ГОСУДАРСТВЕННАЯ КОРПОРАЦИЯ ПО АТОМНОЙ ЭНЕРГИИ «РОСАТОМ»

Best Practices of Pilot & Demonstration Center for Uranium-Graphite Nuclear Reactors Decommissioning

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JSC «PDC UGR»

PILOT & DEMONSTRATION CENTER FOR DECOMMISSIONING OF URANIUM-GRAPHITE NUCLEAR REACTORS

JSC “PDC UGR” Corporate Objectives:
Provision of commercial decommissioning services for the single-type nuclear facilities based on the standardized technologies suitable for distribution at the nuclear industry enterprises and exporting.
Base for the decommissioning technology development -
2 industrial sites of the Reactor Plant (5 shutdown uranium-graphite reactors).

North site (area 11) – 2 industrial reactor plants

South site (area 2) - 3 industrial reactor plants

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INITIAL STATUS OF COMMERCIAL-SCALE URANIUM-GRAPHITE EI-2 REACOR

External appearance of EI-2 reactor

EI-2 is a double-purpose commercial type reactor.
It was commissioned in 1958 and shut down in 1990.

EI-2 building
Plan size 51,3×52,0 m;
Upper section at 31,5 m;
Bottom section at 38 m below ground level.
Underground constructions are made of cast reinforced concrete.

Reactor vault
Plan size 20,6×20,6 m.
Upper section 0,00 m;
Bottom section at – 21,4 m.

3-D model of EI-2 building

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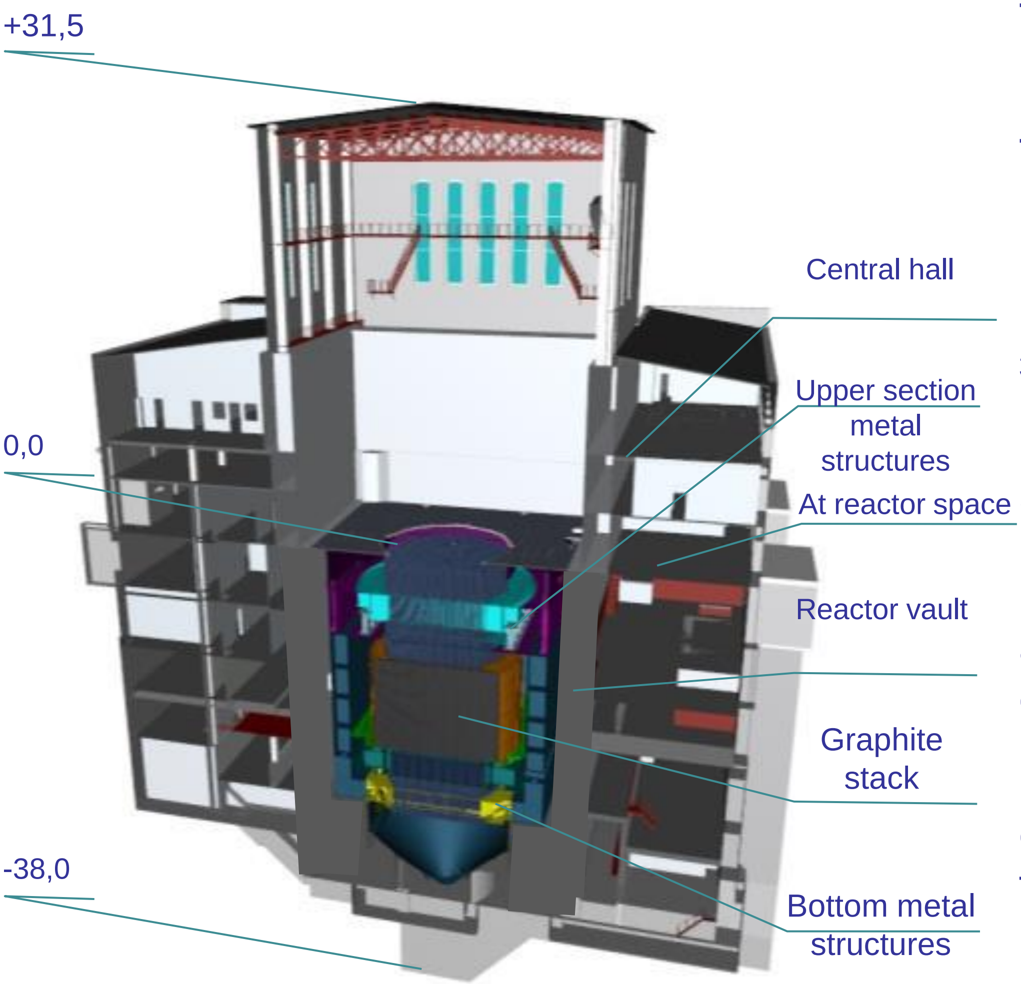

