Dismantling Structures and Equipment of the MR Reactor and its Loop Facilities at the National Research Center "Kurchatov Institute" - 12051

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ABSTRACT

In 2008 a design of decommissioning of research reactors MR and RFT has been developed in the National research Center «Kurchatov institute». The design has been approved by Russian State Authority in July 2009 year and has received the positive conclusion of ecological expertise. In 2009-2010 a preparation for decommissioning of reactors MR and RFT was spent. Within the frames of a preparation a characterization, sorting and removal of radioactive objects, including the irradiated fuel, from reactor storage facilities and pool have been executed. During carrying out of a preparation on removal of radioactive objects from reactor sluice pool water treating has been spent. For these purposes modular installation for clearing and processing of a liquid radioactive waste «Aqua - Express» was used. As a result of works it was possible to lower volume activity of water on three orders in magnitude that has allowed improving essentially of radiating conditions in a reactor hall. Auxiliary systems of ventilation, energy and heat supplies, monitoring systems of radiating conditions of premises of the reactor and its loopback installations are reconstructed. In 2011 the license for a decommissioning of the specified reactors has been received and there are begun dismantling works. Within the frames of works under the design the armature and pipelines are dismantled in a under floor space of a reactor hall where a moving and taking away pipelines of loop facilities and the first contour of the MR reactor were replaced. A dismantle of the main equipment of loop facility with the gas coolant has been spent. Technologies which were used on dismantle of the radioactive contaminated equipment are presented, the basic works on reconstruction of systems of maintenance of on the decommissioning works are described, the sequence of works on the decommissioning of reactors MR and RFT is shown. Dismantling works were carried out with application of means of a dust suppression that, in aggregate with standard means at such works of individual protection of the personnel and devices of radiating control, has allowed to lower risk of action of radiation on the personnel, the population and environment at the expense of reduction of volume activity of radioactive aerosols in air.

INTRODUCTION

In 2008, the Kurchatov Institute and ZAO "Alliance-Gamma" jointly developed the design package entitled "Decommissioning of MR and RTF research reactors located at the National Scientific Centre Kurchatov Institute". In 2009, the package was approved by the head Russian expert review authority and state environmental review authority. The package was then approved by the Federal Agency for Science and Innovations.

The MR reactor was developed as a multi-purpose pool-type reactor (the design power 50 MW). In 1963-1993 the MR was used for material researches. It was equipped with 9 loop-type facilities, which made it possible to explore thermal, hydrodynamic and strength parameters of cores and basic equipment of power reactors intended for various purposes in conditions as close as possible to on-site operation.

The reactor core (1m high), together with its working and experimental channels, coolant pipelines, headers and other metallic structures, is installed into the pool over 9 m deep, filled with distilled water and surrounded with concrete biological shield. The reactor site is situated in the western part of the main Institute's territory. The territory of NRC "Kurchatov Institute" is now surrounded with apartment blocks, situated as close as 100–200 meters northwestward from the reactor.

The RTF reactor, the purpose of which was to be used for physical and technological research, was commissioned as part of the first Soviet integrated science-of-materials experimental facility in April 1952. After 10 years of intense operation, in 1962 the RTF was shut down and partly dismantled, and next to inside the same room the more powerful MR loop reactor was built.
Dismantling was performed on all fuel and loop channels of the RTF reactor, vertical experimental irradiation channels inside the reactor core and reflector, pipelines and process equipment of the primary cooling circuit, loop circuits equipment, etc. The part of the RTF reactor that had not been dismantled – the graphite stacks of the core and reflector – remained inside the steel enclosure in the MR reactor room.

The decommissioning option chosen for the reactors was immediate dismantling of structures and equipment (DECON) of the MR reactor and its loop facilities, including dismantling of the vault with internal structures of the RFT reactor. The end state of decommissioning was defined as status suitable for creation of an industrial complex for management of spent fuel and radwaste to be used during decommissioning of other research installations located on the same site.

MAIN TASKS AND TIME SCHEDULE OF MR AND RTF RESEARCH REACTORS DECOMMISSIONING

The design of "Decommissioning of MR and RTF research reactors located at the National Scientific Centre Kurchatov Institute" determined as basic tasks of the project:
- dismantling of reactor cooling circuits and loop facilities;
- dismantling of in-vessel devices in the MR reactor pool;
- dismantling of equipment under the reactor hall floor;
- dismantling of in-vessel devices in the RTF reactor pit;
- decontamination of the reactor pool and the storage pool in the central reactor hall;
- decontamination and final survey of reactor technological premises and buildings;
- cleaning and rehabilitation of the reactor site after completion of dismantling works.

