DISMANTLEMENT OF BUILDING STRUCTURES IN MR REACTOR HALL

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The article presents the technologies applied during the dismantlement of building structures and auxiliary systems in the central hall of MR research reactor at the site of NRC Kurchatov Institute. Contaminated structures and systems were mainly removed using remote methods and power-supplied equipment. The latter ones were selected based on safety requirements provided the compliance with the environmental standards that accounted for the location of the reactor in a densely populated area of the Moscow city. The project was aimed at providing the compliance of MR reactor hall with the criteria specified in the decommissioning designs and describing its final state. The paper summarizes the key results and recommendations on the radiation safety of RW management, as well as the lessons learned during the performed operations seeking for their further application at other facilities.

Keywords: *research reactor, radioactivity, radioactive waste, radioactive contamination, radiometric diagnostic methods, remotely controlled mechanisms.*

Introduction

Decommissioning of research reactors with some individual structures being contaminated to levels exceeding those of power reactors suggests potential occurrence of latent contamination at all stages of their decommissioning. Radioactive waste (RW) inventory identified at the stage of a comprehensive engineering and radiation survey (KIRO) and specified in the decommissioning designs basically involves the contaminated equipment. Other contaminated items and materials such as building structures of the reactor itself, hidden old active drains, hidden auxiliary contaminated pipelines and other elements were not indicated in the designs by state regulatory authorities. Dismantlement of these facilities and management of the radioactive waste generated at this work stage is considered as the main goal of the final decommissioning stage for MR and RFT research reactors of the Kurchatov Institute. In 2011—2015, MR reactor equipment and systems, as well as its experimental loop installations were dismantled [1—2]. Then the equipment from MR reactor core was dismantled and the graphite stack of the RFT reactor was removed [2—3]. Later, in 2016—2019 active drains in the process areas of the reactor were dismantled allowing to proceed to the dismantlement of building structures in the MR reactor hall.

Auxiliary systems and facilities located in the MR reactor hall

In addition to MR and RFT reactors themselves, MR reactor hall involved a spent fuel storage facility, MR reactor storage pool, RFT RW storage facility, cutting unit and some other units. Figure 1 presents the layout of the units subject to the dismantlement in the MR reactor hall.

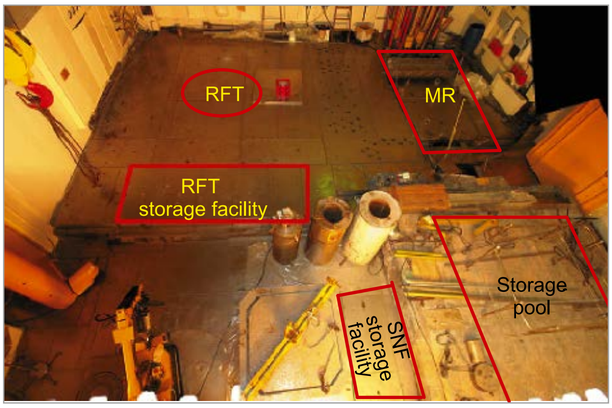

Figure 1. Layout of dismantlement areas in the MR reactor hall

Dismantlement of the above systems and decontamination of relevant building structures to the levels corresponding to the final state specified under MR and RFT reactor decommissioning designs was considered as the main goal to be accomplished during the operations that were to be performed in this premise [4].

Dismantlement of SNF storage structures

The dry SNF storage facility was located in the southeastern part of the central reactor hall close to MR reactor storage pool. It involved 30 vertical cylindrical cells arranged in 3 rows (10 cells in each row). The cells were built inside a concrete mass located below the floor level of the central reactor hall. Each row had 5 cells lined with 168 × 6 mm pipes and 5 cells lined with 140 × 6 mm pipes. The pipe lining was made of stainless austenitic steel X18H9T. The depth of the storage cells, i. e., the distance from the upper loading surface to the bottom of the cells, accounted for 4,900 mm. In a plan view, the storage cells were located at the nodes of a rectangular grid with a step of 200 × 200 mm. Each storage cell was sealed with an individual protective plug, the flange of which was attached to the loading surface and had a thickness of 30 mm.

Figure 2 presents the design features of the SNF storage facility and its layout in the central reactor hall.

