THE UTILIZATION OF 10-MW RESEARCH REACTOR IN TASHKENT

B. YULDASHEV*
Stanford University, Stanford, CA 94305-6165, USA

U. SALIKHBAEV, A. DOSIMBAEV, S. BAYTELESOV, E. IBRAGIMOVA, A. KIST,
Yu. KOBLIK, Sh. MAKHKAMOV
Institute of Nuclear Physics, Ulughbek, Tashkent, 702132, Uzbekistan

M. ABDUKAYMOV, P. CHISTYAKOV
Radiopreparat Enterprise of Institute of Nuclear Physics, Ulughbek, Tashkent, Uzbekistan

ABSTRACT

We present the short review of basic and applied research as well as data on the commercial production of reactor isotopes with use of 10-MW water-water research reactor of the Institute of Nuclear Physics of Uzbekistan Academy of Sciences in Tashkent. Despite the relatively long time of operation (since 1959), few modernization projects have been done. The reactor operates more than 5000 hours a year and serves also for elemental analysis (neutron activation), radiochemistry, radiation hardness and fission products studies as well as for changing the properties of optical and semiconductor materials. Until 1997 the reactor had been operating with the use of highly enriched fuel (90% enrichment). Starting from the middle of 1997 it has been converted to use 36% enriched fuel. By the end of 2007 the preparatory works on the full conversion to 19.7% enriched fuel should be completed. We also present the results of our experience in sending highly enriched spent fuel back to country-origin (Russia) for the first time in last 16 years.

---

* On leave of absence from the Institute of Nuclear Physics, Tashkent, Uzbekistan

1. INTRODUCTION.

The water-water research reactor WWR-SM of the Institute of Nuclear Physics of Uzbekistan Academy of Sciences (Tashkent) was commissioned in October 1959. From 1959 till 1978, the reactor has been operating at a power of 2 MW. After reconstruction and upgrading works from 1974 till 1977, its power increased up to 10 MW, which, being supported by research in radiochemistry and organizing production lines, allowed the start of the commercial production of various types of reactor isotopes for medicine and research.

The reactor belongs to the standard type of research reactors supplied from 1960-70's by the former Soviet Union to several research centers, including some countries in Eastern Europe. At earlier stages the reactor was using 10%-enriched fuel. Starting in 1972, it has been converted to 90%-enriched fuel, which was used until 1997. In 1998 the reactor was converted to 36%-enriched fuel as a first stage of program for full conversion to 19.6% fuel by 2007 or 2008.

Currently, the reactor is widely used (the average operational time is mote than 6000 hours per year) for basic and applied research in nuclear physics, radiation physics of condensed matter, modification of materials, radiochemistry, activation analysis, as well as for testing new types of reactor fuel and reactor materials. Applied research includes creation of technologies for new type of isotopes, application of neutron diffraction methods, studies in radiation hardness etc. For most of its time the reactor operates for the production of radioisotopes.

2. REACTOR PARAMETERS AND FUEL HISTORY.

The reactor WWR-SM has a cylindrical core of about 58 cm in diameter and 60 cm in height, 10 control rods of which 3 are safety rods (B_4C), 6 - shim rods (B_4C) and one is automatic regulating rod. The neutron reflector consists of beryllium and graphite. The reactor has 44 vertical and 10 horizontal channels. The average total flux of neutrons is about $3.0*10^{14}$ neutrons/cm^2/sec. Normally the reactor operates from 5000 to 6000 hours per year depending upon requests and orders. There is one 480 hour operating cycle per month.