In accordance with the design, the time schedule of MR and RTF reactors decommissioning is to be divided in four key stages.

2008-2010 – the first stage included dismantling of the loop channels in the storage pool, removal of experimental fuel assemblies from the spent fuel storage facilities in the reactor hall, removal of the spent fuel assembly from the loop channel with liquid metal coolant, from the MR reactor core and its placement into the spent fuel storage facility, as well as reconstruction of the reactor engineering and technical support system as required for performance of the decommissioning work.

2011-2012 – the second stage began the dismantling of cooling loops equipment and pipelines, loop facilities and auxiliary equipment.

2013-2014 – the third stage will include dismantling of the equipment located in the sub-deck space of the reactor room, and internals of the MR and RTF reactors.

2015 – the final stage will include a post-completion radiological survey of the process rooms, loop installations and reactor site area; decontamination of the process rooms; site remediation and issue of report to de-regulate the reactors site.

PRELIMINARY STAGE OF THE DECOMMISSIONING

According to the time schedule of decommissioning design in 2008-2010 preliminary works were performed. These works included a radiation survey of the reactor rooms and equipment, removal of spent fuel and reconstruction decommissioning support systems, a horizontal borehole leading into the steel RFT reactor enclosure was drilled by a diamond drill through the biological protection to measure the radiation fields and radionuclide contents of the pit. Results of these works made it possible to update the information on the reactor conservation technology and on the technical status of pit structures and reactor vessel. In order to assess the current status and forecast the workability of systems needed for engineering and technological support of decommissioning measures, surveys of the following systems were performed: radiometric monitoring, special vent system, special sewage, water supply, electricity supply and heating. Engineering survey of the reactor building was also carried out. It was determined that inside the RTF vessel the level of gamma radiation is high (up to 30mSv/h) due to the presence of Co-60 produced from neutron activation in the stainless steel vessel, and to the presence of the graphite stack contaminated with Cs-137. It was carried out an inspection of the SNF repository located in a reactor hall of MR. With use of methods of remote diagnostics and remote operated robots (BROKK-90) identification of the objects which are in the repository and removal of spent fuel to Center SNF repository has been performed. After completion of spent fuel removal, reconstruction was performed on systems to be used for support of decommissioning activities on the MR and RTF reactors – such as radiation monitoring, special ventilation, power and water supply, fire alarms and heating.

A radiation survey was performed on both RTF and MR (including its loop facilities), which encompassed over 600 equipment items situated in about 70 technological rooms. This survey confirmed that the contamination of systems, equipment and pipelines of both the reactor and its loop facilities is mainly caused by their internal surfaces contaminated with Cs-137, Sr-90 and Co-60. The radiation survey of the reactor rooms and equipment was carried out in order to determine the contamination levels on equipment and rooms themselves, as well as identification and removal of canisters containing spent fuel and high-level radiation sources to provide a significant reduction of radiation levels in the work zones [1-3].

The survey in high levels of radiation was performed using remotely controlled robotics. This demanded that instrumentation be created for the robotics to be guided towards objects with high levels of radiation and that methods be devised for the radwaste to be characterised and segregated by level of radioactivity. A remotely controlled system for spectrometric radiation surveys of radioactive objects was created, along with the Gamma-Pioneer radiation reconnaissance measuring complex mounted on board the Brokk-90 robotic machine [4].

The spectrometric system includes a set of devices that is the standard for a γ-scanner: a collimated spectrometric detector installed on a swivel, a colour video camera aligned with the detector collimator, a control unit, a Kolibri spectrum analyser, an on-board computer and a power supply unit for the detector and video camera. The system used two detectors based on the scintillator-photodiode assembly with CsI(Tl) scintillators 20 cm^3 and 5 cm^3 in volume. For identification of uranium isotopes in solid radwaste, a semi-conductor CdZnTe detector was used, with scintillator volume 60 mm^3. Also developed for that purpose was a procedure based on identification of characteristic uranium-emitted radiation in the low energies spectrum of the surveyed object (E≤120 keV).

