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# BER-II UPGRADE

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ABSTRACT

The paper gives a brief information on the physical improvements and the technical data of the Berlin Research Reactor BER II, which was upgraded from 1985 until 1990. The licensing procedure is described and the regulations applied.

## General

The Hahn-Meitner-Institut is one of 13 national research centers in the Federal Republic of Germany. Basic research in close cooperation with the universities of Berlin is the main task of the institute. Thus, the Berlin Research Reactor BER II is an important facility in this program. The upgraded BER II will be a medium-flux neutron source (with a usable reflector flux of about $10^{14}$ n/cm$^2$sec) for standard applications, such as neutron scattering, material research and activation analysis. The BER II is a swimming pool reactor and was operated at a power of 5 MW from December 1973 until it was shut down in August 1985 for a general physical and technical improvement and upgrading.

The physical aim of the BER II upgrade is to increase the usable thermal neutron beam flux by a factor of 10 and the cold neutron flux by a factor of 130. This is the results of the following:

- The power of the reactor is increased from 5 to 10 MW
- The fission density is increased by a smaller core. The core grid has 7 x 6 = 42 MTR fuel element positions. The smallest

core is the so-called compact core, which uses only 4 rows of positions. The two rows of positions closest to the beam tubes R2 and R3 are filled with beryllium (see fig. 1).

- The reflection efficiency is increased by a beryllium reflector. The beryllium reflector, which is 30 cm thick, surrounds the core and produces a well pronounced flux peak about 5 cm from the core edge. To this flux maximum 10 beam tubes are adapted (a horizontal and vertical cut through the reactor is seen in fig. 1 and fig. 2). The flux gain of beam tubes ending in a beryllium reflector instead in a light water reflector is due to the well pronounced flux peak and due to the lower flux depression factor.
- The cold neutron flux density is increased by a cold source of hypercritical hydrogen at about 25 K. The cold source is installed in the conical beam tube (see fig. 1) and is feeding (via 7 neutron guides) a new neutron guide hall of approximately 1200 $m^2$.

The reactor and the cold source are ready for nuclear operation, but the Hahn-Meitner-Institut is still waiting on the operation license, which is expected in May 1990.

## Materials of in-pool structures

The in-pool structures, which are in the neutron radiation field, are of the aluminum alloy $AlMg_3$ (core structures, beam tubes, primary cooling ciruit pipes, pool liner, inlet and outlet pipes of the purification circuits). Other in-pool parts are of stainless steel (inlet and outlet pipes of the hot water layer), the heat exchanger, the primary pumps, the pipes of the secondary cooling circuit).

Data

| | Standard core | Compact core |
|---|---|---|
| - Reactor power [MW] | 10 | |
| - Thermal neutron flux [n/cm$^2$sec] (unperturbed in Be) | $10^{14}$ | $1,5 \times 10^{14}$ |
| - length of typical cycle [days] | 60 | 33 |
| - Fuel | Uranium-Aluminum | |
| - U-235 enrichment [%] | 89 - 93 | |
| - Type of fuel element | MTR (Material Test Reactor) | |
| - Weight of U-235 per plate [g] | 7,83 | |
| - Active length [cm] | 60 | |
| - Inner plate thickness [cm] | 0,127 | |
| - Outer plate thickness [cm] | 0,15 | |
| - Number of fuel elements (23 plates) | 30 | 18 |
| - Number of control elements and absorbers (17 fuel plates) | 6 | |
| - Type of absorber (In, Ag, Cd) | fork | |
| - Max. absorber speed [cm/sec] | 0,05 | |
| - Total absorber efficiency [%] | -18,2 | -22,6 |
| - Reflector (rectangular, 30 cm thick) | Beryllium | |
| - Coolant | $H_2O$ | |
| - Total flow [m$^3$/h] | 1050 | |
| - Reflectorflow [%] | 18 | |
| - Number of primary pumps | 3 | |

Experimental Facilities:

| | |
|---|---|
| - Vertical facilities in core (1 MTR position each) | 2 |
| - Vertical facilities in Be | 3 |
| - Horizontal beam tubes | 10 |
| - Fast rabbit (beam tube T1) | 1 |
| - Cold Source (conical beam tube) | 1 |
| - Neutron guides | 7 |

