INITIAL DECOMMISSIONING PLANNING FOR THE BUDAPEST RESEARCH REACTOR

by

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The Budapest Research Reactor is the first nuclear research facility in Hungary. The reactor is to remain in operation for at least another 13 years. At the same time, the development of a decommissioning plan is a mandatory requirement under national legislation. The present paper describes the current status of decommissioning planning which is aimed at a timely preparation for the forthcoming decommissioning of the reactor.

Key words: research reactor, decommissioning, radioactive waste treatment

INTRODUCTION

There are several nuclear facilities in Hungary, namely: 4 nuclear power units, 2 research reactors, a temporary spent fuel storage facility, 2 radioactive waste repositories, and a closed uranium mine, but there are no nuclear facilities at the decommissioning stage and the local experience is quite limited in this respect. Hungarian nuclear legislation covers all of the required IAEA, OECD, and Euratom recommendations. There are approved initial decommissioning plans for these facilities which are based on and in compliance with the said recommendations; they are to be revised every 5 years. Hungary has established a quite classical system for the preparation of future decommissioning plans for its nuclear facilities. The necessary organisation – a Public Agency for Radioactive Waste Management (PURAM) – has been set up, as it has been previously done in many Western European countries [1]. There are low- and intermediate level radioactive waste repositories located at various sites in Hungary.

The handing over of high level RAW storage is planned for 2047, when the decommissioning of nuclear power plant (NPP) units will come into the limelight. The handling of spent fuel assemblies will be in accordance with IAEA and OECD recommendations.

FACILITY HISTORY AND CURRENT STATUS

The Budapest Research Reactor (BRR) is a light water tank-type reactor (figs. 1 and 2). It first went critical in 1959. The initial fuel was of the EK-10 type and its thermal power was 2 MW_t. The BRR is operated by the KFKI Atomic Energy Research Institute of the Hungarian Academy of Sciences (AEKI). The Final Safety Reports [2] contain the descriptions of relevant reactor details.

The reactor site is located in the western part of Budapest, in a wooded, low built area. The surface mildly slopes downhill with a gradient of 443-403 m, Baltic height, with a single motor road leading to the site.

Population: 0-1 km zone, 460 people. 30 km zone: Budapest and 103 settlements with 2 million 626 thousand people altogether.

Water supply: Exclusively from the Budapest Water Authority Network. No ground water or pumps. No significant agricultural activities in the area. The average temperature is 8.6 °C. Average rainfall, 680 mm.

Geology: Pannonian era deposits: clayey sand, sand and sandstone form the geological composition of the underground. The final layer is made up of dolomite and limestone.

Earthquakes: Since 1763, within the 110 km zone, there have been 195 earthquakes more powerful than 3° (EMS scale). There is a probability for a 6° quake every 104 years, 7° quake every 165 years and an 8° quake every 260 years.

The reactor building is made of two interknit buildings forming a T-shaped structure. The base of the structure covers a surface of 1700 m^2. The reactor hall is a steel pillar structure with brick walls and a service floor. The walls of the service floor are made of concrete and heavy concrete. The hall's internal height is 16 m, its span 21 m. The three measuring halls were built subsequently, according to a former Soviet Union design.

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Figure 1. – Reactor hall of the BRR

Figure 2 – The aerial view of the BRR site
1 – reactor building, 2 – reactor hall, 3 – ventilation system, 4 – secondary circuit pump room, 5 – cooling tower, 6 – auxiliary building, 7 – liquid radwaste storage facility, 8 – solid radwaste storage facility, 9 – CNS's measuring hall, 10 – cryo-system, 11 – TOF's measuring hall

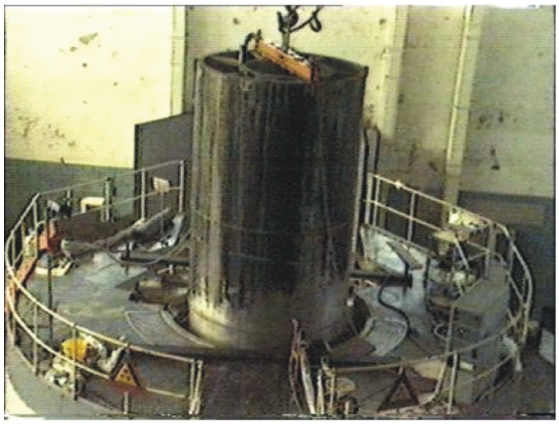

Figure 3. Lifting of the reactor vessel

Figure 4. Dismantling of the concrete wall in the primary circuit pump house

The administrative building is 5-stories high, brick, simple in structure. The floors are connected by a cable tunnel.