Section view of EI-2 bulding

Total weight of metal structures within reactor vault is 3000 t.

Total weight of graphite stack – 1422,6 t.

Graphite stack volume – 804 m^3.

Graphite activation products - ^{3}H, ^{14}C, ^{36}Cl, ^{60}Co.

^{14}C activity (~10^5-10^6 Bq.g) constitutes 95% of all irradiated graphite activity.

Between 1961 and 1987 there were 9 accidents with nuclear fuel unit loss of containment.

Irradiated graphite can cause contamination of environment with technogenic radionuclides.

JUSTIFICATION OF EI-2 DECOMMISSION VARIANT

To justify the decommission variant the following was taken into account:

- all 13 commercial-scale uranium graphite reactors in Russia are located in zones where near surface disposal, underground disposal facilities and radioactive waste disposal sites formed during the defense program realization already exist;
- graphite stacks of uranium-graphite reactors located below ground level;
- passportization data of irradiated graphite, radionuclides location forms;
- Results of calculations which indicated that in-situ entombment decommissioning variant of uranium-graphite reactor demanded less labor and dosimetric costs than liquidation from material, technical and economical point of view.

Scientific justification of mothballing facility for special radioactive wastes creation was completed.

Current physical shape of reactor graphite is the most compact one. Any kind of treatment can cause the radioactive waste volume incensing, its physical form can change which leads to evolving of new risks and costs.

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MOST IMPORTANT CRITERIA FOR EI-2 DECOMMISSIONING CONCEPT DEVELOPMENT

1. Optimization approach – radioactive impact during the decommissioning activities must remain as low as possible and achievable taking into account economic and social factors (ALARA principle).

2. Next generation protection approach – forecasting levels of exposure for the next generations shall not exceed the levels currently set in regulatory documents.

3. Multibarrier approach – safety of decommissioning activity shall be maintained by appliance of the barrier systems on the way of ionizing radiation and radioactive material proliferation to environment.

BACKGROUND OF EI-2 DECOMMISSIONING

2008	“Decommissioning concept of nuclear facilities, radiation sources and disposal sites” enacted from 30.01.2008 by General director of “Rosatom”.
2009	“Conception of decommissioning of uranium-graphite nuclear reactors using radiation safe on-site entombment approach” enacted from 28.12.2009 by order of General Director of “Rosatom” in 2010.
2011	Federal Law N 190-FZ from 2011 «About radioactive waste treatment …»
	“Local concept of decommissioning of uranium-graphite nuclear reactors of JSC “Siberian Group of Chemical Enterprises” (SGCE) using radiation safe on-site entombment approach finalized by the Director of Nuclear and Radiation safety Department of “Rosatom” in 2011.
	“Minutes of meeting as of 08.09.2011 about in-situ entombment of EI-2” enacted from 03.10.2011 by the Department of Nuclear and Radiation safety.
2012	Comprehensive engineering and radiation survey, decommissioning project, R&D on materials and safety validation report completed.
	Licensing for decommissioning activities.
	Practical work started.
2015	Completion of all practical works, mothballing facility for special radioactive wastes creation.

