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ASSESSMENT OF THE DOSE LOAD DURING THE DISMANTLING OF THE WWR-M REACTOR

The WWR-M is a light-water-cooled and moderated heterogeneous research reactor with a thermal output of 10 MW. The final decommissioning planning is in progress now. The general decommissioning strategy consists of the dismantling and separate removal of the bulky elements as a whole (in one piece) without preliminary segmentation. The dismantling of the primary and secondary cooling loops is considered as one of the key tasks; a separate dismantling design has been developed. The baseline principles for the technical solution and safety are presented in the given paper. Results of the dose assessment showed that the work can be performed at a collective dose of less than 20 man-mSv.

Keywords: WWR type research reactor, decommissioning, cooling loops, dismantling, exposure dose.

1. Introduction

The research reactor WWR-M was designed and constructed in 1957 - 1960, the first criticality was achieved in February 1960. This is a heterogeneous water-moderated pool-in-tank type research reactor operating with thermal neutrons at a power level of 10 MW giving a maximum neutron flux of $1.5 \cdot 10^{14}$ $cm^{-2}s^{-1}$ at the core center. WWR-M is one of the oldest reactors of its kind in the world and has an excellent safety record. Today the reactor status is an operational installation. The Institute for Nuclear Research of the National Academy of Sciences of Ukraine (INR) in Kyiv is the operator and possesses all the required licenses and permissions for reactor operation. Since May 2001 INR has had a permanent license for the reactor operation, which will be in force until the reactor's final shutdown. The time-frame of the reactor's final shut-down has not been specified yet and the reactor operation is carried out now in accordance with the separate permissions issued every time for several years. The basis of such an extension is grounded by the revised operational Safety Analysis Report. The current timeframe of operation had been extended by the decree of the Regulatory Body and it will be in force until the end of 2023 and then new permission for the reactor operation should be issued.

At the same time in accordance with the acting national legislation, the forthcoming decommissioning of a reactor must be considered by the operator as early as possible, independently of a possible lifetime extension [1]. Requirements for the planning of the decommissioning of nuclear installations as well as for other activities directly related to the decommissioning (for example, spent fuel and radwaste management, licensing, etc.) are established by the Ukrainian legislation, match good international practice and comply with the recommendations of IAEA, ICRP, and other international organizations [2 - 5].

The current Decommissioning Concept for the WWR-M reactor foresees the strategy of immediate dismantling with the reference to the plans for further site use [6 - 8]. In accordance with the selected decommissioning strategy, the sequence of decommissioning stages was established alongside the scope of works and measures at these stages, their durations as well as the necessary conditions and infrastructure for the timely and effective decommissioning execution.

The final step of the decommissioning planning foresees the development of the detailed decommissioning project aimed at a timely preparation of all necessary documents for the planning and implementation of the decommissioning process as a whole. An internally-consistent cost-effective detailed decommissioning program with a set of substantiating and supporting documents will be a result of the given project. The mainframe of this project should be the dismantling design elaborated for the separate equipment, systems, and elements of the reactor. Analysis of the technical tasks has revealed that these components should be considered independently and, therefore, a specific design for each of them must be developed along with the selection of a suitable method for dismantling.

The specificity of the decommissioning process is the presence of residual radioactivity (radioactive contamination and activation) on some parts of the equipment and premises. Technological processes of the equipment dismantling are created on the basis of machine-building technologies (including moving operations), the final choice of the design technological solutions is defined after a thorough analysis of the compliance with radiation safety requirements, including the possibility of adaptation to these requirements. The essence of the radiation safety requirements is constant for all stages of the reactor's life cycle, including its decommissioning, namely, non-exceedance of the limits for the main doses of exposure to personnel and the population, as well as standards for emissions, discharges, and concentrations of radioactive substances in various natural environments.

The equipment dismantling technology includes the technological processes of direct equipment dismantling from the place, moving it to the area of processing, fragmentation, packaging of the segmented fragments, moving containers (packages) to the radioactive waste processing sites or to the storage facilities organized on the territory (or outside the boundaries) of the reactor site. It is also possible to partially or completely cut the equipment onsite and store it without cutting. The scope of the technology includes preparatory work on the technical organization of work areas and movement paths, power supply systems, ventilation, etc. Dismantling technology also includes measures and procedures for ensuring radiation safety, such as the use of radiation protection and sanitary barriers, dosimetric control, handling of secondary radioactive waste, etc.

The technical project for the dismantling of the WWR-M reactor includes three main tasks, namely, the removal of the reactor vessel, the dismantling of the cooling loops, and demolishing of the concrete structures. Each of these tasks requires a separate approach. When developing the technical solutions for these problems, available experience of similar work on reactors abroad has been used [9 - 14]. As a result, the design for the vessel removal was proposed at first [15, 16] and then the dismantling design for the cooling circuits was elaborated. The description of the technical solution with the relevant safety assessment is the subject of this paper.