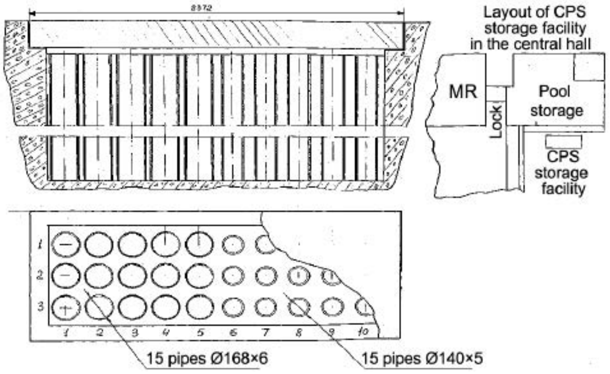

Figure 2. Design features of an at-reactor dry SNF storage facility and its layout in the central reactor hall

To identify the contamination levels, gamma-ray logging was performed and inner pipe surface activity in the storage cells was measured (by smear method). Table 1 presents the logging results whereas the measurements of pipe surface contamination are summarized in Table 2.

Table 1. Gamma-ray logging cartogram for SNF storage facility in the MR hall, μSv/h

Depth, m	Cell No (see Figure 2)			
	2–10	2–7	2–4	2–1
0	160	20	12	42
–1	35	5	5	44
–2	15	5	5	42
–3	15	7	7	20
–4	25	12	32	30
–4.4	100	-	42	70
–4.5	1,750	100	300	2,000

Table 2. Measured contamination of pipe surfaces (bottom) by smear method, β-part/cm²·min

Cell №	1	2	3	4	5
1	1,300	1,000	1,200	1,700	8,000
2	1,200	500	2,400	3,000	8,000
3	2,800	6,000	2,000	10,000	>1,000,000
Cell №	6	7	8	9	10
1	9,000	170,000	170,000	>1,000,000	>1,000,000
2	10,000	10,000	7,000	>1,000,000	23,000
3	30,000	35,000	3,100	11,000	60,000

Data from Table 1 and 2 show that pipe surfaces in some cells have high levels (over 10^6 β-part/cm²·min) of radioactive contamination.

Spent fuel storage facility was dismantled in 2 stages (Figure 3): the first stage involved partial dismantlement of biological shield blocking the access to the SNF storage facility; at the second stage, metal structures of the storage facility were dismantled, these structure along with the concrete scrap were segregated, the radioactive waste was packed into containers and removed to a storage area.

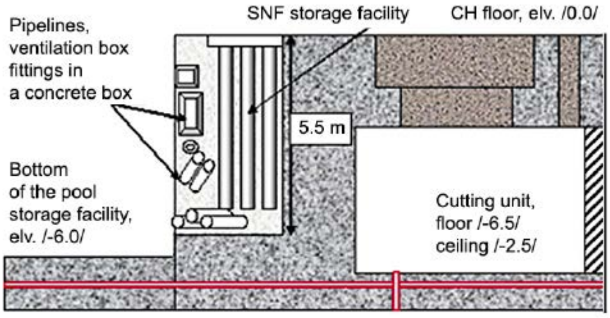

Figure 3. Layout of SNF storage facility and a cutting chamber

To dismantle the storage facility, BROKK-400 complex installed on the site at an elevation of 0.0 m from the side of the small gate and BROKK-330 installed on the deck in the storage pool at an elevation of -6.0 m was used. Depending on the operations performed, BROKK-330 was equipped with a hydraulic hammer, hydraulic shears, grapple or abrasive cutting machine, whereas BROKK-400 was fitted with a hydraulic hammer. Resulting solid radioactive waste (SRW) was packed into KMZ and KRAD-1.36 containers.

Since the inner surface of the pipes in the SNF storage facility was contaminated up to 10^6 β-part/(cm^2·min), measures were taken to prevent radioactive releases beyond the pipe lining during their dismantlement and fragmentation. The inner surface of the pipes was treated with a localizing composition VL using WAGNER installation. The treatment was performed during two shifts at an interval of 3 hours. Subsequently, fabric plugs impregnated with VL composition were inserted into each pipe.

Cell pipe plugging was followed by the dismantlement of the concrete matrix around the storage facility using BROKK-400 equipped with a hydraulic hammer. The operations were performed from a platform installed above the cutting chamber.

During the dismantlement of the concrete matrix surrounding the SNF storage facility, local ventilation system was used with the air tapped from the dismantlement zone and its further transfer to a purpose-designed ventilation box located close to the small gates of the hall.

Figure 4 presents the dismantlement stages of the spent fuel storage facility.

