Experience of MR and RFT Reactors' Decommissioning in RRC "Kurchatov Institute" - 11050

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ABSTRACT

Research channel-type nuclear reactor «MR» has been developed and commissioned in Russian Research Centre «Kurchatov Institute» in 1962-1963. "MR" reactor replaced the old one - "RTF" type reactor. MR is one of 12 units located in Kurchatov Institute. It started the operation in 1963, and shut down in 1992. Reactor is located in the water pool on the 9 m depth. Nine loop units with different cooling medium are the experimental basis of MR. When MR has been shut down, the loop channels were disconnected and placed into water pool. Nuclear fuel has been unloaded and moved to the dry repository. Decommissioning design has been developed by Russian Research Centre «Kurchatov institute» and JSC «Aliance-Gamma» in 2009 year. According to the decommissioning design the final state of reactor MR will come to: - Equipment and systems of reactor shall be dismantled completely; - Technological facilities of reactor and MR territory shall be decontaminated and remediated according to the regulations. D&D design has been approved by Russian Authority in July 2009 year. In August 2009 the equipment supply and preliminary works have been started. Dismantling works are scheduled to start in 2011.

Features of the reactor MR which have made an essential impact on the development of the project on decommissioning are shown. A status on decommissioning of reactors MR and RTF is resulted.

The work performed on the reactor MR in preparation for decommissioning, which include: removal of irradiated fuel from near reactor storage, disposal units of loop channels, acting above the water surface in a pool storage are described, identification, sorting and disposal of radioactive objects from gateway of the reactor is carried out.

The technologies for dismantling works were identified and the stages of work on the decommissioning of reactors MR and RTF is presented.

The assessment of radiation effects on the population and the environment during the dismantling operations, which is determined by the amount of dismantling operations, the level of radioactive contamination of the reactor structures and equipment, as well as the technologies used for their removal is completed. The results of the estimation of radiation effects on the population and the environment during routine operation to dismantle the equipment and in emergency situations are reduced.

INTRODUCTION

In 2008 the Federal Target Program (FTP) "Nuclear and Radiation Safety Assurance in 2008 and in period to 2015" was adopted, which provided for financing of decommissioning of research reactors, including those belonging to the Kurchatov Institute: MT, RTF and the reactor situated on the Gas Plant site.

In accordance with the FTP "Nuclear and Radiation Safety Assurance in 2008 and in period to 2015" (item 147), Kurchatov Institute is presently decommissioning its MR and RTF reactors. In compliance with the procedure in force in the Russian Federation, both MR and RTF underwent comprehensive radiation and engineering surveys, which allowed the Conceptual Decommissioning Program and documents on planned works' safety validation to be prepared.

SPECIFIC FEATURES OF THE MR REACTOR AND SITE

Multi-purpose loop-type material research reactor MR was developed and built in 1962–63, (the design power 50 MW). From the constructive viewpoint, it became the first representative of the new research reactor type – channel-type reactor submerged in a water pool.

The MR reactor 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 site is situated in the western part of the main Institute's territory, and the reactor sanitary protection zone is limited by the external perimeter of its site. As a result of intensive urban construction in Moscow, the Institute's territory is now surrounded with apartment blocks, situated as close as 100–200 meters northwestward from the reactor.
In 1993, after 30 years of active operation, the MR was ultimately shut down. Now, in accordance with the Federal Standards and Rules regulating the use of nuclear energy, the reactor is operating in the "ultimate shutdown" mode.
The MR has some specific features, which had considerable influence on the development of its decommissioning project, i.e.:

- primary circuit and loop facility rooms overfilled with equipment;
- availability of some equipment with large size and/or mass;
- high radiation levels produced by equipment installed in the technological reactor rooms (up to 20 mSv/h);
- complex routes available for removing the dismantled equipment from the reactor primary circuit and loop facility rooms situated in the basement;
- the need to remove the dismantled equipment through access ports in the technological rooms' ceiling at ground level;
- reactor site proximity to the city apartment blocks and to intensive cargo and passenger traffic.

