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PROJECT
Preliminary studies for the decommissioning of the reactor compartments of the former Paldiski military nuclear site and for the establishment of a radioactive waste repository

FINAL SEMINAR

Task 3

Determining the possibilities of commissioning the reactor compartments

A.N. Abramov, J.M. Simanovsky, T.V. Shidlovskaya
JSC ATOMPROEKT
A.A. Kvar
JSC FCNRS

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Task 3. Determining the possibilities of commissioning the reactor compartments

Subtasks for Task 3:

SUBTASK 3.1. ASSESSMENT OF DIFFERENT METHODS USED FOR DECOMMISSIONING REACTOR COMPARTMENTS

SUBTASK 3.2. COMPARATIVE ASSESSMENT OF ALTERNATIVE METHODS USED FOR DECOMMISSIONING REACTOR COMPARTMENTS

SUBTASK 3.3. DEVELOPMENT OF THE CONCEPT OF DECOMMISSIONING SELECTED AS A RESULT OF THE ASSESSMENT

SUBTASK 3.4. DESCRIPTION AND ASSESSMENT OF THE WASTE TO BE GENERATED IN THE COURSE OF THE DECOMMISSIONING WORKS

SUBTASK 3.5. DECOMMISSIONING SAFETY ASSESSMENT, TAKING INTO ACCOUNT THE WASTE QUANTITIES TO BE GENERATED

Task 3. Determining the possibilities of commissioning the reactor compartments

Four main concepts (scenarios) of the decommissioning of the reactor compartments have been considered within this project:

- **Concept A: equipment removal and fragmentation into large fragments (without reactor cutting), with the aim of reducing collective radioactive exposure, followed by placing the fragments into shielded containers and dispatching for disposal in a newly built RW repository.**
- **Concept B: equipment removal and fragmentation into small fragments (without reactor cutting) using decontamination in order to minimize the number of RW to be disposed of.**
- **Concept C: RCs disposal as a whole in situ in the existing sarcophagi, after their reinforcement.**
- **Concept D: RCs disposal as a whole in a near-surface RW repository built near the main building in the territory of the former training center.**

3.1. Assessment of different methods used for decommissioning reactor compartments

OVERVIEW OF INTERNATIONAL EXPERIENCE IN REACTOR COMPARTMENTS DECOMMISSIONING

Experience of France
Experience of the UK
Experience of the USA
Experience of Germany
Experience of Russia

The major current international practices for reactor compartments decommissioning - deferred decision - long-term storage for decay of residual radioactivity.
The further management of reactor compartments is still under the research and development stage.
Reactor vessel cutting needs employment of large funds and construction of specialized facilities - reasonable for the decommissioning of a quantity of reactor compartments and seems not to be economically justified for the Paldiski facility due to it's unique character.

Subtask 3.2. Comparative assessment of alternative methods used for decommissioning reactor compartments

Alternative methods of concepts C and D (disposal as a whole) currently used for deferred decision in the international practices of the long-term storage.

Negative aspects: safety, limited selection for disposal options, non-compliance to international recommendations of the IAEA in relation to the radioactive waste disposal and may will be in conflict with the IAEA requirements which are assumed to be used in the future, especially if to take into account that the decommissioning is expected after 50 years of safe storage.

Preliminary indicative assessment of decommissioning methods

Concept	man-hours	years	Collective dose (man – mSv)	Cost, (million Eur)
Concept C	117 000	3.5	110	7.8
Concept D	214 000	5.5	190	12.0
Concept A	328 000	6.6	600 - 700	24.0
Concept B	369 000	7.0	700 - 800	25.0

Concept A (large-size fragmentation) - minimization of the dose loads if compare to Concept B (small-size fragmentation). Concepts A and B require demolition equipment, concrete crushing, special container for the reactor vessels transportation/disposal as a whole. Concept A and B require specialized installations and equipment for mapping of RW inside reactor compartment. Comparing to the concept A, concept B requires more precise cutting of the concrete and decontamination; and, in its turn, it provides for better radwaste management (usage of standard containers), safety, allows to minimize quantities of the radwaste for disposal.

