FEASIBILITY STUDY OF USING OF LOW ENRICHED URANIUM FUEL FOR RESEARCH REACTOR IN SOFIA

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ABSTRACT

The results of the study of arrangement of the reactor core of pool type Research Reactor 200 kW in Sofia are presented. The number of planned horizontal experimental channels of Research Reactor is equal to 8 and vertical ones to 9. The beginning of study performed for fresh IRT2M tabular fuel assemblies containing highly enriched uranium with 36% enrichment is presented. The core modelling calculations are performed by the MCNP4C code. The IRT-2M fuel assembly modelling is tested by experimental data. The configuration of the reactor core including three-tube and four-tube fuel assemblies as well as beryllium blocks is analysed.
The aspects of feasibility of using of developed in Russia pin-type fuel assemblies IRT-MR with low enriched uranium (LEU<20%) in core design instead of IRT-2M ones are discussed.

1. Introduction

A renovated Research Reactor in Sofia is planed to be put into operation in a near two years. It is under reconstruction now. Research Reactor in Sofia has been designed and constructed from 1958 to 1961. First criticality has been reached in September 1961 and the reactor has been put into operation in November 1961. It has undergone two modifications upgrading its power to 1.5 MW in 1965 and 2 MW in 1970. In 1982 the project IRT5000 of the reactor upgrading to 5 MW has been started. The project has been finalised in 1989 but not realised because of severe problems in Bulgaria of economical and political nature. Moreover in the same year the reactor has been shut down. Just in 2001 the government decision about the reactor reconstruction to the reactor with 200 kW power level has been taken and renovation investigation has been started. Initially the reactor core design with using of IRT-2M [1] tabular fuel assemblies containing highly enriched uranium with 36% enrichment has been planed. These are the same fuel assemblies that have been intended for IRT5000 realisation. In 2002 the RERTR Program representatives from Argonne National Laboratory have informed us about the problem of research reactors conversion to low enriched uranium fuel (LEU<20%).

Some results of the first steps of our investigation of the new reactor core design with IRT-2M fuel assemblies and of the core conversion to LEU fuel assemblies IRT-MR [2, 3] are presented below. The reactor core modeling has been carried out by the MCNP4C code [4].

2. IRT-2M fuel assembly modelling and testing

The IRT-2M fuel assembly has been modeled by MCNP code on the base of data presented in [1]. The MCNP models for four-tube assembly and three-tube assembly are presented on Fig. 1 and Fig. 2 correspondingly.

