OVERVIEW OF RUSSIAN P&T PROGRAMME

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Abstract

The status of Russian programmes of RW handling is outlined. R&D programmes of RW incineration are presented, particularly:

- RW transmutation in reactors;
- ADS test facility SAD (Dubna);
- Project of ADS facility at Moscow Meson Factory (Troitsk);
- Design study of the cascade subcritical molten salt reactor-burner;
- Programme of comparative study of the different types of ADS-burners;
- Programme of systematic study of the minor actinide nuclear characteristics: measurements and evaluation.

Introduction

The strategy of the nuclear power in Russian Federation is the closed nuclear fuel cycle (CNFC). The essential feature of this strategy is the principle of the radiation equivalence of the row uranium from mines and buried radioactive waste (RW) [1-4].

At present, the total amount of the nuclear spent fuel in storage of Russia is ~16 thousand tons. It grows annually for 850 tons and only part of them (~ 20%) is directed to RT-1 plant for the regeneration. The conception of "delayed decision" is accepted for the other spent fuel as well as the additional spent fuel from the new nuclear power plants under construction. It is accepted that 50 years is enough to develop the industry of RW handling and transmutation and to organize CNFC.

RW handling

The streamline of the RW handling activity today is preparation of the spent fuel storage which will be able to keep RW safely during next 50 years.

The PUREX-technology is used now for the spent fuel reprocessing but several new ones were suggested and studied:

- gas-fluoride technology, which reduces the amount of solid high level FP up to 1 m^3 for every 1 ton of the reprocessed spent fuel and allows to extract U from the spent fuel without Pu separation [5];

- pirochemical reprocessing which allows to simplify essentially the spent fuel reprocessing and to reduce the amount of low level FP [6].

Some others R&D in this line are presented in the Proceedings of the recent conference on the radioactive waste management (St. Petersburg, 2004) [7].

RW transmutation

Two main strategies of RW transmutation are studied today in Russia: transmutation in critical reactors and in ADS-burners.

Reactor transmutation

In the BREST conception (fast reactor with the lead coolant) developed at RDIPE [8] the RW – transmutation takes place in the active core of reactor. The fuel composition of this reactor consist of the spent fuel of thermal reactors cleaned from fission products (FP) up to level 1÷5% only and enriched by Pu and minor actinides (MA) up to level ~ 10% and $\lesssim$ 5% respectively. Such a fuel composition does not need in the subsequent Pu regeneration and allows to burn-up annually the MA-production of several thermal reactors of the same power as BREST reactor. Isotopes ^{99}Tc and ^{129}I are incinerated in the thermal blanket (~ 250 kg per year in reactor BREST-1200). The radioactive equivalence in such a schema can be achieved in 80 years if buried FP will be purified from MA to the level ~ 10^{-3}. ^{90}Sr and ^{137}Cs are buried separately: their radioactive equivalence is achieved in ~ 200 years [9-11].

Experimental study of MA burning in the fast neutron spectrum of reactor BOR-60 was carried out in the framework of DOVITA-programme during the last ten years at RIAR (Dimitrovgrad) [12-14]. On the basis of these researches the actinide burner fast reactor (ABFR) was suggested. The experimental study of MA transmutation has been performed also at BFS-stand (IPPE, Obninsk) [15].

In the transient multicomponent nuclear power the problem of RW-transmutation should be solved using special critical reactors or ADS-burners.

The transmutation capability of the Na-cooled fast reactor BN-800 was studied at IPPE (Obninsk) [16-17]. It was shown that one reactor BN-800 in principle can transmute MA from 5-6 thermal reactors of the same power.

The conception of RW-burning in the heavy water reactor is developed at ITEP (Moscow) [18-19]. The authors insist that the transmutation potential of thermal reactors is not yet studied properly.

ADS transmutation

Large scale nuclear power has a future on the fast reactor basis only. RW-transmutation problem in this case will be solved naturally as a byproduct of the nuclear power generation.

