Full-scale reconstruction and upgrade of the Budapest Research Reactor

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Abstract. The BRR is a tank-type research reactor (RR), moderated and cooled by light water. The reactor, which went critical in 1959, is of Soviet origin. The initial thermal power was 2 MW. The first upgrade took place in 1967 when the power was increased from 2 MW to 5 MW, using a new type of fuel and a beryllium reflector. A full-scale reactor reconstruction and upgrade began in 1986. The upgraded 10 MW reactor received the operation license in November 1993. Since that time the reactor has been operating on average ≈3500 hours/year without any significant problem.

In the early nineteen-eighties, about 8-10 years before the 30-year service life elapsed, discussion began to decide whether to extend the life of the reactor or start the preparation for final shut-down. Due to the general consensus of necessity for further reactor operation, in 1983 the government made the decision to go ahead with reconstruction and upgrading. The design work started in 1984 while the reconstruction project began in 1986. According to the modernization plan a partial decommissioning preceded the modernization, during which, with the exception of the civil engineering construction, all equipment was replaced. The reconstruction was finished in the technical sense by the end of 1990, but due to the political changes in the country, the institute could only apply for a license for reactor start up in 1992. In 1992 a consortium, namely Budapest Neutron Centre (BNC), was founded by four academic institutes to coordinate the reactor utilization and ensure a scientific background for managing the utilization strategy. With guidance from the BNC the experimental facilities around the beam ports were put into operation continuously in the first 2-3 years after the reactor start up, but investment in several facilities was postponed for several years. One of the postponed utilizations was the cold neutron source (CNS), which was eventually commissioned in 2001. The installation of a multi-frame time-of-flight (TOF) diffractometer was completed in 2004. Currently 12 research facilities are operating.

Reviewing the last 15-20 year period with respect to the reactor reconstruction milestones, including the preparation phases for restarting regular operation and the lunch of utilization, highlights many experiences. These experiences and lessons learned may prove useful to members of the RR community if faced with the dilemma of choosing between renewal or irreversible degradation.

1. Facility Background

The Budapest Research Reactor (BRR) has been operated by the Hungarian Academy of Sciences KFKI Atomic Energy Institute (AEKI). The BRR was built in 1957-1959 to a standard VVR-S design. It is a tank type reactor with light water moderation and cooling. The reactor went critical in March 1959. In 1967 the original power of 2 MW was increased to 5 MW with a change of fuel type from EK-10 to VVR-SM. The core was also modified by the installation of a solid beryllium reflector surrounding the core. After this first upgrade the reactor remained in operation until 1986 when it was a shut down for second upgrade.

During its initial 27-year operation period the reactor was used as a basic facility for neutron scattering, radiochemistry, shielding investigation and radio-isotope production. More than this however, its mission was to establish and afterwards maintain the culture of nuclear research in the country.

The main data and operational record

Reactor type:	Light-water cooled and moderated tank-type reactor with beryllium reflector (the beryllium has been used since the time of 1st upgrade)
Physical start up:	March 25, 1959.
Fuel assembly:..	EK-10 then VVR-SM after the 1st upgrade

Thermal power:...................................... 2 MW then 5 MW after the 1st upgrade
Shut down for upgrade:.......................... March 29, 1967
1st upgrade:... Partial upgrade
Physical start up after 1st upgrade: .... September 4, 1967.
Shut down for reconstruction:................. May 9, 1986

❖ **Operation record**

Average annual operation: .... 2480 on 2 MW; 3230 on 5 MW
Total operation time:.............................. 8322 hours
Total MW-days:..................................... 12647 MWday
Shut down for upgrade:.......................... May 9, 1986

2. Reconstruction and Upgrade Scope

The first study of the development goals of the BRR was completed in 1974 by the Hungarian Academy of Sciences. Following this, several feasibility studies were also conducted by different organizations from the Hungarian and foreign scientific communities, including industrial representatives and the Kurtsatov Institute in Moscow. In these studies, the utilization demands were primarily considered from the perspective of fundamental and applied research but also stressed the importance of education, training and even industrial applications. Although these studies were mostly undertaken from a scientific perspective, the technical possibilities were also considered.

