PROGRESS IN THE DECOMMISSIONING PLANNING FOR THE KIEV'S RESEARCH REACTOR WWR-M

by

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The Kiev's research reactor WWR-M has been in operation for more than 50 years and its further operation is planned for no less than 8-10 years. The acting nuclear legislation of Ukraine demands from the operator to perform the decommissioning planning during the reactor operation stage as early as possible. Recently, the Decommissioning Program has been approved by the regulatory body. The Program is based on the plans for the further use of the reactor site and foresees the strategy of immediate dismantling. The Program covers the whole decommissioning process and represents the main guiding document during the whole decommissioning period, which determines and substantiates the principal technical and organizational activities on the preparation and implementation of the reactor decommissioning, the consequence of the decommissioning stages, the sequence of planned works and measures as well as the necessary conditions and infrastructure for the provision and safe implementation.

Key words: research reactor, decommissioning, dismantling, radwaste management

INTRODUCTION

Decommissioning is the final stage of the nuclear installation lifecycle and implemented by means of the demolition or diversification of the buildings and constructions with the removal of radioactive substances and return of the site for restricted/unrestricted use. At that, unconditionally, the protection of human and environment against the radiological and man-caused impacts should be provided. Decommissioning is a complex process including the decontamination, equipment dismantling, demolition of constructions and radwaste management.

Requirements for the provision of activity on the decommissioning of nuclear installations as well as the activities directly connected with the decommissioning (for example, the spent fuel and radwaste management, the licensing, *etc*.) are established by the acting legislation of Ukraine. The operator of a nuclear installation at the different stages of the lifecycle should prepare itself for the forthcoming decommissioning. During the operation, the Decommissioning Program (DP) should be developed by the operator and must be approved by the regulatory body.

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The research reactor WWR-M is still in operation. The Institute for Nuclear Research (INR) of National Academy of Sciences (NAS) of Ukraine is the reactor operator and has all the required licenses and permissions for the reactor operation. Recently, the DP for the reactor WWR-M has been approved by the regulatory body. This paper presents both the prerequisites and main features of the DP as well as the basic directions of further decommissioning planning aimed at the timely preparation for the reactor decommissioning.

REACTOR CURRENT STATUS

The WWR-M reactor is the heterogeneous water-moderated pool type research reactor operating with thermal neutrons at the power of 10 MW_t, giving a maximum neutron flux of 1.5 10^{14} $cm^{-2}s^{-1}$ at the core center. The reactor is equipped with 9 horizontal experimental channels, a thermal column, and 13 vertical isotope channels inside the beryllium reflector. It is possible to install 10-12 vertical channels in the core. The reactor general layout is shown in fig. 1.

The WWR-M reactor was commissioned on February 12, 1960. There was not any single accident