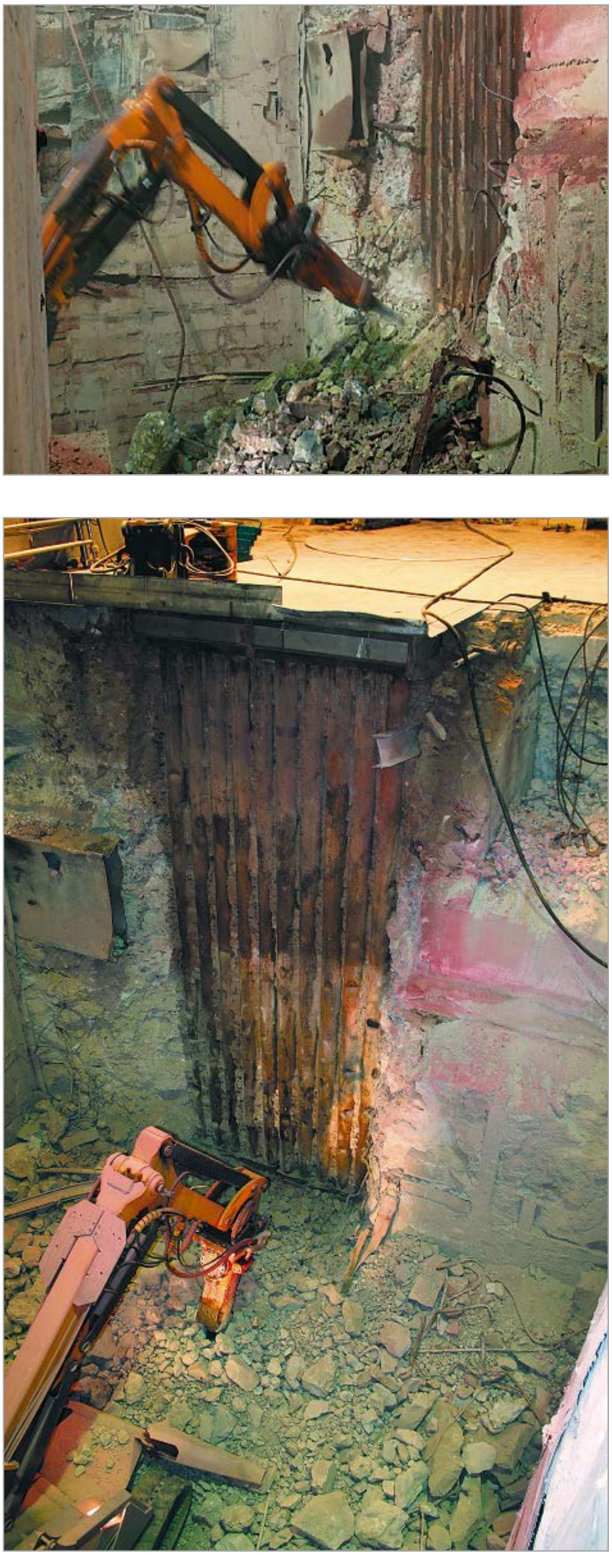

Figure 4. Dismantlement of the SNF storage facility

Reactor vessel’s lower support structure dismantlement

The lower support structure of MR reactor vessel involved 2 elements (Figure 5). A 30 mm thick stainless steel support plate was mounted at the bottom of the reactor pool shaft. In addition to

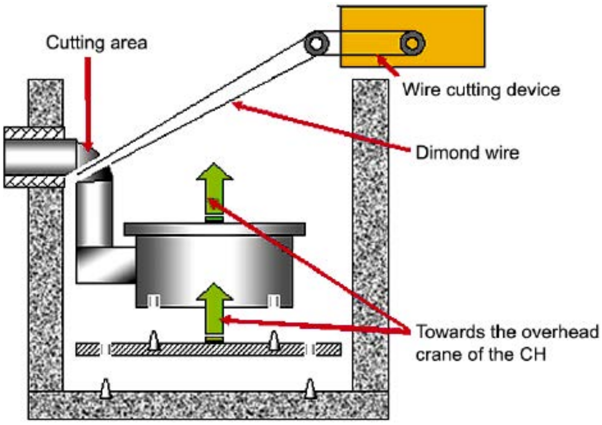

Figure 5. Dismantlement of the reactor's lower support of the reactor

being a primary structural member, the upper part was also designed as a collector of reactor pool's water circulation system. An overhead crane, plasma cutting, abrasive hand tools and a cable cutting installation were applied during the dismantling operations.

The upper part of the structure had a D400 pipeline branch with a pipe outlet going outside the reactor pool. A diamond wire cutting system was used to separate the reactor support from the shaft body. The cutting machine was located at the deck of the pool at an elevation of 0.0 m, the cutting itself was performed at an elevation of –8.0 m. When the pipeline was cut from the lining, the lower support structure was removed from the reactor pool using the bridge crane of the reactor hall. Figure 6 presents the stages in which the operations on the dismantlement of the reactor vessel's lower support were performed.