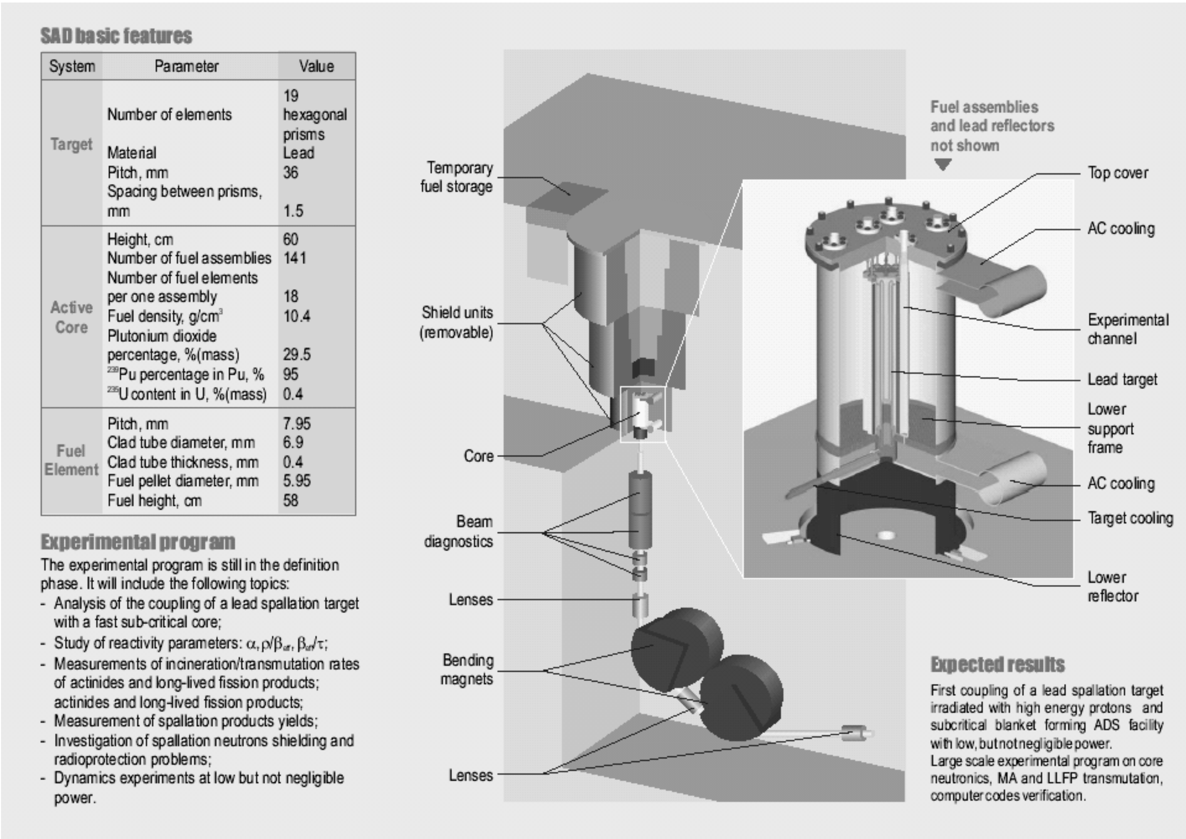
But in the transient phase of nuclear power development or in the case if society will decide to stop the nuclear industry, ADS is the most reliable reactor-burner due to the safety reasons: the small fraction of MA delayed neutrons and bad Doppler-effect in the absence of ^{238}U prevent the creation of the safety critical reactor-burner.

There are several works in this line in Russia outlined below:

Subcritical assembly at Dubna (SAD)

The design study of ADS-test facility SAD is completed and SAD construction has started at JINR (Dubna) this year [20]. SAD layout is presented on Figure 1. The experimental programme consist of the measurements of subcriticality, MA fission rates, spallation product yields and studies of reactivity feedbacks (α-value, ρ/β_{eff}, β_{eff}/τ, etc.), as well as benchmark experiments for testing numerical codes.