2. Construction and layout of the cooling loops

Cooling of the reactor (removal of heat from the structural elements of the core and the reactor vessel) is carried out by the coolant, which is pumped through the core. The cooling system of the reactor is two-circuit.

The purpose of the *primary cooling loop* (PCL) is the provision of the coolant circulation from the reactor to heat exchangers. The primary loop coolant (distilled light water) is directed top-to-down through the core and beryllium reflector and then, by means of the outlet pipeline, is directed to pumps and heat exchangers (two parallel branches). The coolant is returned back by means of the inlet pipeline. The *secondary cooling loop* (SCL) is designed for cooling the primary loop. Cooling of the heat exchangers is carried out by means of a water-filled, closed loop composed of pipelines having different diameters alongside the pumps and cooling tower. The PCL *water cleaning system* (WCS) is employed for the removal of contamination (crud) from the primary loop water generated due to the contact of constructional materials with the coolant (corrosion and erosion of these materials and any fission products from failed fuel). Primary circuit water is cleaned by the filter system and consists of thermal-oxidative ion-exchange filters (IEF) (anionic and cationic filters). The cleaning rate is about 2.4 m^3/h.

The PCL, SCL, and WCS equipment are located in the pump-premise floor area about 100 m^2) below the reactor on the basement floor at a level of –5.4 m. The pump-premise walls are made from heavy concrete with a thickness of 1.0 m; the floor of 1.4 m thickness is the ground of the reactor hall. There are two technological openings between the pump premise and the reactor hall. The pump-premise is equipped with a crane with a lifting capacity of 1 t. The under-reactor niche is adjacent to the pump premise, where the bottom of the reactor vessel with the connecting flanges is located. The niche is attended by staff only for the control of the vessel and pipe-lines conditions. The niche dimensions are equal to 5.0 m (height) and 2.7 m (diameter). The layout of equipment in the PCL pump-premise is shown in Fig. 1.

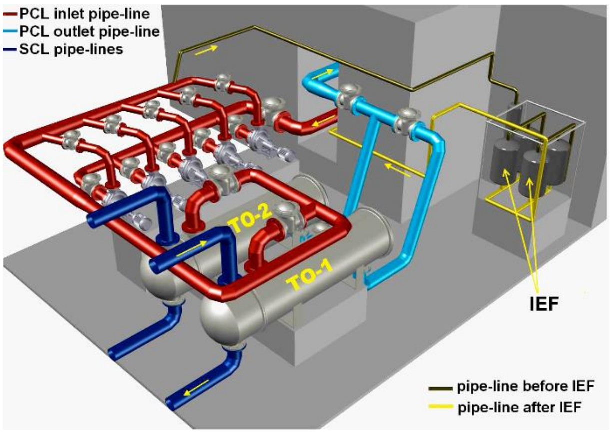

Fig. 1. Layout of equipment in the PCL pump-premise (TO-1, TO-2 – HE).
(See color Figure on the journal website.)

Two flange connections are located in the upper part of the niche below the reactor vessel at a height of 4.5 m. The flanges are tightened by the radiation resistant lining and fastened by the steel bolts M20 (12 for each flange). PCL inlet and outlet lines are routed to the pump-premise through the window in the concrete wall, which has dimensions 3.2·1.2 m and is piled with the brick wall. The PCL inlet and outlet lines are made from aluminum alloy (98 % Al) having a diameter of 370 mm. The valve gates D350 and D300 for the pipe-lines have a weight of 439 kg (manual control) and 468 kg (remote control, equipped with electromotor) correspondingly. Altogether 16 valve gates of different sizes and destinations are located in the PCL, namely, one ahead and behind the pumping unit (10 pieces); one ahead and behind the heat-exchangers (4 pieces); and one ahead and one behind the reactor vessel (2 pieces).

Heat-exchangers (*HE*) of the horizontal type are made from steel (Fig. 2). The main feature of such HE construction is the rigid piped bunch, i.e. the bunch is fastened inflexibly with the tube lattice and this prevents pipe displacement inside encasement. The SCL water pressure was maintained higher than in the PCL with the goal to prevent SCL radioactive contamination in the case of seal failure. The heat exchangers have a total heat removal area of 2 × 329 = 658 m^2. The heat exchangers are installed horizontally on a steel substructure that is cast into a concrete floor.