Accident Analysis

The maximum credible accident is a flow blockage in a fuel element (which may occur because of mechanical failures of fuel plates or because of particals in the cooling water). The plate melting is detected by the gamma dose rate due to fission production activity of the primary cooling water and the limits of the time derivative of the neutron flux density of the power instrumentation due to the void effect. The reactor will be shut down and the confinement of the reactor hall will be closed. The melting will never exceed one MTR fuel element and the resulting doses in the neighborhood of the HMI would be small against the limits set by the German regulations for accidents in power reactors [1].

The loss of primary coolant water (pool-water) is prevented by a double barrier system at all pool wall penetrations (double armatures in pipes or double walls in beam tubes for example). This and the following failures lead to a reactor shut down and are not connected with an activity release:

- The failure of one of the three primary coolant pumps (detected by pressure drop in the primary cooling circuit and by the change of the rotating speed).

- The failure of the secondary coolant systems (detected by an increase of the water temperature in the primary coolant system).
- Reactor power excursions due to a complete withdrawal of all control rods during the start-up procedure (detected by the period limit and the neutron flux density limit of the medium power instrumentation and the neutron flux density limit in the power instrumentation).
- The reactor power excursion due to a complete withdrawal of all control rods during power operation (detected by the limits of the absolute and differential neutron flux density of the power instrumentation).

## Licensing procedure

In the Federal Republic of Germany, the regional state governments are responsible for the licensing procedures of nuclear reactors. Appropriate licensing authority in Berlin was at first the "Senator für Wirtschaft und Verkehr", later called the "Senator für Wirtschaft und Arbeit" (meaning "administration for economy and labor"). Since June 1989 the licensing authority has been shifted to the "Senatsverwaltung für Stadtentwicklung und Umweltschutz" (meaning "administration for city development and environmental protection"). In 1979, the HMI proposed at first the license of the BER II improvement connected with a power increase to 10 MW. Until 1982 the safety report of the upgraded research reactor BER II was submitted to an expert, the "Gesellschaft für Reaktorsicherheit" (Cologne). During this time, the safety report was rewritten twice to make it equal to the German regulations of safety reports of nuclear power plants [2]. The last two editions of the safety report were written by the Interatom GmbH, Bensberg, the later builder of the BER II upgrade.

In autumn 1982 the safety report was presented to the public and in October 1983 the public hearing was held within 4 days.

Due to public objections and a demand of the authority, the HMI was obliged to present a study on consequences of destructive interactions from outside the reactor.

The result of this study was that only events such as a crash of a fast flying military aircraft on the reactor has the potential to destroy the concrete wall of the reactor pool in a way that the core falls dry. The occurrence probability of such an event is $2 \times 10^{-7}$ per year. The dose (integrated over 50 years, but with limited ingestion [3]) in the neighborhood of the HMI is about 50 rem. The calculations are in correspondence with the assessment of accident risks in German power plants [4].

Core melting accidents without the loss of the pool water but with loss of the integrity of the reactor building lead to a radiation dose which is a factor of more than 100 below this value. Sport planes and helicopters may have the potential for such a damage. The occurrence probability of these types of events is $2 \times 10^{-7}$ per year as well.

Because of the low occurrence probability of these hypothetical accidents and the relatively small consequences of it, the licensing authority decided that the small research reactor BER II has not to be protected by an outer concrete shell against aircraft crashes. The construction permission for the BER II upgrade was issued in August 1985. The cold source was explicitely excluded of this licence, it was shifted into a consecutive procedure.

Against the construction license was sued at law. The legal procedures are still continuing. By preliminary decisions of the court the continuance of the construction was guaranteed. But the construction of the interface structures of the reactor to the cold source (the plug carrying the cold source and the conical beam tube in fig. 1) was suspended until the HMI had also presented the safety analysis of the cold source to the public and had held a public hearing about it. This was done between March and June 1987. In late autumn 1988 the licensing authority issued the construction permission for the cold source. Also against this license the plaintiffs sued at law. Meanwhile, the upgraded research reactor and the cold source are ready for the nuclear operation. Experts for the erection of the reactor and the cold source were the "Technischer Überwachungsverein Berlin e.V." (meaning Technical Surveillance Association Berlin) and the "Technischer Überwachungsverein Norddeutschland e.V., Hamburg". The experts ensured the quality control of materials and executions and ascertained the equality of the constructions with the rules of German nuclear safety regulations. The final experts report is disposed and we hope to get the operation license in May 1990.