Using these systems and the procedures that were developed, key dose-contributing sources and structures were identified, removal of which helped reduce the dose rate levels in the work zones and remove the canisters containing spent fuel from the reactor rooms [1-3]. Also for the purpose of removal of spent fuel and highly radioactive sources, a radiation survey was performed on the radwaste and spent fuel storage facilities. In particular, using remote diagnostics instruments and remotely controlled Brokk-90 robots, identification of objects present in the spent fuel storage facility in the reactor room was performed, and spent fuel was removed to the centralised spent fuel storage facility of the Institute.

DISMANTLING OBJECTS AND TECHNOLOGIES

All available objects were divided for convenience into three groups, which required utilisation of similar dismantling technologies. The first group included the cooling circuits of reactor loops и loop installations located outside of the MR reactor pool and the vault of the RTF reactor. These will be dismantled using remotely controlled mechanisms fitted with various operating pieces. Openings leading to process rooms will have to be expanded to enable equipment delivery and evacuation of containers with radwaste. The second group covers equipment located in the MR reactor pool. It will be dismantled inside the pool shielded by a layer of water. In this connection, a remotely controlled mechanical manipulator arm installed upon a special platform will be used. The last group covers internals located inside the RTF reactor vault. The dismantling activities associated with the removal of graphite stacks and cutting the reactor vessel will be performed using a remotely controlled mechanical manipulator arm installed upon a special platform. After removal of the graphite blocks, the reactor vessel will be dismantled with large fragments being cut off in an air environment with subsequent further fragmentation into transportable pieces performed inside the pool shielded by a layer of water.

According to the results of radiation survey in the process rooms of the cooling circuit, MR reactor loop installations, review of weight and size characteristics of surveyed reactor equipment and its loops, an assessment was made of the expected amount of solid radwaste to be generated as a consequence of the dismantling effort, divided into classes depending on the level of γ-radiation dose rate. In accordance with the classification of solid radwaste depending on its specific activity level (OSPORB-99-2010), decommissioning of MR and RTF reactors will result in the generation of solid radwaste that will chiefly fall into the intermediate and low level categories, of which about 300 m^3 and 1.500 m^3 will be expected, respectively. The total activity of solid radwaste generated from the dismantling of the reactors equipment and loop installations will be expected to reach approximately 1.0×10^{14} Bq (2.700 Ci).

RADIOACTIVE WATER CLEANING

Radiation situation in the MR reactor hall are substantially defined by presence of radio nuclides in the reactor pool and pool of storage. Dose rate in a working zone at the beginning of works was 1-5 mSv/h. Cleaning of radioactive water of pools by means of «Aqua - Express» facility has been performed for decreasing of the dose rate. This facility was developed by “Alliance-Gamma” enterprise [5]. Productivity of the facility was 0.3 m^3/h. Four filter-containers were connected in parallel, to increase the facility productivity up to 1 m^3/h. The facility worked in a continuous mode. In the first stage of the work 155 m^3 of water were cleaned, then filter-containers should be changed. In the second stage with a new filters 867 m^3 of water were cleaned. As a result a dependence of total activity in the reactor pool via the cleaning water volume is shown in Fig.1.

