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Safe and Effective Utilization of WWR-SM Research Reactor after Conversion

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ABSTRACT

WWR-SM research reactor fully converted to LEU in December 2009. After conversion reactor was upgraded and modified few times. Some of it equipment and constructional parts were replaced to strengthen safety of its operation. Many scientific and research works are carried out using WWR-SM research reactor by laboratories of INP and institutions of Uzbekistan well as local and foreign businesses. INP jointly with foreign laboratories performed scientific works related to reactor fuel, nuclear materials.

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1. WWR-SM NUCLEAR REACTOR

WWR-S research reactor with power of 2 MW, built in the Institute of Nuclear Physics of Academy of Sciences of the Republic of Uzbekistan, achieved first criticality in September 1959.

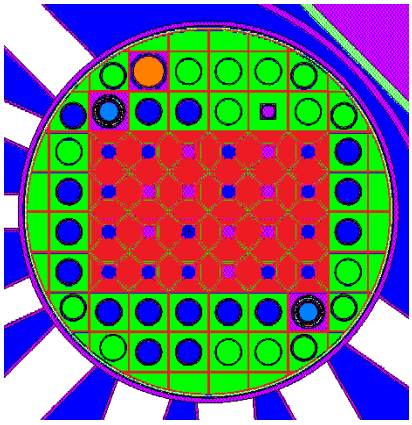
Reconstruction of the WWR-S, conducted in late 1971, with the replacement of the core vessel and reflector provided the opportunity to increase its capacity from 2 to 10 MW and the reactor was given symbolic name WWR-SM.

Conversion of WWR-SM reactor from 90% enriched fuel to the use of IRT-3M type FA 36% enriched on U-235was launched in August 1998, and completed in February 1999.

In 2009, the reactor was completely converted from 36% enriched fuel to the use of LEU IRT-4M type 19,75% enriched nuclear fuel.

The most characteristic abilities to load the reactor core are shown in Fig. 1. This is loading of 24 six-tube IRT-4M type FA.

Horizontal cross-section of the reactor core



The vertical cross-section of the reactor core

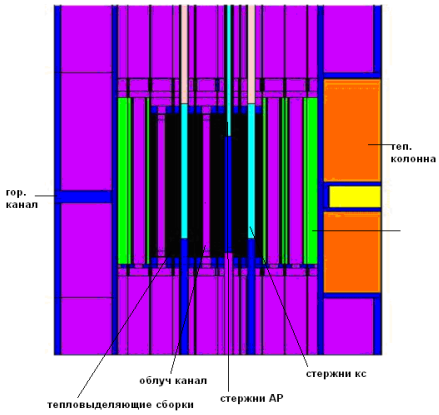


Figure 1. Horizontal and vertical cross-sections of the WWR-SM reactor core.

The maximum thermal neutron flux in the reactor core with 24 IRT-4M type fuel assemblies - 1.2×10^{14} N/cm^2*s, and the maximum fast neutron flux - 5×10^{13} N/cm^2*s.

After conversion to LEU fuel reactor had losses of about 20% in thermal neutrons flux. Maximum reachable fuel burnup decreased from 70% to 55%. Less excess reactivity is collected for the next cycle.

For these reasons, it was decided to increase the number of fuel assemblies in the active core from 20 to 24.

2. SECURING WWR-SM NUCLEAR REACTOR

IAEA, US Department of Energy, the European Commission and other international organizations, pay more attention to improving the safety of operation of the reactor, to improve its operational capabilities.

In 2004, the IAEA started a project UZB4/005 “Improving the safety of operation of the reactor WWR-SM INP”.

In 2006 - UZB9004 - Improving Operational Safety of the Research Reactor at the Institute of Nuclear Physics- Reconstruction of reactor radiation safety (put into operation a new system of stationary radiation monitoring “Pelican”) and personnel was trained in the use of the system.

In 2007 - UZB9005 - Improving Operational Safety of the Research Reactor at the Institute of Nuclear Physics (Phase II) - beginning of the project on production, supply and commissioning of complex of instrumentation and automation control systems of WWR-SM research reactor.

In 2010 - UZB1001 - Strengthening Nuclear Safety and Improving Use of the Research Reactor at the Institute of Nuclear Physics.

In 2011 - Acquisition of temperature and pressure sensors for the control and protection system of the reactor.

In 2011 - Acquisition of UPS (160 kVA) for the emergency core cooling system.

THE WORK PERFORMED UNDER THE IAEA PROJECT UZB/9/004-005.