Dismantlement of the MR reactor pool lining

The reactor pool was lined with a concrete biological shielding having a rectangular shape in the upper part of the reactor tank (5.0 × 5.6 m and 4.3 m high) and a cylinder one in its lower part (3.6 m in its diameter and a height of 4.8 m) (Figure 7). The total depth of the pool accounted for about 9 m.

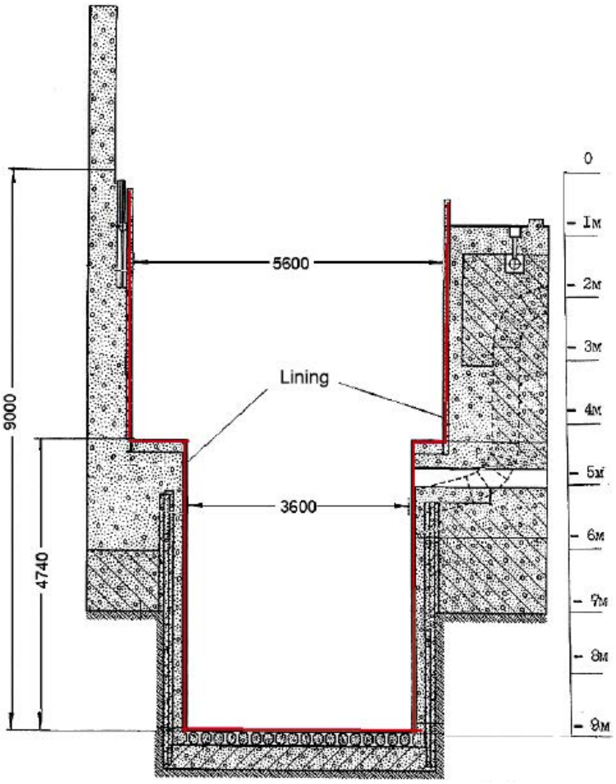

Figure 7. Pool of MR reactor

The reactor pool lining was dismantled using a plasma cutting device; in open access areas, the metal was cut using abrasive tools. Remotely controlled BROKK mechanisms (RCM) equipped with hydraulic hammers were used to cut the metal sheets from the biological shielding of the reactor [5]. Figure 8 demonstrates the operations on the dismantlement of the MR reactor pool lining.

A total of ~ 100 tons of metal (stainless steel) radioactive waste resulted from the dismantlement of the reactor pool lining.

Figure 6. Staged dismantlement of reactor vessel's lower support

Figure 8. Dismantlement of MR reactor lining: using a plasma cutter and RCM BROKK equipped with a hydraulic hammer

Dismantlement of MR reactor's biological shielding

A jackhammer installed on the RCM BROKK and a diamond cutting technology (Figure 9) based on the equipment designed by CEDIMA (Germany) was applied to dismantle the reinforced concrete massif constituting to the biological shielding of the MR reactor shaft.

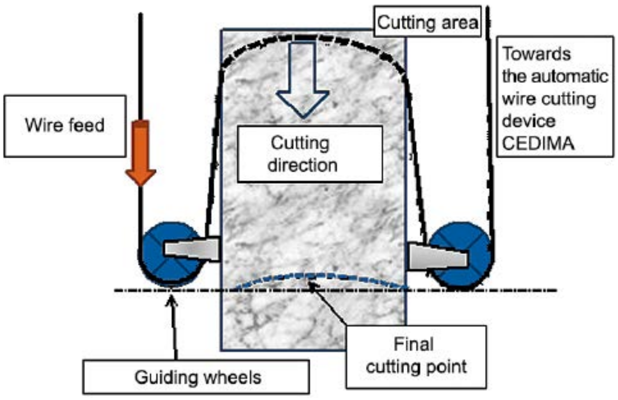

Figure 9. The workflow for wire cutting installation CEDIMA

When marking the cuts, the weight of the resulting reinforced concrete fragments was taken into account — no more than 5—6 tons. When the holes were drilled using a perforator with a concrete drill, a drill length of 1,200 mm was considered as the maximum one with an extension. A reverse loop method was used to cut 2—2.2 m-thick walls of the lock (Figure 9).

Two cuts — vertical and horizontal were normally required to cut out a unit with an average size of 1.5—2.0 m^3 (weight 4–5 tons) from the massif. Then the unit was lifted with one of its edges gripped by BROKK-330 hydraulic hammer and wedged from two or three sides. A belt sling with an adequate load capacity was inserted into the resulting gap, and the unit was reloaded by the bridge crane of the reactor hall onto a rail transport trolley, taken out of the building and subsequently moved to a temporary storage facility using a forklift.