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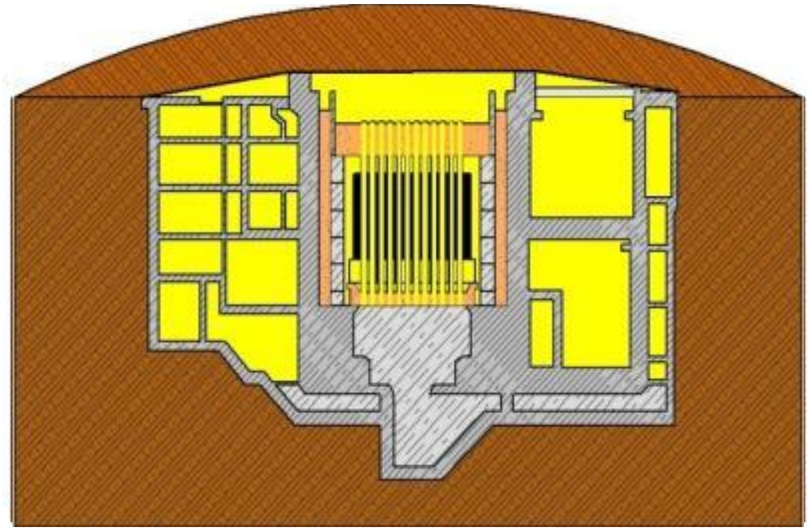
CONCEPT OF EI-2 URANIUM-GRAPHITE REACTOR DECOMMISSIONING



1. Complete dismantling of support systems and equipment in Building 190 except for reactor installation.
2. Concrete placement in the bottom elevation rooms and sub-reactor areas up to the bottom biological shielding.
3. Void-free filling of in-core areas using the barrier mixtures based on natural clay.
4. Decontamination of engineering structures.
5. Dismantling of superstructures of EI-2 building.
6. Setting-up a barrier for weather impact on the entombment facility.

EI-2 uranium-graphite reactor decommissioned as of the end of 2015 (target value of the Federal Target Program) is defined as a mothballing facility for special radioactive wastes.

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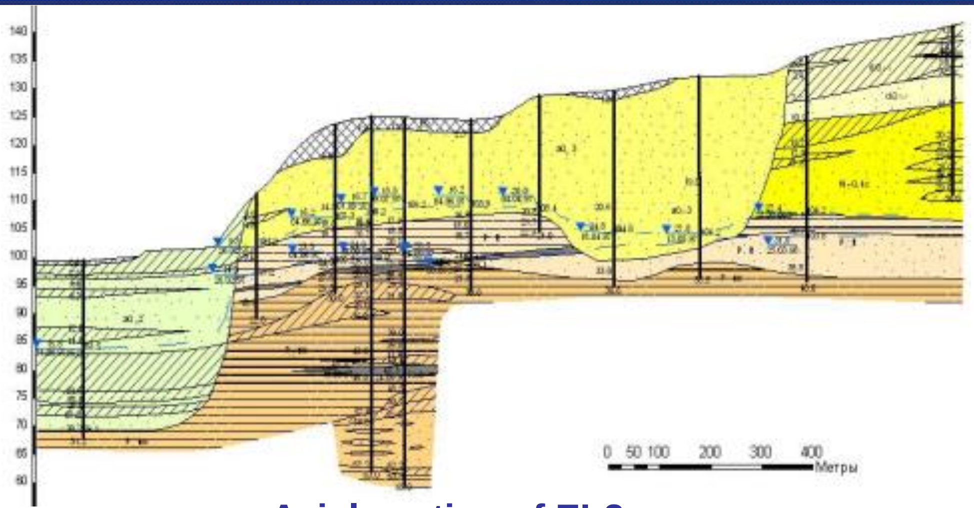
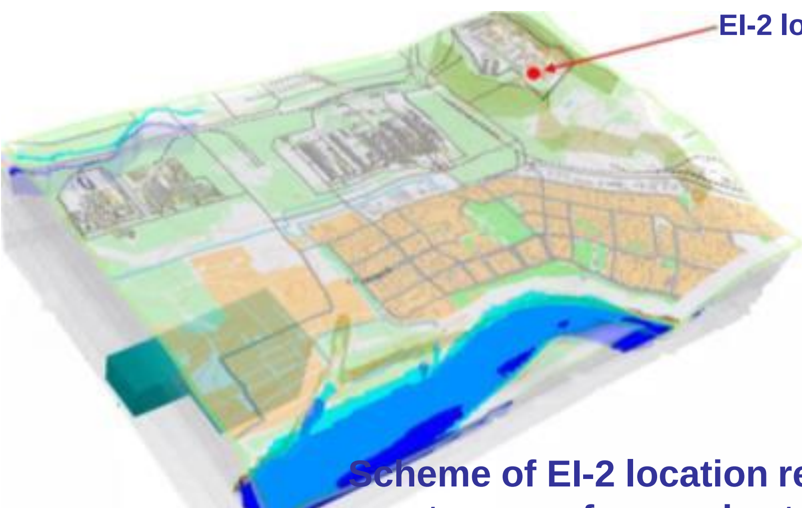
PREDEVELOPMENT ANALYSIS