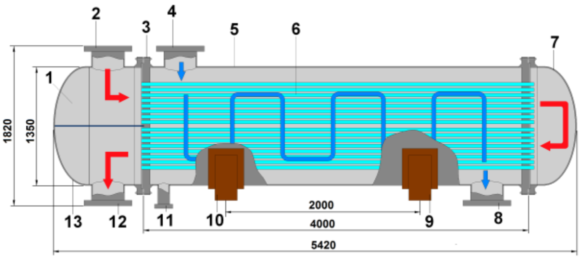

Fig. 2. HE: *1* – distribution chamber; *2* – PCL input flange; *3* – guide grid; *4* – SCL input flange; *5* – HE shell; *6* – tube bundle; *7* – detachable lid; *8* – SCL output flange; *9* – moving support; *10* – stationary support; *11* – drain flange; *12* – PCL output flange; *13* – detachable lid.

PCL pipelines are divided into pipelines that are cut off by valves from the reactor vessel and are ones that could not be cut off. Cutoff pipelines are made of stainless steel, and non-cutoff pipelines are made of aluminum alloy.

The water circulation in PCL is provided by *five pump units* (three are in operation; two others are as backup), each of them consisting of the pump and electric motor on a common bed plate. The stop valve is installed ahead of each unit; the check valve and stop valve are located behind the unit; this allows the unit to be switched off for repair and maintenance. The unit dimensions are 1910 × 675 × 724 mm; the weight is 837 kg.

The PCL water purification system is designed to remove impurities from the coolant, which arise due to contact with the structural materials (corrosion of these materials, nuclear fuel fission products). *The thermal-oxidative filter* is designed for water cleaning from colloidal and suspended particles. This filter is a cylindrical vessel made of stainless steel fulfilled with sorbent. *The unit of the IEF* is composed of 4 similar filters filled with resins. Each filter is a cylindrical vessel made of stainless steel (diameter of 330 mm; the height of 1700 mm); the resin is located in an internal storage cell.

The *SCL pipelines* are made of pipes having different diameters and lengths, which provide water circulation between heat exchangers and the water-cooling tower (located at a distance of 80 m from the reactor building) by means of the SCL electric motors. Only a small part of these pipes is located inside the PCL pump premise. The longest pipe in this system is a pipe with an outer diameter of Ø426 × 9 mm. The pipe is situated underground, the main purpose is to supply water by pumps from the cooling tower (located in the SCL pump-premise) to the heat exchangers and return water to the cooling tower for cooling.

The weight of each cooling circuit component is given in Table 1.

3. Radiation conditions

The PCL pump-premise is the most radiologically hazardous area. The initial estimations of the radiation conditions at the working area for the work planning were performed by means of the available information collected during normal reactor operation. For an actualization and clarification of the radiological data, an additional and more detailed inspection has been performed [17]. This inspection has consisted of direct dose rate measurements using portable devices, radiation mapping, and determination of the surface contamination by means of the wet smear sample analysis. These measurements were performed with all fuel elements removed from the core and the PCL completely drained. In addition, the information on radiation conditions obtained during the replacement of sections for the PCL pipelines was used [18]. Based on the results of the measurements, a map of the dose rate in this room was drawn up (Fig. 3).

The results of the radiological inspection revealed that the dose rate is predominantly due to the activation of both the vessel and in-vessel components materials, while the contribution to the dose rate from the internal contamination was minor.

The data show that the dominant fission product is ^{137}Cs and the dominant activation product is ^{60}Co, other radionuclides such as ^{125}Sb, ^{144}Ce, ^{152}Eu, ^{65}Zn, ^{154}Eu, and ^{110m}Ag are present in much smaller

Table 1. **Composition and weight of the cooling loop's components**

Component part	Weight, kg
PCL	
Main pipelines (different diameters and lengths)	5695
Circulation pump units (5 pieces)	837 × 5 = 4185
Stop valves: – Dn200 (10 pieces) – Dn300 (5 pieces) – Dn350 (1 piece)	 212 × 10 = 2120 650 × 5 = 3250 600
HE (2 pieces)	7694 × 2 = 15388
Cooling pipelines (different diameters and lengths)	1800
By-pass purification system: – pump unit – pipelines O57 – stop valves Dn50 – housings of IEF	 277 150 110 800
Emergency cooling system: – pump units (4 pieces) – pipelines Dn50	 200 × 4 = 800 300
SCL	
Main pipelines (different diameters and lengths)	39222
Circulation pump units (3 pieces)	773 × 3 = 2320
Stop valves: – Dn300 (3 pieces) – Dn400 (9 pieces) – Dn200 (10 pieces)	 344 × 3 = 1032 533 × 9 = 4797 183 × 10 = 1830

amounts, however, it is reasonable to assume that ^{90}Sr is also present at approx. in the same amount as ^{137}Cs. The measured ratio of the cobalt and cesium activities lies in the range of 60 : 40 to 90 : 10 %. The alpha-spectrometry results on smear samples showed that uranium isotope contamination is practically negligible (~10^{-4} Bq/cm^2).

