Prospects of WWR-SM Reactor LEU Conversion and Spent Fuel Shipment Activity Status.

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ABSTRACT

The WWR-SM research reactor in Uzbekistan has operated at 10 MW since 1979,. using Russian-supplied IRT-3M fuel assemblies containing 36% enriched uranium. Burnup tests of four full-sized IRT-4M FA with 19.5% enrichment were successfully completed to a burn up of about ~60% in 2000-2002. IRT-3M tube type and IRT-MR pin-type FA with U9Mo-Al LEU fuel could be tested at WWR-SM reactor as soon as prototypes will be manufactured. These two type FA assemblies with density of 4.7gU/cc and 5.1g/cc correspondingly are suitable for the reactor core conversion to use LEU fuel with core size of 20 FA. The spent fuel shipment status and unused fresh fuel shipment to Russia are informed.

INTRODUCTION

The WWR-S research reactor at the Institute of Nuclear Physics of the Uzbek Academy of Sciences is located in Ulugbek, 30 km north-east of Tashkent. The reactor was put into operation at a power level of 2 MW and reconstructed in 1971-1979 to upgrade the reactor power and enhance its experiment capacity [1]. The reactor power was upgraded using IRT-3M type, 90% enriched fuel assemblies (FA) [2]. INP started activity on WWR-SM research reactor core conversion to lower enriched fuel in 1987. Irradiation test of IRT-3M type 36% enriched fuel assemblies (FA) was completed in 1989 [3]. First IRT-3M type 36% enriched (FA) was loaded into the WWR-SM reactor core in 1998 and reactor core was fully converted to use 36% FA in early 1999. Presently the reactor operates at 10 MW power with 36% enriched IRT-3M FA. The reactor core consists of 18 FA and beryllium reflector. (Fig.l). Reactor is used for research in nuclear physics, material sciences, solid state physics, nuclear engineering, neutron activation analysis and isotope production.

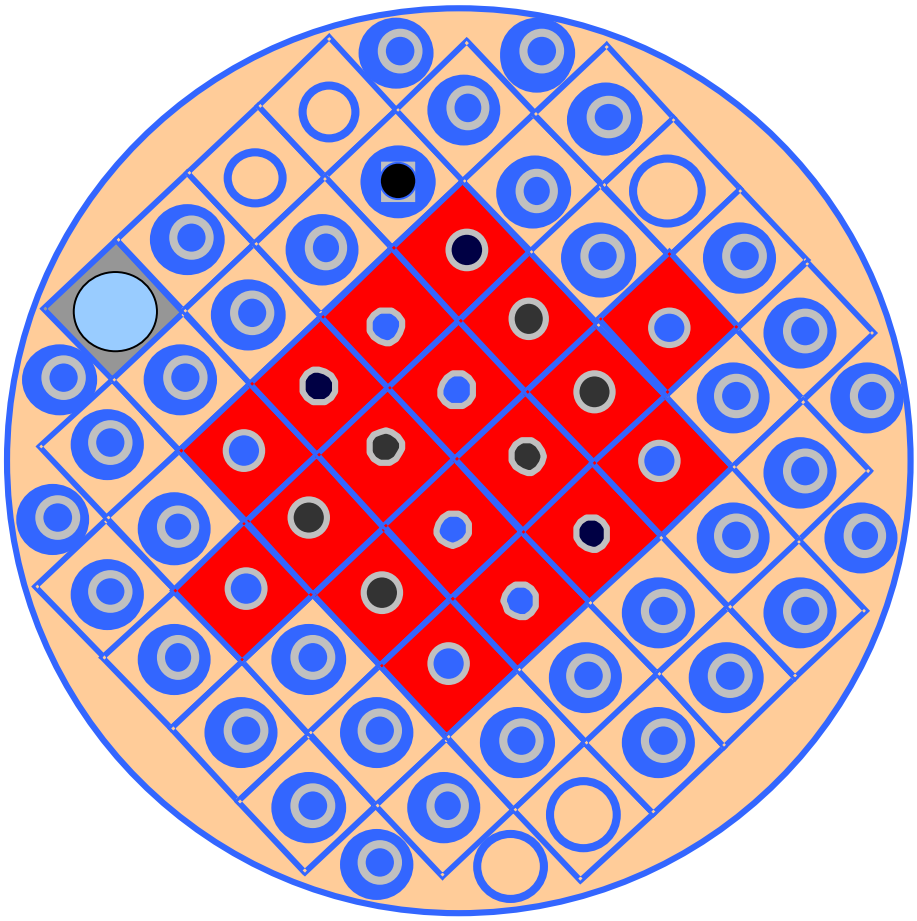

Fig. 1. Core diagram

BURNUP TEST.