The ventilation building with its 84 m high chimney is situated 20 m south-west from the reactor building. The cooling towers and auxiliary buildings are 100 m away, liquid waste storage underground, away from reactor (AFR) storage hall 130 m further.

The first upgrading of the reactor was carried out in 1967. At the time, the original fuel was substituted with that of the VVR-SM type, with a higher enrichment percentage (36%), a beryllium reflector assembled around the reactor core, and its thermal power increased to 5 MW_t.

The second upgrading was executed from 1986 to 1990. That was a full scale reconstruction. The reactor vessel, core grid, beryllium reflector and the primary and secondary circuit loops were replaced (figs. 3 and 4). A new control room, new radiation measurement lines *etc*., were constructed. Moreover, the experience gained by the reactor staff during the reconstruction constitutes a valuable technical basis for subsequent decommissioning planning.

The physical start-up was in 1992 and the power start-up in 1993. At present, the reactor operates with a power of up to 10 MW, with the maximal thermal neutron flux of 2.5 10^{14} $cm^{-2}s^{-1}$. The performed upgrade will extend the reactor's lifetime for up to 30 years and the final shut down is planned for 2023. Currently, the average operating time is 3500 hours per year. The average isotope production is 250 capsules per 50.000 irradiation hours. The BRR has 10 neutron beam ports with 12 physical research facilities. Its average efficiency is about 80%. It is worth mentioning that the BRR is equipped with a cold neutron source and a "time of flight" spectrometer. There were neither incidents nor accidents which might have reached INES levels during the 51 years of operation.

The BRR is a part of the Russian research reactor fuel return program, under the auspices of the IAEA. In September 2008, the first transfer of highly enriched spent fuel was completed and the next one is planned for 2013, when all of the highly enriched spent fuel will be returned to the Russian Federation.

Parallel to the spent fuel transfer, the operator will convert the reactor to low enrichment fuel use next year.

The first Periodic Safety Report [3] was made in 2003. The regulatory body (Hungarian Atomic Energy Authority – HAEA) did not find any significant problems and renewed the license for further 10 years. In 2005, the staff of the BRR has prepared the first Preliminary Decommissioning Plan. The plan covers safety requirements, demolishing technologies, and necessary human and financial resources.

NATIONAL LEGISLATION REQUIREMENTS

The key document in Hungarian nuclear legislation is the Act on Atomic Energy (AAE) [1], which was approved in 1996. The Act considers all legislative, authority-related and operational experience gained during the construction and operation of the Paks NPP. It also considers the technological advancements made since the issuing of the previous AAE of 1980, along with international obligations. It has also taken into account the requirements of the Joint Convention on the Safety of Spent fuel Management and Safety of Radioactive Waste Management. The AAE envisages that the Radioactive Waste Repository Public Company is to implement the decommissioning procedure. The whole process must be implemented under the supervision of the Hungarian Regulatory Body. The licensee is obliged to develop decommissioning plans. Later this year, new nuclear safety codes and standards are expected. The details of the decommissioning procedure will be described as a separate volume of the safety code.

Nuclear safety requirements and related regulatory activities are regulated by the Governmental Decree 89/2005 and its annexes, the so called Nuclear Safety Codes (NSC) [4]:

- NSC No. 1 on the authority procedures applied to NPPs,
- NSC No. 2 on the quality of management of NPPs,
- NSC No. 3 on the requirements for the design of NPPs,
- NSC No. 4 on the safety requirements for the operation of NPPs,
- NSC No. 5 on the safety of research reactors,
- NSC No. 6 on the safety of interim spent fuel storage facilities, and
- NSC No. 7 glossary of terms.

The issue of decommissioning has been covered by NSC No. 1, 5, and 6 and defined as the final phase of the life-cycle of the above mentioned facilities. As for the remaining phases, a safety licence is required. For that purpose, a multi-step licensing procedure was established where the first step is that of obtaining an official approval to terminate the operation. The following requirement is that of obtaining a valid environmental protection licence based on environmental impact assessment and a public hearing. As in all other phases of the life-cycle of the facilities, special authorities are to be involved in the licensing processes, *e. g*. the State Public Health and Medical Officer Service which will be licensing radiation protection programmes on a case to case basis [5]. During the dismantling, decontamination and other steps, an ongoing task of the authorities is to control the exposures within the facilities and around them, and to monitor the releases into the environment [6]. The emergency plan [7] has to be updated with new /likely scenarios and all necessary organisational changes need to be adjusted to that, accordingly.