Since the majority of the radionuclide contaminants are beta-gamma emitters, they can be easily detected and measured by beta-gamma counting and gamma-spectrometry. The total surface beta-contamination within the working area lies in the range of 80 to 600 beta-part./(cm^2·min).

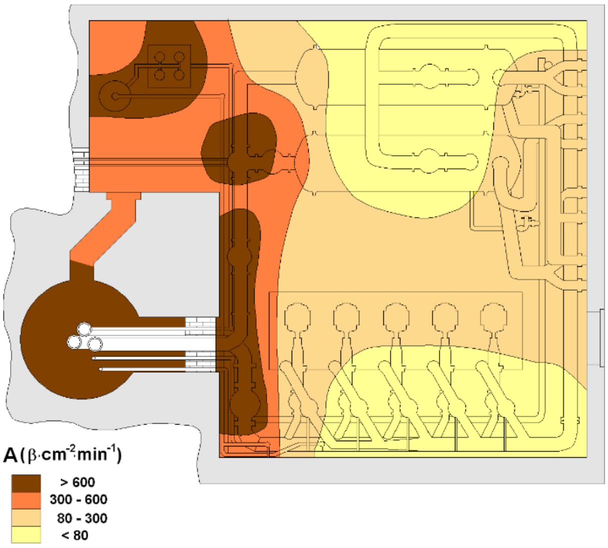

Fig. 3. Dose rate map.
(See color Figure on the journal website.)

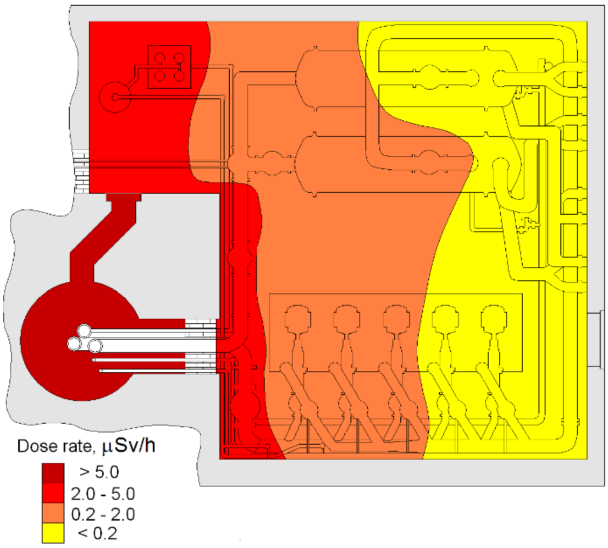

Fig. 4. Contamination map.
(See color Figure on the journal website.)

The outlined map of the radiation measurements made during characterization formed the necessary basis of information to provide a description of the health physics conditions and a good overview of the parts that had been contaminated (Fig. 4). Surface contamination on the SCL components has not generally been detected.

4. Schedule of the dismantling activities stage-by-stage

4.1. General considerations

It is clear from the PCL layout that the dismantling works should be performed in a confined space where protective shielding and remote operation cannot be provided. Therefore, proper work planning and implementation of effective radiation protection is the most important feature of this project.

The dismantling strategy consists of the following: a) dismantling to be performed “from top to bottom” for the preservation of stability; b) dismantling and removal of the separate bulky elements should be performed as whole pieces, where possible, without preliminary segmentation; c) subsequent segmentation of such elements, if necessary [19 - 21].

Dismantling of the reactor is to be carried out in three main stages. The first stage includes dismantling the equipment around and inside the reactor and biological shielding. The second stage includes the dismantling of the PCL and SCL equipment. The demolishing of the biological shield is carried out in the third stage. Consequently, stage one should be completed first for the realization of stage two. Previously, a conceptual project for the dismantling of the PCL was proposed [22], and then this project was revised and detailed.

Dismantling of the PCL includes:

– dismantling of two pipeline segments;

– removal of the HE;

– dismantling of the primary circuit components;

– dismantling of the ion exchange and thermal-oxidative filters.

The complex of dismantling works is divided into two parts: 1) preparation for dismantling; 2) actual dismantling, which includes removal of the residual materials.

Preparation for dismantling includes:

– inspection of structures to be dismantled;

– installation of temporary fences to prevent dust, garbage, pollution;

– preparation of the access paths;

– delivery and installation of equipment, preparation of equipment for temporary fastening of structures during dismantling.