2.1.Strategic arguments for reconstruction and upgrade

As a result of the preliminary studies mentioned above a general consensus had shaped for further reactor operation and even a demand for increasing flux density started to form. The strategic arguments for the necessity of further reactor operation and upgrade were grouped around four issues as follows:

- *Radioisotope production:* the reactor should ensure further isotope production for medical and industrial application. The importance of the production of short-lifetime isotopes was emphasized.

- *Basic and applied research:* research activities in the field of condensed matters, materials science, activation analysis, radiochemistry, nuclear gamma spectroscopy, reactor safety, health physics, etc. would be highly desirable to continue and/or extend or in some cases start.

- *Technological and commercial applications:* demands for investigations relating to nuclear reactions based on neutron, neutron induced embrittlement study, and the surveillance of the power plant's pressure vessels can only be met through the using of a research reactor. In addition to these are industrial and commercial applications: silicon doping, development of nuclear instrumentation, tests and certification for industry by neutron and gamma radiography etc. These promote prosperous service applications for reactor.

- *Education and training:* contribution to university and postgraduate education, training for nuclear engineering, and hosting international training courses (e.g. at the behest and with the participation of the IAEA) are all duties of the reactor and an essential source of political interest.

2.2.Decision for reconstruction and upgrade

The first development conception [1] was elaborated in 1981 by the leading Hungarian power plant design company (ERŐTERV). The conception was elaborated according to the new trends in nuclear research and applications, as well as modern reactor safety requirements including IAEA’s recommendations (e.g. as defence-in-depth). The conception took into account all feasible and available possibilities such as: fuel questions, core configuration with increased irradiation places, technical capabilities including utilization issues, as well as future operation and maintenance questions. The conception made a real cost-benefit analysis (comparable to a modern day SWOT analysis) and defined the design basis and design requirements including safety issues. Finally, on the basis of the considerations listed above, the reconstruction and upgrade project was drafted including the outline project schedule and resources needed including financial and human demands.

Due to the general consensus and the well-founded strategic arguments for the necessity of further reactor operation, in 1983 the government made the decision to go ahead with the reconstruction and upgrade of the BRR.

3. Reconstruction and Upgrade Project

After the political decision the budget calculations and project scheduling started immediately. The technical design (conceptual, technical and workshop design) and licensing work were started in 1984. The project implementation itself began in 1986, following 27 years of operation since initial reactor criticality.

3.1.Budget and project schedule

A significant part of the investment grant was secured from governmental sources as the project was afforded so called “capital state investment”. To obtain this nomination, which ensured a high priority for the project, in many respects was due mostly to the strong support of the IAEA. However, domestic and foreign scientific public opinions also helped the project get a green light. Although the greatest part of the investment costs were covered by the governmental budget, the IAEA, in addition to the continued moral support, contributed financially with direct procurement of beryllium elements, primary pumps, valves built in the primary loop and hot cell facilities (manipulators and their accessories).

The financial resources covered the reactor reconstruction and reactor upgrade costs in all respects. The reactor technically was made according to the design. All reactor systems and auxiliary units were implemented. However it become obvious at the very beginning that the investment of some utilization facilities should be postponed to avoid delaying the project start or (more likely) the reactor restart.

Due to the careful preparation and financial planning the project was performed according to the reconstruction conception from the design stage right through to the implementation. Originally the shutdown was estimated to take place by the middle of 1985. However the design and licensing was delayed by one year, thus the partial shut down was performed in May 1986. The project implementation together with partial decommissioning was scheduled for 24-month period. The reconstruction was finished (in the technical sense) by the end of 1990 but due to the political changes in the country, the reorganization of the institute and other non-technical considerations, the AEKI could only apply for a license for reactor start up in 1992, after a two-year period of uncertainty. During these two years of indecision, the reactor was essentially ownerless and the reactor came very close to being dismounted (this possibility was considered as a real alternative).