## Regulations

The German licensing authorities require backfitting according to current regulations for science and technology for technical approvement. A large number of guidelines and regulations concerning design, construction and operation of nuclear power plants have to be followed. The most important of these regulations are given below. Thus, planning permissions had to cover:

- The double energy supply system with double Diesel emergency power station and double D.C. supply for safety relevant systems [5, 6, 7, 8, 9, 10]
- Lifting equipments [11, 12]
- The fire protection [13]. An automatic sprinkler system is installed in the reactor building.
- Activity control [14]

- Instrumentation and reactor protection [15, 16, 17, 18, 19, 20, 21, 22]. The transdusers and actuators of the control system are of double redundancy, the measuring circuits of the safety system are of diversity (two different measuring methods of each variable) and of triple redundancy.
- Design against lightning effects [23]
- Communication devices [24]
- Radiological protection [25, 26]
- Requirements for the operating manual [27]
- Requirements for the testing manual [28]
- Quality assurance [29, 30, 31, 32]
- Work protection [33, 34]
- Requirements for the documentation [35, 36]
- The safeguard system [37]
- Disaster control [38, 39, 40, 41]
- Spent fuel disposal [42]

References

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[2] Merkpostenaufstellung mit Gliederung für den Standardsicherheitsbericht für Kernkraftwerke mit Druckwasserreaktor oder Siedewasserreaktor. Bekanntmachung des Bundesministers des Inneren vom 26.07.1976 (GMBl, 1976, S. 418)

[3] Radiologische Auswirkungen von EVA auf den Forschungsreaktor BER II. Gesellschaft für Umweltüberwachung mbH, GUW-84.1983.03, Juni 1984, im Auftrage des HMI-Berlin

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[5] - [34]:
Sicherheitstechnische Regeln des Kerntechnischen Ausschusses, Carl Heymanns Verlag.
English version is available from:
Kerntechnischer Ausschuß
Geschäftsstelle Germany
P.O. Box 101650
D-Köln 1 (FRG)

[5-10] KTA-No. 3702.1, 3702.2, 3703, 3704, 3705, 3403

[11-12] KTA-No. 3902, 3903

[13] KTA-No. 2101.1

[14] KTA-No. 3601

[15-22] KTA-No. 3904, 3501, 3502, 3503, 3504, 3505, 3506, 3507

[23] KTA-No. 2206

[24] KTA-No. 3901

[25-26] KTA-No. 1501, 1507

[27] KTA-No. 1201

[28] KTA-No. 1202

[29-32] KTA-No. 1401, 1408.1, 1408.2, 1408.3

[33-34] KTA-No. 1301.1, 1301.2

[35] Richtlinie des Bundesministers des Inneren "Grundsätze zur Dokumentation technischer Unterlagen durch Antragsteller/Genehmigungsinhaber bei Errichtung, Betrieb und Stillegung von Kernkraftwerken" vom 04.12.1981 (GMBl-1981, S. 542)

[36] Richtlinie des Bundesministers des Inneren "Anforderungen an die Dokumentation bei Kernkraftwerken" vom 05.08.1982 (GMBl. 1982, S. 546)

[37] Bundesminister des Inneren "Sicherungsmaßnahmenkatalog"

[38] Bekanntmachung des Bundesministers des Inneren "Rahmenempfehlung für den Katastrophenschutz in der Umgebung kerntechnischer Anlagen" vom 17.10.1977 (GMBl. 1989, s. 94)

[39] Bekanntmachung des Bundesministers des Inneren "Empfehlung zur Planung von Notfallschutzmaßnahmen durch Betreiber von Kernkraftwerken" vom 27.12.1976 (GMBl. 1977, S. 48)