In the Conceptual program as a main decommissioning variant was eccepted a variant DECON – immediate stage-by-stage dismantle of designs and the equipment of reactor MR and its loop installations, including dismantle of equipment in staff of RFT reactor. Validity of a choice of the given variant of the reactor decommissioning was confirmed by the multiple-factor analysis and its comparison with other alternative variants (SAFSTOR, ENTOMB).

STATUS OF PRE-DECOMMISSIONING WORKS

Works of a preparatory stage were spent to the period after definitive shutdown of MR reactor:
- Radiating survey of reactor RTF;
- Working out of the design and working documentation of decommissioning of research reactors MR and RFT;
- Reconstruction of systems of maintenance of decommissioning of reactors MR and RFT;
- A removing of spent nuclear fuel from the channel of loop installation, containing a metal coolant and the spent fuel from the dry storages in the MR reactor hall;
- A removing of loop channels from pool storage in the MR reactor hall;

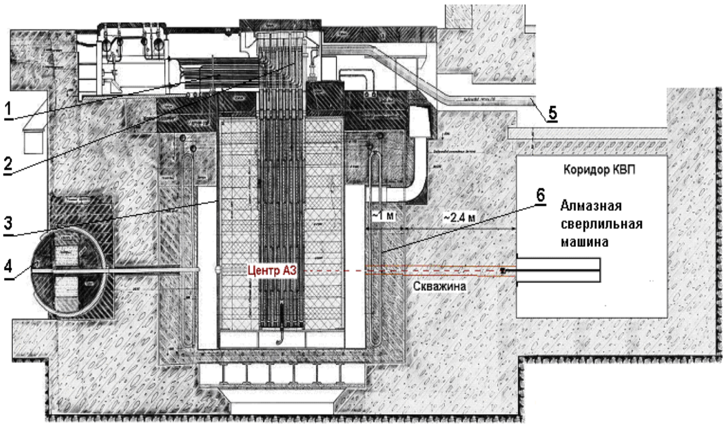
RADIATION SURVEY OF RFT REACTOR

The MR reactor was preceded by the RTF. This reactor intended for physical and technical research was launched as part of the USSR's first complex experimental material research base in April 1952. After 10 years of intensive operation, in 1962, the RTF was shutdown and partially dismantled, while the loop-type MR reactor of higher capacity was constructed in the same building.

The RTF decommissioning included dismantling of all its working channels, loop channels and vertical irradiation experimental channels situated in the reactor core and reflector; primary cooling pipelines and primary process equipment; loop facilities' equipment, etc.

The residual part of the RTF – i.e. its graphite core/reflector stack – was left in its original steel vessel in the MR reactor hall, and covered with a layer of concrete protected by steel slabs from above.

Longitudinal and normal cross-sections of the RTF are shown in Figs. 1.



1 – inlet and outlet working channels' water cooling pipelines;
2 – working and loop channels;
3 – steel vessel;
4 – choke;
5 – inlet and outlet loop channels' cooling pipelines;
6 – lateral protection concrete cooling system
Fig. 1. Longitudinal section of the RTF

Since the RTF reactor pit was inaccessible, a horizontal borehole leading into it was drilled by a diamond drill rig through the biological protection in the reactor hall. Then the radiation fields and radionuclide contents of the pit were evaluated using diagnostic devices. Photo and video shooting of the pit internals was performed using video cameras.

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.

A specific feature of the RTF is that its in-vessel devices are situated in the limited volume of the pit, where the level of gamma radiation is high (up to 30 mSv/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.

Specific features of MR and RTF reactors described above imposed certain restrictions on the choice of dismantling technologies, in order to assure population safety and environmental protection.

DEVELOPMENT OF DESIGN OF DECOMMISIONING OF RM AND RFT REACTORS

In 2008, the Kurchatov Institute has prepared the project entitled “Decommissioning of MR and RTF research reactors in the Federal State Institution “Russian Research Center ‘Kurchatov Institute’”, which since then received positive conclusions from state expert authorities (FSI Glavgosexpertiza Rossii and State Ecological Expertise) and was approved by the Federal Agency for Science and Innovations.