3.2.Project management and human factor

It should be mentioned that good management is a key factor in a successful project. This was the roll of the reactor staff during the reconstruction. Although the reconstruction had a general contractor for design and implementation, the project was supervised and guided by the close cooperation of the institute director and reactor manager. The reactor specific design (core design, thermo-hydraulic calculations, etc.) and safety assessments were also made by the nuclear physicist and engineers of the institute and these calculations were validated by the experts of the Kurtchatov Institute. The panel reviews of the technical designs were also fulfilled by the reactor experts of the institute.

Regarding the effective job, the partial decommissioning work was entirely carried out by the reactor staff. Whereas the implementation was the task of the contactors. Nevertheless the quality controls, factory tests, the assembling and testing of subsystems, general functional tests, verification and validation procedures, as well as the setting the baseline data (BLD: initial parameters as “0”-status) were done with the active participation of reactor staff too.

It should be mentioned that all tasks concerning the reactor staff could be managed with the standard human sources available at the reactor. There was no needed for any additional temporary employment of workers. It should be mentioned also that during the two-year period of uncertainty, several well-trained experts were head-hunted by multinational companies coming into the country, and left the reactor. In some cases it was many years before their replacements could be found.

3.3.Technical and safety features of the reconstructed reactor

In our case it was very important that the calculations and the foreign experience (Rossendorf, St. Petersburg) proved the biological shield of the reactor to be of sufficient strength with the increased power. In order to satisfy the safety criteria essential technical measures were made during the reconstruction. These steps resulted in the safety of the facility having been increased significantly. However, a lot of further technical measures have been made in consequence of reactor technique development. On the basis of the PSAR [2] these features can be summarized as follows:

- *Core.* The core furthermore is built of VVR-SM fuel assemblies. The number of fuel is increased in order to increase the power, but to increase the flux further the power produced by one element is increased as well. This fact necessitates that the cooling of assemblies be more intensive. It is ensured by the adequate design of the primary cooling system (pipes, pumps, heat exchangers, etc.)

- *Safety and control rods*. The increased number of irradiation places, where the neutron flux is relatively high, resulted in a rather complicated core. To ensure a suitably long refuelling cycle, that the number of control rods also had to be increased. Whereas before two safety rods were sufficient, now three rods are built in to guarantee a safe shut down.

- *Measuring and control system.* As the core became more sophisticated, control of the operational parameters became more important. Therefore the measuring and control system was required to be more reliable. The measurements are generally redundant (triplicate) and the safety and warning signals of the nuclear instrumentation are evaluated using a majority vote (two out of the three).

- *Material of vessel and primary loop.* One of the most important safety criteria is to avoid loss of coolant accident (LOCA) failures. Thus the materials of the primary loop were very carefully designed. The material of the vessel and grid is an aluminium alloy named R-AlMg2.5 (this is a modified version of the alloy 5052; the material composition is the same but the aluminium base material is purer). Material of the pipes is 18/8 type stabilised austenitic steel with nuclear grade certification.

- *Safety systems.* Two battery stations and two diesel generators were installed to ensure UPS for the emergency system. The safety logic is up-to-date and highly reliable. Fail-safe principle is realized in the actuation of the safety rods. Regarding emergency cooling a passive cooling system (gravity tank) was constructed which provides core cooling for one minute after the loss of electric power. In addition to the make-up water system, which was also improved, an emergency water feedback system was constructed to collect and feed back the water from the reactor well and pump room in case of LOCA type incidents. In addition a sprinkler system has been installed to cool the core in the case of extensive LOCA failure.

- *Secondary cooling system.* The previous open secondary circuit was replaced by a new, closed system, which contains two cooling towers. The secondary circuit is designed for 20 MW.

- *Systems and measures to avoid radioactive release.* The sealing of the reactor hall was strengthened to form a quasi-containment area. In addition a recirculation ventilation system was commissioned which could be activated if the limit of radioactive release would be violated.

- *Nuclear spent fuel (NSF) storage.* A new AR-pool was installed with high-density grid with boron carbide absorbers. Also new storage pipes were installed in the AFR-pool, which could be hermetically sealed.