Figure 1. **Layout and basic parameters of SAD**

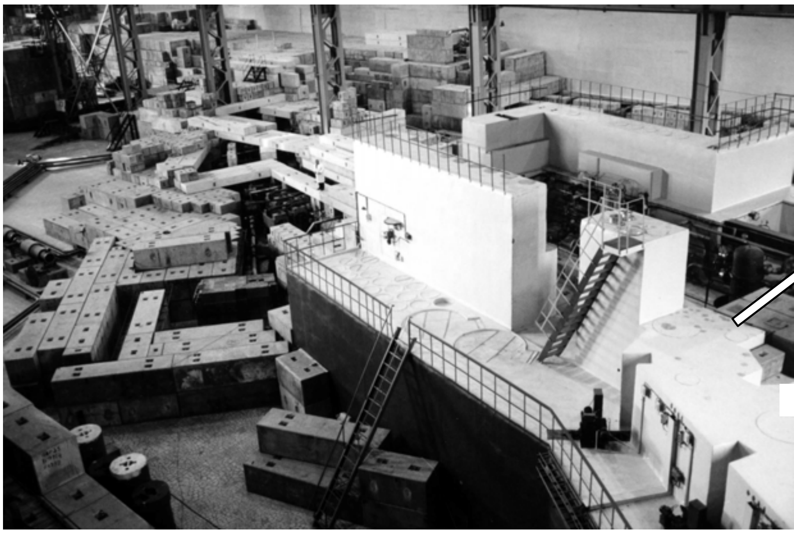


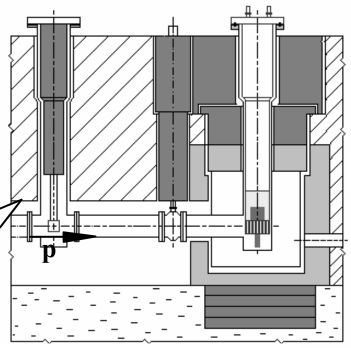
SAD will be the first real ADS which contain all the essential components: proton accelerator with beam power ~ 1 kW (energy 680 MeV, current ~3 μA), spallation lead target and fast spectrum subcritical core with power ~ 20 kW (U with ~ 30% Pu contamination).

ADS facility based on MMF-linac

Moscow Meson Factory (MMF, Troitsk) has all the infrastructure for using it as ADS test facility with blanket thermal power ~ 5 MW. Upgrade project is prepared now and it is waiting for financing and interest from ADS-community (see Figure 2 and Table 1) [21].

Figure 2. **Experimental area of MMF and schema of ADS-target**





ADS-target

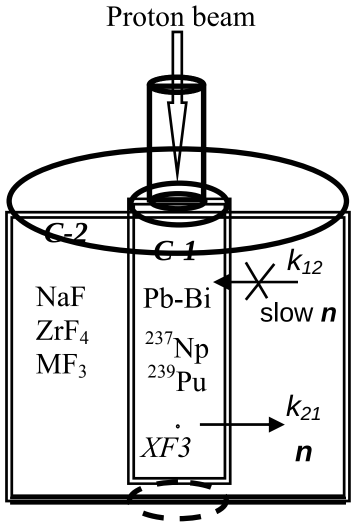
Table 1. **Basic characteristics of the planned ADS facility at INR**

Accelerator:	Proton energy	500 ÷ 600 MeV
	Average current	0.15÷0.3 mA
Target:	Material	Tungsten, other materials
	Thermal power	75÷150 kW
	Coolant	Water
Core:	Thermal power	3÷5 MW
	Coolant	Water and PbBi
	Fuel	Enriched Uranium, MA
	Neutron spectrum	Fast resonance

Cascade subcritical molten salt reactor (CSMSR

In the framework of ISTC project #1486, the design study of CSMSR-burner has been performed [22]. The essence of this reactor is cascade scheme of neutron flux amplification (Figures 3-4) which allows to reduce several times the power of accelerator-driver [23]. The parameters of CSMSR-burner have been estimated [24-26].