DECOMMISSIONING STAGES

It is supposed in accordance of the design to perform the MR decommissioning in four subsequent stages:

Stage 1, which includes preparatory works, should be completed in 2008–2010. Its basic activities are:

- dismantling of loop channels in the storage pool; removal of experimental fuel assemblies from SNF repositories in the central hall; removal of the fuel assembly from the loop channel containing liquid-metal coolant from the reactor core to SNF repository;
- reconstruction of reactor engineering and technical support systems to the extent required for its proper decommissioning.

In the frame of the Stage 2 (2011–2012) the dismantling of equipment and pipelines of the reactor cooling circuits and loop facilities, as well as of auxiliary reactor equipment should be executed.

In the frame of the Stage 3 (2013-2014) the equipment dismantling under the reactor hall floor, and dismantling of in-vessel devices of both the MR and the RTF should be performed.

Stage 4 (the last) should be completed in 2015. It will address the following basic tasks:

- final radiation survey of technological rooms, loop facilities and the reactor site;
- decontamination of technological rooms;
- rehabilitation of the site and issuance of the reactor deregistration certificate with the regulatory authority.

SELECTION OF DISMANTLING TECHNOLOGY

The choice of dismantling technology was determined both by personnel safety assurance requirement, and by the requirement of minimal impact of works on the city population. Dismantling procedures in the rooms containing non-polluted reactor and loop facilities’ equipment do not require any special technologies or tools. Dismantling operations in these premises will be carried out using both “flame” (plasma, oxyacetylene, contact arc) and “cold” cutting methods.

As concerns the rooms filled with strongly contaminated equipment, there it is planned to apply special technologies, which make it possible, on the one hand, to minimize the time of personnel exposure to radiation fields in order to reduce dose burdens, and on the other hand, to minimize the radiation impact of dismantling operations on the city population and environment.

It is planned to use remote-control mechanisms (BROKK) operated from a radiation-safe room using video monitors. In such a case, dose burdens on the personnel would be 10–100 times below those produced by the application of traditional working methods.

THREE GROUPS OF OBJECTS TO BE DISMANTLED

All objects to be dismantled were roughly divided into three categories requiring similar dismantling technologies.

The first category includes the equipment of the reactor cooling circuits and loop facilities situated beyond the MR reactor pool and the RTF reactor pit. This equipment category will be dismantled by remote-control mechanisms equipped with various attachable adapters. It will be also necessary to extend the door openings between the technological rooms to delivered the hardware and remove containers with radwaste.
The second category includes the equipment currently stored in the MR reactor pool. This equipment will be dismantled inside the pool, under water. In this connection it is supposed to use a remote-control mechanical arm manipulator installed on a special platform.
The third category includes in-vessel devices from the RTF reactor pit. For dismantling operations involving removal of the graphite bricks and reactor vessel cutting, it is supposed to use a remote-control mechanical arm manipulator installed on a special platform. After graphite bricks are removed, it is planned to dismantle the reactor vessel by chopping it into large fragments in air conditions, and subsequent fragmenting into transportable segments under water in the cooling pond.

RADIOACTIVE WASTE

Amounts of solid radioactive waste (SRW) to be produced by dismantling depending on the gamma dose rate were assessed on the basis of results of the radiation survey performed in technological rooms of the MR cooling circuit and loop facilities, and analyses of weight/size parameters of the reactor and loop equipment.
Estimated SRW amounts to be produced by dismantling operations are given in Table 1.

