INCREASING THE NEUTRON FLUX AT THE BEAM TUBE POSITIONS OF THE FRG-1

P. Schreiner, W. Krull and W. Feltes*

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

* Siemens AG, KWU NBTS
Freyeslebenstraße 85, D-91050 Erlangen

Presented at the 6th IGORR Meeting
April 29 - May 1, 1998, Taejon, The Republic of Korea

INCREASING THE NEUTRON FLUX AT THE BEAM TUBE POSITIONS OF THE FRG-1

P. Schreiner, W. Krull and W. Feltes*

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

* Siemens AG, KWU NBTS
Freyeslebenstraße 85, D-91050 Erlangen

Abstract

The GKSS research center Geesthacht GmbH operates the MTR-type swimming pool research reactor FRG-1 (5MW) for 39 years. The FRG-1 has been converted in February 1991 from HEU (93%) to LEU (20%) in one step and at that time the core size was reduced from 49 to 26 fuel elements. Consequently the thermal neutron flux in beam tube positions could be increased by more than a factor of two. It is the strong intention of GKSS to continue the operation of the FRG-1 research reactor for at least an additional 15 years with high availability and utilization. The reactor has been operated during 1996 for more than 240 full power days.

To prepare the FRG-1 for an efficient future use, a large set of nuclear calculation have been performed to reduce the core size in a second step from the current 26 fuel elements to 12 fuel elements. To achieve this reduction the fuel loading has to be increased from 3,7 g U/cc to 4,8 g U/cc. The calculational 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 thermal neutron flux will be at the position of the cold neutron source, it will be increased from $7.5*10^{13}$ to $1.2*10^{14}$ n/cm^2 sec.

The constructive modification for the new core facilities (grid plate with shroud and the support for the reactor core) are finished and the application for the license is on the way.

The thermohydraulic and safety calculations are on the way and will be completed autumn of 1998 to allow the application for a license for the core size reduction end of 1998. Comparing this conversion procedure with the first conversion procedure we are hopefully to get a license in 2000.

Introduction

The research reactor FRG-1 has been originally designed and constructed in 1957/1958 (criticality on October 23, 1958) to serve general scientific research needs in different aspects of fundamental research and some applied research like cracking phenomena of organic coolants and isotope production. It is clear that during the lifetime (40 yr) of the research reactor the research areas have changed more than once. The outcome of such changes results on the one side in new experimental facilities at the beam tubes and on the other side in design changes at the reactor. The following design changes have been made: increase of fuel loading, increase of burnup, reduction of enrichment, reduction of core size, new control rods, installation of a cold neutron source. At present the FRG-1 is being used with high availability for beam tube experiments for fundamental and applied research in biology, materials research, neutron radiography, neutron activation analyses etc /1,2/.

At the moment we are considering an additional core size reduction by more than a factor of two (see table 1) to increase the thermal neutron flux at the beam tubes by approx. 70 %. For this purpose the U-235 density have to be increased from 3.7 g U/cc to 4.8 g U/cc. So, finally the size of the reactor is being reduced from 48 fuel elements to 12 fuel elements over the last 10 years.

Table 1: Comparison of present and future core

	present core	future core
Thermal Power (MW)	5	5
Number of fuel elements	26	12
Plates per fuel element	23	23
Number of control rods	5	4
Plates per control rod	17	17
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		optimized

Calculational Methods

The diffusion theory and burnup calculations were performed for the reactor design using the DIF3D and REBUS-3 codes and seven energy-group cross sections generated using the WIMS-D4M code and ENDF/B-V data /3,4/. The Monte Carlo calculations were performed using the MCNP code and ENDF/B-V data /5/. The model for the future core with the beryllium reflector and the beam tubes is shown in Figure 1.

For the burnup calculations each standard element was modeled as three separate regions, one region representing the fueled portion of the element and two regions representing the sideplates and the other non-fueled portions of the element position. Each control element without Absorber blades was modeled in a similar manner, except that two additional separate regions were included to represent the aluminum guide plates and their associated water channels.