Axial section of EI-2 area



Scheme of EI-2 location relative to area of groundwater discharge

1. **Geological research in EI-2 zone.**
2. **Sorption capacity of geological environment.**
3. **Sorption parameters for the most significant long-lived radionuclide in massive material of aquafer.**

Radionuclide	Allocation coefficient in massive material, m^3/kg
^{3}H	No sorption
^{14}C	No sorption
^{36}Cl	No sorption
^{90}Sr	0,30-0,48
Cs isotopes	6,5-9,3
U isotopes	0,14-0,21
^{237}Np	0,62-1,5
Pu isotopes	4,8-6,9
Am isotopes	5,5-7,8
^{244}Cm	5,5-7,8
^{60}Co	1,6-3,0

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PREDEVELOPMENT ANALYSIS

Barrier material choice

Criteria:	Solution:
Performance stability during the period of nuclear waste potential threat, ecological safety, accessibility.	Natural materials
High sorption capacity of radionuclides with different by chemical properties, plasticity	Mixture of natural materials on the base of natural clay or clay rock
Low water conductivity, natural compression, good flowability	Machine processes mixtures with definite humidity and granulometric composition

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RESEARCH RESULTS

1. The composition on the base of machine processed mixture of natural clay as the barrier material was developed;

2. On the base of calculative approach it was confirmed that forecasting activity of radionuclides considered 10^{-3} Bq/kg eliminating C-14 and Cl-36 from the area of groundwater discharge to river Tom (modeling timeframe – 10,000 years);

3. It was confirmed that under any events evolution scenario the most mobile C-14 and Cl-36 radionuclides will not exceed action level.

4. On the base of these researches which justify safety of in-situ entombment scenario the project of decommissioning of EI-2 uranium-graphite nuclear reactor was developed and license was provided to implement this work.

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TECHOLOGIES

CLASSIFICATION OF TECHNOLOGIES ON THE STAGE OF PROJECT DEVELOPMENT AND DURING THE DECOMMISSIONING OF EI-2 REACTOR

- Technologies used for comprehensive engineering and radiation survey used during the survey of the equipment, buildings, and areas
- Dismantling technologies for main and accessory equipment, buildings and constructions
- Barrier construction technologies safety conservation of reactor facilities and content of nuclear waste disposal facilities
- Nuclear waste treatment technologies accumulated during the reactor operation time and decommissioning

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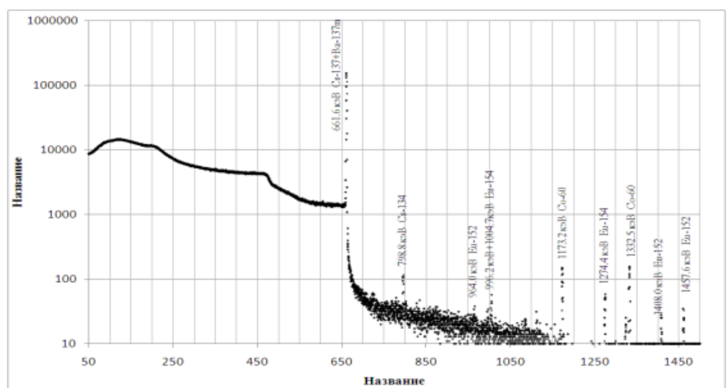
COMPREHENSIVE ENGINEERING & RADIATION SURVEY TECHNOLOGIES

Radiation survey

Mobile spectrometric complexes and outdoor sample-collective appliances were used.