Table 1. Amounts of solid radwaste produced by dismantling

Stage	Dismantling operation	Radwaste amount, m^3	OSPORB-99 categories		
			LLW	MLW	HLW
1 (2008–2010)	1. Dismantling of loop channels in the storage pool	36.0	28.8	7.2	-
	2. Reconstruction of support systems	200.0	200.0		
2 (2011–2012)	Dismantling of equipment and pipelines of cooling circuits and loop facilities	1067.5	810.2	253.8	3.5
3 (2013–2014)	1. Dismantling of MR in-vessel devices and of equipment under the reactor hall floor	243.5	223.3	20.2	-
	2. Dismantling of the RTF in-vessel devices	140.1	132.5	7.7	-
4 (2015)	Decontamination of premises and site rehabilitation	73.0	73.0		
Total:		1760.2	1467.8	288.9	3.5

The note: OSPORB-99 -The basic sanitary rules of maintenance of radiating safety.

These assessments show that, in accordance with solid radwaste classification depending on their specific activity (OSPORB-99), decommissioning of MR and RFT reactors will produce solid radioactive waste belonging mainly to medium-level and low-level categories, respectively ~300 and ~1500 m^3.
In the same time, the cumulative activity of solid waste to be produced by dismantled equipment of the reactor and loop facilities will make about 1.0×10^{14}Bq (about 2700 Ci).

RECONSTRUCTION OF ADDITIONAL SYSTEMS OF MAINTENANCE OF DECOMMISSIONING.

At a preliminary stage of works reconstruction of additional systems of decommissioning of reactors MR and RFT has been performed: radiometric control, special ventilation system, electrical supplies, water supply, the fire alarm system and heating.

REMOVAL OF THE SPENT NUECLEAR FUEL FROM THE REACTOR SITE.

In 1996, spent working and loop fuel assemblies have been removed from the reactor core and storage pool and placed in the “dry” spent nuclear fuel (SNF) repository of the Center. However in SNF repository which is in a hall of reactor MR, 26 spent assembles were stored, two assemblages were in pool – storehouse and one in reactor pool. This irradiated fuel was necessary for removing for limits of a platform of the reactor prior to the beginning of dismantling works.
Inspection of the SNF repository located in a reactor hall (fig. 2 see) has been carried. 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 [1].

Fig. 2. Radiation survey of SNF repository and the removal of spent fuel from it and from the reactor pool.

REMOVAL OF THE LOOP CHANNELS FROM REACTOR POOL

During operation of the reactor ~150 channels of loop installations of the reactor have collected in the reactor pool. In order to improve the radiation situation in the reactor hall, loop channel sections protruding above the storage pool water surface were cut off and removed (Fig. 3). Loop channel sections were removed by BROKK-330 and BROKK-180 robots available in RRC KI and controlled remotely using the dedicated video system. BROKK-180, equipped with a clamp hook, gripped each loop channel element, and BROKK-330, equipped with hydraulic shears, cut it off (Fig. 3). After that, BROKK-180 placed this cutoff channel element in the concrete container (Fig. 3) [2].

PERSONNEL AND POPULATION DOSE BURDENS DURING DECOMMISSIONING OPERATIONS

It is planned to complete MR and RTF equipment decommissioning works in about 4 years. Based on this assumption, the average dose burden on the personnel would make about 140 man·mSv. Dismantling on the MR reactor would require about 40 workers. Thus, the average dose burden on the personnel engaged in the MR and RTF dismantling operations would not exceed 4 mSv. Dismantling operations connected with the MR and RTF decommissioning will involve the discharge ($\sim 3\cdot 10^{7}$ Bq) of radioactive nuclides (Cs-137, Sr-90 and Co-60) through the 60-meter-high chimney of the special vent system. Fig. 4 illustrates annual external and internal exposure doses calculated for the population using the licensed code “Nuklid”.

Fig. 3. Removal of loop channels from the reactor pool.