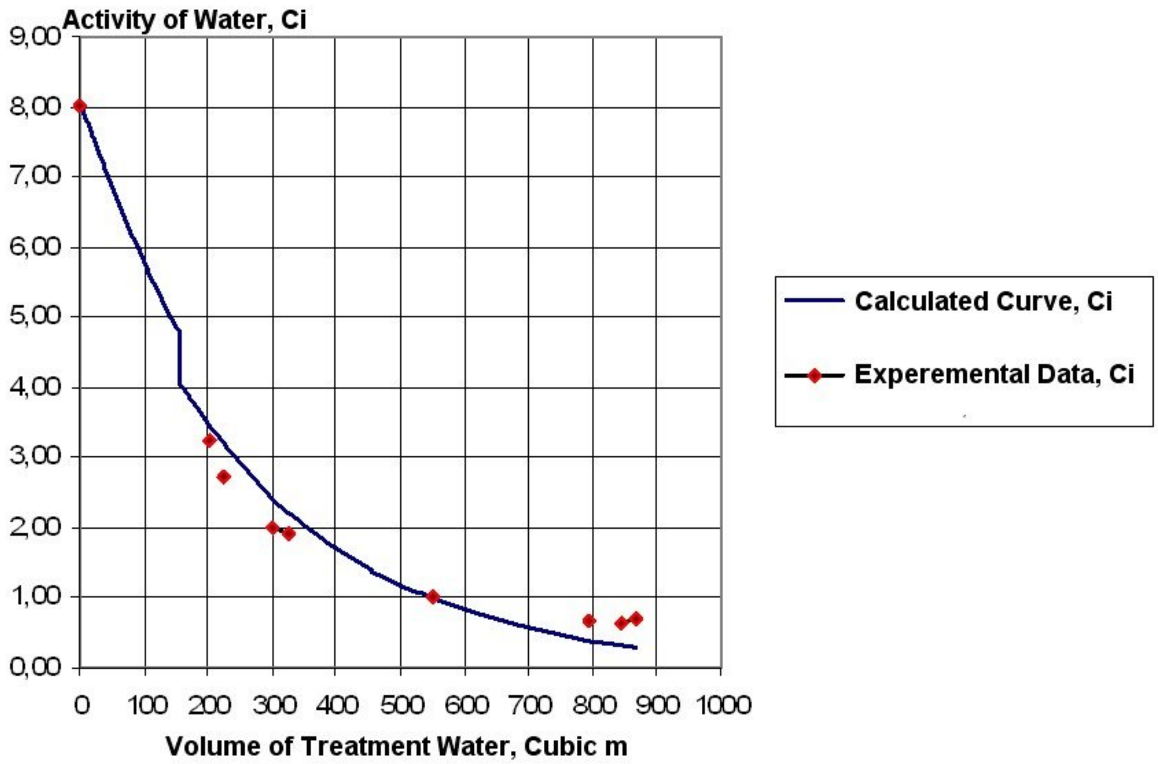

Fig.1. Decreasing of total activity in the reactor pool via the cleaning water volume

As a result of the treatment of pool water of MR reactor the activity of Cs-137 has decreased almost in 30 times. The theoretical limit of water treatment is about 10000 columnar volumes that there corresponds of 1000 $м^3$ for the block of the filter - containers. In the second stage it is cleared nearby 700 $м^3$ of water. By estimations, in pool water of the reactor remains less than 1.2×10^{10} Bq (0.3 Ci) of Cs-137.

DISMANTLING EQUIPMENT OF THE LOOP FACILITIES

Over the time of operation, the MR reactor pool has accumulated about 100 reactor loop facility channels. In order to improve the radiological situation in the reactor room, measures were implemented to remove the parts of the loop channels that appeared above water level in the storage pool. Loop channel elements were removed by the Brokk-330 and Brokk-180 robotic systems, which remotely controlled using a specially designed video surveillance system.

To determine most radiated parts a distribution of activity along the loop channel was measured. A gamma visor with coded aperture, a collimated measuring system “Gamma pioneer” and collimated spectrometric semi-conduction system were used for determining of activity distribution and radionuclide composition of contamination along the loop channels [6]. The measurements of the channel activity are shown in Fig.2. The loop channel was taken from the water of pool storage, the collimated spectrometric semi-conduction system measured the spectrum of gamma radiation, gamma visor got the gamma image of the channel and “Gamma pioneer” scanned the channel along its length. A space resolution of scanning was near 5 cm. These measurements then were used at cutting of the channel by the Brokk robotic systems.

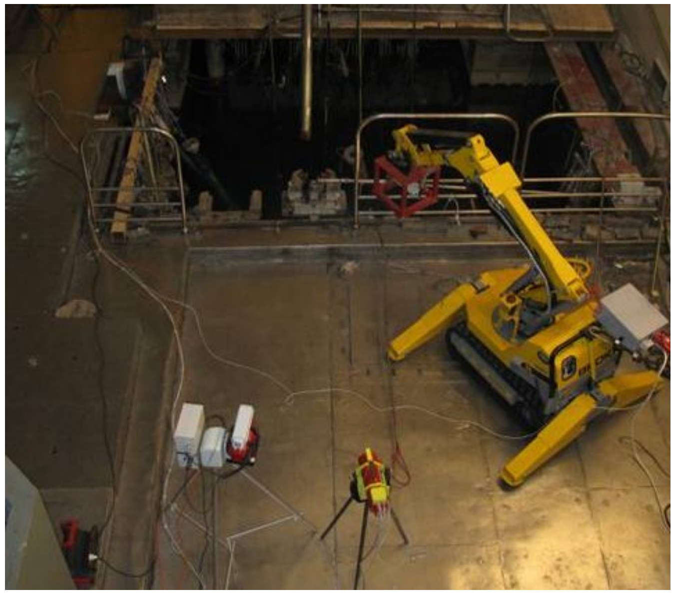

Fig.2. Measuring of activity distribution along the loop channel.