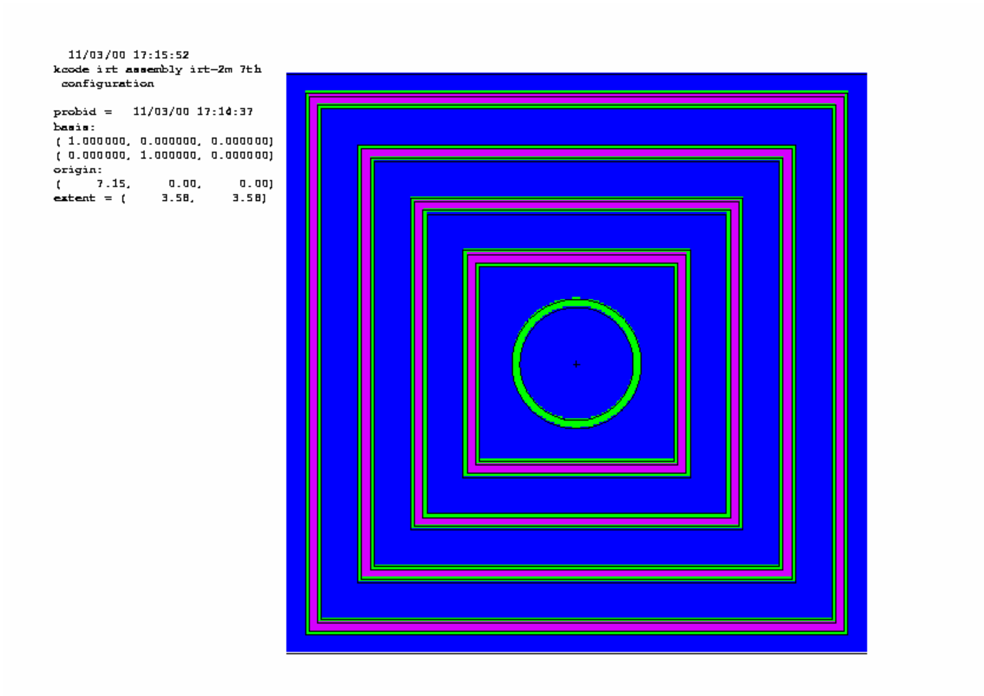

Fig. 1. Four-tube IRT-2M assembly MCNP model

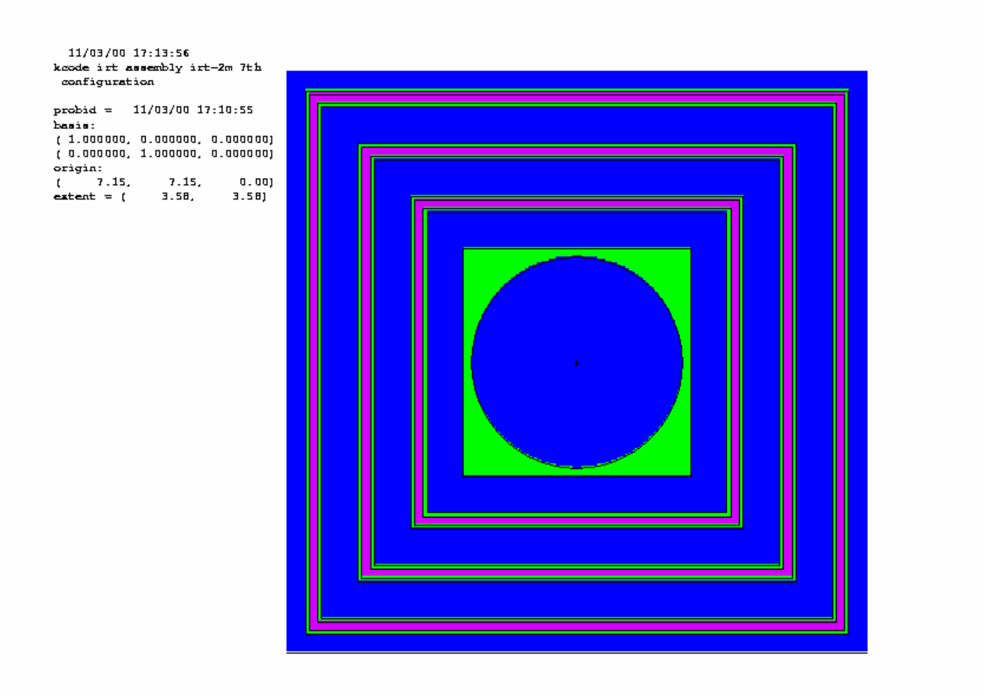

Fig. 2. Three-tube IRT-2M assembly MCNP model

The IRT-2M fuel assemblies modeling has been tested by experimental data presented in [5] for two critical core configuration with 15 fuel assemblies (FA) (Fig. 3} and 13 FA (Fig. 4).

