# FRG COMPACT CORE
# - ONE YEAR EXPERIENCE -

W. Knop and P. Schreiner

GKSS-Forschungszentrum Geesthacht GmbH
Max Planck-Straße, D-21502 Geesthacht

## Introduction

The GKSS research centre Geesthacht GmbH operates the MTR-type swimming pool reactor FRG-1 (5 MW) for more than 40 years. The FRG-1 has been upgraded and refurbished many times to follow the changing demands of safe operation and today's needs of high neutron flux for scientific research. High neutron fluxes with highest availability is the permanent demand of the science on the operation of a neutron source.

## Core compaction

A first step for the increase of the neutron flux was carried out approx. 10 years ago. In February 1991 the FRG-1 was converted from high-enriched uranium (HEU 93 %) to low enriched uranium (LEU 20 %) in one step. At the same time the reactor core was reduced from 49 to 26 fuel elements. Therefore neutron flux density at the beam tubes could be increased by more than the factor of two /1/.

The consistent way of the neutron flux enhancement of the FRG-1 as a national neutron source was achieved with new reduction of the core size at the beginning of 2000, in order to further increase the thermal neutron flux density at the beam tubes and particularly at the place of the cold neutron source. For this compaction the reactor core was reduced from 26 to 12 fuel elements. Figure 1 shows the model of the new 3x4 FRG-1 core. To achieve this reduction the fuel loading had to be increased from 3,7 g U/cc to 4,8 gU/cc. A arrangement of 3,7 and 4,8 g U/cc fuel elements had been used for the first three 3x4 cores to achieve a certain burnup. Two standard and one control fuel elements will be replaced per cycle. Tabl 1 shows a comparison of the old (26 fuel elements) and new compact core/2/.

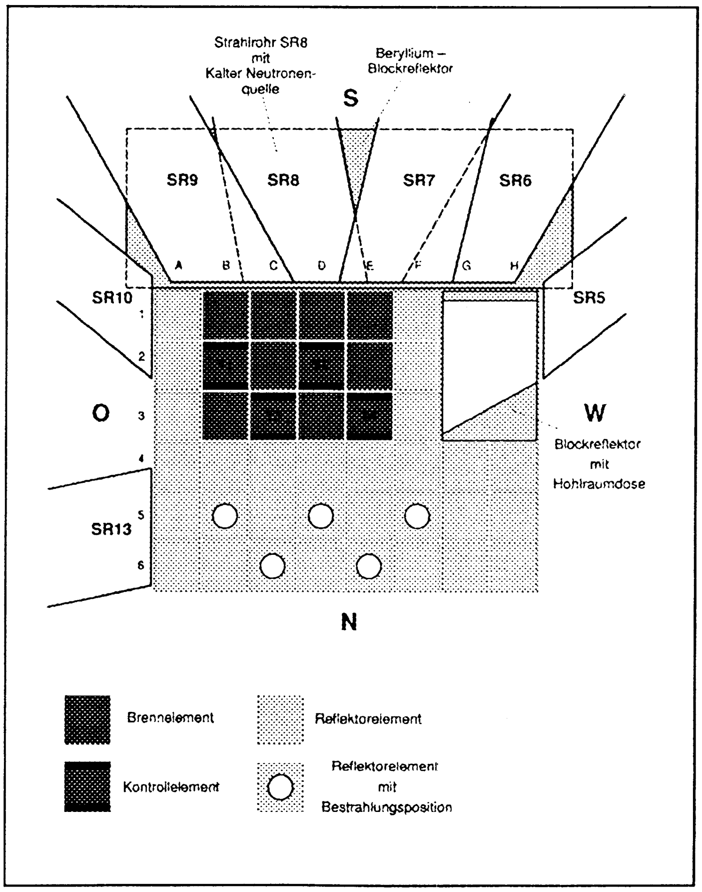


**FIG.1: Model of the 3 x 4 core with Beryllium reflector and beam tubes**

**Table 1: Comparison of the two cores**

| | 26 fuel elements | Compact core |
|---|---|---|
| Thermal Power (MW) | 5 | 5 |
| Number of fuel elements | 21 | 8 |
| Number of control rods | 5 | 4 |
| Fuel | $U_3Si_2$ | $U_3Si_2$ |
| U-235 enrichment (%) | 19,75 | 19,75 |
| Fuel density (g U/cc) | 3.7 | 4.8 |
| U-235 content per fuel (g) | 323 | 420 |
| ave. heat flux (W/cm$^2$) | 12 | 25 |
| Coolant velocity (m/s) | 1,6 | 2,9 |
| Reflector | $H_2O$,Be | Be |
| Front end of beam tube | | optimised |

The neutron fluxes were calculated for each beam tube position. The calculated results indicate that the increase in thermal neutron flux for the beam tube is between 50 and 160 % depending on the position of the beam tube. The maximum axial integrated unperturbed thermal neutron flux will be at the position of the cold neutron source, it will be increased from $7.5*10^{13}$ to $1.3*10^{14}$ n/cm$^2$ sec. Beam tube 8 with the cold neutron source serves around 65 % of the experiments of all beam tubes of the FRG-1 and is therefore the most important beam tube.