Since its reconstruction reactor is operated intensively 5000 — 6000 hours/year (Fig.2). This allowed to perform burnup test of experimental fuel for acceptable time. Burnup of IRT-3M 36% and IRT-4M 19.75% enriched fuels were performed. Burnup test of 36% enriched IRT-3M . FA was started in 1987. Three 36% enriched IRT-3M FA were tested up to more than 60% bum up. Two of the FA had 6-tubes and one had 8-tubes. The fuel assemblies remained in core for a total of 10,300 hours. It was concluded that the FA under test are reliable and operable up to more than 50% burnup. The reactor conversion to 36% enriched fuel was started in September 1998. After five transition cycles, by February 1999 whole core consisted of 36% enriched fuel.

Lower enriched IRT-4M type FA lifetime testing was begun in October 2000. Four IRT-4M type FA assemblies were loaded into the reactor core. Fuel meat was of UO_2-Al composition with density of uranium 3.0g/cc. Lifetime testing was completed in February 2002 with burnup

about 60% [4].

Burnup tests of the pin-type and tube type LEU FA with U9MO-Al meat is planned after completion of their irradiation and post-irradiation tests at MIR-M1 reactor in Dmitrovgrad as soon as test FA for WWR-SM will be manufactured.

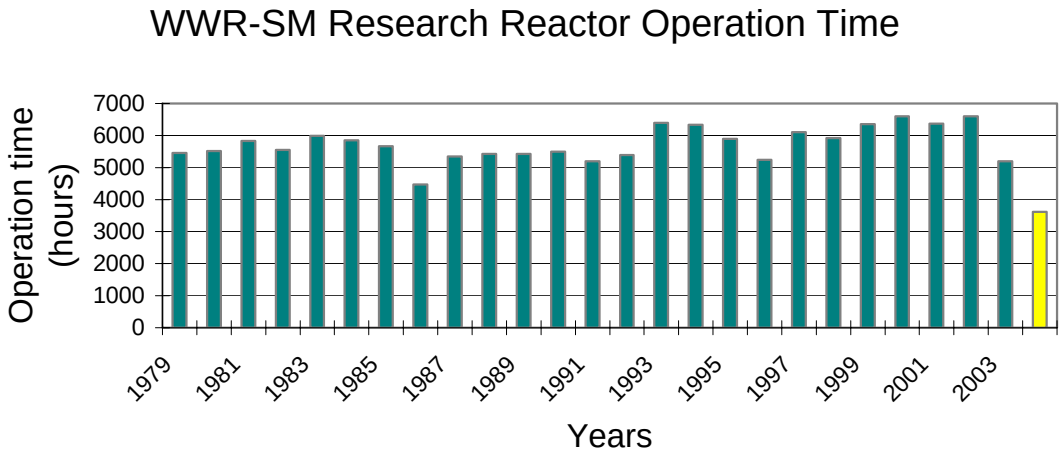

Fig. 2. Reactor operation time.

In view of expected burnup test of the IRT-3M tube-type and IRT-MR pin-type fuel assemblies, the works on safety enhancing of the reactor have been done or is in progress.

- Control rods were replaced during year 2003. Safety margin now is about 5.9% Δk/k.
- Project on radiation control system replacing, sponsored by IAEA is in progress.
- Emergency power system is improved. Diesel-generator of 40 kWt power and UPS of 8 kVA are connected up to the reactor power supply system.

Present reactor operation conditions with 36% enriched IRT-3M FA is shown in the Table 1.

Table 1. WWR-SM reactor operation conditions.

Reactor thermal power	10 MW
Coolant flow rate	1250 m^3/h
Coolant input temperature	45 °C
Coolant output temperature	52 °C
Pressure drop	0.4 MPa.
Burnup	~60%
Control rods worth	12.5%

CORE CONVERSION.

Successful conversion of the WWR-SM reactor to use 36% enriched fuel encouraged the works on further conversion to LEU fuel. Number of feasibility studies for LEU conversion of the WWR-SM reactor were performed since 1998. Equilibrium fuel cycle performances of the reactor using HEU (90%) and HEU (36%) IRT-3M fuel compared with one of IRT-4M were studied [5]. The results showed that to match the cycle length of the HEU (36%) core the LEU (19.7%) fuel density of 3.8g/cc is required.

Neutronic performances of LEU fuel meat of U9Mo-Al in tube type IRT-3M FA and pin-type FA assemblies compared with HEU 36% enriched U20-Al fuel meat for the reference 4x4 core were studied in [6]. More detailed feasibility studies of the WWR-SM reactor conversion were performed for several core sizes and several fuel assembly types with different loadings in [7]. Results of those studies showed that the core size of 20 FA is the most preferable. The results of those studies for the core size of 20 FA with different FA design are shown in Table 2.

Table 2. Fuel assemblies parameters, fuel cycle performance, experiment performance for 20 FA core.