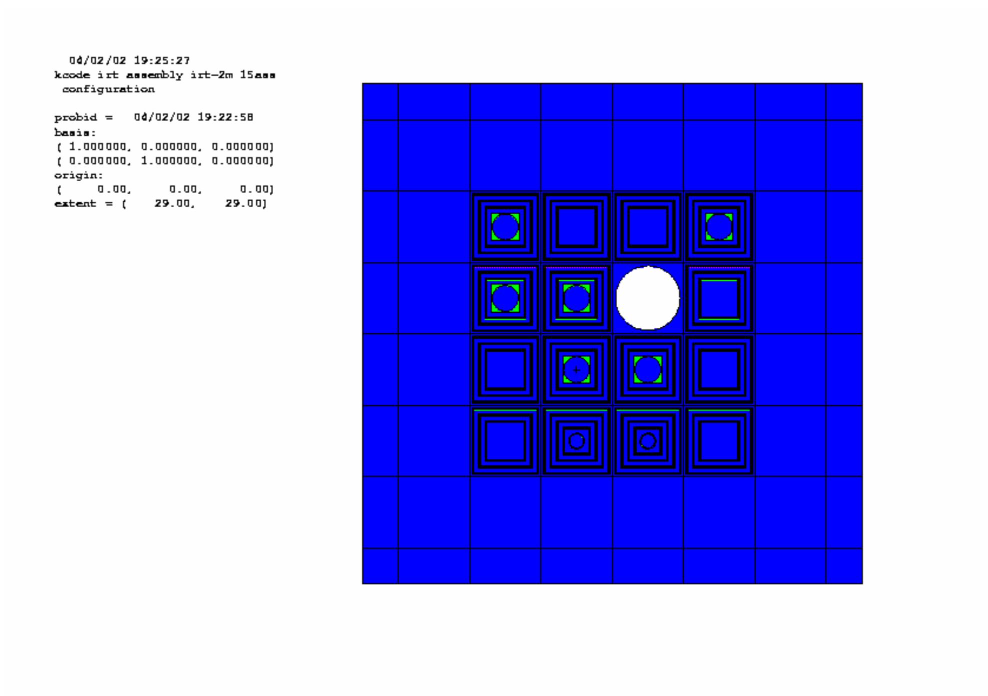

Fig. 3. 15 FA IRT-2M core configuration

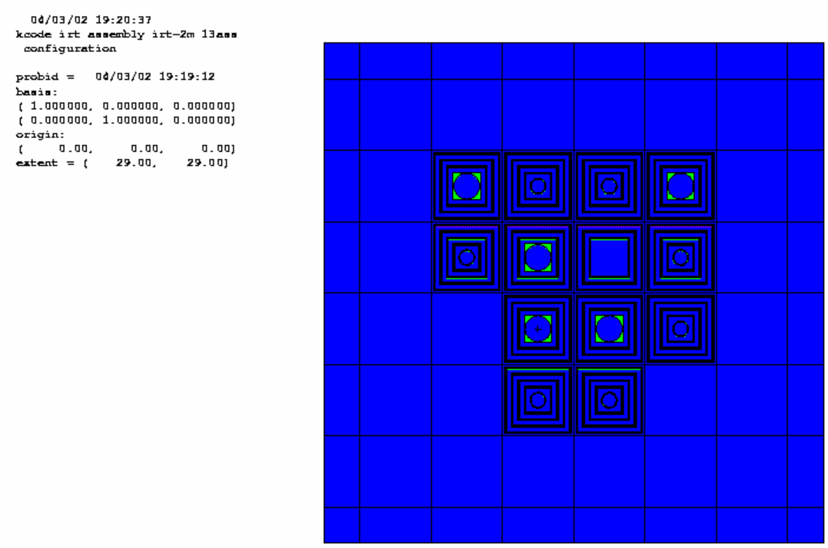

Fig. 4. 13 FA IRT-2M core configuration

The results of comparison between calculated and experimental values of effective multiplication constant k_{eff}, are presented in Table 1. According these results a very good consistency between calculated and experimental data has been obtained. That gives us a confidence in applicability of the fuel assemblies' models in further study of core configurations. Such investigation has been started and the model of one of analyzed configurations is presented on Fig. 5. There are ten FA (five four-tube and five three-tube) surrounded by beryllium blocks and two led shielding plates in this configuration.

Table 1. Comparison of calculated and experimental results for k_{eff}

Configuration	Exp	Cal
15 FA	1.0127	1.0148 ± 0.00021
13 FA	1.0010	1.0025 ± 0.00024

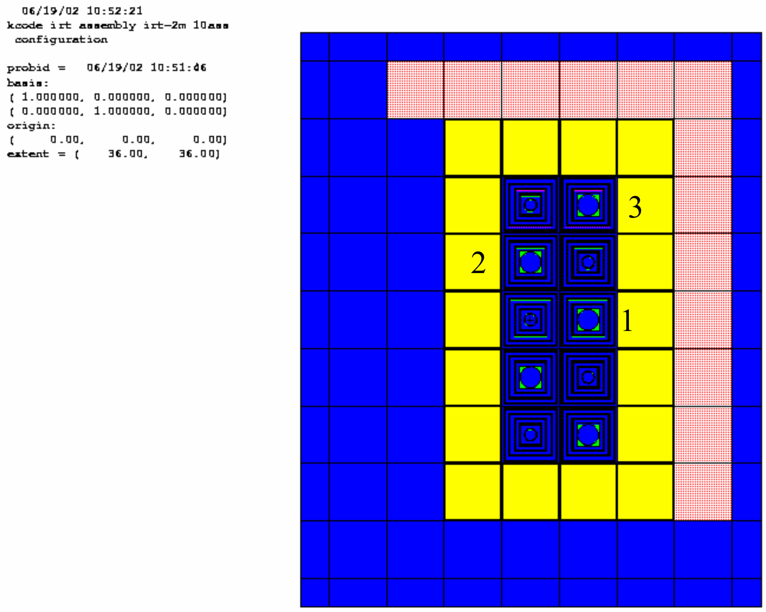

Fig. 5. 10 FA IRT-2M core configuration

The three-tube FA is used for inserting of control rod. The calculation has been carried out as for all control rods withdrawn out of core so for the cases when some of them are fully inserted. The results of k_{eff} calculation are presented in Table 2. These data could be applied for the rods reactivity worth calculation. The rod numbering is shown on the Fig. 5.