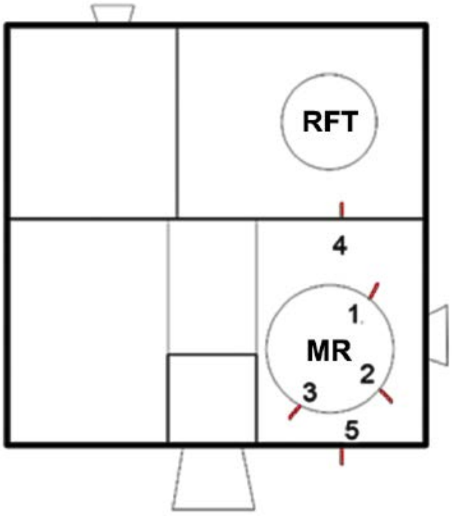

Figure 10. Layout of the wells in the concrete shielding of the reactor

5 wells (Figure 10) were drilled to evaluate potential RW generation inventory from the dismantlement of MR reactor concrete lining.

Table 3 presents the scanning results accounting for the above wells in the biological shielding of the MR reactor. Calculations show that in case of a radioactively contaminated item with ^{137}Cs being considered as the main dose-contributing radionuclide, a 1 µSv/h dose rate of gamma radiation inside a well drilled in a concrete shield would correspond to ^{137}Cs specific activity of 3 kBq/kg in the concrete.

Table 3. Gamma scanning results accounting for the wells drilled in the MR reactor shielding, µSv/h

Well №	Depth, m						
	0	0.1	0.2	0.3	0.4	0.5	0.6
1	9.5	2.3	0.7	0.4	0.2	0.2	–
2	25	18	3.3	0.45	0.45	0.2	–
3	10	1.7	0.65	0.45	0.2	0.2	–
4	10	6	0.8	0.6	0.2	0.2	–
5	12	9.5	10	11	10.8	8.4	4.3

Table 4 shows the evaluated ^{137}Cs specific activities in the concrete shielding.

Table 4. Evaluated ^{137}Cs specific activities in the concrete shielding, kBq/kg

Well №	Depth, m						
	0	0.1	0.2	0.3	0.4	0.5	0.6
1	29	7	2	1.2	0.6	0.6	–
2	75	54	10	1.5	1.5	0.6	–
3	30	5	2	1.5	0.6	0.6	–
4	30	18	2.4	1.8	0.6	0.6	–
5	36	29	30	33	32	25	13

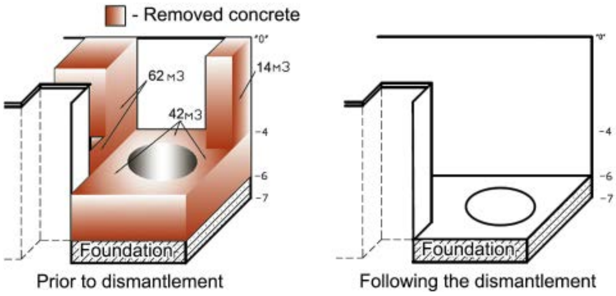

Figure 11. Layout of the dismantled part of MR reactor's shielding

Figure 12. Dismantlement of MR reactor's concrete shielding using a wire rope cutting tool

Figure 11 shows the layout of the dismantled MR reactor shieling.

Figure 12 presents the flowchart followed to dismantle the biological shielding inside the MR reactor.

Both concrete rubble and large fragments were generated during the dismantlement of the biological shielding. Concrete rubble was packed into transport containers and large fragments were transported to a designated temporary storage site awaiting subsequent fragmentation into smaller elements allowing to meet packaging requirements established for the transport containers.

The total amount of low- and intermediate-level waste from the dismantlement operations in the MR reactor hall amounted to 130 m^3 of non-metallic and ~ 110 tons of metal waste.

Conclusion

A number of specific aspects relevant for the RW management were identified during the decommissioning of MR and RFT research reactors of NRC Kurchatov Institute. First of all, the volumes of conditioned RW turned out to be higher than those specified in the designs. However, the use of clearly regulated measures, additional means of radiation control, remote radiation survey methods and remotely controlled tools applied during the dismantlement operations have provided the compliance with the radiation safety requirements. The methods used and the proposed engineering solutions may serve a basis for the development of decommissioning designs for other nuclear and radiation hazardous facilities.

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Bibliographic description

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