[40] Bekanntmachung des Bundesministers des Inneren "Änderung der Empfehlungen zur Planung von Notfallschutzmaßnahmen durch Betreiber von Kernkraftwerken" vom 18.10.1977 (GMBl. 1977, S. 664)

[41] "Richtlinie für die Emissions- und Immissionsüberwachung kerntechnischer Anlagen" vom 16.10.1979 (GMBl. 1979, S. 668)

[42] Bekanntmachung des Bundesministers des Inneren "Grundsätze zur Entsorgungsvorsorge für Kernkraftwerke" vom 19.03.1980, Bundesanzeiger No. 58 vom 22.03.1980

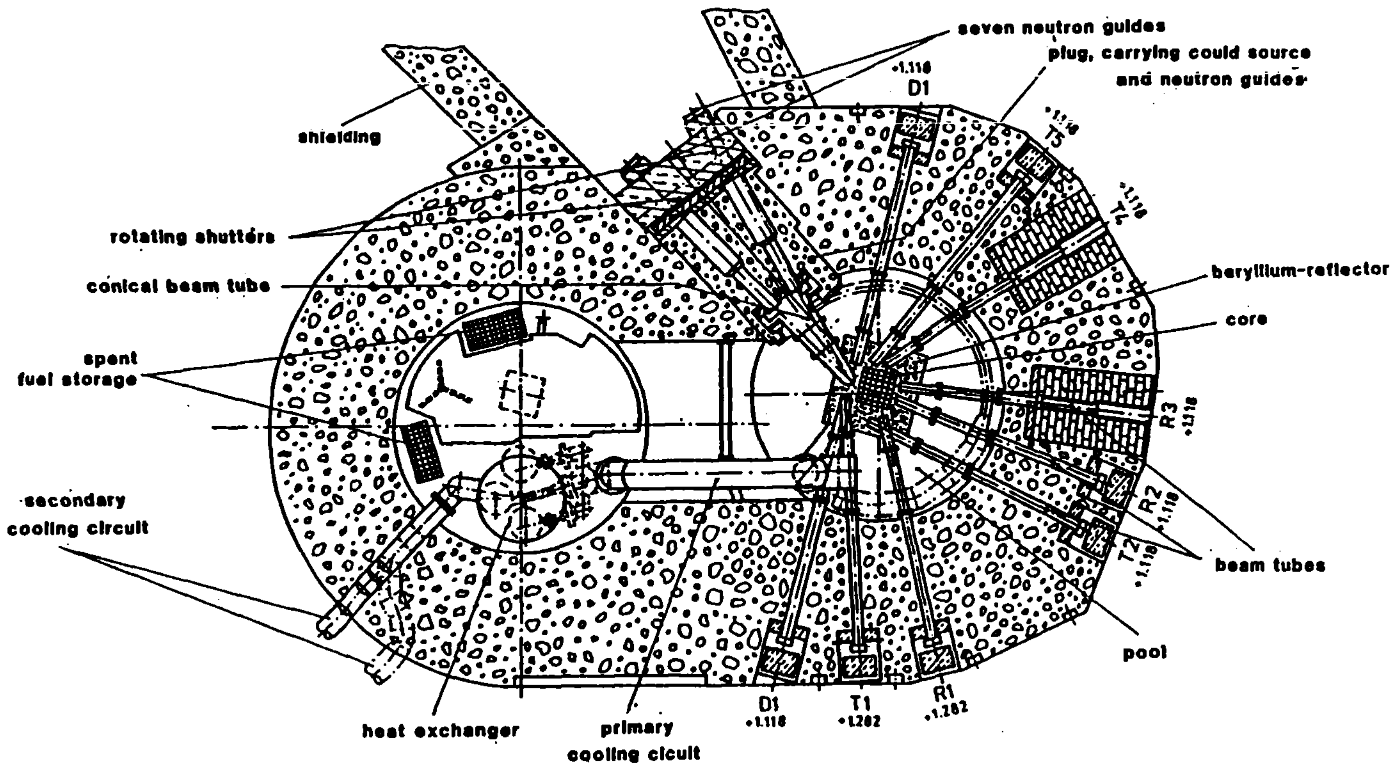


Fig.1 **BER II - horizontal cut**

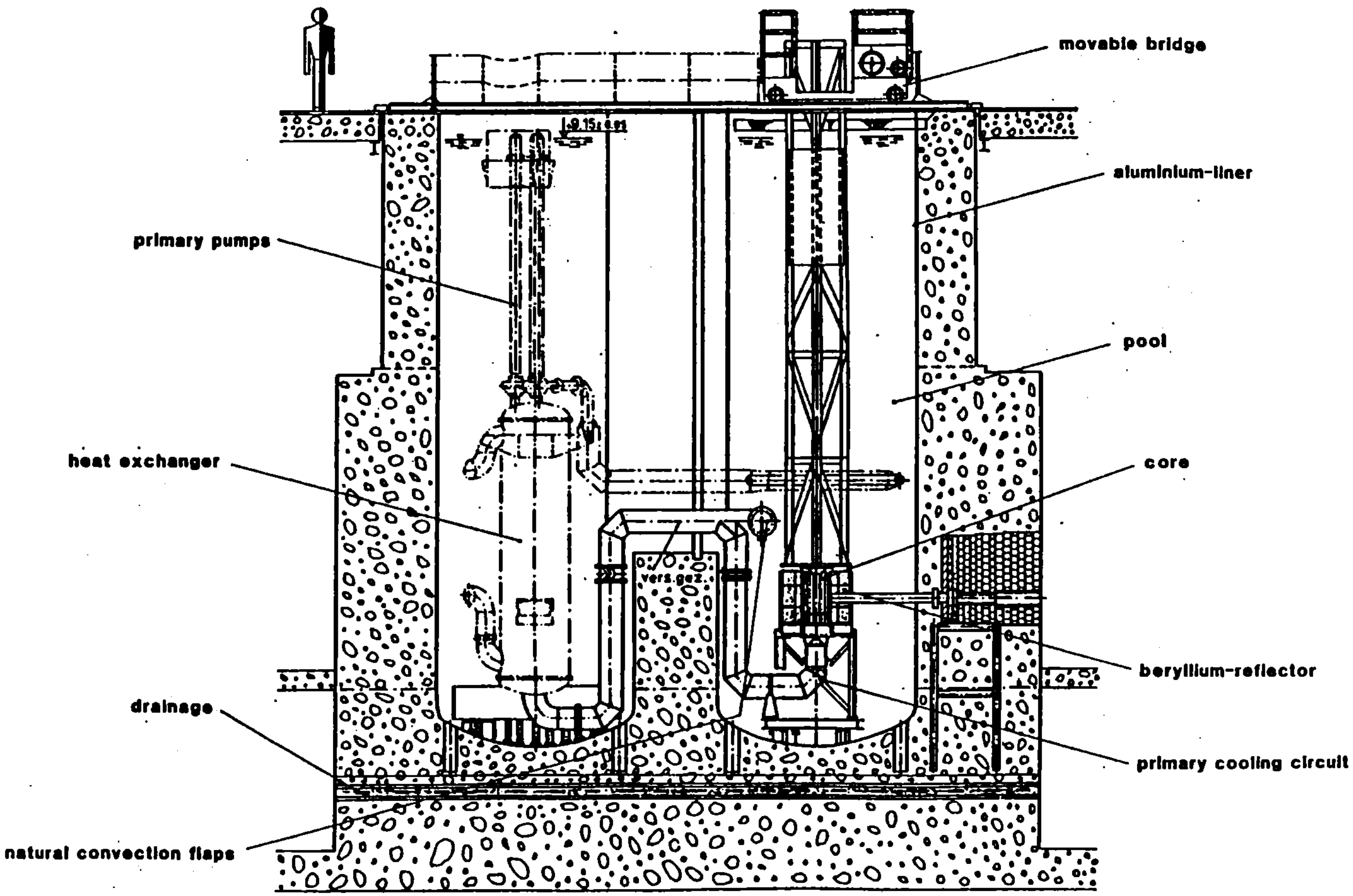


Fig.2 **BER II vertical- cut**