FA type	6 tube IRT-3M	Pin-type IRT-MR	6 tube IRT-4M
Meat	U9Mo-A1	U9Mo-A1(1.75x1.75)	UO_2A1
Enrichment	19.7%	19.7%	19.7%
U, glee	4.7	5.1	3.0
U-235/FA, g	317	340	265
Max. power at, MW	12.2 (ONBR=1.4)	11.7(ONBR=1.61)	12.1(ONBR=1.4)
Cycle length	25.1	25.1	10
FA/year	16.6	16.6	28.9
Experiment performance	0.93	0.95	0.99

IRT-4M tube type FA with U_20-Al fuel meat is only LEU fuel which took burnup test. However, following LEU status definition [8], it is not suitable and acceptable. IRT-4M is not suitable taking into account RERTR criteria for conversion: LEU core should use the same. number or fewer FA/year than HEU [8]. This FA is not acceptable for WR-SM reactor for the significantly shorter cycle length as compared with present HEU IRT-3M 36% FA. Cycle length of 10 days would not enable to produce some isotopes like P^{32} and P^{33}, which are of most important isotopes presently produced at WWR-SM reactor. In addition, increased number of FA used per year entails rise in operation cost, spent fuel storage problem and shipment expenses. While spent fuel shipment became serious economical and organizational problem for INP, number of fuel assemblies used per year is important in respect to spent fuel shipment.

The results of analytical studies and development of pin-type FA with U9MO-Al [9,10] and thermal-hydraulic studies of IRT-3M tube type FA with U9MO-Al [11] show that for the preferable core size of 20 FA "candidate" FA for WWR-SM reactor conversion are: IRT-3M FA and IRT-MR FA with U9MO-Al (1.75x 1.75mm).

SPENT FUEL SHIPMENT STATUS.

Spent fuel shipment activity at the INP was started in 2001. Several visits of DOE representatives to INP resulted in developing preliminary plan, which was modified many times

and finally took acceptable shape. It was decided to ship spent fuel by train for INP had experience on spent fuel shipment by train, railway station is about 5 km from INP. Shipment by train allows to reach Kazakhstan boarder by-passing Tashkent city. The plan and procedures were developed in accordance with this decision. Developing plan it had to be taken into consideration the facts that shipment will be done at quite new conditions, that Uzbekistan has only one research reactor and has no developed infrastructure in nuclear industry, new legislations (in Uzbekistan, Russia, Kazakhstan). Finally, plan was developed which consist of several tasks.

- Preparing All the Necessary Documentation and Licensing (identification, preparation and approving plans and procedures, obtaining national licenses and necessary permissions for spent fuel shipment).
- Facility Upgrades and Preparation
- Spent Fuel Shipment.

The separate plans were developed to receive necessary approvals and certificates in Russia and Kazakhstan as the transit country. To get approval of the Russian authorities, Russian partner must develop project, which substantiate ecological safety of the spent fuel importation and take positive decision of the Ecological Committee of the Russian Federation. This is subject of the contract between "MAYAK" and INP, which is in progress. Positive decision of the Ecological Committee will allow to sign contract between INP and "MAYAK". on spent fuel transportation from the WWR-SM research reactor to "MAYAK" site. Transit approvals through the Kazakhstan territory must be taken under the subcontract between "MAYAK" and KATEP-AE – Kazakhstan organization.

Presently many of the planned tasks are completed, and work on others coming to the end very soon. The order of the government on spent fuel shipment to Russia have been issued. So works on obtaining permissions and approvals from other government and regulatory organizations under way.

The task on shipment itself will be started after completion of all other aforementioned tasks: It will consist of 4 stages or 4 shipments.

The contract between INP and "MAYAK" on spent fuel shipment have been agreed and will be signed as soon as positive decision of the Ecological Committee of the Russian Federation will be taken.

The task on getting transit approvals through the territory of Kazakhstan is near to completion.

The tasks, which are not completed and are in progress now are expected to be completed by the end of January 2005. In this case spent fuel shipment can be completed within about three months.

The spent fuels to be shipped have been listed. It consists of spent FA discharged from the reactor core not later than the year 2001. There are different FA the reactor have been operated with: IRT-2M, 4 tube 90% enriched, IRT-3M, 6 and 8 tube 90% enriched, IRT-3M 6 tube 36% enriched and a small amount of unused fresh fuel. Total amount of the spent fuel and unused fresh fuel assemblies is 264 units. At first, it was planned to ship unused fresh fuel along with spent fuel. Long lasting procedures to get necessary approvals and certificates for shipment of spent fuel and different procedures and requirements for spent and fresh fuel transportation led to the decision to ship unused fresh fuel separately from spent fuel.

UNUSED FRESH FUEL SHIPMENT.