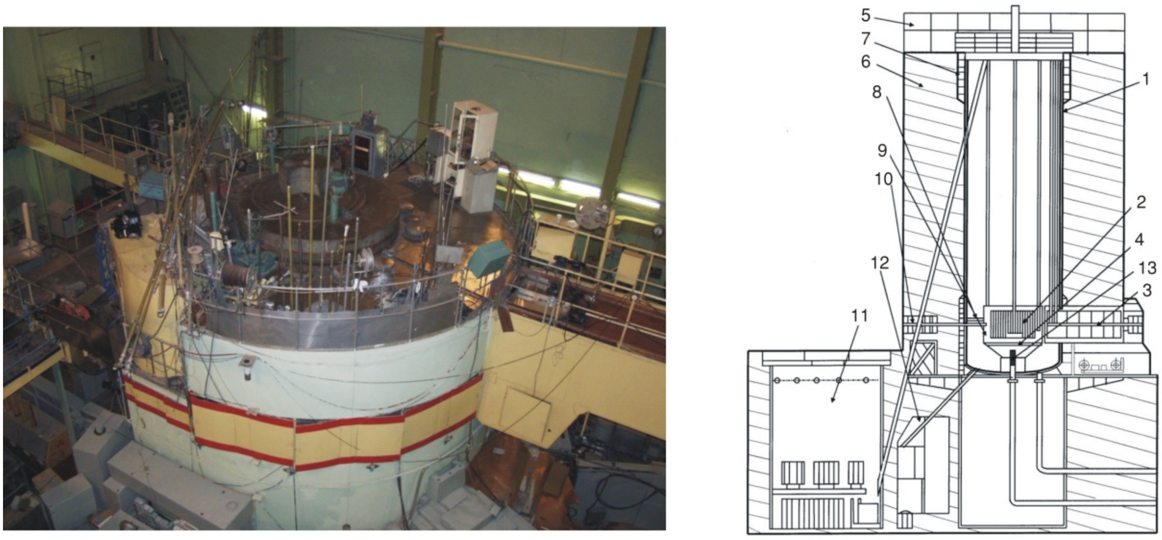

Figure 1. General view and reactor vertical cross-section
1 – reactor vessel; 2 – reactor core; 3 – thermal column; 4 – top (guiding) and bottom (supporting) grid of core; 5 – reactor head; 6 – biological shield (heavy concrete); 7 – cast iron; 8 – grid for water flow smoothing; 9 – beryllium reflector; 10 – horizontal channel; 11 – SNF storage; 12 – "hot-cell"; 13 – filter

situation with the exceeding of norms and conditions of the regular operation for 50 years of the reactor operation. There have been no contaminations above the established levels by radionuclides and aerosols for the free access premises through the long-term reactor operation. Since May 2001 INR has the permanent license for the reactor operation. This license will be in force until the reactor final shut-down. The reactor final shut-down term is not yet established and the reactor operation is carried out now in accordance with separate permissions for some years. The basis of this permission extension is the revised operational Safety Analysis Report, which must be approved by the regulatory body. By a recent permission the reactor operation has been extended to 2014 with the possibility of further extension.

Surveys performed since 1988 provide the evidence that there are no negative changes beyond the design limits in the reactor vessel and primary circuit components. The part of the reactor's elements, equipment and systems has been in operation since the reactor commissioning in 1960. Modernization of the reactor systems and replacement of specific equipment aims to increase the safety of the reactor operation. All reactor systems have been upgraded completely or partially during the long reactor life.

In July 2004, the NAS of Ukraine approved The Strategic Plan for the use of research reactor WWR-M of the INR [1]. The main goal of this plan is the work co-ordination between the operator, researchers, and users from different organizations; determination of the user's needs and installation capabilities; provision of the reactor sustainable operation by means of stepwise implementation of the planned strategic tasks. The plan determines the strategic goal as the provision of the reactor operation until 2015. This term is being reconsidered for a further extension.

OVERVIEW OF THE REGULATORY FRAMEWORK

As a whole, the normative-legal basis of Ukraine is sufficient for the decision on present-day tasks connected with the provision of safety and protection of the personnel, population, and environment at the decommissioning of nuclear power platns (NPP) and research reactors (RR) in Ukraine. In this area the normative-legal basis corresponds to the international practice, accounts the recommendations of the IAEA, ICRP, and other international organizations [2, 3].

The main normative document [4] contains the definition of term "decommissioning": *Decommissioning means such set of measures after nuclear fuel removal that excludes the operation of the facility in purposes for which it was constructed and provides personnel and the public safety and the environment security.*

Further to this definition, the goal, scope and possible ways are determined.

Decommissioning of the facility is undertaken to exclude the possibility of further use of the given facility with the purposes for which it was constructed.

Decommissioning of the facility is undertaken for the achievement of such site conditions that eliminate any restriction on the site use. It provides for:

– stage-by-stage removal of the sources of ionizing radiation being subject to regulatory control, and

– abolishment of the restriction regime and reduction of radiation monitoring in the supervision zone and sanitary-protective zone of the facility.

The mentioned document [4] establishes the following stages of decommissioning: *final closure, preservation, long-term storage, and dismantling.* Decommissioning of the facility is preceded by the stage of *termination of operation*. The main objective of this stage is the facility transformation to the condition, which corresponds to the absence of nuclear fuel on the site or fuel location within the site boundaries except inside nuclear fuel storage facilities, which are aimed for long-term safe storage. The necessity of each separate stage and sequence of stage priorities should be defined and substantiated during development of the decommissioning strategy. The stages of facility decommissioning can be implemented either completely or partially for different part of the facility according to the chosen strategy.