Subtask 3.2. Comparative assessment of alternative methods used for decommissioning reactor compartments

Concepts C and D are characterized by:

- relatively low collective radiation exposure of the personnel to perform work that can make up for a rough estimate over 50 years after putting for safe storage.;
- virtual absence of additional RW during the whole cycle of the works;
- no negative influence on the environment objects during the performance of the works since during transportation and storage the RCs will remain air-tight and shall not emit RW;

- disposal of long-lived intermediate-level waste above ground (reactor, shielding tank) does not meet the standards of the Republic of Estonia and IAEA;
- no complete immobilization of the reactor compartments internal contents;
- concept D implementation will require the creation of a special vehicle for the transport of large-sized and heavy packages with a lifting capacity of at least 1000 tons, as well as the construction of a transport way from the main technological building to the RW repository.

Subtask 3.2. Comparative assessment of alternative methods used for decommissioning reactor compartments

Option A is characterized by:

- moderate labour costs and collective radiation exposure;
- fewer amount of equipment required for decommissioning works compared to option B;
- fewer amount of secondary RW compared to option B;

Option B is inferior to option A by the following indicators:

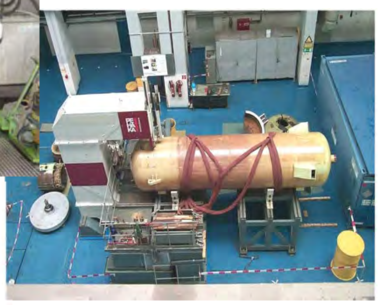
- labour costs;
- collective radiation exposure;
- amount of equipment and systems for waste decontamination,
- costs of waste processing and purification of the gas environment;
- amount of the secondary waste to be generated.

However, implementation of option B is characterized by:

- **reduction of primary RW; (RC and the nuclear installation equipment is to be cut into small fragments, which are subject to decontamination with the aim of exempting most of the metal waste from regulatory control, and, thus, it is possible to minimize the RW amount to be disposed of);**
- **reduction of volume and number of RW packages to be disposed of;**
- **reduction of the number of standard size protection containers to be developed.**
- **reduction in the size of RW repository facilities, which will result in cost saving during RW repository construction**

Subtask 3.2. Comparative assessment of alternative methods used for decommissioning reactor compartments

Technical analysis
Analysis of techniques for fragmentation and decontamination



Cost of the equipment
Analysis of equipment for fragmentation and decontamination

Subtask 3.2. Comparative analysis of concepts A and B by preliminary indicative expert estimation

Evaluation criteria	*Option*	*Evaluation*	*Points*
Time of work	A	100	score
	B	95	score
Man-hours for the whole set of works	A	100	score
	B	90	score
Dose loads for the whole set of works (man – mSv)	A	100	score
	B	85	score
Amount of primary RW to be generated (cubic m.)	A	60	score
	B	100	score
Amount of the secondary RW to be generated (% from Σ RW)	A	100	score
	B	70	score
Quantity of standard sizes of the containers to be newly developed (transport and disposal containers, pcs.)	A	75	score
	B	100	score
Economics (cost estimation, mln. Euro)	A	100	score
	B	90	score
Safety assessment (general safety)	A	75	score
	B	95	score
Environmental impact assessment	A	85	score
	B	80	score

Subtask 3.3. Development of the concept of decommissioning selected as a result of the assessment

Concept B small-size fragmentation

- Choice of concept for RC final DC at the former Paldiski training center
- Possible end-points: Green and Brown field
- Application scope of the Concept
- Regulatory Background
- Strategy of RC decommissioning
- Justification of the Strategy
- Sequence of work and measures
- Description of works on the preparation for the dismantling works at the site
- Construction and equipping of "packaging workshop"
- Sequence of work on dismantling of the RC and reactor equipment (using remote-controlled dismantling machineries and equipment) including decontamination
- Transportation of waste
- The final outcome - Dismantling of sarcophagi and building structures of main technological building of the Paldiski facility
- Safety during RCs decommissioning
- The technical gaps and preventive measures to mitigate them
- Assessment of Estonia's technical preparedness

Facility final condition	Regulatory control extent
«Brown field»:	The regulatory control is realized in the scope of:
territory of radiation hazardous facility	*compliance with all requirements for radiation hazardous facilities*
territory of general purpose industrial facility	*compliance with individual requirements for public radiation safety*
«Green field»	*Complete absence of regulatory control*