Results of these calculations confirm that the exposure caused by radionuclide fallouts on the ground will provide the main contribution to the radiation dose to be received by the population. However, in normal operation conditions the population exposure even in the closest vicinity to the Institute will not exceed $5 \cdot 10^{-6}$ mSv/year, that is much below the admissible limit of 1 mSv/year set by Russian Radiation Safety Standards.
Dose burdens caused by radioactive fallouts, inhaled intake and radioactive cloud will be 80 and 2500 times less, respectively.
Along with normal operation, the computer assessments also considered off-normal (emergency) situations, which could potentially occur during reactor dismantling. Analysis of these emergency situations during decommissioning showed that, from the environmental impact viewpoint, the greatest risk would be presented by a fire in the reactor premises, because the increased temperature caused by the fire would impact on the equipment contaminated by radionuclides, thus resulting in additional formation and discharge of radioactive aerosols. Cumulative release of radioactive aerosols in case of fire may reach about ~$3 \cdot 10^{4}$ Bq. Radiation impact of such an accident was assessed using the licensed software code "Nuklid–Avariya".

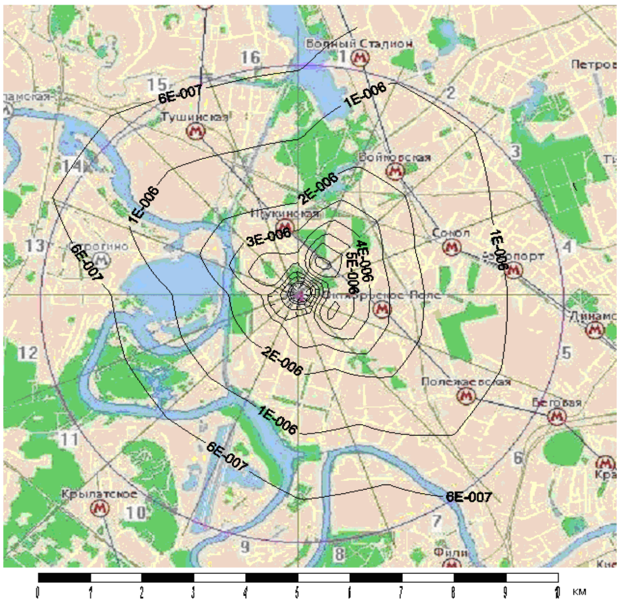


Fig. 4. Isographs of dose burdens induced by radioactive aerosols' deposition on the ground surface, mSv/year

Calculated results for radiation impact of an accident involving fire in the technological room containing the most contaminated equipment are given in Table 2.
The above results confirm that, even in case of an accident involving fire in the regenerator room, the level of radiation impact on the population would be significantly below the admissible limit.

Table 2. Calculated radiation impact from radioactive aerosols released at ground level for the case of an accident involving fire in technological premises

No	Exposure type	Distance from reactor, km				
		0.200	0.500	1	3	5
1	External exposure from contaminated ground surface, mSv/year	$8.0 \cdot 10^{-7}$	$8.0 \cdot 10^{-7}$	$4.0 \cdot 10^{-7}$	$1.0 \cdot 10^{-7}$	$2.0 \cdot 10^{-8}$
2	Internal exposure caused by inhaled radionuclides, mSv	$4.0 \cdot 10^{-7}$	$4.0 \cdot 10^{-7}$	$2.0 \cdot 10^{-7}$	$5.0 \cdot 10^{-8}$	$9.0 \cdot 10^{-9}$
3	External exposure from radiation-contaminated cloud, mSv	$4.1 \cdot 10^{-10}$	$4.0 \cdot 10^{-10}$	$2.0 \cdot 10^{-10}$	$5.0 \cdot 10^{-11}$	$9.0 \cdot 10^{-12}$

RESULTS AND CONCLUSIONS

During the preparation for the decommissioning of reactors MR and RTF the radiation survey of equipment and their facilities was carried out. The characterization of the high-level waste at the sluice hatch between the storage pool and the pool of the reactor MR was executed. For each cells of the dry reactor repository the type of the object and canister, the object size, weight, presence of markings, the technological status and suspension (the presence of corrosion, violating of the guy), the radiation characteristics of objects were determined. According to the developed regulations of the extraction works, repacking of the high level radwaste and the spent fuel in the made canisters and their moving to special repository of the spent fuel in the Center were executed.

Currently, design of decommissioning of the above reactors is developed, all the necessary allowances are received, documents for obtaining a license for decommissioning are prepare.

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