PLANS FOR THE SITE USE

Currently, due to some objective reasons, it is impossible to plan further specific use of the site and reactor building. In addition to the reactor facility, there is the isochronous cyclotron U-240 and the electrostatic generator EG-10 on the INR site. The design lifetimes have not been established for these research installations and, therefore, they will be in operation for a long time, even after the completion of decommissioning of RR WWR-M. A further operation of the cyclotron and generator will require continuing the restriction regime on the institute's site independently of the state and conditions of the reactor's site.

The reactor is equipped with two types of "hot cells", namely, the "heavy hot cells" allowing the investigations of samples with the activity of up to 25000 Ci* and the "light hot cells" (up to 250 Ci), the latest ones are shown in fig. 1. The "heavy hot cells" building is adjacent to the reactor building. These "hot cells" do not belong to the reactor administratively, but they are used by the Radiation Material Science Division of the INR. It seems to be reasonable to continue the "hot cells" operation after the completion of the reactor decommissioning.

Therefore, it is foreseen to use the reactor's building with the "hot cells" as a separate laboratory for the development and application of radiation technologies, after the transfer of the reactor building, the part of existing infrastructure for the reactor operation provision and the reactor auxiliary building to this laboratory. The directions of utilization of this laboratory will be determined during next few years taking into account the specific needs of industry, in particular, the needs of nuclear power industry of Ukraine.

It is necessary to mention that some time ago the possibility to construct a new research reactor on the existing site near the WWR-M reactor was considered. In spite of the obvious advantages for such a decision, the construction of a new reactor is entirely impossible today. This is due to the stronger restrictions of acting legislation concerning the location of new nuclear installations. Therefore, in the case the construction is accepted, a new research reactor will be located outside Kiev [5, 6].

DECOMMISSIONING STRATEGY

WWR-M reactor was designed and constructed in the late 50's and the decommissioning was not considered at the design stage. Preliminary decommissioning planning was initiated in the document "The Decommissioning Concept of the RR WWR-M of INR NASU" [7], where possible approaches for the future decommissioning were outlined in general, along with two variants of the decommissioning strategy which were considered – (a) immediate dismantling of the reactor during 3-4 years; (b) deferred dismantling, which would be realized after the safe storage period during 30 years.

The next step of the decommissioning planning is the DP [8-10], which was the further development of "The Decommissioning Concept". The goal of the DP is to determine the main organizational and technical measures directed to the preparation for decommissioning and implementation of decommissioning of the WWR-M. It is intended to give detailed and redundant information about the planned decommissioning activities. The DP also addresses social, economic, and environmental problems to be solved. The DP was developed considering the IAEA's recommendations and worldwide experience from countries which already perform the decommissioning of theirs research reactors [11-13].

The DP covers the whole decommissioning process and it is the main guiding document during the decommissioning period. The DP is a subject to revision by established order at least every 5 years in correspondence with the status of its practical implementation as well as when it will be necessary accordingly to the changes of requirements of the acting legislation, the development of technique and technologies, the changes of financial-economical and social-economical conditions. There is no the legal requirement for the five year period for revision, therefore, such duration was determined from our experience and defined by the actual needs of decommissioning planning. The various detailed decommissioning plans/projects will be developed from the strategy presented in the DP.

* 1 Ci = 3.7 10^{10} Bq

Considering the unique features of the WWR-M reactor, the DP is directed to the solution of the following tasks:
– comprehensive and timely planning of all kinds of the decommissioning activity,
– use of the modern methods for the management of all kinds of the decommissioning activity,
– use of the novel decommissioning technologies and technical tools,
– implementation of the safety norms, rules and standards for the personnel protection,
– use of the permanently acting system for the collection, treatment, and storage of information having a significant impact on the decommissioning process,
– provision for the impact gradual decreasing on the personnel, population, and environment from the WWR-M by means of the phased implementation of activities,
– minimization of the radwaste generation, treatment, and final disposal,
– consecutive release of the reactor's site from the ionizing irradiation sources, which are a subject of regulatory control, to the free release levels,
– provision for the social protection for the reactor's personnel, and
– public relations and information distribution on the decommissioning problems with the goal of safety confirmation of measures, which are planned or carried out.