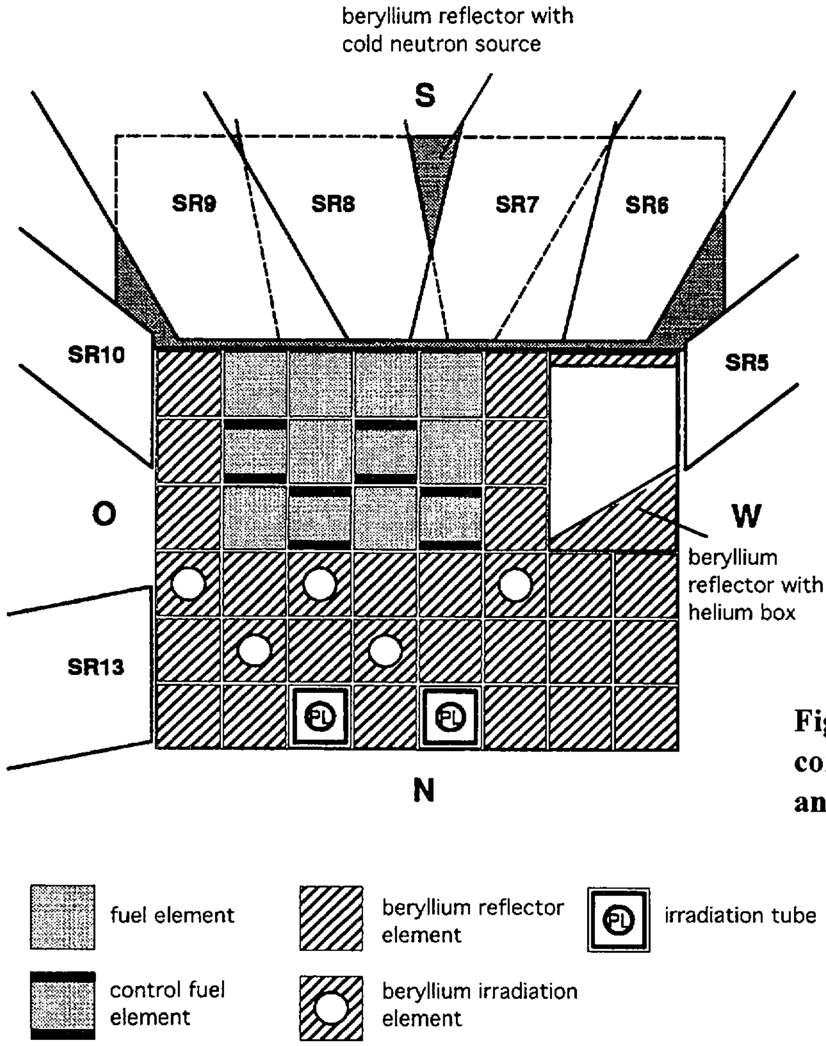

Figure 1: Model of the future core with beryllium reflector and beam tubes

Neutronic and Burnup Results

The neutron fluxes were calculated with MCNP and DIF3D at each beam tube. The results of the unperturbed neutron fluxes in the beryllium reflector for the beam tube positions 7, 8 and 9 are shown in Figures 2 to 4. The maximum thermal neutron flux will be at the beam tube position 8, the one with the cold neutron source. 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. The optimization of the core size are directed to increase the thermal flux of the cold neutron source position to the largest extent possible. The increase of the thermal neutron flux at the cold neutron source between the present core and the future core will be 70 %.

A comparison of the axial integrated unperturbed neutron fluxes that were obtained from the Monte Carlo and the diffusion theory calculations are shown in table 2. The peak thermal fluxes obtained from the Monte Carlo and diffusion theory calculations are in reasonably good agreement.

Table 2: Comparison of MCNP and DIF3D peak thermal fluxes

	MCNP	DIF3D
beam tube 7	1.02 10^{14} n/cm^2 s	0.98 10^{14} n/cm^2 s
beam tube 8	1.19 10^{14} n/cm^2 s	1.20 10^{14} n/cm^2 s
beam tube 9	0.94 10^{14} n/cm^2 s	0.98 10^{14} n/cm^2 s

Depletion calculations were performed to determine the cycle length in the equilibrium core using the REBUS-3 code. The main results of these calculation are shown in table 3. The cycle length was computed to be 80 full power days. The reactivity for the equilibrium core is 6.4 % at the BOC and 0.5 % at the EOC. The average burnup at BOC is 17.8 % and at EOC is 28.7 %. The average discharged burnups in the standard and control elements are nearly the same. Two standard elements and one control element are foreseen to be replaced per cycle.