- *Waste management.* Two new storage tanks with 150 m^3 capacity each were installed with a renewed drainage network. The existing four storage wells were also renewed to ensure safe temporary storage for the gathered solid waste.

3.4.Licensing related analyses and obligatory documentations

Due to the three-level design procedure (conceptual-, technical- and working designs) and the applied quality management and control system the project has been well documented and the certificates and records for demonstrating compliance with the requirements are settled and retained. The test records of commissioning procedures, as well as setting the so-called “0”-status of the systems are also retained. Prior to investment SAR (for licensing the shut-down and reconstruction), preliminary SAR (prior to reactor start-up for licensing the physical start-up) then final SAR (for operation licensing after physical and energetic start-up) were elaborated according to the status of the reconstruction project. According to nuclear safety regulations the most important documents for reactor start-up and continued operation were also elaborated.

Of course the set of documents that served the licensing procedure on the basis of operational experiences were reviewed. In terms of the results of the periodic safety review (PSR), which was conducted in 200-2003, it can be stated that the obligatory documents exist, that they are generally up-to-date and have been improved by experience.

3.5.Utilization

In 1992, during the period of uncertainty, a consortium, the Budapest Neutron Centre (BNC), was founded by four academic institutes to coordinate the reactor utilization and ensure a scientific background for managing the utilization strategy. With guidance from the BNC the experimental facilities around the beam ports were put into operation continuously in the first 2-3 years after the reactor start up. Later on, as the budget was available and/or ensured, the postponed utilization facilities were also put into operation. One of the postponed utilizations was the cold neutron source (CNS), which was eventually commissioned in 2001 with the strong financial support of IAEA and EC. In the framework of the utilization program in 2003 a hot cell rehabilitation project was completed with the financial support of a Hungarian Government grant. The installation of a multi-frame time-of-flight (TOF) diffractometer was completed in 2004 with the sponsorship of the Hahn-Meitner Institute Berlin and the institutes of BNC.

4. BRR after the reconstruction

The newly independent AEKI applied for licensing in 1992. After having got the license for the first period, the start-up procedure of the reactor was begun in 1992. The reactor reached first criticality on 12 December 1992. The licensing and testing period took nearly a year (physical start-up, measurements at zero power, approaching nominal power, and at nominal power). The license for regular operation at nominal power was issued on 25 November 1993, without any restrictions. The regular operation started immediately on 26 November 1993. An aerial view of the site, Rector Hall and Control Room can bee seen in the attached photos (see *Photos 1-3*).

Main technical data

Vessel:.. Aluminium alloy (height: 5685 mm; ∅ 2300 mm)
Fuel: .... VVR-SM(-M2); initial enrichment: 36 % 235U; Average burn-up: 60-65 %
Core geometry:................................ Hexagonal (height: 600 mm; ∅ 1000 mm)
Equilibrium core: .... 227 fuel assemblies (in single equivalent)
Control: .... • 3 safety rods (B4C); • 14 shim rods (B4C); • 1 automatic (fine) rod (SS)

Nominal thermal power:.................. 10 MW
Mean power density in the core: ..... 61.2 kW/litre
Neutron flux density in the core:..... • $2,5 * 10^{14}$ n/cm^{2}s (thermal in the flux trap)
•$1 * 10^{14}$ n/cm^{2}s (approx. max. fast flux in the fast channel)
Cooling system:............................... Two closed loops (primary and secondary loop)
Primary loop:.................................. • $Q_{nominal}$: 1650 m^3/h
• T_{inlet} : 45 °C; • T_{outlet}: 50 °C
Secondary loop:............................... • $Q_{nominal}$: 1850 m^3/h
Ventilation system:.......................... • Stack air flow rate: ≈ 60000 m^3/h
• Pressure in technological rooms: gradually decreasing (-5…-25 mm wh)
Experimental channels: .... • Vertical irradiation places: ≈ 40 channels
• Horizontal irradiation beam ports: 8 radial & 2 tangential