Hungarian NSC contain provisions stipulating that the decommissioning is to be considered at its design stage and that a preliminary decommissioning plan constitutes a mandatory part of the documentation prior to the commissioning itself. The decommissioning plan is to be regularly revised in accordance with the regulations in force, the results of the revision to be submitted to the HAEA. The finalized decommissioning plan is a prerequisite for granting an operating license.

For the execution of activities related to the decommissioning plan, a specialized organization designated to carry out the disposal of radioactive waste and spent fuel was created under Governmental Decree 240/1997 (XII. 18.) [8], covering the decommissioning of nuclear installations, as well as the suggestions for possible financial resources for carrying out the designated goal. This decree authorized the Director General of the HAEA to establish a non-profit organization for above mentioned purposes. A public utility, the so called Public Agency for Radioactive Waste Management (PURAM) was established in 1998. The financial resources for the operation of PURAM are provided by the Central Nuclear Financial Fund established in accordance with the AAE [1].

DECOMMISSIONING STRATEGY AND PLAN

The expected lifetime of the reactor is 30 years and the final shut down is planned for 2023. At the BRR site, enclosing and dismantling will be carried out simultaneously. According to the plan, the main building will remain a research facility for future needs (TOKAMAK, Van der Graaf accelerator *etc*.) or any other activities related to the production of radioactive materials. The final aim is partial decommissioning.

We can vouch for the safety of the enclosure for 2 years following the final shutdown.

Spent fuels will be moved out of the spent fuel storage 1 to 2 years after the final shutdown.

After the transport of spent and fresh fuel, we will hand over the site to the company responsible for the decommissioning (Hungarian RW repository Ltd.). Further decommissioning activities will be carried out by the said company.

To be dismantled are: the active core, reactor vessel, gravity vessel, and the primary loop. We will dismount the rest of the systems afterwards. The originating waste materials are to be transported out in several steps. The last phase will be that of dismantling the ventilation and dosimetric systems.

The site will be "clean" at the end of decommissioning.

The demolition of the administrative building and inactive laboratories is not envisioned by the decommissioning plan.

Nuclear safety codes contain provisions that decommissioning is to be considered at the design stage and that an initial decommissioning plan is a mandatory part of the documentation prior to commissioning. The plan is to be regularly revised, in accordance with the regulations in force; revision results are to be submitted to the HAEA. The finalized decommissioning plan is a prerequisite for granting an operating license. All decommissioning plans have to cover organizational and qualification aspects, along with accompanying technical issues. In the first phase of the planning, it is necessary to establish a system of requirements taking into account dose limits and personnel protective tools. The method for radioactive management and storage will also be determined.

The endpoint of preliminary decommissioning planning is the radiometric survey of the facility. The workplaces shall be decontaminated and these areas shall be rendered usable for all non-radiological activities. In all probability, the site will meet these requirements in entirety. In all other cases, the premises and workplaces will be reviewed according to international practice.

At present, the initial decommissioning plan (IDP) for BRR is under revision. This plan is being developed in accordance with Nuclear Safety Codes (Volume 5) [4] and IAEA Safety Report Series No. [9] 45. The plan encompasses the following:
- facility description,
- decommissioning strategy,
- project management (legal issues, safety culture, training, time schedule),
- decommissioning activities (dismantling and demolition),
- surveillance and maintenance,
- waste management [10],
- cost estimates and funding mechanism,
- safety assessment (safety criteria [2], OLC's [11], hazard analysis /normal and abnormal events/ [2]),
- environmental assessment,
- health and safety,
- fire protection, and
- quality assurance [12].

This IDP has one more chapter, that of the "open questions" dealing with the unsolved problems and open questions. Our biggest problem lies in the final disposal of beryllium elements.

According to regulations, our IDP must be updated and revised every five years and, one year before the final shutdown, the licensee must prepare the final decommissioning plan (FDP). In case of an unforeseen incident or accident, the research reactor must be in the safe enclosure state before the approval for the FDP is granted.