Conservative approach for indication of the maximum doses and labour

327 342 man - hours
2 152 man - mSv

After obtaining data of engineering and radiation surveys will be reverified at the predesing and design stages

Indicative assessment** of the cost for the B Concept -* **46.25 mln. euro, measured according to the 2015 prices, VAT included*

Subtask 3.3. Development of the concept of decommissioning selected as a result of the assessment

INDICATIVE WORK SCHEDULE AND SEQUENCE OF WORKS

1. Preparatory works	
1.1	Preliminary studies on decommissioning in 2014- 2015
1.2	Introduction of changes into legal and regulatory framework of the Republic of Estonia (RE)
1.3	Comprehensive engineering and radiological survey of the Site and reactor compartments (RCs)
1.4	Feasibility study and environmental impact assessment of the former Naval Training Center (Paldiski) decommissioning
1.5	Coordination and approval of the concept of final decommissioning of the former Naval Training Center (Paldiski)
1.6	Taking decision on the final decommissioning of the former Naval Training Center (Paldiski), including a decision on funding.
1.7	Development of program including plan of its implementation. Development of design documentation. Licensing.
2. Works on the site of the former Naval Training Center (Paldiski)	
2.1	Infrastructure refurbishment (equipment for waste management, handling, environmental protection and safety)
2.2	Preparation for waste management (preliminary): relocation, handling, packing and placement of waste (solid)
2.3	Dismantling of building structures of the RCs and its premises, waste handling and disposal of low-level waste,
2.4	Dismantling of the equipment of the primary circuit and pressurized water reactor, waste handling and disposal
2.5	Intermediate processing and exemption of waste that remains after previous (earlier) activities, (and) dismantled infrastructure
2.6	RC building decontamination
2.7	Decontamination and complete cleaning of the site
2.8	Complete disassembly of the building and facilities on the site
2.9	Area remediation
Final stage	
3.1	Procedure of exemption of the former Naval Training Center (Paldiski) from regulation for the radiation hazardous facilities
3.2	Site transfer to national economy (restricted use)
3.3	End-pont “Brown Field”

Subtask 3.4. Description and assessment of the waste to be generated in the course of the decommissioning works

- **streams of solid waste during the decommissioning of the stands 346 A and 346 B:**
- **waste whose activity is conditioned by the induced activity of the reactor structural components**
- **waste whose activity is conditioned by the corrosion and fission products on the structural surface and primary circuit equipment;**
- **waste from non-radioactive reactor structures and reactor biological shielding**
- **waste placed in storage in the reactor compartments before mothballing of the stands;**
- **waste generated from the dismantling of the concrete poured into the reactor compartments before mothballing of the stands;**
- **waste generated from dismantling the sarcophagi.**
- **contamination is determined by the following nuclides: ^{55}Fe; ^{60}Co; ^{59}Ni; ^{63}Ni; ^{94}Nb; ^{152}Eu; ^{154}Eu**
- **the main radionuclide determining the activity of RW of the reactor compartments after 50 years of storage is ^{63}Ni (80% to 99%);**
- **radioactive waste with a specific activity of more than 4000 Bq / g (4E + 06 Bq / kg) includes reactors of the stands 346A and 346B and shield tanks ($A_{un\cdot\ reactors}$ =(3,0E+8÷ 2,3E+9) Bq/kg; $A_{un\cdot\ SH.\ tank}$ =(4,6E+6÷ 1,6E+7) Bq/kg). This waste, according to the classification of the Republic of Estonia, is low- and intermediate-level long-lived radioactive waste.**
- **the specific activity of the rest of the equipment is less than 4,000 Bq/g. According to the Estonian classification of long-lived radioactive waste with a concentration of less than 4,000 Bq/g in individual waste packages and on the average of 400 Bq/g for all packages, it is allowed to be disposed of together with low- and intermediate-level short-lived radioactive waste.**

Substage 3.4. Preliminary indication of waste volumes of stands 346A and 346B decommissioning various options