Unused fresh fuel consists of fuel elements and assemblies used for the reactor operation at 2 MW power before its reconstruction in 1971. These are rod type fuel elements and assemblies. Drawing of fuel assembly of C — 36 type shown in Fig. 3

EK — 10 and C — 90 type FA have the same design and sizes as C — 36.

Close cooperation between DOE USA, IAEA, INP AS of Uzbekistan and Russian Research and Development Company "SOSNI" resulted in signing trilateral contract: IAEA — INP — "SOSNI" in August 2004. According to this contract there was very short time to get all necessary permissions for shipment of unused fuel. The work on this project went on in several parallel courses:

Developing draft order of the government on permission to ship unused fuel to the Russian Federation and obligation of respective ministries and regulatory bodies to assist.

Legislative and technical justification.

Developing transportation route and plan and their approval by appropriate body.

Drawing up the detail plan for fuel assembly reloading, transportation and safe and secure transportation.

Develop detail plan of personnel training and its implementation.

Accept mission from "SOSNI" to estimate physical condition of the fuel assemblies and elements and checking weight of elements. Develop layout of fuel assemblies and elements in transportation cask and their packing in accordance with requirements.

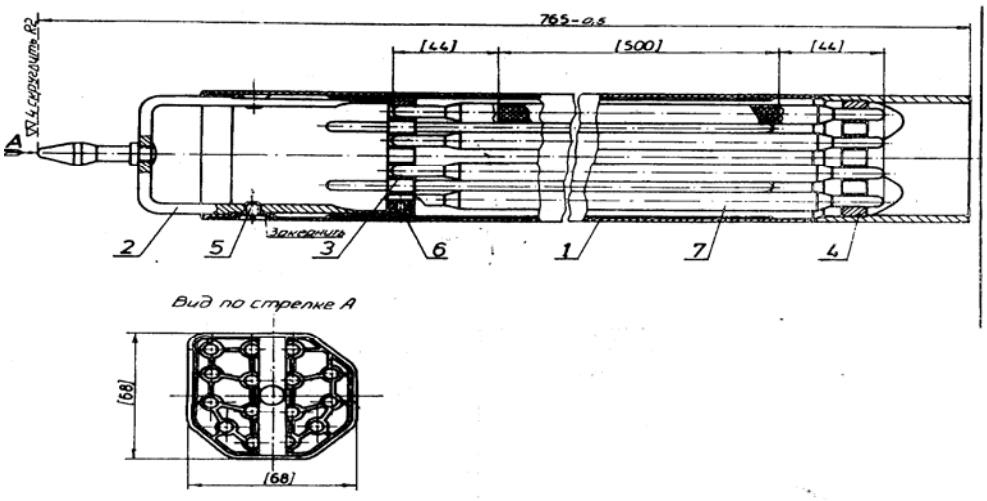

Fig. 3. C – 36 rod type FA.

Appropriate measures to provide security of transportation were taken.

Transportation of two transport casks of TKC-16 type to the reactor site, their loading with fresh fuel, sealing and trucks convoying to the airport were done within one day September 9, 2004.

Shipment of spent fuel should be done using special train and transportation cask of TUK-19 type. The TUK-19 cask capacity is 4 spent fuel per cask and shipment of unused fresh fuel in this cask would occupy six positions. Now with the shipment of unused fresh fuel there ' will be another 6 positions for spent fuel assemblies.

Number of each type of shipped fresh fuel is shown in the Table 3.

Table 3. Unused fuel shipped to Russia.

Type of fuel	Enrichment, %	Number of FA or FE	Number of fuel elements in FA
Fuel assemblies			
S -36	90	1	16
S -36	36	4	16
EK-10	10	6	16
Total		11	
Fuel elements			
S - 3 6	90	3	-
S - 3 6	36	4	-
EK-10	10	5	-
Total		12	

CONCLUSIONS.

The WWR-SM reactor operation time and conditions suitable for burnup test of IRT-3M 19.75 U9Mo-Al tube type and IRT-MR 19.75% U9Mo-AI pin-type fuel assemblies.

The fuel assemblies IRT-3M (19.5%) tube type and IRT-MR (19.5%) pin-type with U9Mo-Al and fuel loadings of 317g and 340 correspondingly could be used for WWR-SM reactor conversion to LEU after successful irradiation test.

IRT-4M LEU FA is not suitable and acceptable for WWR-SM reactor conversion to LEU because of significantly short cycle length and number of FA used per year as compared with currently used HEU 36% IRT-3M FA.

Based on fuel cycle and experiment performances and thermal-hydraulics performances core size for WWR-SM conversion is 20 FA core.

Spent fuel shipment project is in progress and can be completed in April, 2005:

S-36, S-90 and EK-l0 rod-type unused fresh FA and FE shipment to Russia successfully completed in September 9, 2004.

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