The main gamma radiated radionuclide was Co-60, the activity of Cs-137 was 4-10 times less. The total activity of a separate channel achieved up to 10^{12} Bq, the most radiated part of the channel was the part which was placed in the core of MR reactor. The length of this part was near 1 m and the specific activity of this part could reach the value of 10^{10} Bq/kg. These measurements allowed to separate a high level, medium level and low level parts of the channel and to determine packages for its transportation. The high level parts were placed in Centre high level radwaste storage, medium and low level waste were packed into reinforced concrete and metallic containers respectively and then were removed to SIA "Radon" enterprise. In 2011 the removal of first circle pipelines and equipment of the loop facilities was performed. The dose rate over the first circle pipeline and equipment of loop facilities was measured before the removal of them. As an example one can see at Fig.3 the results of measurement for the pipeline of water cooling loop.

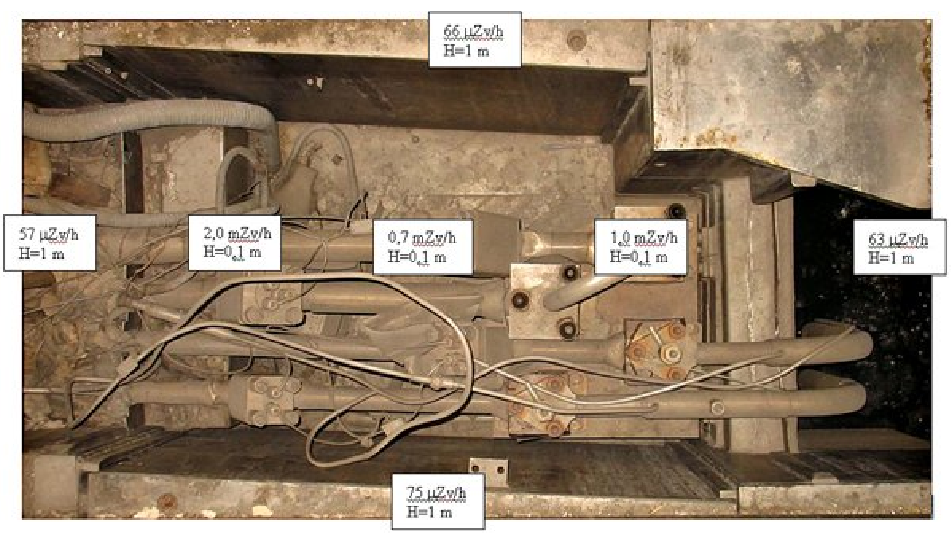

Fig.3. Results of dose rate measurements over the pipeline of water cooling loop.

Cutting of the pipelines and removal of the loop facility equipment was performed by the remotely controlled robots Brokk and using dust suppression system (see Fig.4).

Fig.4. Removal of the equipment of loop facilities.

Metal protection slab was removed and pipeline was opened. The robots cut the lines and placed the waste into container, then the slab installed at its place and the next one was opened. After that the pipelines and equipment of the loops were removed from their premises.

CONCLUSIONS

As a result of the preliminary phase of the work, a design package for decommissioning of the MR and RTF research reactors was developed, dismantling technologies chosen and tested, diagnostics equipment necessary for the performance of work built, radiation survey of the reactor rooms carried out, and spent fuel removed to a centralised on-site storage facility. All these measures enabled larger-scale dismantling work to start in 2011.

It should be noted that the solutions and measures envisaged for implementation by the MR and RTF reactors decommissioning project will allow for the dismantling work to be performed in a manner that secures radiation safety of both the participating personnel and residents of the surrounding neighbourhoods. The dismantling of the equipment of loop facilities and cleaning of water in the MR reactor pool were performed.

In 2012 the works to dismantle the high radiated structures of MR and RFT reactors will be started. It is planned that these works will be completely finished in 2014.

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