– removal of the operation media from the closed circuits;

– electrical disconnection;

– removal of the pump grease;

– removal of the combustible materials that are not needed for dismantling works;

– opening of the hatches to the reactor hall;

– decontamination of the external surfaces;

– additional survey for the actualization of radiation conditions;

– testing of the tools and equipment;

– installation of additional lighting, local ventilation, and dust-depression mean.

The dismantling process itself includes:

– dismantling of the equipment (in its entirety, disassembling into elements, segmentation into fragments, etc.) from the regular place;

– removal of the separated structures, inspection, sorting, stacking;

– transportation of the dismantled equipment, its elements, fragments in containers or without containers between areas within the reactor building;

– segmentation (shredding) of equipment, its elements or fragments into smaller fragments;

– separation of materials suitable for reuse;

– shipment and transportation of materials from places of disassembly to places of their further use.

All dismantling works will be carried out in sequence, which does not lead to an increase in the influence of any negative factors. During the dismantling works, the main attention will be drawn to: a) the strength and stability of the structures remaining after the dismantling of the supporting and adjacent elements; b) preventing structures from falling when their fastenings (bolts or welding) are released.

4.2. Dismantling of two separate pipeline sections

Dismantling of two separate sections of the inlet and outlet pipelines (Fig. 5), which are directly connected to the reactor vessel, is allocated to a separate task. This is a challenging technical task due to the necessity of handling the large size components with complex geometries under conditions of high-level radiation fields, and therefore, it required detailed planning aiming to reduce staff exposure. First, the brick wall in the niche passage will be demolished to provide access to the beneath-reactor niche. Then both pipelines will be disconnected from the reactor vessel. During the next step, these pipes will be disconnected from the valves and fastening elements. The transportation of these segments to the reactor hall will be carried out by crane through open hatches.

4.3. Extraction of HE

The heat exchangers can be removed as one piece. This sub-task can be solved by means of a technological hatch between the pump premise and the reactor hall. First, the heat exchanger detachable bolted lids will be removed and transferred without any difficulties. The internal pipes, on the other hand, will not be so easy to remove. The heat exchangers will then be dismantled from their base support in order to be lifted intact by a crane. Torch-cutting methods (oxy/acetylene) may be used, if required, for dismantling. Mechanical saws or hand tools may also be used. Before the removal, all the openings will be sealed. The last operation is the lifting of the heat exchangers by means of a bridge crane to the reactor hall (Fig. 6) for the segmentation and packaging and then with their subsequent transportation to the disposal site.

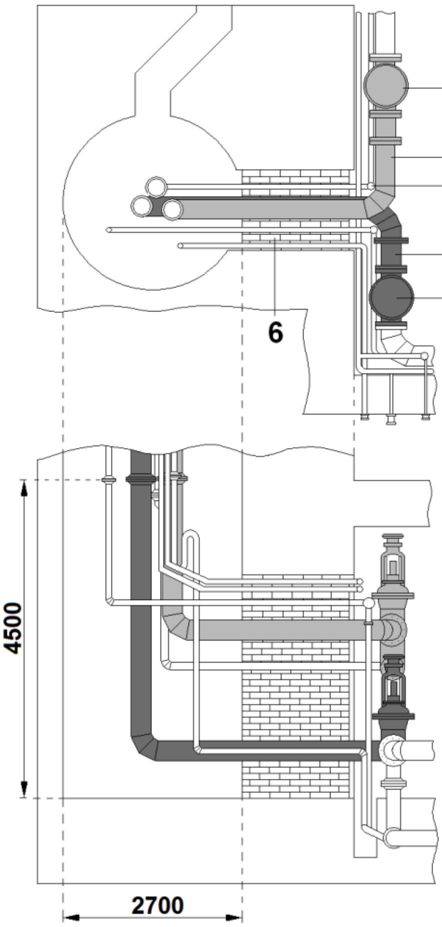

Fig. 5. The layout of the PCL pipe lines: *1* and *5* – valve gate; *2* – outlet line; *3* – valve gate on the water cleaning line; *4* – inlet line; *6* – brick wall in the niche passage.