Figure 3. **Cascade schema of CSMSR: the back thermal neutron flux from Core-2 to Core-1 is suppressed (k_{12}≈0)**

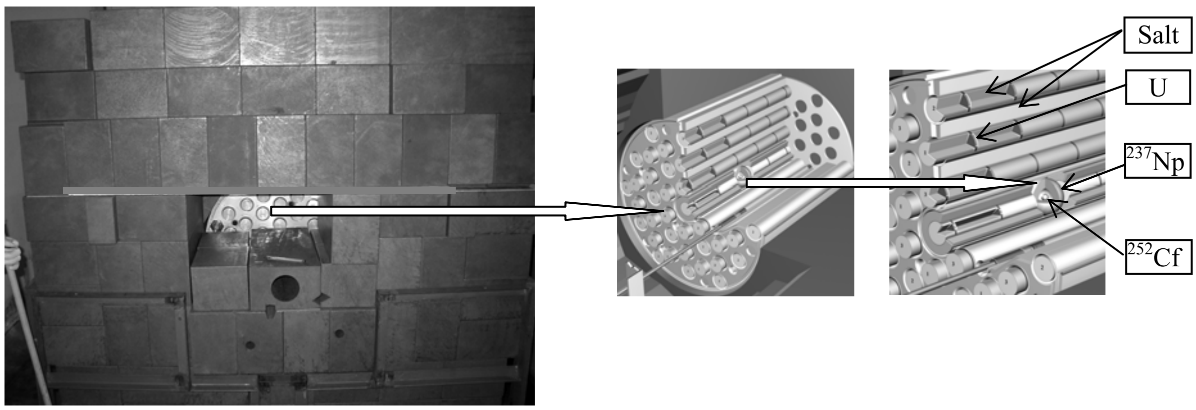


Subcriticality $\Delta k=1-k_{eff}$ of cascade two core assembly is

$$\Delta k = \frac{\Delta k_1 + \Delta k_2}{2} - \sqrt{(\frac{\Delta k_1 - \Delta k_2}{2})^2 + k_{12}k_{21}} \ ,$$

where Δk_1 and Δk_2 are subcriticalies of cores C-1 and C-2.

Figure 4. **Experimental setup for study of the neutron flux cascade amplification**



Comparative study of different types of ADS-burners

There are three main approaches to RW transmutation via ADS-burner:

- heavy metal ADS (fast neutron spectrum);
- molten salt ADS (intermediate spectrum);
- heavy water ADS (thermal spectrum).

Everyone of this ADS-burners has its own advantages and shortages but up to date there is no their systematic comparative study on the common basis of uniform criteria.

Last year Minatom RF has approved the programme of the comparative study of all these types of ADS-burners (burning efficiency, MA loading, MA/Pu ratio, reprocessing features, etc.).

Systematic study of MA nuclear characteristics

R&D of MA transmutation by any method need as a first step the reliable data of MA nuclear characteristics. At the moment the precision of these data is not sufficient [27-31]. The programme of systematic measurements and evaluation of nuclear characteristics of all MA isotopes in the energy range 0.05 eV÷30 MeV has been suggested recently [32]. It is planned to measure differential and integral characteristics of 22 isotopes of U, Pu, Np, Am, Cm, Bk and Cf (see Table 2) using the purified set of MA isotopes, qualified teams and unique installations: high flux reactors SM-3 and BOR-60 (RIAR, Dimitrovgrad), BFS stand (IPPE, Obninsk), linac LU-50 (VNIIEF, Sarov), tandem generator (IPPE, Obninsk), lead slow-down 100 t spectrometer (INR, Troitsk).

Cross-check of the integral and differential measurements as well as the data evaluation and preparation of files compatible with reactor codes will be done by the world known Russian team.

