creating huge amount of staff with high skills and experiences on nuclear applications in Vietnam. However, due to the limitation of neutron flux and power level, the out-of-date design of the experimental facilities and the ageing of the reactor facilities, this research reactor can not meet the increasing user's demands. So building a new research reactor with multi purposes, high power (10 to 20MW) is essential to increase nuclear potential of the country, to meet the requirements of energy and non- energy related applications, creating staff for nuclear industry. The main role of a new research reactor is to serve the nuclear power development program, promote the application of nuclear science and technology, and training scientific and operational staff for the nuclear facilities in the future.

In preparation for new project in the future, VN call on the international and regional cooperation from the neighboring countries which possess research reactor such as China, Korea, Japan, Indonesia and Thailand. This collaboration should be initiated and supported under IAEA RCA, FNCA technical cooperation projects in the field of expertise training related to technology of research reactors as well as other application field.

- Cooperation on exploiting and applications such as materials irradiation, exploiting the channel
- Cooperation on the implementation of research support for nuclear power plant using the research reactor
- Calculate the design and safety analysis (neutron, thermal-hidrolic calculation programs such as MVP, MCNP, SRAC, RELAP, ...) in the fitting of additional research facilities around the reactor, such as: design horizontal channel, vertical channel, channel Silicon Doping irradiation, irradiation fuel channel power reactor (test loop).
- Cooperation on research of new RI production for medicine and industry use
- Cooperation on Human resource development in Nuclear Science and Technology

- Receipt of researchers from others countries for visits, fellowship,

- Organization of regional training/workhop
- Participating in regional research projects (RAS)
- Information exchange
- Bilateral cooperation programme in new research reactor project on design, safety analysis, ...