Table 2. Calculated values of k_{eff} for 10 FA configuration

Rods inserted	k_{eff}
0	1.09332 ± 0.00027
1	1.04615 ± 0.00028
1 and 2	1.00638 ± 0.00025
2	1.05497 ± 0.00027
1 and 3	1.02258 ± 0.00027

3. IRT-MR fuel assembly modelling and testing

The IRT-MR is 164-pin-type FA containing low enriched uranium LEU (19.7%). The horizontal cross section of the IRT-MR FA is presented on the Fig. 6.

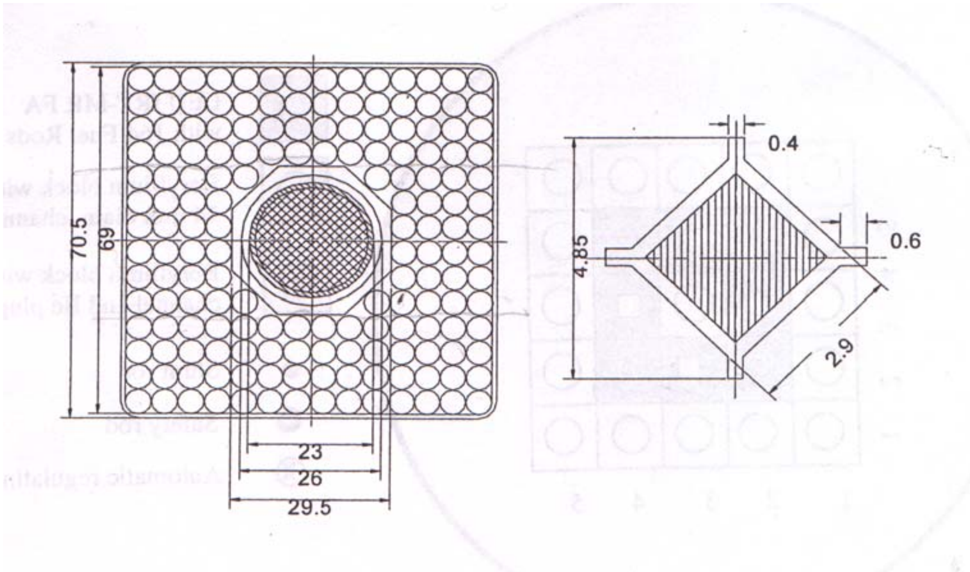

Fig. 6. Horizontal cross section of IRT-MR FA

The LEU fuel meat consists of a U-Mo alloy (9 wt% Mo) dispersed in aluminum. Every assembly pin contains 2.62g of U-235 [2]. The IRT-MR FA has been modeled by MCNP code on the base of data presented in [2]. The MCNP model for the assembly is presented on Fig. 7.