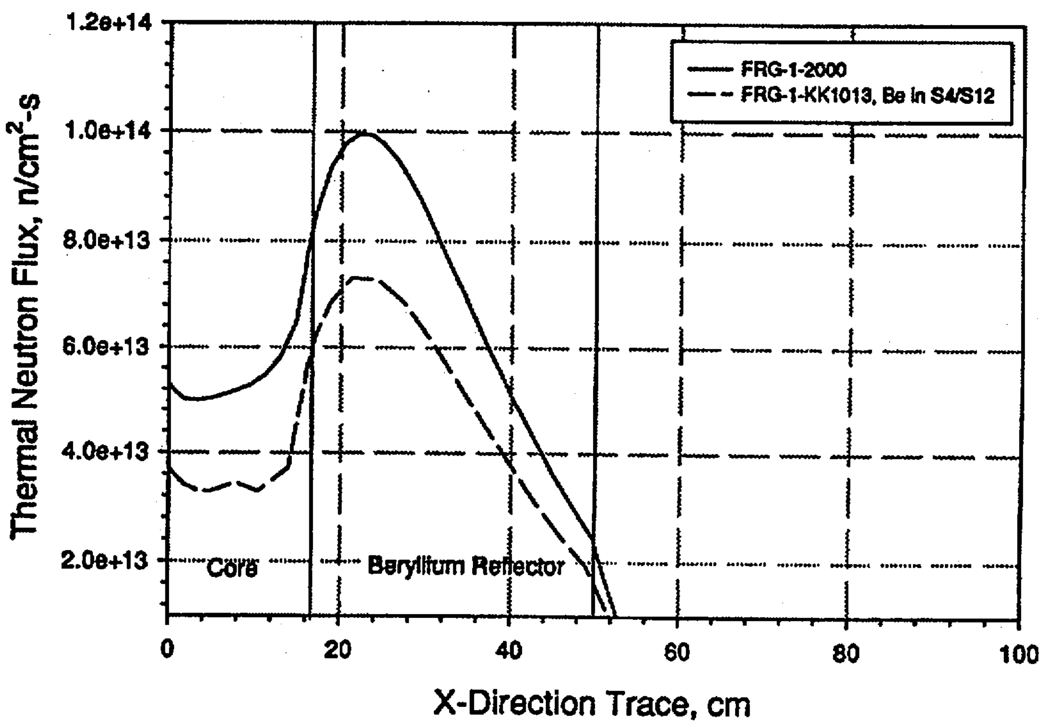

Figure 2: Axial integrated unperturbed neutron flux in beryllium reflector at beam tube position 7

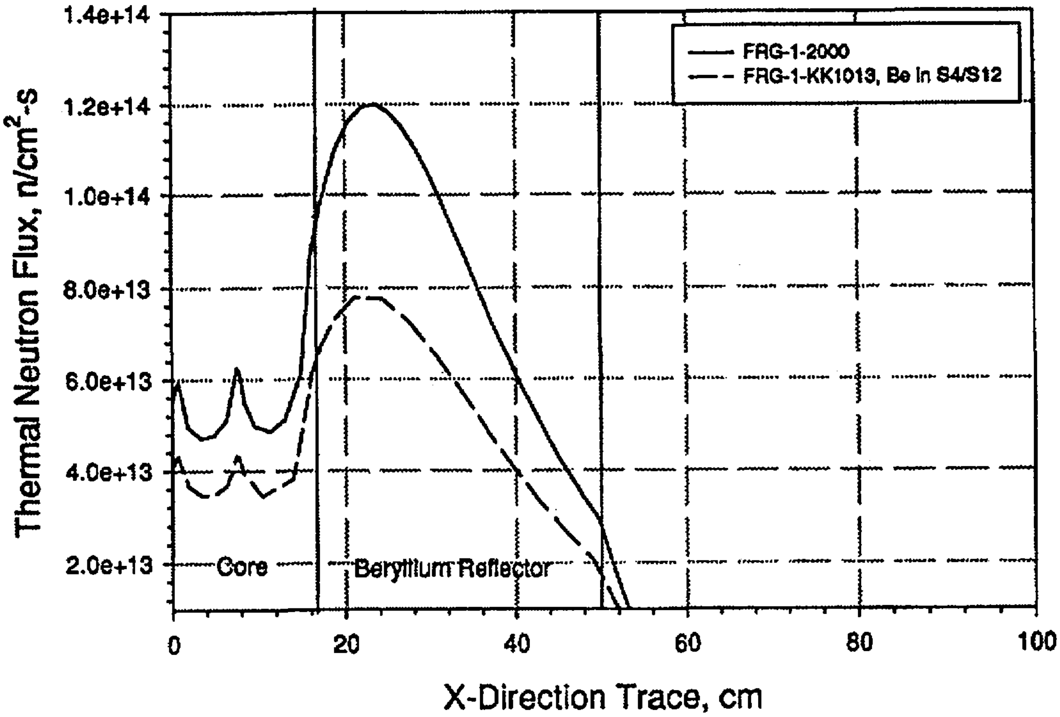

Figure 3: Axial integrated unperturbed neutron flux in beryllium reflector at beam tube position 8