DP foresees the strategy of the immediate dismantling reasoning from the plans of the further site use [9]. In accordance with the selected decommissioning strategy, the sequence of decommissioning stages was established along with the content 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 ultimate goal of the reactor decommissioning is the unlimited site use with the transfer of the reactor building, the part of existing infrastructure for the reactor operation provision and the reactor auxiliary building to the separate laboratory for the development and application of radiation technologies.

THE SEQUENCE OF DECOMMISSIONING

Activity for the preparation of decommissioning during the reactor operation

At the reactor operation the set of works directed toward the preparation of decommissioning will be performed. The following measures are carried out permanently:
– classification, accounting, and forecast of the radwaste volumes, which will be generated during the reactor operation and decommissioning,
– collection, processing, and storage of information related to the buildings, the constructions and the reactor systems and elements, which will be required for the reactor decommissioning,
– activities aimed at the preparation and removal of the spent nuclear fuel,
– gathering of the material and technical resources for the decommissioning,
– development of the decommissioning documentation,
– application for and approval of the decommissioning license, and
– public relations on the decommissioning problems.

Termination of operation

The termination of operation stage precedes the decommissioning, namely, the final stage of reactor operation, which will be performed after the decision-making about the reactor final shutdown. Basic goal of activity at this stage is the conversion of the reactor into the state when the spent nuclear fuel (SNF) is absent from the rector site, *i. e*,. SNF was removed from the reactor core and cooling pond for the safe long-term storage.

After removal of SNF, the operational license will be cancelled and cannot be renewed. The following decommissioning activities will be carried out in accordance with the decommissioning license, which does not foresee the SNF management.

Thus, the following works and measures are foreseen during the termination of operation stage:
– removal of the SNF away from the reactor site,
– final shutdown of systems, which cannot be used; all reactor systems and elements will be shutdown excluding those that provide the regular operation, such as the ventilation, the radiation control, the cooling of the spent fuel storage *etc.,*
– disconnection and removal of the working mediums from the technological schemes and equipment,
– removal of potentially hazardous substances, which are not required for the future utilization,
– decontamination of the reactor systems and elements,
– removal and transfer to processing of radwaste, which was collected during the reactor operation or generated at the termination of operation stage,
– execution of the complex engineering and radiation inspection (CERI) with the goal of data collection related to the engineering and radiation conditions at the reactor; this information will be used at the development of decommissioning documentation as well as at the planning and execution of decommissioning activities,
– implementation of measures directed to the life support and maintenance of the systems, which

will be in operation at the next decommissioning stages,
- guarantying the availability of the material and technical resources for the final closure and dismantling stages,
- staff training for the decommissioning works,
- development of decommissioning documentation, which is necessary for the permission on the beginning of the final closure stage, and
- implementation of administrative and organizational measure corresponding to the changed status of the reactor.

Final closure

The goal of the final closure stage is the reactor transformation into condition, which excludes its use as the neutron source. The reactor does not exist as the neutron source after the fuel removal from the core and the equipment of experimental channels will be dismantled. Thus, the main goal of the stage will be reached.

The following measures are planned at this stage:
- execution of additional radiometry and dosimetry surveys of the reactor premises; the creation of contamination maps,
- creation of more precise inventory of the radioactive contaminated and activated reactor systems,
- dismantling of experimental installations located at the reactor horizontal channels,
- dismantling of external reactor systems, which do not have an influence on safety and cannot be used at the dismantling stage,
- preservation and strengthening (if necessary) of the protective barriers to prevent spread of contamination; the reinforcement of protection around the biological shield, especially near the gate valves,
- arrangement of the temporary storage places to simplify the operation (the utilization of disengaged premises),
- extraction, conditioning, storage, and transfer to the disposal of radwaste generated at the stage of the final closure,
- design, assembling, operation and maintenance (with the subsequent dismantling) of the additional equipment assigned for the extraction of radioactive and hazardous substances (if necessary),
- guarantying the availability of the material and technical resources for the dismantling stage,
- development of decommissioning documentation, which is necessary for the permission on the beginning of the dismantling stage,
- designing the necessary technological documentation,
- implementation of administrative and organizational measure corresponding to the changed status of the reactor, and
- execution of other activities and measures foreseen by the implementation program for this decommissioning stage.