For the new 3x4 core a constructive modification (grid plate with shroud and the support for the reactor) was necessary. We finished this modification in January/February 2000. The new shroud reduced the coolant bypasses so that the coolant velocity increased to 2.9 m/s (Fig.2)

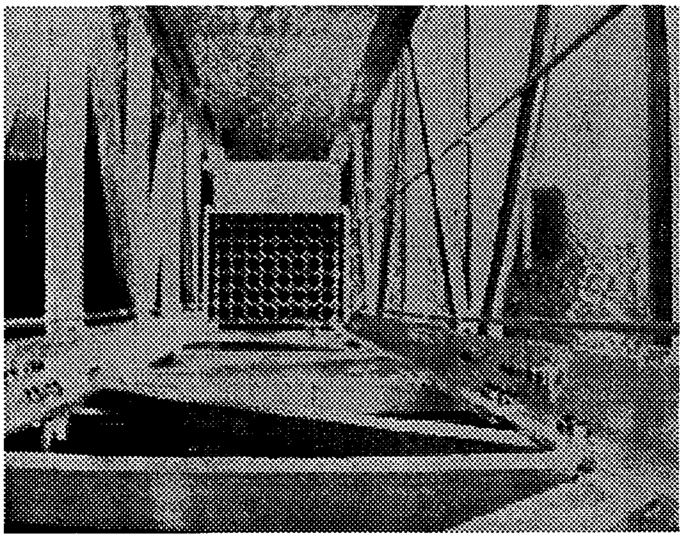
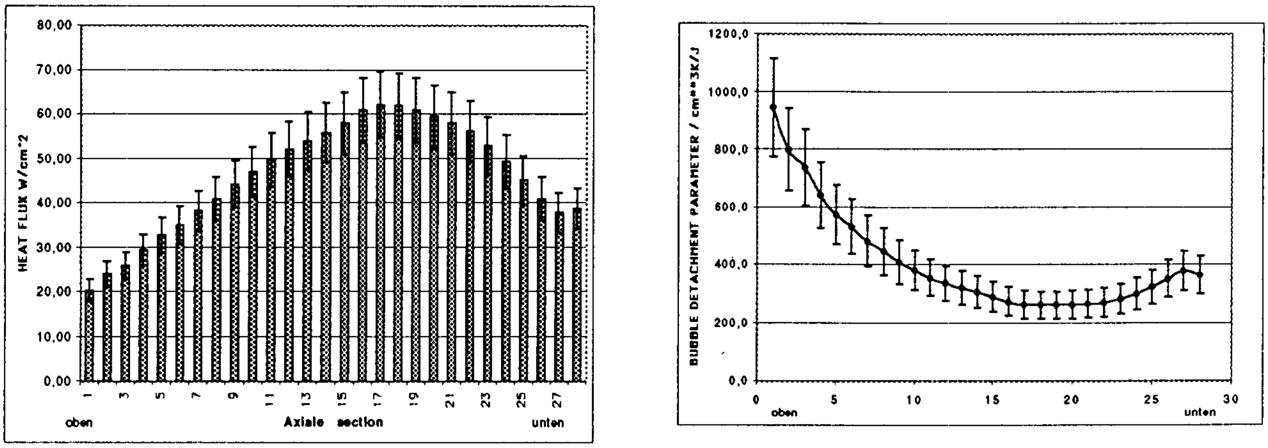


**Fig.2: The new FRG-1 grid plate**

On March 08.2000 we obtained the license and started immediately with the compaction from 26 to 12 fuel elements. An arrangement of 3.7 and 4.8 g U/cc fuel elements had been used for the first three 3x4 cores to achieve a certain burnup. Two standard and one control fuel elements will be replaced per cycle. We need 6 cores to reach the equilibrium core. Extensive programs like critical experiment, control rods calibration, stuck rod proof, fuel element-formfactors and bubble detachment parameter were necessary for the initiation of the first six cores. The last two parameters are determined from Cu-wire activation. For this activation we inserted Cu-wires into each standard fuel element and irradiate the wires for 30 min at a power of 10 kW. The result from the Cu-wire measurements ( formfactors, temperature, heat flux and bubble detachment parameter ) are in good agreement with theoretical calculation / 3/. Figure 3a/b show the measurements of the heat flux and bubble detachment parameter in the hot channel of the first core. The existing safety margin to the flow instability is 9.1, the necessary safety margin to the flow instability is 1.48.