As a part of the decommissioning process, extensive use of knowledge of nuclear reactor demolition technologies similar to "green field" dismantling is envisioned. Also, along with international experiences and new technologies, previous Hungarian experiences might serve the purpose. For instance:
- radiological surveillance by a gamma chamber monitoring system,
- mapping the rooms by a 3-D laser scanner,
- underwater cutting technologies,
- electrochemical decontamination, laser ablation,
- remote-controlled breaking hummers, and
- cutting with a diamond surface cable.

ASSUMED DECOMMISSIONING SEQUENCE

The first stage of the BRR decommissioning is the removal of fuel from the reactor core to the inside spent fuel storage. The BRR site has 2 spent fuel storages. The first is the at-reactor (AR) storage with underwater storage technology; capacity 786 pieces of fuels; minimum resting time 1 year; average resting time 3 years. The AFR storage is located 130 m to the south-west from the reactor building. Underwater storage technology; capacity 2256 pieces of fuels. Our calculation for 2023 is 650 pieces of spent fuel and 50 pieces of fresh fuels. The final disposal will probably be in the Russian Federation, but since this is still uncertain, the cost of shipment and disposal cannot be determined as of yet.

After that, the following sequence of decommissioning activities will be implemented:

2-year safety enclosure. This is the period needed for the BRR staff to carry out preparations for the transportation of fuels from the site and the decontamination of the activated systems and elements.

Emptying the reactor hall (removal of non-active and low-active materials).

Dismantling the secondary loop (instalment of the temporary cooling system for the inside spent fuel storage; draining (emptying) of the pipelines, pool and cooling tower, oil drainage; dismantling of the electric power supply cables and switch-room; dismantling of equipment inside the cooling tower; dismantling of the pumps and valves in the secondary circuit pump room; excavation of the main tubes; demolition and removal of the tubes; dismantling of the pipelines in the reactor building basement; terrain correction).

Partial dismantling of the hot-cells and laboratories (removal of radwaste; decontamination; dismantling and removal of the cutting machines and tools; dismantling of the transport trolley, manipulators and isotope lift).

Dismantling of beam shutters and the cold neutron source plug. This equipment and devices have to be dismantled before the reactor vessel is lifted out.

Reactor core dismantling (dismantling of the control rod gears and removal of non-active elements; control rods mechanism extraction and its placement into the spent fuel storage; dismantling of the sleeve pipes; dismantling of the chamber mechanism; lifting out the detectors and placing them into the spent fuel storage; the transfer of beryllium blocks to the spent fuel storage; dismantling of the reactor cover; dismantling of the mountings and fittings to the aluminum mounting board; drainage of the reactor vessel water ~ 2 m; practice extraction of the beryllium reflector with inactive models; transfer of beryllium reflector segments; transfer of active wastes away from the spent fuel storage).

Lifting of the reactor vessel (dismantling and transportation of the mountings, fittings and aluminum board; draining of the filter resin, emptying the primary loop, washing and decontamination; opening of the under-reactor area for the primary circuit pump room; dismantling of pipe flanges; test extraction of the reactor vessel under radiation surveillance; construction of a temporary stand; reactor vessel extraction; coating of the vessel's external surface (behind the temporary shielding); moving of the vessel to the temporary stand, placement and transport; placing the vessel to the place of deposition; mounting back the reactor cover).

Lifting and removal of the gravity vessel (construction of a temporary stand; demolition of the wall; dismantling of pipe flanges, lifting out the vessel by a mobile crane and its transportation from the location).

Primary circuit dismantling (dismantling of the fittings, measurements and cables; dismantling of the electric power supply cables and switch boxes; construction of temporary stands, lifting stands, removal of floor segments; dismantling of the pipelines and valves; blinding the pipes; wrapping, sorting and transportation of waste; dismantling, wrapping and transportation of the pumps and heat exchangers; lifting and transportation of the filter buffer vessel; demolition of the biological shield; dismantling of the filter pipelines, valves, filter columns; dismantling of the gravity pipelines and valves; decontamination of the pump room and putting back floor segments; dismantling of the temporary stands).

Heavy concrete shelter demolition (dismantling and removal of horizontal channel shutters; dismantling of the reactor bridge; demolition of the steel base plate in the biological shield; construction of a temporary stand; cutting machine installation; construction of a temporary cooling system for the cutting machine; demolition of the heavy concrete biological shield; wrapping, sorting, and transporting waste out; dismantling of the cooling system; dismantling of the temporary stand; floor casing – for a breakthrough between the reactor hall and the primary pump room; concreting; dismantling of the casing).