Waste denomination	Stand 346 A		Stand 346 B	
	Mass, kg	Volume, m^3	Mass, kg	Volume, m^3
Concept A Dismantling of RC with large-sized fragmentation				
Long-lived ILW, LLW from dismantling of RC primary circuit equipment	115,000	220	210,000	384
Waste from RC dismantling (removed from under control and non-radioactive)	740,000	370	740,000	370
Radioactive waste from the concrete cutting with RW inside the compartments (categories of ILW compartments with IRS, LLW, VLLW - for the rest of the concrete compartments)	656000	73	906000	55
Waste from sarcophagus dismantling (non-radioactive)	650,000	650	610,000	610
Total RW	**180,000**	**~293**	**300,000**	**439**
Total of non-radioactive waste	**1,390,000**	**1020**	**1,350,000**	**980**
Concept B Dismantling of RC with small-size fragmentation				
Long-lived ILW, LLW from dismantling of RC primary circuit equipment	115,000	197	210,000	288
Waste from RC dismantling (removed from under control and non-radioactive)	740,000	370	740,000	370
Radioactive waste separated from the concrete inside the compartments (category of ILW compartments with IRS, LLW, VLLW - for the rest of the concrete compartments)	15,000	17	10,000	17
Concrete (non-radioactive)	50,000	50	80,000	80
Waste from sarcophagus dismantling (non-radioactive)	650,000	650	610,000	610
Total RW	**130,000**	**214**	**220,000**	**305**
Total of non-radioactive waste	**1,440,000**	**1070**	**1,430,000**	**1060**
Concepts C and D RC disposal as a whole				
Radioactive waste of category ILW, LLW in RC volume	920,000	~700	1,040,000	900
Waste from sarcophagus dismantling (non-radioactive)	650,000	650	610,000	610
Total RW	**920,000**	**700**	**1,040,000**	**900**
Total of non-radioactive waste	**650,000**	**650**	**610,000**	**610**

Substage 3.4. Preliminary indication of waste volumes of stands 346A and 346B decommissioning various options

For transporting and disposal of the RPVs of stands 346A and 346B it is recommend one type of container (2,8x4,8), although the size and weight of the RPV of 346B is much more than 346A (50 t and 30 t). According to the IAEA regulations for the transportation the Type A package is required for this RW. Developing an appropriate container, designed for all required types of impacts is very expensive task, and is estimated at about 500 000 euro and the cost of manufacture of such a container could be about 80 000 euros. Therefore, it is desirable to develop as little as possible of new containers and if possible to use existing ones. In order to save funds it seems to be useful to develop one type of container for every suitable case. Concept B requires container of type A package for the disposal of both RPV and for fragments of two shielding tanks.

Development of the container: development of the construction, conducting computational studies for conformity with the required parameters, prototyping, conduct confirmation testing for compliance with the requirements, manufacture of sample, cask certification.

Subtask 3.5. Decommissioning safety assessment, taking into account the waste quantities to be generated

Initial event	Initial events consequences
External effects of natural and man-made disasters	
Earthquake (4.7 by the Richter scale)	Structures designed for earthquake of 7 points on MSK-64 scale (approximately 4,8 on the Richter scale)
Hurricanes, tornadoes	May result in the partial destruction of the roof and falling of the fragments of the bridging.
Rains (abnormal)	Does not result in flooding of the building (location on flat terrain at ~ 25 m above sea level)
Typhoons and tsunamis	MTB building is located outside the impact area of the hydrological phenomena.
Snow load 1.8 kN/m	The bridging is designed for such loads
Thunder / lightning	All electrical equipment is grounded and earthed, lightning protection is provided for
Air shock wave as a result of explosion	The pressure of the air shock wave in case of explosion of a tank is approximately 2.5 kPa and it does not lead to the destruction of MTB structures.
Fall of an aircraft / flying object	No considerable damage from light aircraft (up to 5 t). Heavy aircraft (20 t or more) will destroy the sarcophagus structure, can cause depressurization of RC shell, but not break unit primary circuit, a possibility of fire break-out will not lead to dispersion of radioactivity in the atmosphere.
Internal impacts caused by accidents inside the building	
Fire inside MTB building	Heating of contaminated equipment during a fire not lead to dispersion of radioactivity in the atmosphere.
Fall of the overhead crane	Deformation of the of the pressure shell, possibility of mechanical equipment damage of the primary circuit (crumple, breaks of the shell, etc.). The release of radionuclides is insignificant.
Fall of the reactor vessel (RV)	Release of radionuclides is insignificant, the radiation background slightly increased, and the event does not prevent further work (after 50 years of storage - dosage rate from reactor vessel be within 0.2 mSv/h.
Fall of the SRW container (destruction of the container)	When falling from various heights, there are various consequences. The container can become depressurized, but reactor vessel will remain inside the container. No release of the radioactivity from reactor vessel. Radiation environment around the container will remain within the emergency standards.