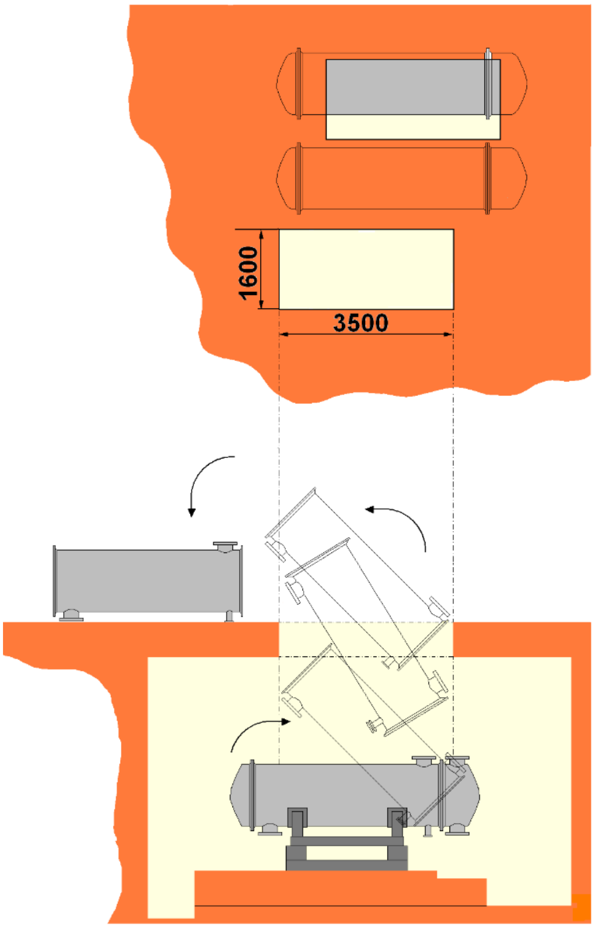

Fig. 6. Sequence of the HE extraction.
(See color Figure on the journal website.)

It was decided that the pipes from the heat exchangers, which have surface contamination, will not be cleaned. This decision was made on the basis of trials with the selected pipe sections, where some cleaning was probed. This turned out to be an inefficient and ineffective method in terms of resources. All the pipe segments could fit into containers.

4.4. PCL pipes and gates dismantling

The PCL components that will be dismantled can be categorized as follows: pipes, piping hangers, valves (check and cut-off valves), pumps, supports, instrument gauges, flanges, screws, and gaskets. The first actions should be taken before the cutting on disassembling the mentioned equipment wherever possible so as to reduce the number of cutting points. Specifically, the isolation and cut-off valves, pumps, and supports will be unscrewed and disassembled from the system without cutting. Any liquids or sludge which is present in the piping should be drained and tested to determine the final utilization method. Liquids or sludge should be emptied into drums, capped, and packaged for removal. The PCL pipes, after disassembling will be cut into pieces to the dimensions required for effective decontamination and/or characterization clearance. The pipes will be cut into pieces of 2 - 3 m in length, since this size will enable a relatively easy transfer of the segments. The piping will be cut by means of circular mechanical saws. Lining sheets will be placed on the ground and on the wall around the cutting location when it is considered necessary for contamination control. During cutting, the operator will perform according to a “cutting map” showing where to cut and how to dismantle the pipe pieces.

Cutting procedure planning will have to consider:

– shape and geometrical dimensions of the component;

– weight, supporting structures, transport equipment;

– material composition;

– removable surface contamination;

– non-removable surface contamination;

– radiation field in the working area;

– dimensions of the cutting volume.

Being part of the PCL, the pipe system itself is contaminated inside. Items that could not be cleared are defined as radioactive waste and disposed of. All items that could be cleaned on the site are disposed of as regular scrap. Since the pipe dimensions will be small and the volume is insignificant, it is decided to dispose of the pipe system as radioactive waste.

4.5. Filters removal

The WCS (thermal-oxidative and IEF) are connected to the PCL. These objects will be cut off in order to be lifted by the crane. The filters are shielded by lead blocks, which will be removed in advance. Torch-cutting methods (oxy/acetylene) will be used to disassemble the columns from their support base. Mechanical saws, air-powered saws, or hand tools may also be used.

4.6. SCL pipes and gates dismantling

Most of the SCL pipelines are located outside the pump-premise in a clean area, so it will be dismantled using the conventional methods without any need for radiation shielding.

4.7. Segmentation

Considering the significant volumes of the generated radwaste and the presence of large elements, it is necessary to create technologies for waste fragmentation, as well as technologies for recycling the contaminated structures (mainly metal) [23].

Prior to the start of dismantling works, priority infrastructure development measures will be implemented to ensure dismantling and decontamination works, as well as safe processing and storage of RAW.

The organization of the RAW processing area in the reactor hall provides for:

– arrangement of sites for the temporary storage of large-sized contaminated equipment;

– building up the installation for fragmentation of equipment with a circular cutting machine;

– arrangement of the decontamination site;

– commissioning of the facility for radiation inspection of material release;

– arrangement of sites for the temporary storage of clean equipment.

The cutting area will be arranged in the reactor hall (Fig. 7). Size reduction will be carried out in situ; then the segmented parts will be transferred to the interim storage. The PCL components that are difficult to be further segmented, such as the heat exchangers, will be removed intact and temporarily stored in an appropriate place in order to be appropriately managed in the future.