1: Reactor Building with the Control Room being on the 2nd floor ♦ 2: Reactor Hall ♦ 3: Engine room with air filters of the Air Ventilation System ♦ 4. Secondary Pump Room ♦ 5. Cooling Towers ♦ 6. Auxiliary Building accommodating the Diesel Generators and Compressed Air System ♦ 7. Building of the Liquid waste storage facilities (under the foreground area two storage tanks are accommodated ♦ 8. AFR-pool (with solid waste storage wells in the foreground area) ♦ 9. CNS's Measuring Hall ♦ 10. Cryo-system of CNS ♦ 11. TOF's Measuring Hall

Photo 1 Aerial view of the BRR site

Photo 2 Panorama view of reactor hall

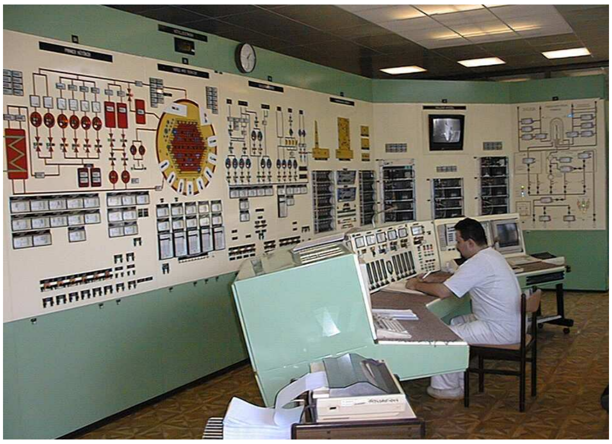

Photo 3 Control Room

4.1.Operation record of the BRR

From the time of start-up the upgraded reactor has been operating on average ≈3500 hours/year without any significant problem. The operation time record (scheduled and performed) is displayed in *Fig. 1*, while the operation cycles performed in 2005 are shown in *Fig. 2*.

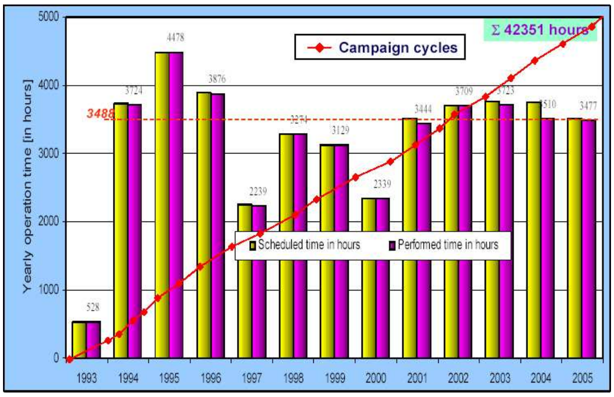

Fig. 1 Operation time record

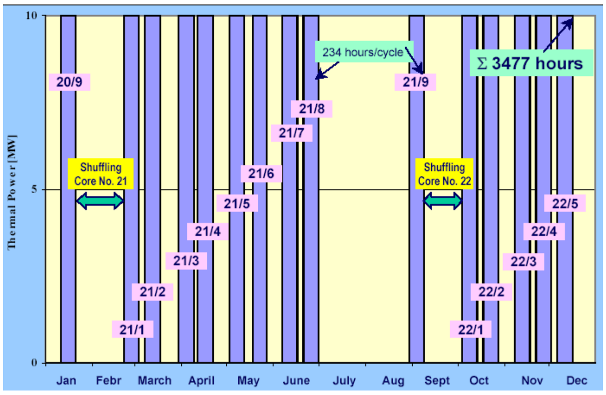

Fig. 2 Operation cycles in 2005

Upon comparing the yearly operation data (see *Fig. 1*) it can be seen that the actual operation was close to the scheduled plan (coincidence>93 %). From the restart in 1993 the BRR fulfilled 22 refuelling cycles (campaigns), as indicated on the graphs of *Fig. 2* (the numbering on the graphs means: No. of campaign/No. of operation cycle). It can be seen from the figure that the length of a typical operation cycle is 234 hours at 10 MW nominal power and a campaign consists of 9 operation cycles.

