CONVERSION PROGRAM OF THE WWR-K RESEARCH REACTOR CORE TO USE LOW ENRICHMENT URANIUM

F.M. Arinkin, A.V. Vatulin, Sh.Kh. Gizatulin, P.M. Egorenkov,
T.M. Zhantikin, Zh.R. Zhotabaev, Yu.A. Stetskiy, A.Zh Takibaev.,
S.V. Talanov, P.V. Chakrov

The thread of proliferation of nucleus materials, which can be used in military purpose, has concentrated world community attention on reconversion of research reactors, who are the main users high enriched fuel, on low enriched one. The studies in this area are executed within the framework of international program RERTR under the aegis of Argonne National Laboratory and the DOE, USA. The Russian part of program is coordinated A. A. Bochvar All Russian Research Institute of Inorganic Materials (VNIINM). During the action of this program the new designs of fuel have been made on base of Uranium dioxide (UO_2-Al) and silicide (U_3Si_2-Al), and compositions U-Mo-Al, which have higher Uranium content in comparison with UAl_x alloys. The majority fuel compositions have passed testing in research reactors with broad range of Uranium density in compositions and depths of depletion. That has allowed proceeding with practical decision of the task to reduce of the enrichment [1].

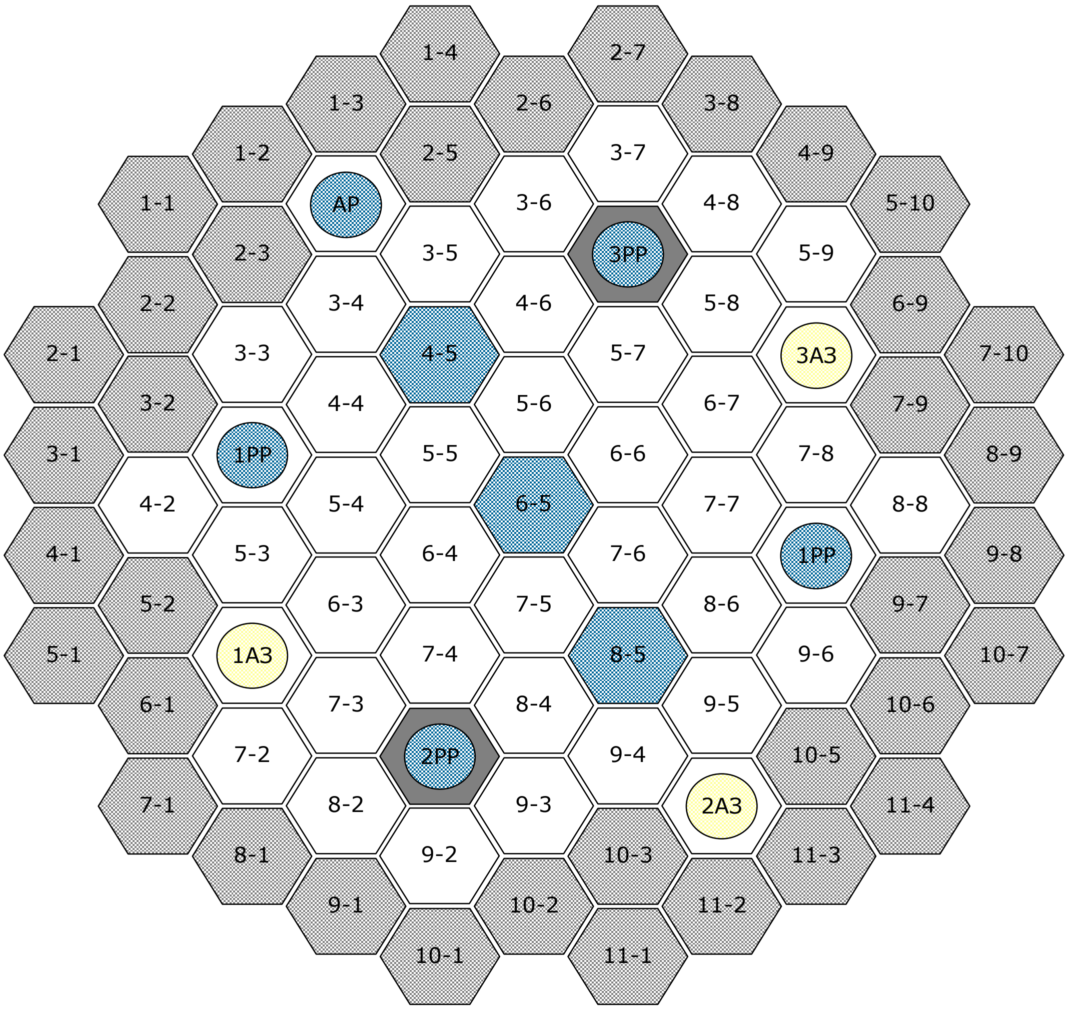
History reference

Water-water reactor WWR-K has been put into operation in 1967. In 1988 the reactor has been shut-down for implementing measures to increase seismic proof systems and technological equipment and to define more exactly the seismic situation on the site. In 1998 the reactor has been again put into operation [2].