Table 2. **List of MA isotopes planned to be measured**

	Isotope	Measuring characteristics	Energy range	Experimental installation
1	^{237}Np	$\sigma_c(E)$, $\sigma_f(E)$, RIC	0.05÷12 MeV	*Linac*
		$\langle\sigma_f\rangle^{*)}$, $\langle\sigma_c\rangle$, $\langle\sigma_{in}\rangle$, $\Delta\langle\sigma_c\rangle/\Delta T$, *CRC* $^{**)}$	0.05÷5 MeV	*BFS*
2	^{238}U	$\Delta\langle\sigma_c\rangle/\Delta T$, $\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$	0.05÷100 keV	*BFS, SM-3*
3	^{238}Pu	$\sigma_c(E)$, $\sigma_f(E)$, RIA,	04÷12 MeV	*Linac,*
		$\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$	0.1÷5 MeV	*BFS*
4	^{239}Pu	$\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$, CRC	1÷5 MeV	*BFS*
5	^{240}Pu	$\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$, CRC	Fiss.thresh.÷5 MeV	*BFS, SM-3*
6	^{241}Pu	$\alpha(E)$, RIF, RIC, $\sigma_f(E)$	0.5÷2000 eV	*Linac*
		$\langle\sigma_f\rangle$	1÷5 MeV	*BFS*
7	^{242}Pu	$\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$	0.1÷100 keV	*SM-3*
8	^{244}Pu			
9	^{241}Am	RP, RIF, RIA, $\sigma_f(E)$	0.05÷12 MeV	*Linac*
		$\sigma_f(E)$	5÷30 MeV	*Tandem generator*
		$\langle\sigma_f\rangle$, $\Delta\langle\sigma_c\rangle/\Delta T$, $\langle\sigma_c\rangle$, CRC	Fiss.thresh.÷5 MeV	*BFS*
10	^{242m}Am	RP, RIF, RIA, $\sigma_f(E)$	0.5÷12 MeV	*Linac*
		$\sigma_f(E)$	1 eV÷30 MeV	*Tandem generator*
11	^{243}Am	$\sigma_\gamma(E)$, RIF, RIA, $\sigma_f(E)$	0.05÷5 MeV	*Linac*
		$\sigma_f(E)$	1 eV÷30 MeV	*Tandem generator*
		$\langle\sigma_f\rangle$	Fiss.thresh.÷5 MeV	*BFS*
12	^{242}Cm	$\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$	0.1÷100 keV	*SM-3*
13	^{243}Cm	$\sigma_f(E)$	5÷30 MeV	*Tandem generator*
		$\sigma_\gamma(E)$, RP, RIF, RIA	0.5÷100 eV	*Linac*
14	^{244}Cm	$\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$	Fiss.thresh.÷5 MeV	*SM-3, BFS*
		$\sigma_f(E)$	5÷30 MeV	*Tandem generator*
		$\sigma_f(E)$, $\sigma_\gamma(E)$, $\alpha(E)$ RIF, RIC	0.5÷200 eV	*Linac*

	Isotope	Measuring characteristics	Energy range	Experimental installation
15	^{245}Cm	$\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$	0.1÷5 MeV	*SM-3, BFS*
		$\sigma_f(E)$	5÷30 MeV	*Tandem generator*
		RP, $\sigma_a(E)$, $\alpha(E)$, $\sigma_f(E)$ RIF, RIA	0.5÷2 keV	*Linac*
16	^{246}Cm	$\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$	0.1÷100 keV	*SM-3*
		$\sigma_f(E)$	5÷30 MeV	*Tandem generator*
		RP, $\sigma_c(E)$, RIC	0.5÷50 eV	*Linac*
17	^{247}Cm	$\sigma_f(E)$	5÷30 MeV	*Tandem generator*
		$\sigma_a(E)$, RIF, RIA, $\sigma_f(E)$	0.5÷2 keV	*Linac*
18	^{248}Cm	$\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$	0.1÷100 keV	*SM-3*
		$\sigma_f(E)$	5÷30 MeV	*Tandem generator*
19	^{249}Bk	$\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$	0.1÷100 keV	*SM-3*
20	^{250}Cf			
21	^{251}Cf	$\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$	0.1÷100 keV	*SM-3*
		RP, RIF, RIA	0.5÷5 keV	*Linac*
22	^{252}Cf	$\langle\sigma_f\rangle$, $\langle\sigma_c\rangle$	0.1÷100 keV	*SM-3*

***)** - $\langle\sigma\rangle$ is the spectrum averaged cross-section.

****)** - *CRC* is the central reactivity coefficient.

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