Sample collection for spectrometry

Mobile spectrometric complexes



Determination of radiological characteristics

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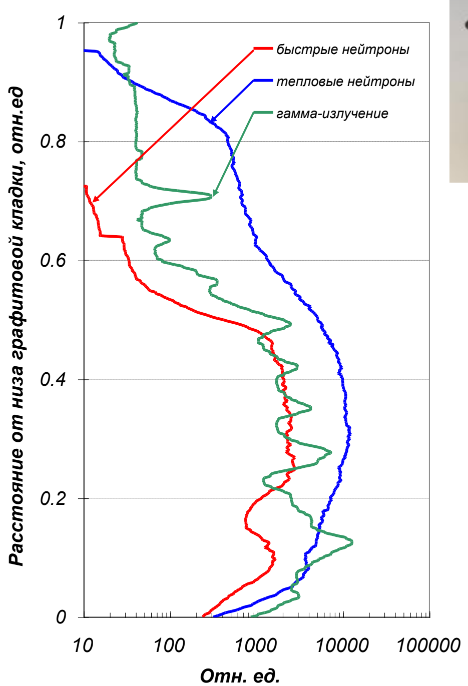
COMPREHENSIVE ENGINEERING & RADIATION SURVEY TECHNOLOGIES

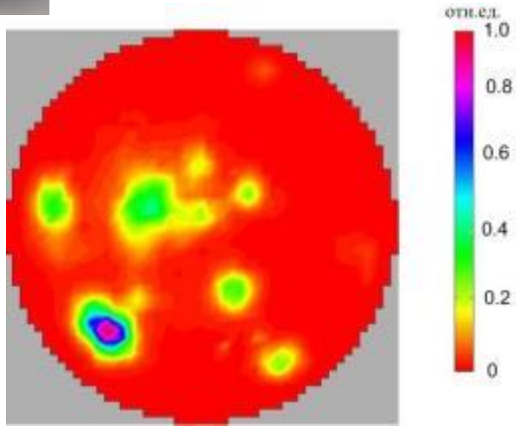
Radiation survey

Updating of content of C-14, Cl-36 and other radionuclides, its location form in graphite, constructional materials and metal structures.



Neutron and photon scanning of reactor facilities

Equipment for gamma neutron logging



Determination of fuel spillage localization areas

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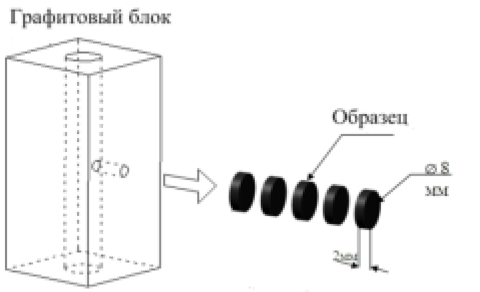
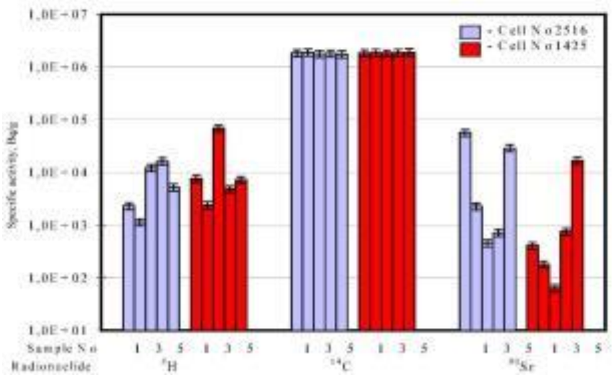
Calculation of mass of fuel spillage



Collection of samples



Determination of isotopic composition and sample activity

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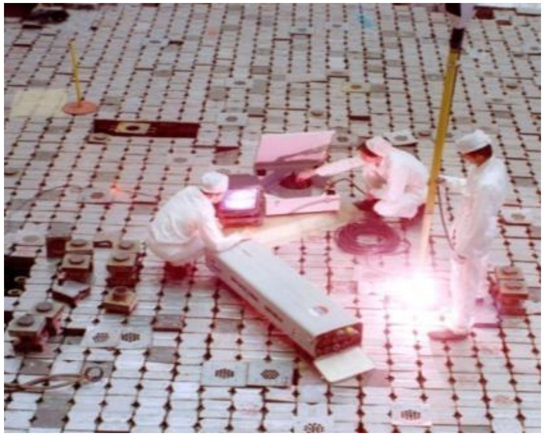
COMPREHENSIVE ENGINEERING & RADIATION SURVEY TECHNOLOGIES

Engineering survey

Evaluation of EI-2 construction materials condition with visual control and non-destructive testing.