The reactor core is placed in lower part of aluminium tank with 2300 mm diameter and under the water layer by 3500 mm thickness. Separator (the basket) of core has 740 mm external diameter, to which five horizontal channels are closely abutted on. The core grid has 85 holes by 50 mm diameter for mounting of fuel assemblies, channels for control rods and vertical irradiation channels. On reactor are used WWR-C type fuel assemblies by two forms: 3-tube (the contents ^{235}U 84 g) and 5-tube (the contents ^{235}U 111 g). Both fuel assemblies have 65.3 mm width across flats. 3-tube fuel assemblies are used for control rods and experimental channels mounting in it. Fuel elements have hexahedral and cylindrical form with 2.3 mm thickness. The fuel UAl_4 composition has enrichment 36% on Uranium-235.

The typical initial charge of the reactor after it's re-entering in operation is given on Fig.1. Herewith: excess reactivity is 5.09%, total efficiency of regulating and shim rods is 6.63% but emergency shut-off ones is 1.85%. During the period after re-starting the reactor is working by short campaigns without fuel overloading at 6 MWT power level.

Fig. I. The typical initial core charge of WWR-K reactor



In this paper are given the first results of the work to convert WWR-K reactor fuel into composition with 19.75% enrichment. The work will be carried out by the cooperation with Russian Scientific Centers "Kurchatov Institute" and VNIINM and under NTI (Nuclear Threat Initiative) financial support.

At this stage the program of the optimal WWR-K reactor core converting to low enriched fuel is formed. In general it included following:

1. The developing of core calculated models with different design of fuel rods and fuel assemblies for corresponding computer codes (diffusion, statistical and others).
2. Carrying out experiments at zero power reactor with WWR-C type fuel assemblies to correct the constants using in calculations.
3. Making neutron calculations of the core to choose the optimal content of U-235 in low enriched fuel rods and to determine the strategy of fuel assemblies overloading at afterburning regime of the core.
4. Determining the technical requirements to the fuel rod.
5. Determining the critical and working core loading by fuel rods both pin and tube types.
6. Calculation of control rods efficiency, optimizing of their composition, amount and place of the location inside the core; determining the characteristics of the neutron field in experimental channels.
7. Carrying out heat-hydraulic calculations and making safety analysis for WWR-K reactor with low enrich fuel.

Besides, it is supposed to carry out the marketing studies to determine the "place" of WWR-K reactor in service, provided by research reactors. The Scheme for carrying out the work of core conversion is given on Fig. 2.