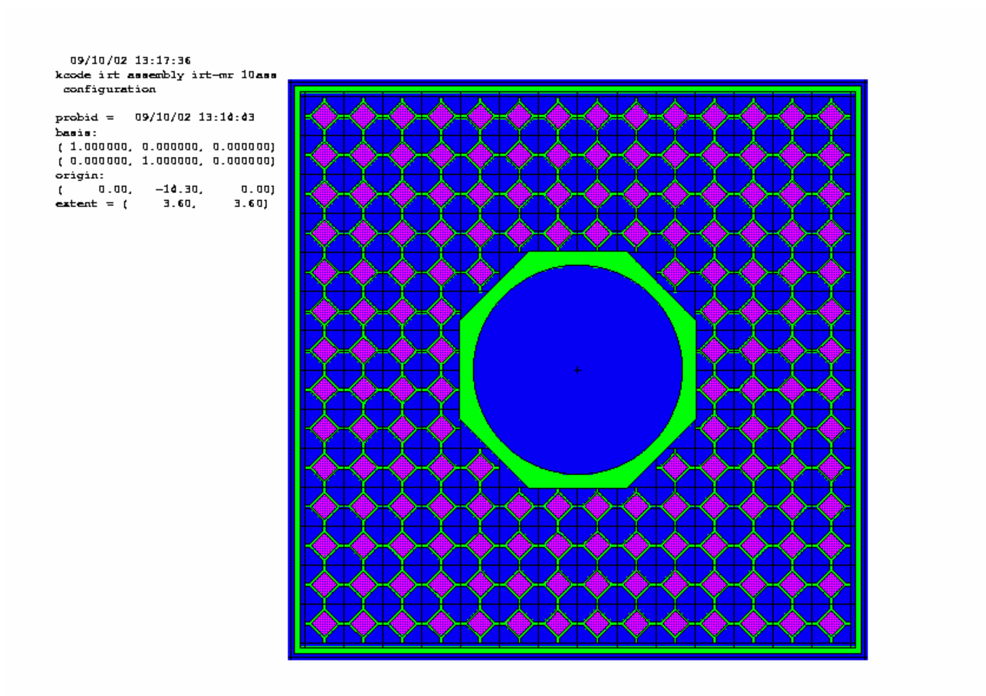

Fig. 7. IRT-MR FA MCNP model

There is no available experimental data for core configurations arranged with IRT-MR FA. That is why we have tested our modeling of IRT-MR by calculations which have been carried out independently at Argonne National Laboratory (ANL) [3]. The calculations in [3] have been carried by the MCNP code for configurations presented in Fig. 8 and 9. The configurations include 8 FA surrounded by beryllium blocks with channels for plugs which are partly withdrawn as it could be seen on the figures.