Subtask 3.5. Decommissioning safety assessment, taking into account the waste quantities to be generated

Analysis of the Risks in Emergency Situations and Assessment of Their Consequences

Assessment of dose exposure in a situation when a source (most active) is opened and becomes completely unenclosed

1) non-destroyed

$$P_A = \frac{Q \cdot K_\gamma}{R^2}$$

2) scattered as along the line at a distance of approximately 50 cm

$$P_A = \frac{2n \cdot K_\gamma}{h} \cdot arctg\frac{l}{h}$$

Description of Emergency Situation	Radio nuclide	Effective Dose of Internal Radiation, Sv, at a distance, km						
		1	1.3	1.8	3	4.5	6	8
Burning of Containers With Solid Radioactive Waste	Co-60	1.88 E-12	2.37 E-12	2.19 E-12	1.78 E-12	1.32 E-12	1.08 E-12	7.57 E-13
	Eu-152	1.97 E-12	2.48 E-12	2.29 E-12	1.86 E-12	1.37 E-12	1.13 E-12	7.91 E-13
	Eu-154	7.43 E-13	9.34 E-13	8.64 E-13	7.05 E-13	5.19 E-13	4.27 E-13	2.99 E-13
	Cs-137	4.39 E-12	5.51 E-12	5.12 E-12	4.18 E-12	3.08 E-12	2.52 E-12	1.77 E-12
	Total	**8.99 E-12**	**1.13 E-11**	**1.05 E-11**	**0.5 E-11**	**6.29 E-12**	**5.17 E-12**	**3.61 E-12**

Most active gamma sources	Activity according to certificate
Cobalt-60 GIK-5-2	*3.16x10[12] Bq*
Cobalt-60 GIK-2-18	*5.11x10[11] Bq*
Category 2 cobalt-60 gamma source GIK-2-14	*1.02x10[10] Bq*

In case of an emergency situation the personnel must leave the emergency situation area and move to a safe place (5 min). One-time individual exposure will not exceed ***0.1 mSv***

Task 3. Conclusion

For a justified selection of the preferred option of dismantling of the reactor compartments prior to the beginning of the project works, it is recommended to carry out a comprehensive engineering and radiological survey.

The preliminary analysis of the proposed options for decommissioning of the reactor compartments (A, B, C, D) with regard for minimization of costs for the construction of repositories suggests that the most preferred option is option B (after 50-year of the safe storage period).

The implementation of option B provides:

- **reduction in number of primary RW (RC and nuclear installation equipment is to be cut into small fragments which are subject to decontamination for the purpose of RW minimization);**
- **reduction in volume and number of RW packages to be disposed of;**
- **reduction in quantity of the standard size of protection containers for RW placement and transportation to be developed;**
- **reduction in the size of RW repositories which will result in cost saving during RW repository construction**

Task 3. Summary

Based on the review and analysis of the current condition of the reactor compartments (RCs) two power stands in safe, controlled storage at the former Russian Navy training center at Paldiski site and the prospects for their further management in the framework of the existing legislation on radiation security of Estonia, taking into account the recommendations of the IAEA in this field, it is possible to make the following conclusions:

In the period of long-term, controlled storage RCs do not have any adverse effects on the environment and population;
During RCs dismantling the possible radiation impact on the environment and the population will not exceed the minimum rated values in accordance with Estonian legal acts on radiation safety;
It has been shown that during storage and dismantling the most severe accidents will not result in excess impact on the environment and the population in terms of pollution of the nearby territory with radionuclides;
The completion of a full cycle of works on RCs dismantling and removal of all potentially dangerous objects from the territory will result in the exemption of industrial sites from radiation monitoring and its transfer for unrestricted use.

To implement the final RC decommissioning the following shall be available:

- devices for detecting foreign objects in concrete;
- techniques for concrete removal from the equipment surface and IRS without any damage to the latter;
- establishment of two RW repositories in Estonia :
  - ✓ near-surface ground-type - for low and intermediate short-lived radioactive waste;
  - ✓ subsurface RW repository - for low and intermediate radioactive waste.

THANK YOU!