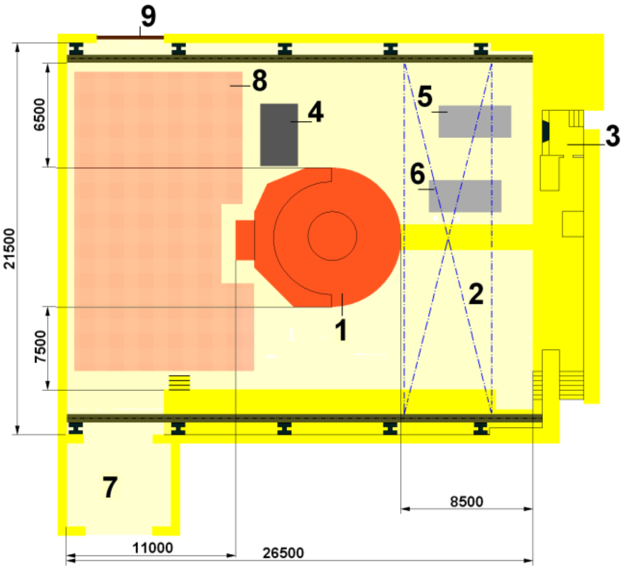

Fig. 7. Reactor hall: *1* – biological shielding; *2* – bridge crane; *3* – crane cabin; *4* – at-reactor cooling pond (SF storage); *5*, *6* – technological hatches to the PCL pump-premise; *7* – tambour to BV-2; *8* – cutting area; *9* – additional gate. (See color Figure on the journal website.)

5. Safety provision at the dismantling

5.1. Exposure dose estimation

It is clear from the PCL layout that the dismantling works should be performed in a confined space where protective shielding and remote operation cannot be provided. Therefore, proper work planning and implementation of effective radiation protection is the most important feature of this dismantling project [24, 25]. From the point of view of radiological protection, the dismantling of any equipment presents a series of features that range from the changing nature of the radiological and conventional risks to the performance of work on equipment that has never before been touched.

The radiation protection of personnel during dismantling is based on the same radiation protection principles as applied during reactor operation with the objective of ensuring proper implementation of the ALARA principle [26]. These principles are: prior determination of the nature and magnitude of radiological risk; classification of workplaces and workers depending on the risks; implementation of

Table 2. **PCC dismantling tasks**

Task	Work time, h	Number of exposed individuals	Work force, man·h	Maximal estimated external dose rate, μSv/h	Individual dose per individual[a)], μSv	Collective dose, man-μSv
Dismantling of two separate segments of pipelines						
Additional radiological survey	6	6	36	100	600	3600
Preparation for the dismantling works	4	9	36	100	400	3600
Demolishing of the brick wall	4	7	28	200	800	5600
Removal of the construction garbage	3	6	18	20	60	120
Dismantling of the valve gates 301 and 305	4	4	16	30	120	480
Dismantling of two pipeline segments	6	4	24	100	600	2400
Successive lifting of all components to the reactor hall	2	4	8	2	4	16
Sub-total:	29		166		2584	15816
HE extraction						
Removal of pipes at the upper part of both HE	12	4	48	10	120	480
Unpiping at the lower part of both HE	6	4	24	12	72	288
Detachment of the detachable lids and removal to the reactor hall	10	4	40	5	50	200
Separation of HE from the supporting piers	4	3	12	6	24	72
Lifting of HE to the reactor hall	4	3	12	1	4	12
Dismantling of the supporting piers	10	4	40	5	50	200
Sub-total:	46		176		320	1252
Pipes and gates dismantling						
Dismantling of the input pipes and valve gates	16	4	64	8	128	512
Dismantling of the output pipes and valve gates	25	4	100	10	250	1000
Dismantling of the drainpipes and valve gates	10	3	30	5	50	150
Dismantling of the pipe supports and mountings	8	3	24	4	32	96
Dismantling of the pumping units	15	4	60	5	75	300
Dismantling of the deaeration circuit	10	3	30	3	30	90
Dismantling of the auxiliary pipes	10	3	30	2	20	60
Successive lifting of segmented parts to the reactor hall	16	4	64	0.6	9.6	38.4
Sub-total:	110		402		594.6	2246.4
Filters removal						
Dismantling of the filter drain-pipes	8	3	24	6	48	144
Removal of the thermal-oxidative filter from the concrete frame	3	4	12	8	24	96
Removal of the IEF (4 pieces)	8	3	24	6	48	144
Removal of the filter frames and shielding	4	3	12	0.9	3.6	10.8
Successive lifting of segmented parts	16	4	64	0.8	12.8	51.2
Sub-total:	39		136		136.4	446
Total:	224		880		3635	19760

[a)] On assumption that one person took part in all dismantling works.

control measures; monitoring of zones and working conditions, including, if necessary, individual monitoring. The setup of the radiation protection system at the dismantling will be a logical continuation of the currently existing system [27]. This system will be rearranged and adapted for the needs resulting from the nature and content of decommissioning works.