Purchase of emergency power supply (UPS 160 kVA)	Upgrading the system for reactor control and protection	Upgraded the radiation protection system

Pic. 2. Equipment, purchased under IAEA projects.

Under IAEA TC project UZB/9/005 for the cost of 1.2 mln. USD WWR-SM research reactor’s electronic part of control and protection system was upgraded. Reason for this action was absence of spare parts for the old system on the market, which were outdated. Replacement of old electronic part of control and protection system led to gathering more accurate and advanced data on reactor operation parameters, data archiving and consequently to increased safety of reactor operation.

Pic. 3. Old control and protection system (CPS)

Pic. 4 Old and new CPS installed and operationg in parallel

Pic. 5 New CPS system.

For future works it is planned to continue the implementation of TC project UZB/9/005, in a framework of which was installed and commissioned emergency ventilation system, including the purchase and installation of radiation monitoring system for radioactive emissions from the reactor building.

IAEA PROJECT UZB/1/001 2013-2015 - Strengthening Nuclear Safety and Improving Use of the Research Reactor at the Institute of Nuclear Physics

In the framework of the project UZB/1/001it is planned to perform the following tasks:

- Reconstruction of the second cooling circuit (new pumps, piping, heat exchangers);
- Improving opportunities on WWR-SM research reactor usage, including the preparation of the production of radioisotopes for medical and industrial purposes;
- Acquisition of beryllium reflectors to create traps of neutrons;

- Performing periodic inspection of equipment to ensure safe operation of the WWR-SM reactor until 2022;
- Research works of INP staff in creation of radioisotope products.

Every year a year preventive maintenance and complex certification of instrumentation and equipment, replacement of fuel assemblies for compensation and emergency protective rods, upgraded wiring diagram pumps to supply water to the cooling system of the reactor is carried out.

Validated test instruments, perform complex tests on instruments and apparatus, safety systems with actuator, the lifting and lowering time of safety rods in the core together with the speed of loading of compensating rods to adjust the loading of positive reactivity. Check the efficiency of the ionization chamber and measure the resistance of the cable insulation.

Quarterly conducted emergency training exercises, as well as supervision on accounting of nuclear materials.

Due to IAEA support in a forms of TC projects, trainings, seminars, the ageing management, safety, physical protection issues are always under control and that leads to reliable and safe operation of WWR-SM research reactor.

3. EFFECTIVE USE OF WWR-SM NUCLEAR REACTOR

The following laboratories of the INP using WWR-SM research reactor nuclear reactor:

№	Name of laboratory
1	Laboratory of physics of nanostructured and superconductive materials
2	Laboratory of radiation physics of semiconductors
3	Laboratory of radiation processes in dielectric materials
4	Activation analysis laboratory
5	Laboratory of nuclear chemistry
6	Activation analysis laboratory of pure materials
7	Laboratory of physics and technology of semiconductor electronics
8	Scientific Group WWR-SM

With the use of a nuclear reactor laboratories of the institute completed and executing more than 10 Government orders on fundamental and applied projects during last 5 years, such as:

- «Experimental studies of the properties and states of nuclear matter at high and low energies»
- «The formation of micro-inhomogeneity and their impact on the fundamental properties of nuclear-doped silicon hydrogenation»
- «Investigation using nuclear-physical methods of complexation of precious and rare earth metals with new (phosphorus) organic compounds»
- «Development of Almalyk MMC dump slag processing methods using nuclear methods»
- «Development of technology for production of radioisotopes, radiopharmaceuticals and sources of ionizing radiation for the needs of medicine and industry»
- «Development of technology preclinical treatment of tumors on the basis of a dedicated channel of a nuclear reactor INP Uzbekistan.»

and etc.

WWR-SM research reactor of INP is used by the following institutions, universities and organizations of Uzbekistan:

1. Institute of Biochemistry,
2. Institute of Bioorganic Chemistry,
3. Institute of Genetics and Experimental Biology,
4. Samarkand State University,
5. Republican Scientific Center of Oncology,
6. Design Office with PH at INP AS RU.

Research reactor WWR-SM performs contractual works on irradiation of samples with different, both local and foreign, businesses and commercial organizations.

State enterprise "RADIOPREPARAT" produces wide range of radioisotopes and radiopharmaceuticals for medical purposes since 1976 using WWR-SM research reactor. These preparations are used in hospitals of Uzbekistan and exported to other countries.

IAEA provided INP with the ^{99}Mo for scientific purposes to study production process of ^{99m}Tc at the WWR-SM research reactor. INP received 3 samples of natural Mo, two of them in the metallic form and one as powder MoO_3. ^{99}Mo was obtained under irradiation of ^{98}Mo with neutrons in WWR-SM research reactor. Results of irradiation and samples' activities are presented in the table below.

