NEW POSSIBILITIES OF THE UTILIZATION OF THE BUDAPEST RESEARCH REACTOR

István Vidovszky[1]

ABSTRACT

The Budapest Research Reactor is the first nuclear facility of Hungary. It was put into operation in 1959. The main purpose of the reactor is to serve neutron research; anyhow the isotope production is important as well. The reactor was extended by a liquid hydrogen type cold neutron source in 2000. The research possibilities are much improved by the CNS both in neutron scattering and neutron activation. This research possibility was offered to the entire user community of Europe (scientists active in member states and associated states of European Community) within the 5th Framework Programme. Eight instruments for neutron scattering, radiography and activation analyses are offered. The majority of these instruments got a much-improved utilization with the cold neutrons. The CNS sponsored partially by the Copernicus project of the EU and by the IAEA was installed at a tangential beam port of the reactor and it extended the use of the reactor, especially in the scientific field. The paper will describe the improved utilization of the reactor.

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[1] *István Vidovszky*
KFKI Atomic Energy Research Institute
H-1525 Budapest POBox 49, Hungary
fax: +36 1 395 92 93
phone: +36 1 392 22 93
e-mail: vidov@sunserv.kfki.hu

BACKGROUND OF THE REACTOR

The reactor was first commissioned in 1959 as a 2 MW thermal power reactor, using EK-10 (10% enriched) fuel. The first reconstruction and upgrading project took place in 1967, when new fuel type was introduced (VVR-SM, 36% enrichment) and the power was increased to 5MW. The reactor was operated till 1986, when the second reconstruction and upgrading project started. The reconstruction was finished in 1990, but due to the political changes in the country the reactor was re-commissioned only in 1992. The operating license was issued in November 1993 and from this time the reactor has been operated in a regular manner on 10MW nominal power.

The Budapest Research Reactor [1] is a tank type reactor, moderated and cooled by light water. The reactor is in a cylindrical reactor tank, made of a special aluminium alloy. The diameter of the tank is 2300 mm; the height is 5685 mm. The heavy concrete reactor block is situated in a rectangular semi-hermetically sealed reactor hall. The area of the reactor hall is approximately 600 m^2. It is ventilated individually.

The fuel of the research reactor is of the VVR-SM and the slightly modified VVR-M2 type [2] (both Russian products). The uranium enrichment is 36%; the average ^{235}U content is about 40-g/fuel element. The fuel elements contain three fuel tubes; the outer tubes are of hexagonal shape, while the two inner ones are cylindrical. The core is surrounded radially by a solid beryllium reflector. The reactor is equipped with boron carbide safety and shim rods. There is a stainless steel rod for the purpose of automatic power control.

The reactor can be characterised by the following main technical data: thermal power: 10 MW, approximate maximal thermal flux: 2.2×10^{14} n/cm^2s, approximate maximal fast flux: 1.0×10^{14} n/cm^2s cooling water inlet temperature: 54^oC, maximum cooling water outlet temperature: 60^oC

The reactor has 10 horizontal beam tubes (8 radial and 2 tangential). The cold neutron source equipment is installed at one of the tangential beam tubes.

In the nineties (and even before) a lot of research reactors were shut down in Europe (e.g. the Austrian research reactor at Seibersdorf near Vienna, the research reactor in Rossendorf near Dresden and recently the Danish reactor at Risø), consequently the significance of the Budapest Research Reactor grew. This gave us the idea to offer the research possibility to the entire user community of Europe. Our offer was accepted and so scientists active in member states and associated states of the European Community could use our research capabilities within the 5th Framework Programme. The following eight instruments were offered: a small angle scattering spectrometer with XY detector, called "Yellow Submarine" (SANS), a powder diffractometer (PSD), a three-axis spectrometer on neutron guide (TAS), dynamic neutron/gamma radiography (DNR), static neutron/gamma radiography (SNR), biological irradiations (BIO), prompt gamma activation analysis (PGNAA), pneumatic rabbit system & activation analysis (RNAA). The user community of Europe utilized this opportunity and in the three years of the contract (2000-2002) the entire possibility, given by the EU (20% of total capacity) was used. We apply for a similar contact in the 6th Framework Programme.

Later a new instrument, a neutron reflectometer (REFL) was installed. The most important instrument of the future might be the time of flight spectrometer (TOF), installed in cooperation with HMI Berlin. The first measurement were promising, anyhow unfortunately TOF has not found its optimal position yet. The new position of TOF will be at a thermal beam, but the transition works need still some time.

The fuel supply, the technical state of the reactor and the available human resources indicate that the reactor can be used for many more years.

THE COLD NEUTRON SOURCE (CNS)

The source [3] is of the liquid hydrogen type. The relatively low heat load (about 250 W) makes feasible the direct cooling of the condensed hydrogen (average temperature near to 14K) in the double walled moderator cell by the cold helium gas. The construction work was completed early

2000, the out of reactor cold tests were performed during the summer shutdown period in 2000. With the operating CNS the reactor was first on nominal power on September 27, 2000. Test operation of the CNS was made in the last four reactor cycles of the year 2000, while the license for the regular operation was issued in January 2001.

The CNS was sponsored partially by the Copernicus project of the EU and by the IAEA. The institute paid the rest of the costs itself.

