FRG-1 COMPACT CORE WITH HIGHER DENSITY FUEL
- Experience from the first to the equilibrium core -

W. KNOP, W. JAGER and P. SCHREINER

GKSS-Forschungszentrum Geesthacht GmbH
Max-Planck-Straße 1 , D-21502 Geesthacht
Germany

ABSTRACT

The GKSS research center Geesthacht GmbH operates the MTR-type swimming pool research reactor FRG-1 (5 MW) for more than 40 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 [1, 2]. 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 the last years for approximately 250 full power days per year. To prepare the FRG-1 for an efficient future use, the core size has been reduced in a second step from 26 fuel elements to 12 fuel elements.

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 and isotope production. It is clear that during the lifetime of the research reactor the research areas have been 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 burn up, 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.

Between 1996 and 1998 we have studied an additional core size reduction by more than a factor of two to increase the thermal neutron flux at the beam tubes (Table 1).

	26 fuel element	compact core
Thermal power (MW)	5	5
Number of fuel elements	26	12
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 standard fuel element (g)	323	420
Average heat flux (W/cm^2)	12	25
Reflector	H_2O,Be	Be
Front end of beam tubes		optimized

Tab 1: Comparison of the 26 fuel element core and compact core

For this purpose the U-235 density have to be increased from 3.7 g U/cc to 4.8 g U/cc. So that finally the size of the reactor is being reduced from 49 fuel elements to 12 fuel elements over the last 10 years [3, 4]. The model for the future core with the beryllium reflector and the beam tubes is shown in figure 1.