Sample	Weight of sample, g	Irradiation time in channel 3-8, hours	Activity, mCi
MoO_3	1,25	20	0,898496
Mo (metallic)	1,02	15	0,619551
Mo (metallic)	4,94	10	1,34975

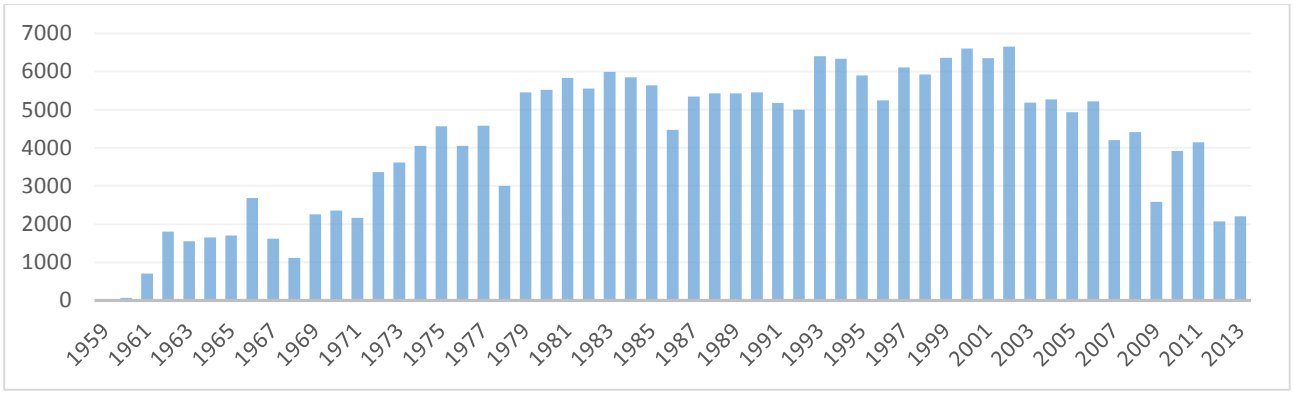
Saturation time for production of ^{99}Mo is about 350 hours of irradiation in WWR-SM research reactor with the possible neutron flux.

Results of experiments show, that ^{99m}Tc can be produced from natural Molybdenum at the WWR-SM research reactor.

Pic. 6. Processing radioisotopes and samples of final products.

INP jointly with Pacific National North-West Laboratory, USA, IAEA performed research of spent nuclear fuel (SFA) using Advanced Experimental Fuel Counter (AEFC) and ^{252}Cf source. AEFC is useful device for IAEA experts to check spent fuel characteristics such as: energy release in SFA, residual mass of ^{235}U in SFA, relative ^{235}U burnup, uniformity of initial uranium enrichment in SFA and power distribution. Before using AEFC, UAEA made measurements of residual 235U mass with indirect method by detecting 662 keV peak of ^{137}Cs in SFA.

WWR-SM research reactor is one of most effectively used research reactors in the world. Reactor operation time was the most intensive in 1980-2005 – 5000 hours and above. Nowadays reactor operates almost twice less hours due to increased cost of fresh LEU fuel. For the moment, there is only one supplier of fuel for the WWR-SM research reactor, and INP looks for other suppliers, who can produce suitable LEU fuel for our reactor.



Pic. 7. WWR-SM research reactor operation hours.

INP has plans on performing neutronic and thermal hydraulic calculations for the new fuel with similar to IRT-4M geometry. Fuel will have similar to IRT-4M outer tube, but without fuel and inside this tube will be installed pin or plate type uranium-silicide fuel elements. Getting good results will lead to manufacturing of a number of test fuel assemblies and performing their life-tests in WWR-SM research reactor.

CONCLUSION

In 2012 all HEU fuel of WWR-SM reactor was shipped to Russian Federation.

In 2015 all HEU liquid nuclear fuel off IIN-3M reactor of FOTON was shipped to Russian Federation. At the present, Uzbekistan do not have any more HEU fuel.

More than 55 years WWR-SM research reactor operates safe and reliable due to the construction of reactor and timely undertaken actions, supported by Uzbekistan government, IAEA, US DOE and Euroatom. Safe operation of reactor allows performing scientific studies of materials, production of radioisotopes and other products in stable and long terms plans. At all times, when reactor operates, almost all irradiation channels are loaded with samples for irradiation for scientific and commercial purposes for local and foreign organizations.