The main part of the CNS is the cold plug. The head of the plug is an explosion-proof vacuum chamber, contains the double-walled moderator cell and it’s connecting pipelines. The vacuum chamber is double walled to allow the cooling of the walls. The moderator cell is a double walled aluminum structure, having cold helium between the walls and hydrogen inside. When the cold operation starts, the helium first makes the hydrogen liquid, than removes the heat generated in the liquid hydrogen and the walls of the cell. The geometry of the moderator cell allows minimal hydrogen temperature with minimal void. The volume of the cell is about half a liter, the initial pressure of the warm hydrogen is 3.5 bar, while the cold pressure of the hydrogen is ~2.7 bar. A helium blanket around the inner hydrogen pipeline ensures the hydrogen safety. The steel body of the cold plug holds the explosion proof vacuum chamber and contains the three neutron guides. The steel body also provides biological shielding and there is a lead beam shutter in its front part. The neutron guide system consists of three curved super-mirror neutron guides having different lengths. The CNS has a powerful refrigerator system, placed in a separate building. The cold plug is connected to the refrigerator by cryogenic pipelines. The pipelines are double walled, the insulation of the cold helium pipeline is provided by special heat insulation coating. The refrigerator system has a PLC based controller, which controls the refrigerator including the gas management system and the compressors. There is a higher lever controller, which controls the helium blanket and handles the emergency situations.

Simultaneously to the construction of the CNS the neutron guides have also been replaced by more efficient ones, using super-mirrors.

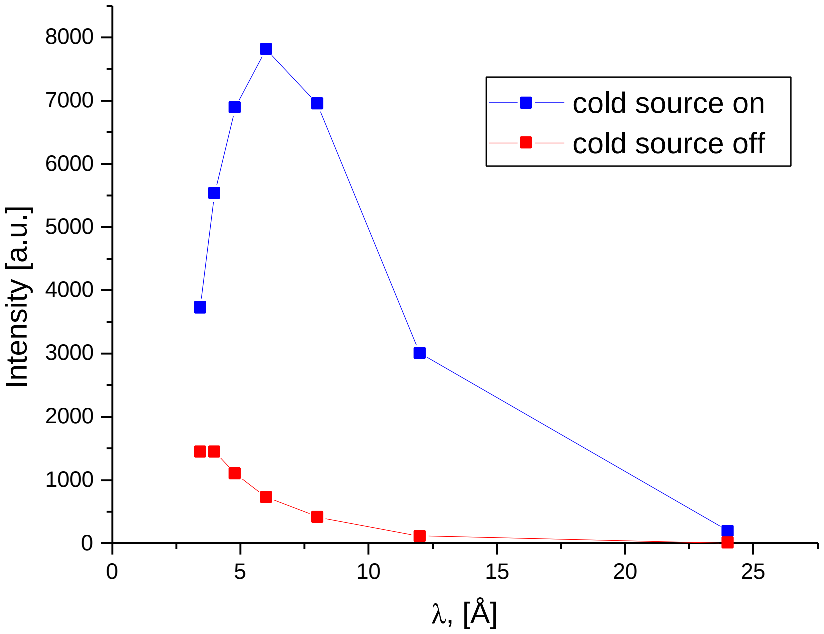
IMPROVED UTILIZATION OF THE REACTOR

As it was said above, the utilization of the reactor can be divided into two main fields: isotope production and neutron physics. The isotope production is not really influenced by the spectrum shift in the low energy range; consequently it does not benefit from the installation of the CNS. Here we consider only the neutron physics experiments.

The utilization of the reactor after the installation of the CNS remained unchanged, however the improvement in some cases is rather significant. Improvements were expected mainly in the field of neutron scattering, i.e. in case of four instruments: SANS, TAS, and REFL. These instruments became much more powerful after the CNS increased the cold neutron fraction. Some neutron activation methods can also benefit from the spectrum shift; e.g. the efficiency of PGAA was also improved. Unfortunately the situation in case of TOF is reverse, i.e. it can much better be used at a thermal beam, than at a cold one.

In case of REFL the number of neutrons reaching the sample position increased by a factor of 92 comparing to the value detected prior the installation of the cold source and of the new neutron guide [4]. The neutron guide alone increases the intensity by a factor of about five. Consequently the contribution of the cold source in the increase is about 18.

In case of SANS the effect of the neutron guide is based on a few measurements. The value is about 2.47. The effect of the cold source is spectrum dependent. To demonstrate the effect of the cold source measurements were made at seven different wavelengths with operational and shutdown CNS. The following figure shows the results of these measurements:



As it can be seen from the figure the improving factors at the different wavelengths are rather different, they are summarized in the following table:

wavelength[Å]	**3.43**	**4**	**4.8**	**6**	**8**	**12**	**24**
factor	2.6	3.9	6.3	10.8	16.8	26.3	32

The total factor describing the improvement can be simply calculated by multiplying the neutron guide factor and the CNS factor. The total factor is 6.4 for the minimum wavelength (3.43 Å), and it is as much as 79 for the extreme wavelength of 24 Å [5].

In case of TAS the gross gain is 14.2, that is mainly due to the spectrum shift, however the components (neutron guide and CNS) were measured only together [4].

The PGAA equipment is positioned rather far from the CNS. A part of the neutron guide is not equipped with super-mirrors; consequently the possibilities are not fully exhausted yet. However the CNS has a significant influence on the PGAA measurements as well. The measured improvement due to the source is 21.7 ± 1.1; i.e. the gain is not less than 20. The contribution of the CNS is about 9, that of the neutron guide is about 2.5. This improvement can still be increased by the modification of the neutron guide.

CONCLUSIONS

The Budapest Research Reactor, the first nuclear facility in Hungary, has been served for more than 40 years as a tool for neutron research and important applications (e.g. production of radioactive isotopes). The reactor became an improved tool for research and applications by means of the cold neutron source, that was installed in 2000, and started its regular operation in 2001. The first years proved that the reactor is improved, further improvements can be expected.

The improved research reactor can fulfil quite many new and continuous tasks in the new century. The fuel supply, the technical state of the reactor and the available human resources indicate that the reactor can be used for many more years.

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