From the beginning in 1959 and at a thermal power of 2MW, the reactor was using 10%-enriched fuel of type EK-10. Since 1971, the reactor started to operate with new fuel, 90%-enriched of type IRT-2M. The upgrading and reconstruction works performed from 1972 to 1978 increased the reactor power up to 10 MW. From 1979 until the middle of 1998, the reactor was operating with 90%-enriched fuel of type IRT-3M. From the end of 1998 until the present the reactor is operating with 36%-enriched fuel also of type IRT-3M. The currently used fuel assembly with 36%-enrichment is made of (UO_2-Al)- alloy (meat) with Al cladding and is 880mm in length of which the fuel meat part is 600mm. There are 6 concentric layers (5 square round tubes inside and 1 external one). The fuel meat thickness is 0.5mm and cladding thickness is a minimum of 0.3mm. In average, the burn-up of fuel is not less than 60%. This has been achieved by several experiments that confirmed the firmness and good behavior of fuel elements despite the producer's 40% of burn-up warranty. There are plans for full conversion of the reactor to the 19.7%-enriched fuel by the beginning of 2008.

For long time our reactor was also a facility for testing new types of research reactor fuel. These studies were performed in cooperation with several Russian research groups and production facilities. For example, the testing of new type IRT-3M fuel elements with 36%-enrichment as well as with 19.7%-enrichment had been done within the last 10-12 years. The results of these experiments were the basis for the approval of new types of fuel.

The spent fuel is stored in three water pools under the reactor hall. There is permanent control of water in all three pools and measurements of such parameters as pH (normally pH=5.5-6.5), electric conductivity (less than 4), specific activity and the content of Al^{+3} ions.

The spent fuel was regularly (once every 2-3 years) sent back to country -origin (Russia) until 1991. After the Soviet Union dissolved in 1992, the Russian Federation parliament passed a law forbidding the return to Russia of any radioactive waste. This resulted in storing of more than 300 highly (90% and 36%) enriched spent fuel assemblies at our facility. That situation created serious threats to radiation safety as well as to nuclear security since the stored material could be a target for nuclear smuggling and terrorism. However, due to initiatives of IAEA, USA, and Russian Federation, the new program RRRFRP (Russian Research Reactor Fuel Return Program) was accepted in December 1999. In accordance with that program, the highly enriched spent fuel from 24 research reactors at 17 facilities in 15 countries – including ours -- could be returned to Russia.

Uzbekistan, and our facility in particular, was the first to return the highly enriched (90% and 36%) spent fuel from research reactor within the mentioned program. In April 2006 the first stage of this program was performed and as result 252 fuel assemblies containing highly enriched spent fuel were returned to the Mayak facility near Chelyabinsk in Russia. The experience gained during this operation can serve as a model and provide guidelines for future RRRFRP projects.

It should be noted that despite relatively high level of burn-up, no traces of leakage or deformation of spent fuel elements were observed within the storage period (up to 14 years)

Also before completing this program, in 2004 we sent back to Russia all available non-standard and never used fresh fuel elements. Within non-proliferation programs, all these actions seriously helped in improving radiation and nuclear safety and security. The mentioned programs were performed in close cooperation with IAEA and related US and Russian organizations.

With almost 50 years of operation and with scheduled upgrades of reactor parts ,we had no serious accident. However, we note that the control system of the reactor should be modernized.

In 1996, a new modern system of physical protection for the reactor and fresh fuel vault was constructed. This included in particular a well protected new vault for fresh fuel and a storage facility for isotopes. Since 1992, Uzbekistan joined Non-Proliferation Treaty and all nuclear materials are under IAEA safeguards.

One month every year and one week per month, are dedicated to maintenance works.

3. THE UTILIZATION OF THE REACTOR.

From the beginning of operations, the reactor WWR-SM was intensively used for basic and applied research in nuclear physics, reactor and fission reactions studies, radiation hardness and material sciences, radiochemistry, activation analysis, isotope production and training.

3.1. Nuclear Physics.

Basic research in the field of nuclear physics conducted at the reactor includes nuclear spectroscopy, especially experiments to study so-called highly excited states of medium and heavy nuclei by use of gamma-gamma coincidence. Another direction is a detailed study of the properties of fission fragments in $n^{235}U$- and $n^{239}Pu$- fission reactions caused by thermal neutrons. For this purpose, a special mass-spectrometer that combines electromagnets and semiconductor detectors has been built. This allowed us to obtain new important results on the properties of fission fragments including fragment energy and angular spectra as a function of their charge and mass. The obtained data contradict some commonly used model approaches.