4.2.Periodic Safety Review (PSR) in 2002-2003

In line with Hungarian safety regulations [3] a periodic safety review (PSR) was conducted in 2002-2003, as a result of which the operation licence was renewed in November 2003 and is now valid until further notice. In the course of the PSR, validation test procedures carried out during the reactor upgrade were repeated. These were the most important parts of the validation test procedures of the reactor systems carried out during the system installation and commissioning in the period of the reactor upgrade. The latest results were compared with the BLD recorded 10-12 years ago during the same validation test procedures. Based on the results of these comparisons and the operation data and event-audit the most important statements were taken as follows [4]:

- There are no significant ageing problems, no unexpected degradation, and no abnormal phenomena appeared on any safety-critical system or component. The degradation is in accordance with the service life of the reactor.

- The 10-year service life of the reactor was safe, the operation passed without any OLC's violation.

- The assumptions of the PSAR are confirmed and its extreme conservatism justified by the experiences of operation and the reassessments of the FSAR.

- The operational environments including human factors and safety culture appearing in the everyday practices promote safe and reliable reactor operation.

4.3. Utilization

The BRR is used for various purposes. This includes, amongst other things, for irradiation and neutron research, the latter being the main utilization (to serve as a neutron source). Irradiations are performed in vertical channels (the reactor has more than 40 channels, including six flux traps that can be used for isotope production and material testing; in one of the channels there is a pneumatic rabbit system that serves for neutron activation analysis). In contrast, experiments are carried out at the horizontal neutron beam ports. The reactor has ten beam ports (eight radial and two tangential) and now nearly all of them are in use. Currently 12 research facilities are operating around the beam ports of BRR. The present layout of the horizontal neutron beam facilities is shown in *Fig. 3*.