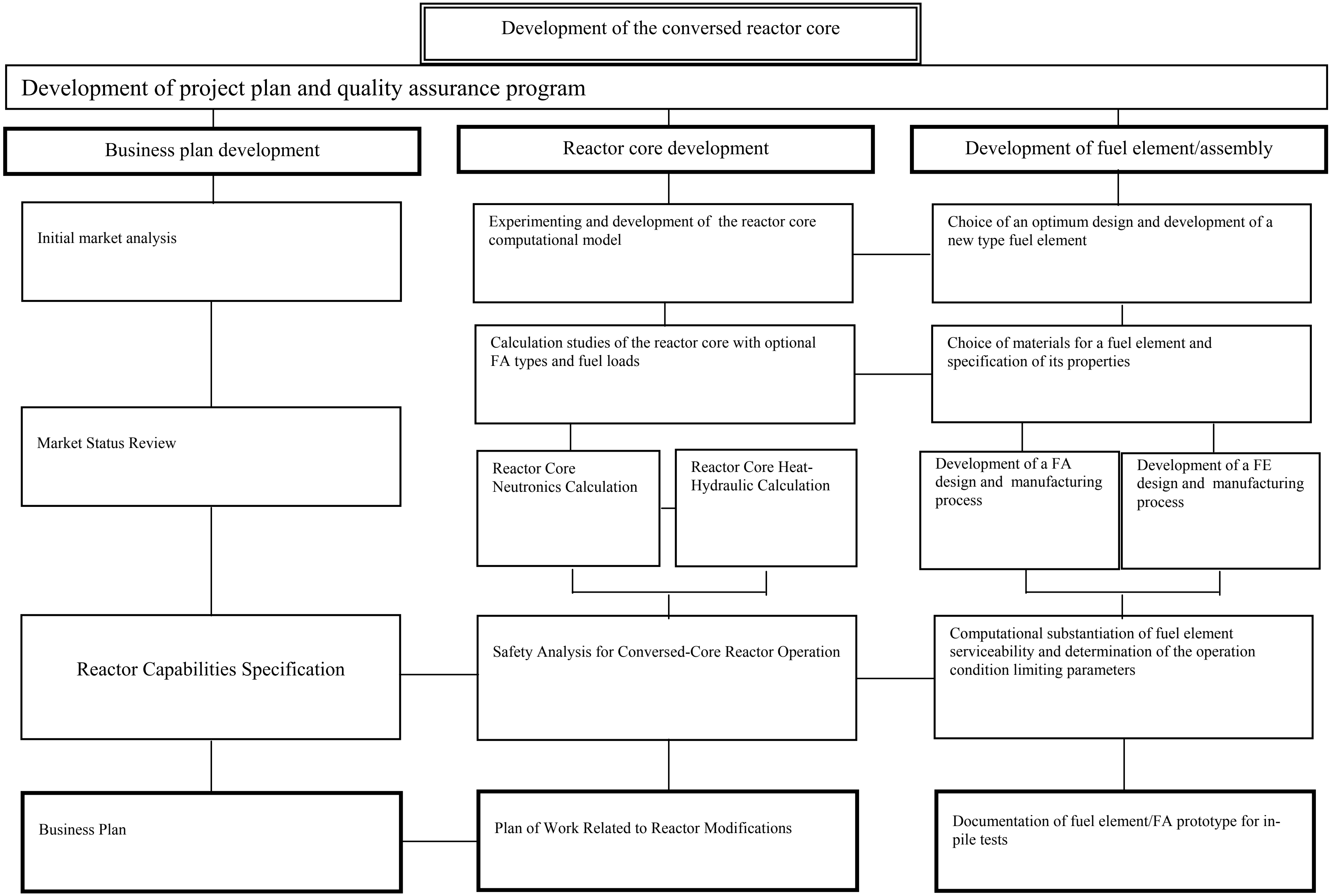
The Fuel composition UAl_4 has 1.0 $g \cdot cm^{-3}$ Uranium density and at reduction of the enrichment before 19.75% does not provide the required critical characteristics of the core. For conservation existing ones, it is necessary to increase density greatly that is impossible for Uranium-Aluminum alloy technologically. At present such fuel compositions with Uranium density up to 3.0 $g \cdot cm^{-3}$. are produced at Novosibirsk chemical concentrates plant. They are based on Uranium dioxide and began mass production of thin-walled fuel assemblies like IRT-3M, IVV-10, VVR-M5 types. Besides, in VNIINM is designed experimental-industrial technology to produce fuel rods of pin type [3]. It is allow increasing the amount a fuel in rod core up to 50 volume % in comparison with 36% for some tube type rods. Testing of experimental assembly with pin rods inside IRT-3M fuel assembly is planned on IR-8 reactor [4].

In connection with aforesaid, on the first stage of calculating studies draft design of fuel assembly with fuel rod on base of the compositions UO_2+Al with 3 $g \cdot cm^{-3}$ density. IRT-3M assembly's type fuel rod (as most technologically advanced) is chose as a basic one. The fuel rod thickness is 1.4 mm, herewith: Al-cladding thickness is 0.45 mm; fuel rod core thickness is 0.50 mm. The WWR-K reactor fuel assembly characteristics in comparison with existing ones are following:

– content of the isotope U-235 is above in 1.9 times (with enrichment 19.75%);

– surface of heat removal, defining heat parameters of fuel assembly is increased from 0.86 m^2 to 1.26 m^2.

Fig. II. Scheme of the undertaking the functioning



Critical calculations for the core with WWR-KM fuel assemblies have been done. Moreover, the amount of control rods for reactivity compensation is increased from 4 (existing) to 6 ones. All control and emergency shut-off rods have been made with small diameter and are intended for installing right inside fuel assembly. On one hand, it has allowed to do them universalize. On another, it is created more uniform control rod grid that has reduced the coefficient of nonuniformity of energy distribution inside the core.

The nominal excess reactivity of WWR-K reactor (the initial work charge) is 5.1% ΔK/K. It is reached when 16 fuel assemblies of I-type and 10 fuel assemblies of II-type (See Fig. III.). For existing core they are 36 fuel assemblies of I-type and 6 fuel assemblies of II-type correspondently. The efficiency of manual and automatic control rods is ~7.4% ΔK/K. The efficiency of emergency shut-off rods is ~1.8% ΔK/K. The core map in burn out regime for fuel assemblies is given on Fig. IV. In cell is showing the relative value of energy release in fuel assembly.

Specified changing will allow creating the more compact core, increasing the degree of the burning-out of fuel in the core and raising density of neutron flux in experimental channels.