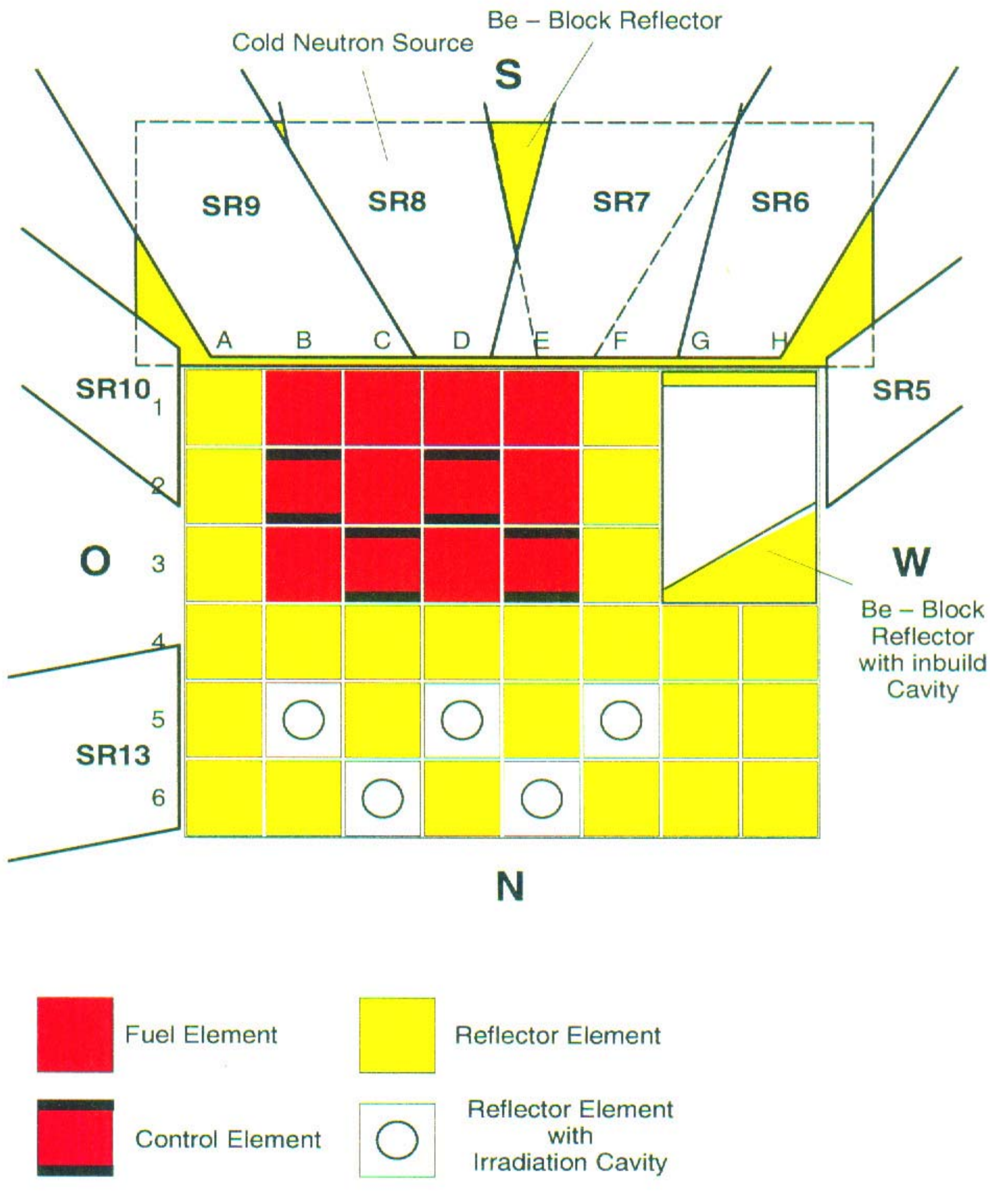

Fig 1: Model of the 3x4 core with beryllium reflector and beam tubes

CONSTRUCTIVE MODIFICATION

The constructive modification for the new core facilities (grid plate with shroud and the support for the reactor core) were licensed in 1999, manufactured and has been changed in January 2000. The new shroud reduced the coolant bypasses so that the coolant velocity increased in the gap between the fuel plates from 1.6 m/s to 2.9 m/s.

RESULTS FORM THE NEW COMPACT CORE

On March 8, 2000, we obtained the license and started immediately with the core site reduction from 26 to 12 fuel elements. A mixture of 3.7 and 4.8 g U/cc fuel elements has been used for the first three 3x4 cores to achieve a certain burn up. Two standard and one control fuel elements are being replaced per cycle following a fixed schedule. Table 2 shows the cycle length for the compact cores number 1 to 11. We need 6 cores to reach the equilibrium core. Extensive programs like critical experiment, control rods calibration, stuck rod proof, fuel element form factors and bubble detachment parameter have been measured. The last two parameters are determined from Cu-wire activation. The results from the Cu-wire measurements are in good agreement with the theoretical calculation

Compact core	Date BOC	Date EOC	Full power days
1. core	March 8. 2000	May 7. 2000	27
2. core	May 12. 2000	July 15. 2000	56
3. core	August 18. 2000	September 28. 2000	52
4. core	October 5. 2000	November 30. 2000	53
5. core	December 5. 2000	March 13. 2001	52
6. core	March 21. 2001	Mai 18. 2001	53
7. core	Mai 22. 2001	July 18. 2001	50
8. core	August 7. 2001	October 6. 2001	55
9. core	October 10. 2001	December 1. 2001	53
10. core	December 4. 2001	May 8. 2002	56
11. core	May 10. 2002	July 5. 2002	51

Tab 2. Cycle length for the 1. – 11. Compact cores

The conversion yields to the expexted neutron gain of 100 % on the cold neutron source (SR 8) and between 0 % and 80 % on the thermal neutron beam (Table 3). This doubling of the perturbed neutron flux at the position of the cold neutron source (unpertubed $1.4*10^{14}$ n/s cm^2) is an excellent guarantee for top research in the future. The cns served 65% of all neutron scattering experiments at GKSS.

Beam tube	Neutron flux Increasing
SR 5	80 %
SR 7	70 %
SR 8	100 %
SR 9	70 %
SR 13	0 %

Tab 3: Increasing of the perturbed neutron flux at the beam tubes

SUMMARY

The constructive modification for the new core facilities (grid plate with shroud and the support for the reactor core) have been changed in January 2000. On March 8, 2000, we obtained the license and started immediately with the core site reduction from 26 to 12 fuel elements. The conversion yields to the expexted neutron gain of 100 % on the cold neutron source and 80 % on the thermal neutron beam.

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