Evaluation of concrete strength

Survey with endoscope through technological channels

Visual control of construction materials and technological equipment

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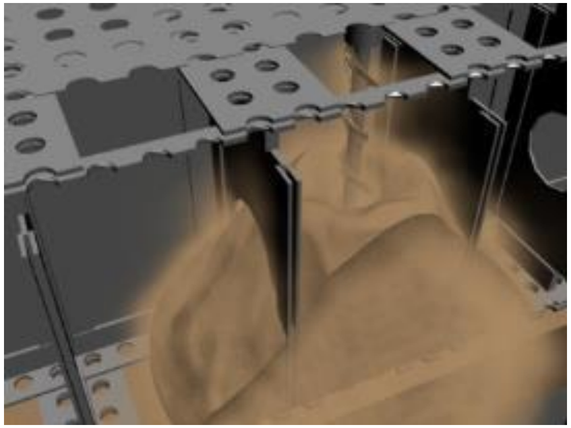
Technology of barrier construction

Construction of additional safety barriers

Achievement of maximum filling of the difficult to access technological spaces by natural clay, including computer modeling and mock-up testing.



Modeling of void-free filling technologies

First stage of mock-up testing

Void-free filling of reactor space by barrier materials. Result of the mock-up testing.

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DECONTAMINATION AND WASTE TREATMENT TECHNOLOGIES

Nuclear waste treatment

Decontamination of different materials

Sludge conditioning


Decontamination of the central hall walls


Decontamination of Aluminum alloy

Sludge conditioning


Sample collection of ceramics with and without sludge inclusions

Mechanical tests of ceramics with sludge inclusions

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PRACTICAL WORKS

Dismantling of systems and equipment, extraction, decontamination, fragmentation, sorting and packaging and placement at the area of temporary storage.

First stage of metal constructions dismantling

End stage of metal constructions dismantling

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PRACTICAL WORKS

Placement of the nuclear waste at the temporary storage area

Transportation of MK-1,36 containers

Containers with nuclear waste at the temporary storage area

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PRACTICAL WORKS

Performance of technological channels to the difficult to access spaces for transporting of barrier materials (works were done with the help of distant visual control devices).

Performance of technological channels though metal constrictions of the upper biologic shield

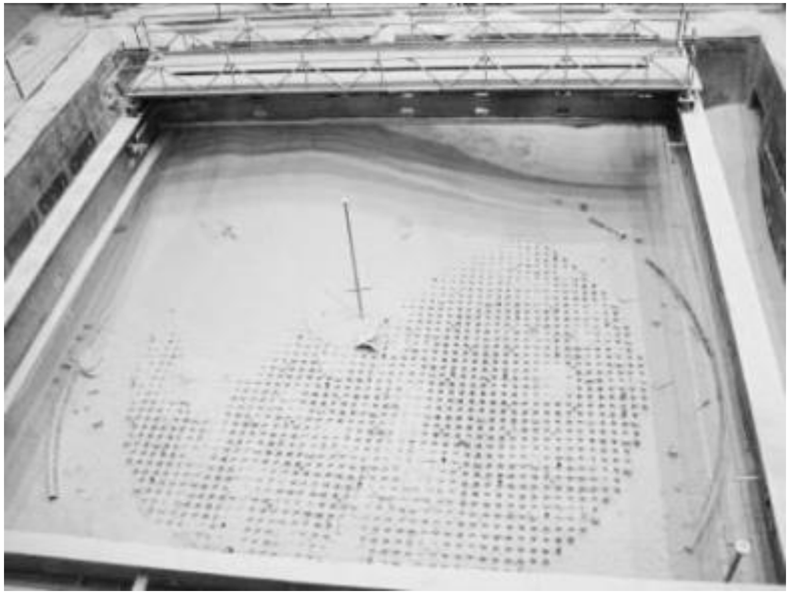
Performance of technological channels though metal constrictions of the lower biologic shield

Area between lower metal constructions

Performance of technological channels though the covers of the outside reactor areas

PRACTICAL WORKS

Channel installation for periodical long-term control of the internal barrier status.