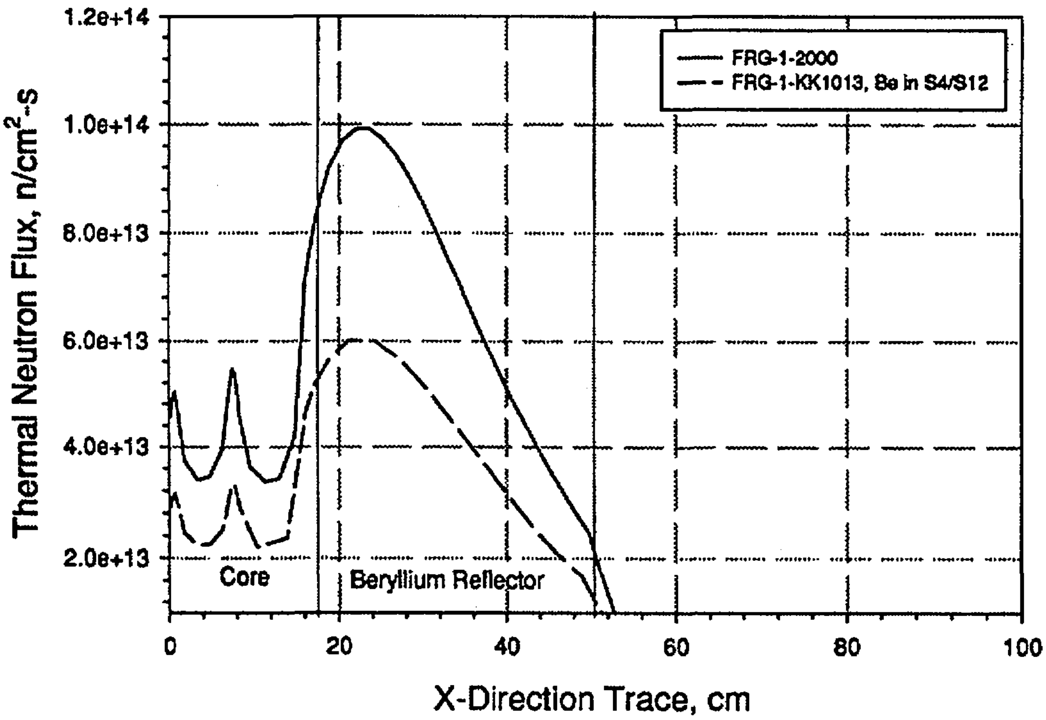

Figure 4: Axial integrated unperturbed neutron flux in beryllium reflector at beam tube position 9

Table 3. Burnup results for the equilibrium core

12.9 % 24.7 %	0 % 12.6 %	0 % 12.9 %	23.5 % 33.7 %
----- 24.3 % 35.0 % -----	12.6 % 23.5 %	----- 0 % 12.7 % -----	24.7 % 34.4 %
33.7 % 43.1 %	----- 12.7 % 24.3 % -----	34.4 % 43.7 %	----- 35.0 % 44.3 % -----

cycle length: 80 full power days

discharge burnup:
standard element: 43.4 %
control element: 44.3 %

core averaged burnup:
BOC: 17.8 %
EOC: 28.7 %

reactivity for the equilibrium core:
BOC: 6.4 %
EOC: 0.5 %

Summary

GKSS envisages to operate the FRG-1 at least until the year 2010. To keep this important neutron source at a high level of incentives for the scientific community GKSS will make all efforts to improve technical performance of the reactor and to develop the experimental facilities supplied with neutrons from the FRG-1. The construction modifications for the new core facilities (grid plate with shroud and the support for the reactor core) are finished and the application for the first part of the license is on the way. The thermohydraulic and safety calculations are on the way and will be completed autumn of 1998 to allow the application for the second part of the license for the core size reduction end of 1998. Comparing this conversion procedure with the first conversion procedure we are hopefully to get a license in 2000.

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/ W. Krull and W. Jager: Status and perspectives of FRG-1 after conversion to LEU, International Meeting on Reduced Enrichment for Research and Test Reactors (RERTR), Seoul, October 6-10, 1996.

/3/ Guidebook on Research Reactor Core Conversion from the use of Highly Enriched Uranium to the Use of Low Enriched Uranium Fuels, IAEA-TECDOC-233, August 1980.

/4/ J. R. Deen, W. L. Woodruff and C. I. Costescu: WIMS-D4M User Manual Rev. 0, ANL/RERTR/TM-23, Argonne National Laboratory, July 1995.

/5/ J. F. Briesmeister: MCNP-A General Monte Carlo N-Particle Transport Code (Version 4A), LA-12625-M, Los Alamos National Laboratory, November 1993.