FIG. 3 a/b: Heat flux and bubble detachment parameter



One year after core conversion, we operate now the fifth compact core. For all cores, the full power days are listed in table 2. Neglecting the first core, the average full power days are around 55 days. In Figure 4 is shown control rods position versus MWd. The maximum position for the control rods are 666mm, but we shutdown the reactor already around 640 mm.

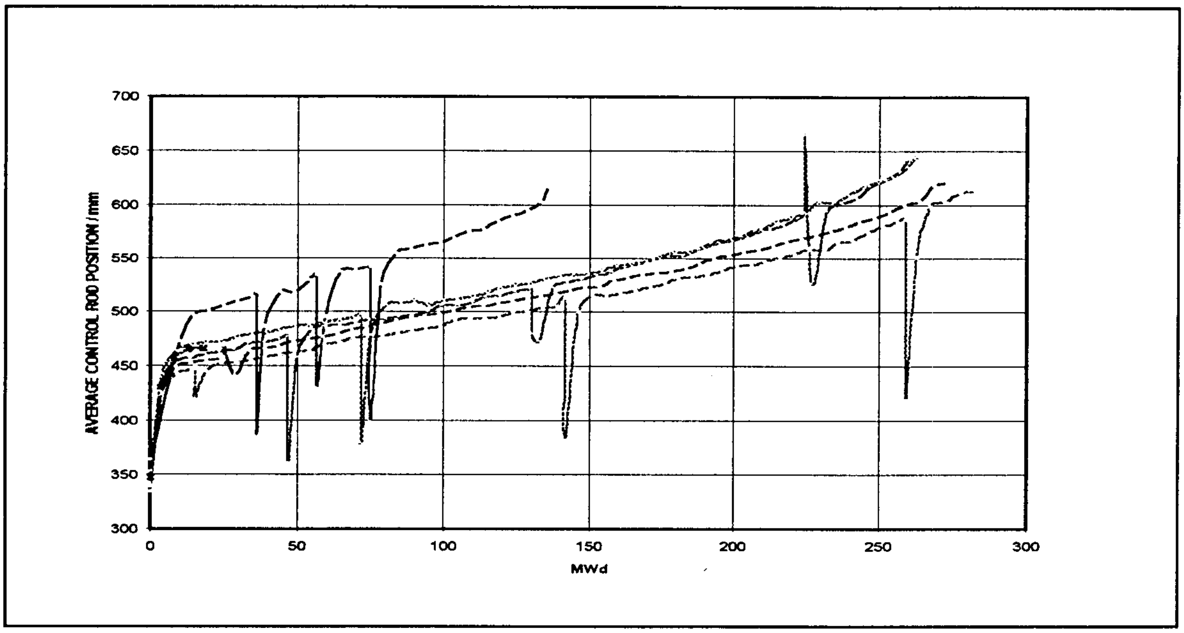
| Compact core | Date BOC | Full power Days (5MW) |
|---|---|---|
| 1.core | Febr. 08. | 27.2 |
| 2.core | May 12. | 56.2 |
| 3.core | Aug.18. | 52 |
| 4.core | Oct. 05, | 55 |
| 5.core | Dec. 04 | 53.2 |

Table 2:

## Summary

The conversion leads to the expected neutron gain of 100% on the cold and 80% on the thermal neutron beam. This doubling of the perturbed neutron flux at the position of the cold neutron source (unperturbed 1.3*E+14 n/s cm**2) is the best guarantee for top research in the future. This core conversion and the renewing of the reactor protection system, primary coolant circuit, emergency power plant etc. makes the FRG-1 fit for the next 15 years reactor operation.

Fig. 4



## References

/1/ W.Krull: Enrichment reduction of the FRG-1 research reactor, International Meeting on Reduced Enrichment for Research and Test Reactors (RERTR), Jakarta, November 4-7,1991

/2/ P.Schreiner, W.Krull and W.Feltes: Increasing the neutron flux after reduction of the core size of the FRG-1, International Meeting on Reduced Enrichment for Research and Test Reactors (RERTR) Jackson Hole, Wyoming USA, October 5 – 10, 1997

/3/ Siemens report: Nr. A1C-1305109-0