Dismantling

The goal of the dismantling stage is the segmentation and removal of the reactor systems and components as well as removal of the radioactive substances outside the reactor site. For this goal the following activities and measures will be performed:
- decontamination of the areas and equipment to facilitate the dismantling activities,
- preparation of the temporary storage areas for the location of dismantled and segmented parts,
- gradual dismantling of following systems:
  technological equipment at the reactor upper part and in the reactor hall,
  metal layer of the thermal column roling-off mechanism and the thermal column shield,
  thermal column's first disk,
  Be-reflector,
  reactor vessel
  armature rod drives,
  ion-exchange and electrophoresis filters,
  primary circuit,
  primary circuit's embedding units,
  biological concrete shield, and
  spent fuel cooling pond (CP-1),
- removal of contaminated components, which can be extracted after dismantling of other components,
- removal of clear auxiliary equipment for the final radiation survey,
- dismantling of non-contaminated structures for the access provision,
- removal of contaminations from all areas and premises,
- refinement of the adjacent territory (where necessary),
- characterization of the radioactive substances for the unlimited re-use or the final disposal,
- conditioning and transfer for the final disposal of the radwaste generated during the dismantling stage,
- characterization of radwaste packages,
- restoration of the reactor site (if necessary) in dependence on the plans of further use, and
- execution of the final radiation survey in the reactor building and within the sanitary protective zone.

After completion of all works which are foreseen by DP:

– implementation of procedures directed to the termination of radiation control (development of the final Safety Analysis Report) and the decommissioning license cessation, and
– implementation of administrative and organizational measure corresponding to the changed status of the reactor site.

Final state after completion of the dismantling stage is in correspondence with the state which should be achieved after the reactor's decommissioning. This state is characterized by the release of reactor's site from the radiation control with the subsequent elimination of restriction conditions for the unrestricted use.

RADWASTE MANAGEMENT

Decommissioning radwaste will be different comparing with the operational one by variety and volumes. This radwaste can be classified in accordance with the radioactive contamination and activation levels (high-, intermediate-, and low-active), the physical conditions (solid, liquid, gaseous), the treatment process (combustible, compacted, melting, *etc.*) [14]. The main part of radwaste will consist of liquid and solid one, at the liquid radwaste will be low- and intermediate active, the solid one will be high-, intermediate-, and low-active.

The following radwaste belong to the mentioned above ones.

Liquid radwaste

– those, which were generated directly at the dismantling operations (water flushing, dust suppression, gas cleaning) along with the decontamination solutions from the cleaning of dismantled segments of constructions and equipment before its further treatment,
– secondary liquid radwaste from the treatment of different radwaste, and
– sewage water from the sanitary gate, waste from the laboratories.

The treatment and solidification of these radwaste are foreseen during the decommissioning.

Solid radwaste

– main technological equipment (entire or segmented), including the reactor's elements, primary circuit pipe-lines, *etc.*,
– non-metal waste from the dismantled auxiliary equipment and pipe-lines,
– metal building constructions after dismantling of premises,
– facing materials (sheet steel, elastron), plasterwork and broken concrete from the mechanical decontamination of premises,
– ventilation and technological filters, filter cotton cloth, heat insulation,
– concrete from the dismantling of biological shield and other premises, and
– construction and household rubbish, organic waste (special clothes, footwear, cleaning materials).

Metal wastes from the dismantling and segmentation of equipment belong mainly to the 1st and 2nd categories; they are contaminated by the activated products of metal corrosion, which were in contact with the heat-carrier of the primary circuit. The largest problems with the non-metal waste are related to the concrete from the dismantling of biological shield. The inventory of the reactor systems is presented in tab. 1.

It is planned to use an *existing infrastructure* for the collection, treatment, and transportation of decommissioning radwaste. However, taking into account big volumes and availability of large-scale elements, it is required to develop the technologies for the radwaste fragmentation (including the metal and concrete) as well as the technologies for the treatment of contaminated constructions (mainly metallic form).