References

1. A. Travelli, Status and progress of the RERTR Program in the year 2000. 2000 International meeting on reduced enrichment for research and test reactors, Oct 1 to 6, 2000, Las Vegas, NV, USA

2. Sb. "Renewal to usages of the reactor VVR-To", NYAC RK, A.O. "Institute to atomic energy", Almaty, 1998.

3. A. Vatulin, Y. Stetsky, I.Dobrikova "Unified Elements Development for Research Reactors", presented at the 1998 International Reduced Enrichment for Test Reactor Conference Sao Paulo, Brazil, October 18-23, 1998

4 . A. V. Vatulin, Yu. A. Stetskii, I. V. Dobrikova, E. P. Ryazantsev, P. M. Egorenkov, V. A. Nasonov "Preparation for in-pile tests of a LEU new type fuel element". 2000 International Meeting on Reduced Enrichment for Research and Test Reactors, Oct 1 to 6, 2000, Las Vegas, NV, USA

Fig. III. The initial work charge map

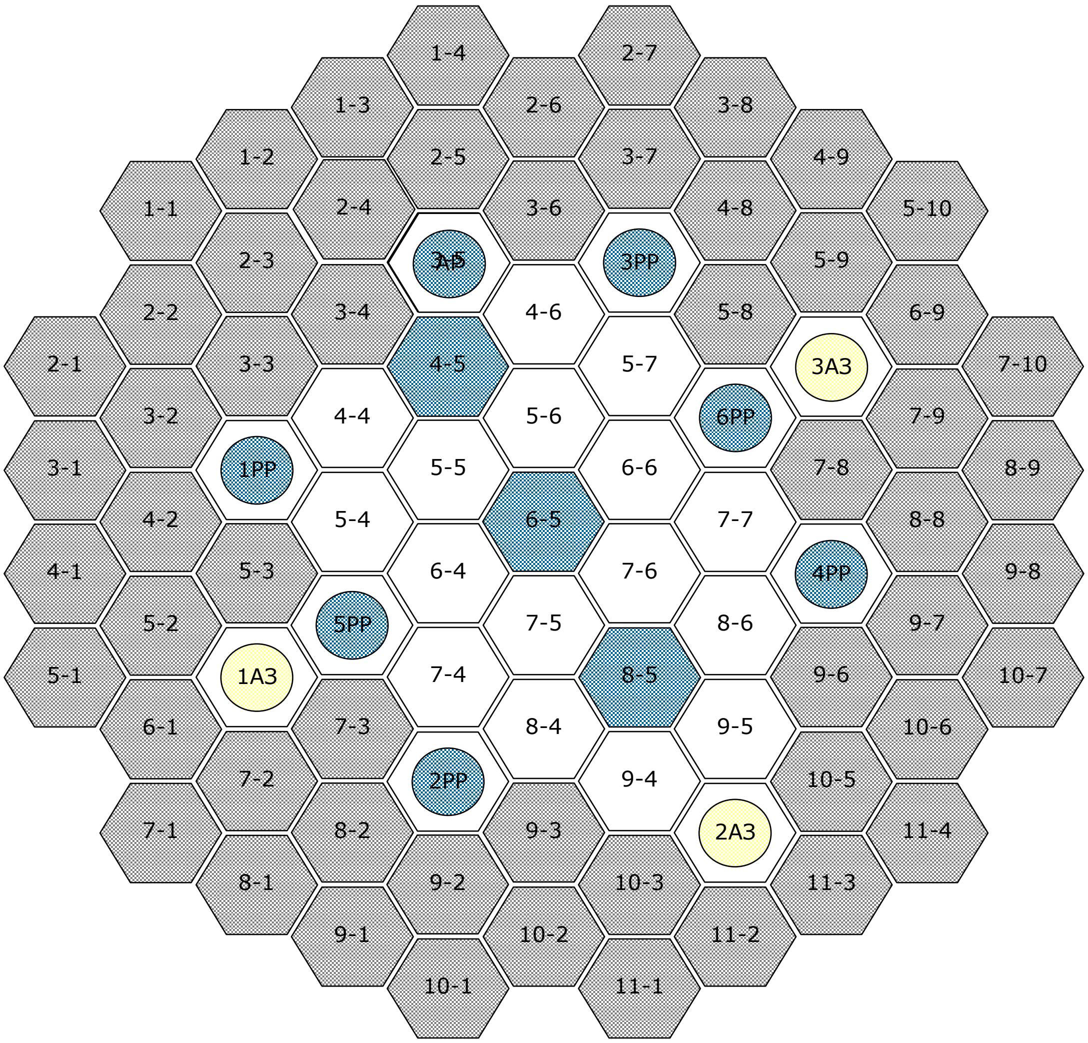


Fig. IV. The core map in burn out regime