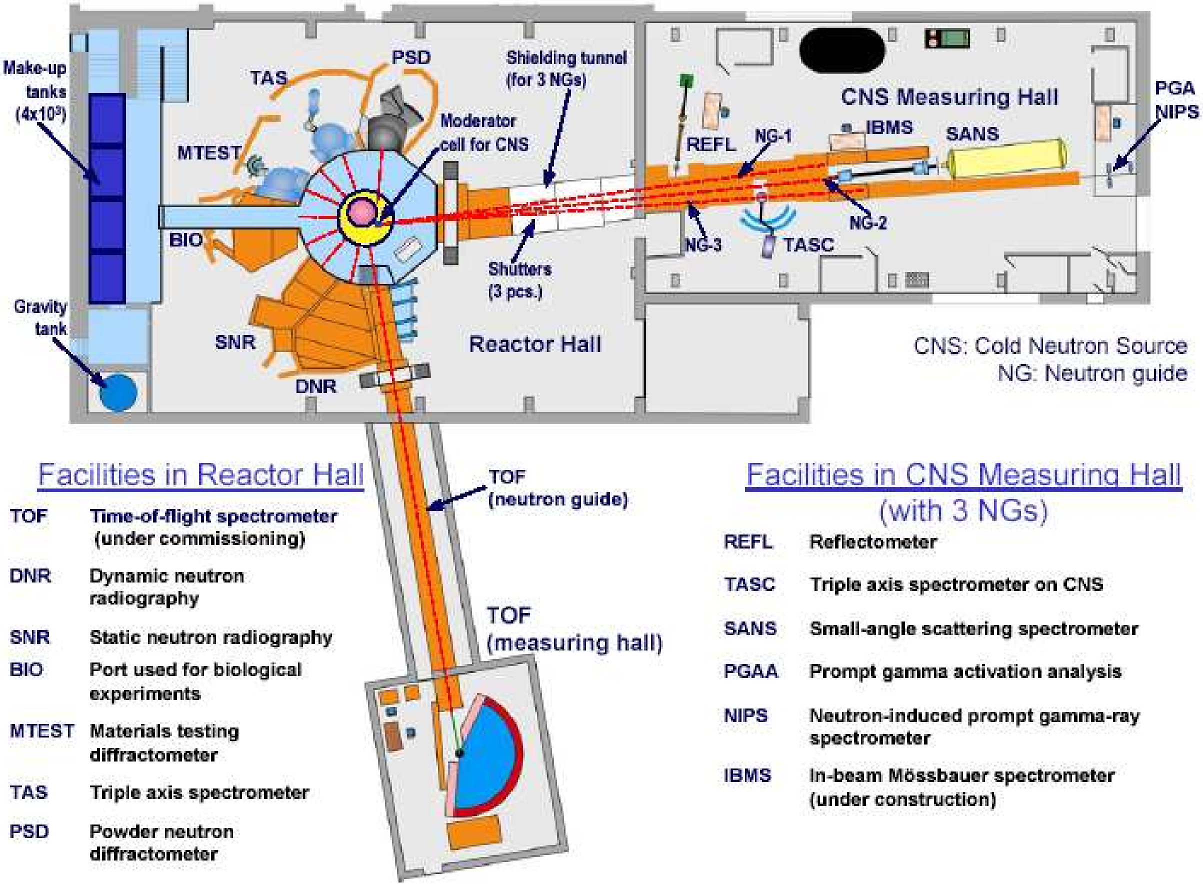

Fig. 3 Layout of the horizontal neutron beam facilities at the BRR

The utilisation of the reactor for basic- and applied research is considered to be the primary application of the reactor. In particular this includes the research fields of: condensed matter, radiochemistry, biological irradiations, reactor physics and technology (with the commissioning the CNS the material research possibilities of the reactor were significantly increased). The reactor is used for isotope production also and, as an industrial application, for neutron radiography and activation analyses.

The BRR's research facilities have been offered to the entire international user community, and in particular, for EU and associated countries of the European Union in the "Access to Research Infrastructures" action of the 6th Framework Programme (FP6). The BRR is foreseen to provide university and postgraduate education opportunities. In addition it should be used to fulfil training for specialists in the nuclear industry and those on international training courses.

5. Lessons learned

Reviewing the last 15-20 year period with respect to the reactor reconstruction milestones, including the preparation phases for restarting regular operation and the lunch of utilization, highlights many experiences. These experiences and lessons learned may prove useful to members of the RR community if faced with the dilemma of renewal or irreversible degradation. The most important conclusions (with lessons learned) can be summarized as follows:

Conclusion No. 1. Looking back at the discussions to settle the future of the reactor; the final shutdown and decommission, as an alternative solution, was really not considered. It could not have happened because the leader representatives of the institute (former KFKI) had an enthusiastic and realistic vision for further reactor operation and utilization. They viewed the reactor operation both from the user and operator perspectives, took the initiative in time and led the discussions throughout the preparation period,

> *Lesson learned:* if the operators and users know what they want (they have a realistic vision) the unconvinced public can be persuaded.

Conclusion No. 2. The preliminary discussion was begun halfway through the service life of the reactor. The real preparation began with the first official feasibility study, made about 8-10 years before the 30-year service life elapsed. Due to this long preparation time a general consensus was gained and well-founded strategic goals were elaborated.

> *Lesson learned:* The preparation of the M&R project has to start early to give sufficient time for elaborating good strategic goals with a general consensus of the scientific and industrial public.

Conclusion No. 3. On the basis of the general consensus and the well-founded utilization arguments, not only the Hungarian decision makers were persuaded to opt for the reconstruction but the IAEA also. Thus the IAEA strongly sponsored the reconstruction with continued moral and financial support. In the preparation phase the moral support of the IAEA was considerable and sufficient to obtain the "capital state investment" status for the project. During the period of indecisiveness the moral support of the Agency that was based on the review of PSAR, helped to win public opinion for reactor start up.

> *Lesson learned.* The financial support of the Agency could be significant, but the moral support absolutely necessary. The moral sponsorship of the Agency can be considerable and it could strongly maintain the M&R project up to the commissioning in any respect.

Conclusion No. 4. In spite of some budgetary deficiencies the project could start more or less according to the scheduled time and was completed in timely manner without any technical reduction. In the case of some utilization facilities, this was due, in part, to decisions taken during the beginning phase to postpone investments.