Control channels in graphite stack and reactor area

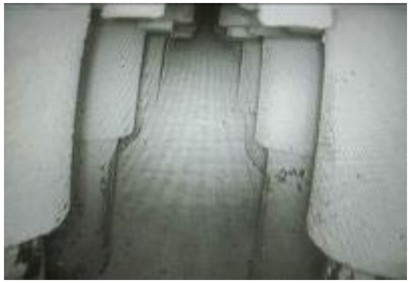
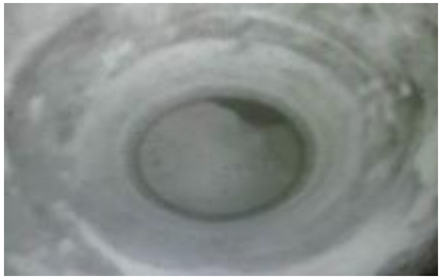
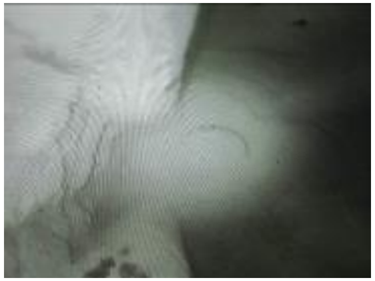
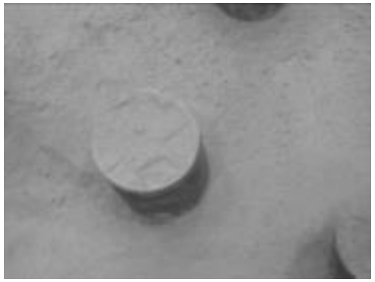
Control channel in technological area

PRACTICAL WORKS

Consistent filling of areas by barrier material



Filling at-reactor areas

Filling of spaces within the reactor vault (under the reactor, interdiaphragm area, reactor area, technological channels, containers at "E" scheme)

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PRACTICAL WORKS

Dismantling of EI-2 building superstructures

Dismantling of superstructures

Dismantling of superstructures of central hall

Construction of protective shield

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RESULTS

1. Composite protective barriers system was created:

- Under graphite stack – 22 m;
- Across graphite stack – 22 m;
- Above graphite stack – 13 m.

2. Volume of barrier material filled:

-Within reactor vault - 4500 m^3;

-Beyond reactor vault (at-reactor areas) - 36 644 m^3;

-Barrier preventing atmosphere impact on the object - 85 820 m^3.

3. Metal nuclear waste disassembled – 1160 t (low-level radioactive waste), packed in 175 containers.

4. Left at site nuclear waste – 2676 t (graphite - 1422,6 t), volume - 975 m^3 (middle-level radwaste) (graphite - 975 t^3) total activity - 1,85×10^{15}Bq, major dose contributor nuclides at the end of the works are Cs-137, Co-60.

5. Packed - 300 m^3 of sludge into NZK-150-1,5P containers (375 pcs).

6. Dismantled of superstructures -11 340 m^3.

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CONCLUSION

1. Mothballing facility for special radioactive wastes is almost completed. This work has never been done anywhere in the world and has no precedent.

2. Decision on decommissioning of the uranium-graphite nuclear reactors should be made on the base of individual approach because of the difference in graphite structure, reactors operation conditions, geological and hydrogeological characteristics of the reactor locations.

3. Decommissioning cost reduction without decreasing the mothballing facilities reliability is possible under certain circumstances:

- When objective input data resulting from the comprehensive engineering and radiation survey are obtained. This allows to avoid conservative design decisions on decommissioning and minimize costs;
- When developing implementing and constant improving of decommissioning technologies and radioactive waste treatment technologies are provided. This allows to optimize the costs of key-turn decommissioning services;
- If decommissioning is held without extraction of metal low-level radwaste from the carbon steel. Researches of Russian academy of sciences A.N. Frumkin Institute of Physical chemistry and Electrochemistry RAS (IPCE RAS) showed that corrosion products improves barrier materials anti-immigration performance

Total cost of mothballing facility creation with dismantling of all metal radwaste	2,3 bln. rub.

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