Demolition of the AR storage (lifting out the storage cover; demolition of the temporary cooling system; dismantling of the measurement; emptying the pool, pumping the water to the liquid waste storage; moving out the grids; decontamination; lifting out and transporting the vessel; putting it back to the cover).

Demolition of the AFR storage (dismantling of the measurement; emptying the vessel, pumping the water into the liquid waste storage; washing and decontamination; moving out the grids and storage tubes; decontamination; lifting out and transportation of the vessel; putting it back onto the covering plate). Remark: The AFR storage hall has 4 pc of deposit shafts for solid radwaste (RW). If we do not come up with a solution for the final disposal of beryllium elements, our solid waste will be stored by underwater storage technology.

Dismantling of the auxiliary systems (dismantling the switch boxes and cables, pumps, pipelines and fittings; lifting out and transportation of the vessels).

Reactor hall and basement cleaning and decontamination.

Partial demolition of the normal ventilation system (demolition and transportation of the iodine and aerosol filters; dismantling of electrical switch boxes and cables; dismantling of pipelines and valves; moving out the ventilators; decontamination).

Demolition of the radioactive waste storages (demolition of pipelines; filtering of the radioactive water; draining clear water; cementation of active water; transportation of active waste; decontamination; demolition of the vessels; building decontamination).

Dismantling of the radiological surveillance equipment.

Demolition of the control room.

Final disposal of radwaste.

The time schedule for the execution of decommissioning procedures is shown in tab. 1. According to the plan, activities involved will be carried out by

Table 1. Demolition schedule

	Work phase	Duration (weeks)*
1	Arrangements, inactive tests	53-104
2	Fuel removal from the reactor core and site	50-52; 105-108
3	Empting of the reactor hall	110
4	Dismantling of the secondary loop	107-114
5	Partial dismantling of hot-cells and laboratories	108-110
6	Reactor core dismantling	109-112
7	Lifting of the reactor vessel	113-117
8	Lifting and removal of the gravity vessel	118-119
9	Primary circuit dismantling	120-126
10	Heavy concrete chelter demolition	127-152
11	Demolition of the AR storage	153
12	Demolition of the AFR storage	154
13	Reactor hall and basement cleaning and decontamination	157
14	Partial demolition of the normal ventilation system	158-160
15	Demolition of radioactive waste storages	161
16	Dismantling of the radiological surveillance equipment	165-166
17	Demolition of the control room	165-166
18	Documentation, reports	167-173

*Week 0 is the date of the final shutdown of the reactor

the existing reactor staff, with the involvement of external personnel only in case of specific tasks such as: the demolition of the biological shelter, removal of asbestos and the transportation of RW away from the reactor site. Following human resources will be needed for the decommissioning of the BRR (tab. 2).

Table 2. Necessary human resources

	Staff numbers	Σ work hours
1-104 week	15-20 people working part-time	40 000
105-128 week	15-20 people	16 500
129-165 week	15 people	21 600
166-173 week	5 people	1 400
Summary		79 500

TREATMENT OF DECOMMISSIONING RADWASTE

Treatment of decommissioning radwaste, clearance, and managing [5]:

(1) At the request of the licensee, the clearance from regulatory control is issued by the Office of CMOS. The licensee has supplemented the request with an estimate of the doses originating from the use, reuse and reutilisation of the substances or their handling as non-radioactive waste, as well as an overall analysis, the conclusion being that clearance is the optimal solution.

(2) Substances containing radionuclides can be released from regulatory control if:
(a) the projected annual individual dose originating from their reuse, reutilisation or handling as non-radioactive waste does not exceed the 30 μSv effective dose, and
(b) if the analysis proves that clearance is the optimal solution to the problem.

(3) In deciding on the issue, the Office of CMOS may apply conditions concerning the use, reuse, and reutilisation of the said substances or their handling as non-radioactive waste.

(4) For the communication of the said decision as per Subsection (2), rules of *Section 22*, Subsection (1), shall be applied.

(5) For radionuclides containing substances released from regulatory control, further provisions of this Decree need not be applied.

Waste sorting

Low- medium- and high level RW sorting is presented in tab. 3.