> *Lesson learned.* The method of postponed investment (or in other words sequential investment at utilization) can be applied. But it should be highlighted that this method can be applied for the utilization only!

Conclusion No. 5. The reactor management supervised the project from the beginning to the final stage. The management acted as a real owner of the project. The partial decommissioning (that effectively achieved IAEA Stage 3 decommission level) was carried out and comprehensively documented by the staff while the on-site job of the reconstruction (in spite of turnkey investment) was made also with their active participation. The experiences gained from this job form a stand-alone database and opinion base for further reactor operation (the everyday practice has already proved this statement).

> *Lesson learned.* The reactor management has to be the owner of the M&R project while the staff should participate in the M&R project. They together may personalize a proactive (foreseen and anticipated) sense of ownership.

Conclusion No. 6. Although the BNC was founded to manage the utilization but during the period of uncertainty it could double the amount of public influence for reactor start up. Also, later on when this consortium put into operation the facilities around the reactor and started to manage the utilization strategy, it became obvious that the BNC could successfully represent the user interests, leaving the reactor management to focus on the safe reactor operation. Thus, a decision was made to separate the reactor operation matters from the utilization ones. Due to this management system, almost from the time of reactor start up the reactor manager was responsible for the safe reactor operation only, leaving the utilization issues to be managed by the BNC. Now this management system is highlighted as being one of the best operational practices.

> *Lesson learned.* Separating the reactor operation issues from the utilization ones can increase the capability to enforce the reactor's interest (two parties could lobby for the same goal). On the other this management solution, can also promote a safe reactor operation.

6. Future Plans

The factors determining the future operation of the BRR and likely to provide the M&R with tasks in the forthcoming years are as follows:

BRR's lifetime. Due to the overall reconstruction and upgrade the reactor lifetime was reset and is calculated from 1993. The lifetime of the deterministic elements (including the reactor vessel itself) is 30 years. This defines the service deadline of the reactor. Assuming that there will be no technical modernization to extend the lifetime[1], the deadline is the year 2023.

Utilization factor. Considering the short and long-term research programs, international obligations and contract obligations for irradiation services (isotope production), users calculate a 40% annual availability factor (≈3500 operation hours in a year). Regarding the strategic issues of the research programs it is estimated that the reactor will work out its remaining service life (until 2023).

Technical and human factors. The PSR certified that there are no significant ageing problems, no unexpected degradation and that no abnormal phenomena was detected in any safety-critical system or component of the reactor. However few technical renewals as safety increasing measures were prescribed by the LA's resolution closing the PSR (about 90% of which have already been completed). Regarding the human factor, a few years ago the aging of the personnel was a real problem but due to a systematic program effected after the PSR we have already employed six young colleagues in the last few years and this program is envisaged to continue.

Fuel factors. As a result of a trilateral discussion between the U.S., RF and the IAEA, a project for repatriate the Russian origin RR fuel was lunched in 2004. The project, namely Russian Research Reactor Fuel Return Program (RRRFRP) is supported and coordinated by the U.S. Department of

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[1] Apart form the continued safety increasing measures and modernisation, no life extension plans are currently proposed.

Energy. The AEKI signed a contract for site preparation at the end of 2005. After signing this contract, two projects were started in this year. The first one is the site preparation for the transfer of Russian origin highly enriched uranium (HEU) SNF from the reactor, while the second one is the preliminary calculation for core conversion form HEU to LEU. Both projects provide tasks for the next 3-5 years.

Licence factor. Although the operation licence renewed in 2003 is valid until further notice, the Hungarian legal system obliges operators of a nuclear facility to prepare a safety review every ten years. This means in practice the licence validity has to be confirmed by a repeated PSR in 2013.

Financial factor. The basic annual operation costs are covered by the governmental budget. Other costs are paid for through grants and sponsorships, as well as income from industrial services. These sources together ensure: sustainable safe reactor operation including waste management resulting from the normal operation; investment in improved safety; and some modernization. The cost of core conversion and the procurement of fresh fuel incur extra charges.

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