3.2. Material Sciences.

There are three main directions of research in radiation material sciences: the study of structural features of materials by means of neutron diffraction, the study of radiation hardness and neutron-gamma modification of physical properties of various objects under intense radiation of neutrons and gamma-quanta from the reactor. The objects of research are very diverse - from optical materials like quartz, glass, minerals, optical fibers and gems, up to semiconductors, reactor materials, composites, ceramics, abrasives, materials for the needs of space research, polymers etc. The unique data are collected on the study of behavior and changing properties of various subjects irradiated by integrated fluxes up to of order 10^{22} neutrons/cm^2. Special attention should be given to studies revealing quite unexpected changes in physical properties of different types of irradiated ceramics like, for example, appearance and enhancement of high temperature superconductivity or increase in storage capabilities for hydrogen and oxygen ions from water electrolysis etc.

The results of the basic and applied research in radiation material sciences resulted in development of irradiation services and production lines for commercial needs of, for example, gem market (radiation coloring of stones), semiconductor industry (neutron doping of silicon) etc.

3.3. Activation Analysis.

One of the important tools in studies of elemental composition of many objects is neutron activation analysis that allows us to determine proportions of various atoms in a given object with very high accuracy and at extremely low concentrations. The methods of activation analysis, mostly based on (n, γ)-reactions, are widely used in many fields. For example, the use of our reactor and the unique methods of activation analysis we developed found important applications in mining, purification of metals and semiconductors, medicine, agriculture, criminology and in many other fields. As an example one can mention that these methods allow one to determine the presence of impurities in semiconductor materials (e.g. silicon or germanium) or in some other purified materials at concentrations as low as $10^{-12} – 10^{-11}$%.

3.4 Radiochemistry and Isotope Production.

Radiochemistry is another direction of reactor utilization in order to study and develop radiochemical methods for production of radioactive isotopes with given properties. One should mention that we possess technologies of mass production of any type of reactor isotopes (e.g. ^{188}Re/W–generators). Unfortunately, due to limited flux of neutrons in our reactor, we are not able to produce all of them at commercial levels (especially if high specific activity is required).

However, we have mass produced reactor isotopes for the last two decades including: ^{32}P (up to 200-250 Ci/month), ^{33}P (5-6 Ci/month), ^{35}S (200-250 Ci/month), ^{51}Cr, ^{54}Mn, ^{55}Fe (7-10 Ci/month), ^{58}Co, ^{60}Co, ^{99}Mo/Tc (up to 30 generators/month), ^{90}Y, ^{125}I (150-200 Ci/month), ^{131}I (200-250 Ci/month), ^{183}Ta, Re/W-188, ^{192}Ir and ^{203}Hg (40-50 Ci/month).

For example, by request of a customer these products can be delivered in different chemical forms as well as ready-to-use labeled compounds. Also the high radiochemical purity and specific activity of these products should be mentioned.

The generator of Technecium-99m deserves special attention. For its production, instead of the traditional and expensive method of extraction from fissile products in hot cells, we used an advanced method of irradiation of enriched ^{98}Mo target. In the former USSR we had provided almost 30% of all of the ^{99m}Tc-generators required for the needs of hospitals and research facilities.

4. CONCLUSION.

Despite almost 48 years of intensive and extensive exploitation, the reactor WWR-SM of the Institute of Nuclear Physics in Tashkent is in relatively “good shape”. In addition, it is the only research reactor in the Central Asia region that operates effectively and even earns some profit. The permanent inspection of its condition as well as continuous efforts in renewing and maintaining vital parts create an optimistic basis for future works for both scientific and commercial needs into next decade at least.