SAFETY PROVISION

Safety provision during the reactor decommissioning is the most important element in the whole technological chain [3, 15]. Each planned action at the execution of decommissioning activities will be considered from the point of view of influence on the following safety components: nuclear, radiation, fire, industrial, *etc*. The staff, population, and environment should be protected from the decommissioning dangers at all stages of decommissioning. Safety at the decommissioning is provided in correspondence with the requirements of acting normative documents, norms, rules, and standards [16, 17]. Radiation, fire, and industrial safety as well as the safety of environment at the decommissioning are provided by the following: the designed systems which remain in operation by regular manner, the organizational and technical measures, and the quality assurance system. Exposure doses of staff, releases and discharges of radioactive substances are not allowed to exceed the limits established by OSPU [18]. The norms establish the following categories of persons being exposed: category A (staff) includes those individuals who directly handle permanently or temporarily sources of ionizing radiation; category B (staff) includes individuals who are not directly dealing with sources of ionizing radiation but due to location of their working places within the premises and on sites of the engineering facilities where radiation and nuclear technologies are available could get additional exposure; category C includes all the public. Exposure dose limits are 20, 2 and 1 mSv per year for the category A, B and C, respectively.

Analysis and safety assessment should start immediately after approval of the decommissioning pro-

Table 1. Inventory of the reactor systems

Equipment type	Main material	Weight [kg]
REACTOR WWR-M		
1. Reactor vessel 2300 × 5705	CAB-1	3600
2. Beryllium reflector ∅920 × 570 500	Beryllium	835
3. Thermal columns	Steel, cast iron, graphite	15000
4. Thermal column rolling-off mechanism	Steel	3884
5. Shieldingn with channels	Steel, cast iron, lead	65000
6. Thermal column shield	Steel, cast iron	30550
7. Deaerator ∅1620 × 5520	CAB-1, cast iron	4220
8. Distiller tanks 3200 2300 1500	Steel 1X18H9T	1800 4 = 7520
9. Spent fuel storage 4000 2840 840	CAB-1, steel 1X18H9T	19000
		Total weight of materials: **149609**
PRIMARY CIRCUIT		
1. Main pipelines	Steel 12X18H10T	6044
2. Circulation pump	Steel 1X18H9T	837
3. Stop valves	Steel 1X18H9T	5320
4. Heat-exchangers – 2 pieces	Steel 12X18H10T	2 7694 = 15388
5. Cooling pipelines	Steel 12X18H10T	1800
6. By-pass purification system	Steel 12X18H10T	1337
7. Emergency cooling system	Steel 12X18H10T	1700
		Total weight of materials: **32426**
SECONDARY CIRCUIT		
1. Main pipelines	Steel 207	39222
2. Circulation pumps	Steel, cast iron	773 3 = 2320
3. Stop valves	Cast iron	7659
		Total weight of materials: **49201**
AUXILIARY SYSTEMS		
1. Special sewage system	Steell 1X18H9T	12748
2. Reservoir – 2 pieces	Steel 1X18H9T	22576
3. Ventilation chimney	Brick	23580
4. External ventilation airways	Steel 1X18H9T	19450
5. Ventilation unit of special ventilation system – 8 pieces	Steel 3	3200
		Total weight of materials: **81554**
		TOTAL: 312790

gram and continue during the development of the decommissioning design with the gradual increasing of the safety detalization and substantiation.

Nuclear safety. SNF is the subject of removal outside the reactor site at the termination of operation stage. The operations for the SNF extraction, storage, and loading will be the same as at the reactor operation. Next decommissioning works will be carried out in accordance with the license, which will not foresee the SNF management and, therefore, the nuclear safety provision should not to be considered in DP.

Radiation safety. Purposeful destruction of protective barriers will take place at the decommissioning and, therefore, the release of radioactive substances in the solid, liquid, and gaseous form or as the aerosols will be potentially possible. For the radiation safety provision at the decommissioning a separate program of radiation protection will be developed. This program guarantees that the radiation protection is optimal and irradiation doses will not exceed the established limits.

The organization and arrangement of the radiation protection system during the decommissioning work execution will be the entirely logical continuation of available system at the reactor operation. The radiation protection system functioning at the reactor decommissioning should be considered as the component part of the regular operational regime. The existing radiation protection system will be adopted for the requirements and needs caused by the character and content of decommissioning works [19, 20].