Table 3. RW category

RW category	Compared to activity concentration
Low level activity	$\frac{AK_i}{MEAK_i}$ 10^3
Medium level activity	$\frac{AK_i}{MEAK_i}$ $10^3 - 10^6$
High level activity	$\frac{AK_i}{MEAK_i}$ 10^6

Remark: AK_i – unit i activity concentration [Bqg^{-1}],
$MEAK_i$ – unit i exemption activity concentration [Bqg^{-1}]

Quantity of waste

Quantity of primary and secondary RAW during BRR decommissioning is given in tab. 4.

Waste handling and final disposal

Medium- and low level activity waste. The ~430 m^3 worth waste after sorting, compressing, and wrapping into disposal steel drums (or containers) of the Hungarian RW storage. The final disposal of beryllium elements remains an open question.

Liquid radioactive waste. The reactor site has 2 pc storage tanks (2 150 m^3). Active water from the first tank will be pumped into the second tank upon ion-exchange filtering. The filtered and radiation protection controlled water will then flow into the drainage pipelines. The remaining active water will be laid over by concrete and handled as solid waste.

Inactive waste. The ~680 m^3 waste is 60% reusable as metal refuse. Dangerous (poisonous) waste amounts to ~10 m^3 (asbestos, accumulators, oils). The

Table 4. Quantity of the primary and secondary RAW

Decommissioning phase	Waste [m^3]			
	Medium level	Low level	Liquid	Inactive
Decontamination		2	10	
Reactor hall emptying		8		60
Secondary loop				350
Hot cells, laboratories	2	10	5	10
Active core	5	3	1	3
Reactor vessel		28*	100	1
Gravity vessel		6*		1
Primary loop	2	20	10	5
Biological shelter	10	200	10	50
Spent fuel storage (inside)		10*	10	1
Spent fuel storage (outside)		5	35	50
Auxiliary systems		2		50*
Building decontamination		1	10	30
Ventilation system		5		10
RW storage	2	30	4	20
Radiation protection system		1		3
Control room				20
Summary	20	330	200	680

*Vessels and tanks geometry

final disposal site is to be handled as a dangerous waste storage site. The final disposal site for the ~270 m^3 construction scrap is to be a public waste storage.

PROBLEM ISSUES AND OPEN QUESTIONS

Changes in norms and regulations. To apply new and generally stricter regulations constitute a great challenge for operating organizations.

Treatment of radioactive waste. The issue of the final disposal of high level RW should be solved by 2023 (at the latest).

Public acceptance. Public acceptance of nuclear technology and its applications is quite good in Hungary. There are some marginal groups, such as the so called Energy Club, opposed to any form of use of nuclear power [9].

Plans. The spent fuel of the BRR may be shipped back to the Russian Federation within the framework of the Russian Research Reactor Fuel Return Program (RRRFRP) [13] in 2014, as it was done previously, in 2008. The spent fuel of the training reactor might be added to this shipment. However, the spent fuel management after the final shut down of the reactors (beyond 2023) remains an open question.

At the end of their lifetime, the dismantling of the reactor systems will be carried out by the operating personnel who have gained experience from previous upgrades and reconstructions. The Hungarian government has pledged to cover the decommissioning costs.

CONCLUSIONS

At present, the decommissioning of the BRR is not an urgent problem in Hungary. At the moment, the plan is that the reactors will be in operation till 2023. Hungarian nuclear norms and regulations are harmonized with IAEA recommendations. New safety codes will cover the decommissioning procedure in its entirety. The accepted initial decommissioning plan creates a good basis for further decommissioning planning. The final disposal of radioactive waste is being developed for the low and intermediate level, with the exception of the high level waste, since HLRW will not come into being from RR decommissioning. Moreover, this paper presents examples of good procedures identified while developing the initial decommissioning plan for a research reactor which could complement the experiance already gained in other decommissioning projects [14-17].

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Габор ТОТ

ПОЧЕТАК ПЛАНИРАЊА ДЕКОМИСИЈЕ ИСТРАЖИВАЧКОГ РЕАКТОРА У БУДИМПЕШТИ

Будимпештански истраживачки реактор је прво нуклеарно истраживачко постројење у Мађарској. Реактор ће даље радити још најмање 13 година. У исто време, сачињавање декомисионог плана представља обавезујући захтев националног законодавства. У раду је описано садашње стање планирања декомисије које је усмерено на правовремену припрему будуће декомисије реактора.

Кључне речи: истраживачки реактор, декомисија, руковање радиоактивним отпадом