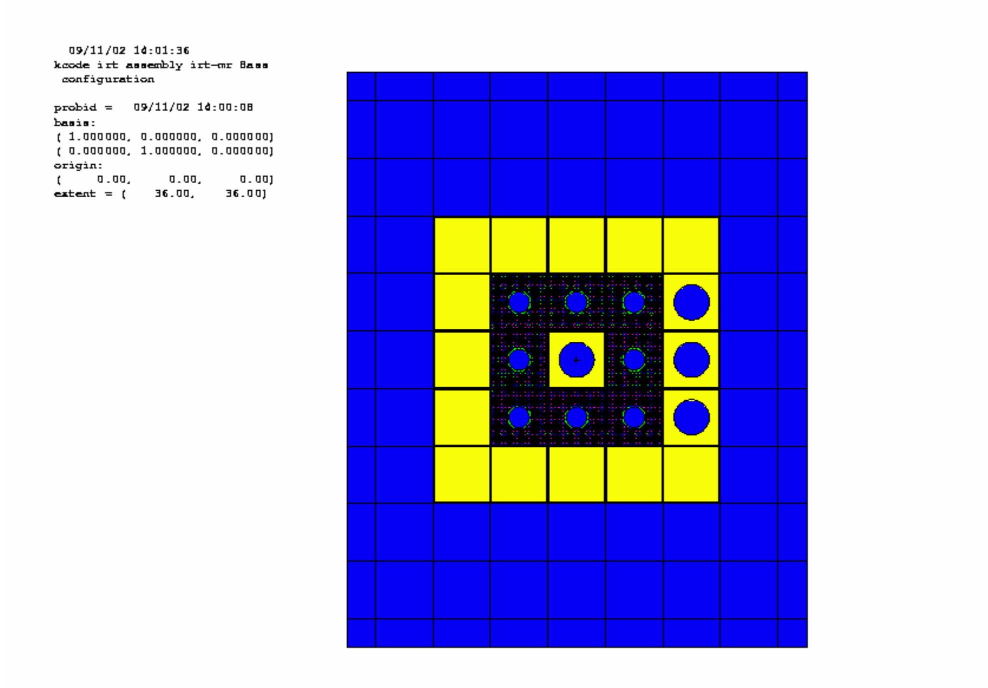

Fig. 8. 8 FA IRT-MR configuration with 4 plugs withdrawn

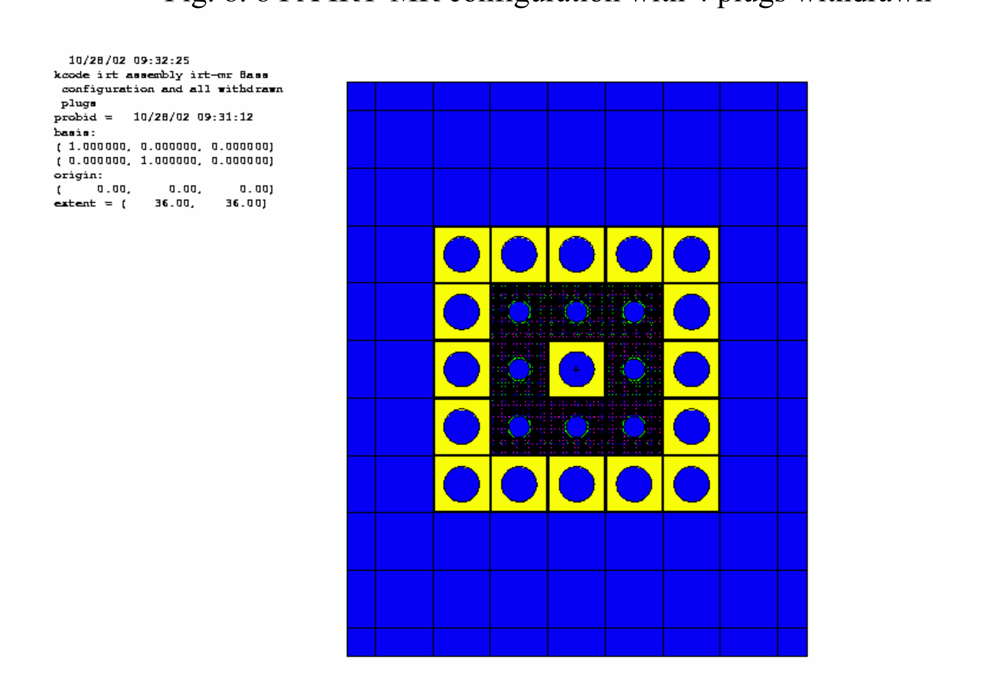

Fig. 9. 8 FA IRT-MR configuration with 17 plugs withdrawn

The results of comparison are presented in Table 3.

Table 3. Comparison of calculated by ANL and INRNE k_{eff} results for 8 FA configuration

Configuration	ANL	INRNE
Fig. 8	1.06960	1.08071
Fig. 9	1.00892	1.03272

It has to be noted that calculations in ANL have been carried out for two values of U-235 containment per fuel pin – 2.30g and 2.90g. For the purpose of comparison the results of this calculations have been avaraged. Additional analyses of all used modeling differences are needed to explain the observed discrepancies. Nevertheless these discrepancies are not too drastic. Especially in both cases the effect of beryllium plugs withdrawn is about 6%. That let us to use our IRT-MR FA modeling for further conversion analysis.

4. Preliminary IRT-2M to IRT-MR conversion analyses

For the purpose of assessing the effect of conversion the comparison calculations have been carried out. The calculations have been carried out for configurations presented on the Fig. 5, 8 and 9. In configuration presented on the Fig. 5 all IRT-2M FA have been replaced by IRT-MR ones. In configurations presented on the Fig. 8 and 9 the corner IRT-MR assemblies have been replaced by three-tube IRT-2M FA and the remainder ones – by four-tube IRT-2M FA. The results of calculations are presented in Table 4.

Table 4. IRT-MR versus IRT-2M values of k_{eff}

Configuration	IRT-MR	IRT-2M
Fig. 5	1.13599 ± 0.00023	1.09332 ± 0.00027
Fig. 8	1.08071 ± 0.00023	1.02529 ± 0.00024
Fig. 9	1.03272 ± 0.00025	0.99760 ± 0.00027

As it could be awaited replacement of IRT-2M FA by IRT-MR FA leads to increasing of k_{eff} values because of almost twice increasing of U-235 containment per assembly. However the value of the increasing does not overcome 5.5% for any calculated configuration.

5. Conclusions

The first steps of fisibility study of using of LEU for Research Reactor in Sofia. In accordance to the obtained results there are no unresolved contradictions in replacing of IRT-2M (HEU) by IRT-MR (LEU) fuel assemblies for the reactor. At least it is related to criticality values because the corresponding criticality increasing could be compensated by beryllium blocks arrangement.

Further investigations are needed for final conclusions about fuel assemblies replacing. Further neutronics, thermal –hydralics and transient analyses are planed to perform together with RERTR Program staff ofArgonne National Laboratory in a near future.

5. Acknowledgements

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6. References

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