The established approach for the staff exposure will be maintained at the reactor decommissioning. The basic principles of the radiation protection at the decommissioning are:

– the staff and population exposures cannot exceed the established dose limits, and
– the individual exposure dose levels as well as the number of irradiated persons should be as low as it can be reached with the account of economical and social factors.

The dose limit for the total external and internal exposure of the A category staff is established to be equal to 20 mSv per year. The increased exposure of up to 50 mSv per year can be allowed in exceptional cases, but this increased exposure should be compensated by that way when the total exposure after the next ten years will not exceed 200 mSv. The goal of decommissioning planning is the guarantee that each individual dose cannot exceed 20 mSv per year and such dose is as low as possible (ALARA principle). The modern recommendations of the International Commission of Radiation Protection have established the dose restriction concept (lower the dose limits). It seems to be reasonable to establish the restrictions at the decommissioning on the base of factor 2 with the goal of the working time determination for the areas with an increased dose rate. This means that the dose limit of 10 mSv per year for the A category staff will be established (this is corresponding to the restriction of daily dose of 70 μSv).

The guarantee of radiation safety for the staff, population, and environment during the reactor decommissioning will be provided by the set of administrative and technical-engineering measures. The main criterion of the radiation protection efficiency will be the absence of the annual dose limit exceeding by the staff. Also, the additional criteria should be accounted for:

– the maximal and averaged annual effective doses of external and internal exposure,
– the collective dose reduction,
– the individual dose reduction,
– the radioactive aerosol reduction, and
– the reduction of cases connected with the control levels exceeding.

Physical protection system. Physical protection at the decommissioning will be arranged on the base of the planned state of the reactor site for the provision of protection against unauthorized access. The physical protection system was commissioned in 1998. This system includes the elements providing the multi-level system for the intruder detection and access control to the secured areas. Thus, the physical protection of the reactor site will be provided by the set of technical and organizational measures directed on the maintenance of efficiency of physical protection, which was created during the reactor operation. Operation of the physical protection system is foreseen during whole decommissioning period till the full completion of all works and measures predicted by the DP.

Fire safety at the decommissioning will be provided by means of organizational, technical, and other measures directed on the fire prevention, decreasing of negative ecological after-effects, creation of conditions for the fast call of fire brigades, and successful fire extinguishing. Existing fire safety system includes the system of automatic fire signaling, and extinguishing tools, such as the fire hydrants, fire extinguishers, and sand boxes. The dismantling of separate elements of the existing fire safety system will occur during the decommissioning works and, therefore, some new additional elements will be necessary. The quantity and inventory of main kinds of fire engineering is established by the requirements of the State standards, building norms and separate normative documents.

Industrial safety. Gradual decrease of the hazard from the reactor and radiation risks and parallel increase of industrial risks is the typical feature of the decommissioning process. Variety of technological tools with the high level of mechanization during the decommissioning works requires a reliable safety measures for the personnel. Therefore, the estimations of these industrial risks and defining of the adequate measures for their elimination or mitigation are important for the decommissioning.

Beside the common safety measures, the special safety and protection measures are established for each installation or equipment, which should be presented in the instructions on assembling, operation and maintenance. For all decommissioning works the safety criteria should be established for the system and equipment in correspondence with the requirements of acting safety norms, rules and standards, and industrial hygiene and sanitary.

External monitoring. The systematic radiation control of influence on environment was performed during a many-year operation of the WWR-M reactor. In accordance with the regulation, the following parameters were a subject of control: the levels of gamma-, beta-, and alpha-activity and content of main radionuclides of reactor's origin (namely, ^{3}H, ^{90}Sr, ^{134}Cs, ^{137}Cs) in the atmospheric precipitates and deposited dust, the water from main institute's collectors, water from open reservoirs, the water from melted snow and birch sap, and the soil and vegetation. Additionally, the content of short-lived and long-lived alpha- and beta-aerosols in the air near-surface layer and dose rate of gamma-radiation in the control points was measured. As a whole, the results of radiation control provide evidence that for the total survey period no increase of radioactive substances in controlled parameters in comparison with the levels typical for Kiev was noticed. This confirms that the reactor operation is safe for the environment. The existing system of environmental radiation monitoring will remain in operation during the reactor decommissioning and it will be adapted for the tasks connected with the decommissioning works [21].