The current Ukrainian legislation limits the occupational exposure of staff to up to 20 mSv/year. Single exposure up to 50 mSv/year is allowed provided the average annual effective dose over 5 years does not exceed 20 mSv/year. The control levels of the reactor staff exposure were established in accordance with the legislative requirements, features of technologies, and experience of the operational works at the reactor as well as on the basis of the achieved level of radiation safety. These values are established at a level below the relevant dose constraint for the execution of operational radiation control in the premises, namely, the value of 14 mSv/year is accepted. At the same time, exposure up to 4 mSv/shift is permissible if necessary.

Analyses of the possible staff radiation exposure during dismantling operations were performed using the following scheme:

– work breakdown into individual activities;

– estimation of required working times and staff;

– estimation of local radiation fields for each activity;

– collective dose calculation.

Doses incurred during dismantling have been estimated by considering the duration of each activity to be undertaken, the number of occurrences when it is performed, and the dose rate. The estimated doses from each dismantling operation are summarized in Table 2.

As can be seen from Table 2, the collective dose for the dismantling works has been estimated at less than 20 man-mSv. This is a conservative estimate, i.e., the work planning was performed taking into consideration the worst estimates regarding the maximum dose rates, the maximum working time, and the minimum distance from the source of radiation. In practice, the staff can complete work in less time and at larger distances than estimated, thus minimizing occupational exposure according to the ALARA principle and reducing the collective dose. The total dose for a hypothetical person would be less than 4 mSv, provided that person participated in all the dismantling work. The assessment results showed that the radiological criterion of 14 mSv/year for the effective dose will be met during dismantling.

5.2. Emergency cases

Any dismantling activity covers a lot of different operations related to the cutting and lifting of the segmented parts of equipment. Dropped load accidents can occur during various stages. Consequences of the equipment falling down, as well as tools or segments, can vary significantly due to different sizes, weights, drop height, and contamination involved.

The following main hazards with potentially significant consequences associated with the dismantling operations were identified:

– drop of heavy loads; this is one of the most common hazards creating the risk of structure damage, airborne release, worker injury, or fatality. Falling heavy items can damage building structures;

– failure of the lifting mechanisms when the load is on the crane hook.

The first one can be caused, for example, by the rope failure or malfunction of the brake gear. The damage repair can be performed by the shift on duty (4 persons) taking about 1 hour and additional personnel is not necessary. The second one can be caused by power disconnection or the breakdown of the electric motor. The availability of the electrician on duty is foreseen for such a case; approximately the same time will be needed for the fault clearing.

6. Conclusions

The design for the dismantling of the cooling circuits of the WWR-M reactor has been developed. Dismantling of components in the pump-premise is a challenging task due to heavy weight, large dimensions, and tight area. This task requires detailed planning in order to reduce the exposure for the staff involved. The proposed design is based on an approach that foresees the dismantling and removal of the separate bulky elements as a whole, without preliminary segmentation. Proper work planning and implementation are considered crucial to achieving this goal. Radiation protection performance is based on the application of appropriate measures in order to prevent unnecessary exposure of staff and this allows reduction of the collective dose. The conservative safety assessment has been performed to substantiate the organizational and technical solutions intended for the dismantling of coolant circuits. The analyzed here case is considered acceptable because the maximum expected exposure dose load received during the planned time is less than the maximum value of the allowable dose set by current regulations.

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ОЦІНКА ДОЗОВОГО НАВАНТАЖЕННЯ ПРИ ДЕМОНТАЖІ РЕАКТОРА ВВР-М

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Реактор ВВР-М є гетерогенним дослідницьким реактором з легководним охолодженням і сповільнювачем з тепловою потужністю 10 МВт. Наразі триває остаточне планування зняття з експлуатації. Загальна стратегія зняття з експлуатації полягає в демонтажі та окремому вилученні громіздких елементів цілими без попередньої сегментації. Демонтаж первинного та вторинного контурів охолодження розглядається як одне з ключових завдань; розроблено проект окремого демонтажу. У даній роботі представлено основні принципи технічного рішення та безпеки. Результати дозової оцінки показали, що роботи можна виконати при колективній дозі менше 20 чол-мЗв.

Ключові слова: реактор типу ВВР, зняття з експлуатації, контури охолодження, демонтаж, доза опромінення.

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