Emergency response. Emergency response system (ERS) is the interconnected complex of technical tools, and resources, the organizational, technical, and radiation-hygienical measures which are implemented by the institute's administration and staff with the goal of emergency response, *i. e*. the prevention or mitigation of radiation impact on the staff, population, and environment in the case of accident at the WWR-M reactor [22]. Main ERS elements are: (1) institute's normative-legal basis, (2) emergency plan, (3) institute's emergency organizational structure, (4) tools of emergency response, (5) system of personnel training, and (6) system of interaction with the external organizations. Emergency response system is a part of the object level of the territorial subsystem of the unified state system for the civil protection of population and territorial domains, which is created in Kiev with the goal of prevention and elimination of emergency after-effects induced by the man-caused, natural, and military reasons within the relevant area.

USE OF PERSONNEL

Preservation and use of the reactor's staff practical experience is one of the priority directions while decommissioning planning and implementation. Application of this experience will allow the reduction of risks of the possible accidents as well as the problems with the recruitment and training of new staff and significantly facilitating the work execution.

The initial decommissioning tasks are the same as the operational ones, for example, the SNF reloading, decontamination, *etc*. The reactor staff has a deep knowledge of the reactor and relevant systems. Therefore, the main part of works will be performed by the reactor staff. Beside the regular reactor staff at the moment of the reactor final shut-down, it is necessary to attract other workers as the consultants, which worked formerly at the reactor maintenance. For the specific works, which are not typical for the reactor operation, it is reasonable to attract the institute's specialists or specialists from another enterprises dealing with the nuclear power.

The acting legislation declares that the State promotes the provision of each nuclear installation during the whole lifecycle by sufficient quantity of well-qualified personnel having a necessary level of education and training with the aim of maintenance at the needed level of safety of such installation. The integrated planning and provision of educational programs should compensate the decrease of skilled staff. Staff training and re-training for the execution of decommissioning works should provide the knowledge of operation of the main systems and mechanisms as well as the safe manner of work execution.

During the reactor decommissioning works, the staff who knows in detail the technology of works, safety instructions and operational instructions for special tools and mechanisms will be used. As a whole, the use of about 70 specialists of the institute for the reactor decommissioning is foreseen. Quantitative and professional composition of working groups will be determined by the executed work.

CONCLUSIONS

Present technical condition of the reactor allows its safe operation for no less than 8-10 years; nevertheless, in accordance with the acting legislation, the decommissioning planning must be performed at the operation stage as early as possible. Recently, the DP has been approved by the regulatory body. The Program is based on the plans for the further use of the reactor site and determines the immediate dismantling as optimal decommissioning strategy as well as provides the basis for the safe, timely and cost-effective decommissioning. A further refining of the decommissioning planning for the WWR-M reactor will be the grave task for the forthcoming period.

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НАПРЕДАК У ПЛАНИРАЊУ ДЕКОМИСИЈЕ КИЈЕВСКОГ ВВР-М ИСТРАЖИВАЧКОГ РЕАКТОРА

Кијевски ВВР-М истраживачки реактор у погону је већ 50 година и предвиђен је његов даљи рад не мање од 8-10 година. Садашње законодавство у Украјини захтева од власника нуклеарног реактора да планира декомисију што је раније могуће, док је реактор још у погону. Недавно, програм декомисије прихватило је регулаторно тело. Програм се заснива на плановима за даље коришћење реакторског места и предвиђа стратегију непосредног уклањања. Потпуно покрива поступак декомисије и представља главни водећи документ током читавог декомисионог периода, који одређује и материјализује водеће техничке и организационе активности на припреми и спровођењу реакторске декомисије, на разматрању утицаја декомисионих фаза, на успостављању редоследа планираних послова и мера, као и потребних услова и инфраструктуре за набавке и сигурну примену.

Кључне речи: истраживачки реактор, декомисија, уклањање, управљање радиоактивним отпадом